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Editors:
C. PAPACONSTANTINOU, A. ZENETOS,
V. VASSILOPOULOU, G. TSERPES

Institute of Marine Biological Resources

STATE OF HELLENIC FISHERIES

Athens 2007

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FORWARD

Dear Reader,

The publication you now have in hand is the outcome of the combined effort of the finest Hellenic researchers and scientists coordinated by the Institute for Marine Biological Resources of the Hellenic Centre for Marine Research. This publication is intended to cover an important gap in the holistic knowledge and awareness of a broad audience on issues related to the current state of the Hellenic fisheries sector. Information related with the scientific breakthroughs in fisheries research, fisheries biology, ecology and ecosystems in Hellas, the state of the commercially important biological resources, the recent technological developments in fisheries, the social and economic state of the Hellenic fisheries sector and the national and European Union fisheries policies and fisheries' management approaches are all subjects addressed in detail and depth and are presented in this volume in a simple manner suitable for all readers regardless their academic background.

This initiative of the Director and staff of the Institute for Marine Biological Resources of the Hellenic Centre for Marine Research is the result of the continuous efforts of both the H.C.M.R. and the Centre of Excellence for Fisheries and Coastal Zone Management for the support of society, the dissemination of research and scientific information and advice and in particular, the support of the national fisheries sector which is one of the socio-economically important primary economic sectors of Hellas. Hellenic fisheries, together with agriculture and livestock production, is the basis of the national economy and in many remote locations, it is the only source of income and job security available to Hellenic citizens. This fact makes the mission of the Institute for Marine Biological Resources more important and therefore, the administration of the Hellenic Centre for Marine Research and myself personally are pleased to see this volume finally published.

The administration of the Hellenic Centre for Marine Research, the Director and the staff of the Institute for Marine Biological Resources hopes that this volume will be a useful source of vital information for students, administrators, officials and the public and express our intention to continue this important activity towards society in return for their support of our work.

Professor George Th. Chronis
Director and President of the Board of Directors
of the Hellenic Centre for Marine Research

PREFACE

Marine capture fisheries are of vital importance to the economic development of Hellas since it contributes to the maintenance of the social and economic coherence of the coastal and insular areas offering security of labour to a large number of persons particularly in remote islands, and it provides animal proteins of high biological value through the sustainable exploitation of the resources.

The Hellenic fisheries' sector, as in other Mediterranean countries, is multi-species and multi-selective and in most cases it is carried out with traditional methods of low yield and capitalization. Fisheries in Hellas are usually operated as a family business, combined with other economic activities, while the fishermen are usually old and not well-trained for the profession. The fishing fleet is mainly composed of old vessels, with small tonnage and power, targeting coastal resources which are landed in a vast number of ports along the extended coastline of the mainland and the islands.

The sustainable management of the Hellenic fisheries needs to be approached from two angles: the management of the fishing fleet and its capacity and on the other hand, the study and monitoring of the effects of fishing activities on the state of the stocks and the environment. The estimates of the Hellenic marine resources are limited and are based on information gathered within research projects which are funded by national or community sources and therefore, the information we have is scarce and geographically limited.

Although the above make the management of the fisheries' resources rather difficult, complicated and of high cost, Hellas was one of the countries that, since the early 1950s, enforced legislation which was aimed at their sustainable exploitation. The accession of the country into the European Union and the enforcement of the Common Fishery Policy (CFP) created the opportunity to further support this effort, particularly through the reformed CFP (2002) which has set the application of the ecosystem-based approach to fisheries' management among its basic priorities. The development of such a system, however, is time consuming, complex and costly and requires the integration of solid scientific advice based on thorough research information.

During the last 20 years, the state of the Hellenic fishery resources shows negative trends, despite the reduction of the fishing capacity in accordance to E.C. regulations for the management of the fishing fleets of the member states, aiming at the reduction of the fishing pressure on stocks. Moreover, the Hellenic fisheries' sector's viability appears to be pessimistic, influenced by a variety of factors related to the capacity to produce sufficient amounts of fisheries' products and the conditions of the market. The above underline the complexity and the sensitivity of the problem and denote that management of Hellenic fisheries should be based on both the sustainable exploitation of resources and the viable development of the sector.

The present textbook aims to familiarize the reader with the organization and problems of the Hellenic fisheries. In fact, although there is a sizeable amount of information and references on various scientific and technical issues, these were scattered and fragmented, while this textbook constitutes a consolidated work including all different aspects, and hence it is trusted to become a useful tool for every scientist and administrator in marine fisheries. The different chapters offer valuable information derived either from the literature or the results of research and development projects conducted by scientists in Hellenic waters and therefore, a good part of the information included herein originates from sources that are not readily available to an ordinary reader.

In a number of papers included in this textbook, date analysis and geographical presentations was made using the application and the models developed in the frame of the research project "Development of an Intergrated Management System" to support the sustainability of Hellenic Fisheries Resources (IMAS-FISH) funded by the Greek General Secretary of Research and Technology.

Costas Papaconstantinou
Director of the Institute
of Marine Biological Resources, HCMR

HOW TO READ THE REPORT

The report is structured around 7 chapters. Homogeneity throughout the chapters was not feasible mainly because of data availability. Thus, issues for which there is lot of data are presented like reviews/reports, whereas issues for which studies are limited are treated like essays based on a few case studies.

Chapter I presents the geomorphology of the Hellenic Seas (sediment, bathymetry) and gives an updated overall picture of eutrophication that is both beneficial and detrimental to Fisheries.

Chapter II pertains to the structure of the ecosystems in the Hellenic fishing grounds including the diversity and details of the most commercially exploited living resources (fish, cephalopods, molluscs, shellfish, fish plankton).

Chapter III provides information on a variety of topics of the Hellenic fishing sector. These include details on the management of fleets and resources as defined by both EU and national legislation, the existing data collection systems and further improvement of their quality, gears used, and certain socio-economic features of professional fishermen.

Chapter IV describes the state of the biological resources in the Hellenic Seas according to the natural ecosystem they usually inhabit and the fishing fleet that exploits them which are divided into (a) demersal, (b) small pelagic, (c) large pelagic or migratory, (d) deep-sea fisheries and (e) lagoon fisheries.

Chapter V addresses the effects of the environment on fisheries and vice versa. The scientific contributions to this chapter are based on a number of case studies. In particular, impact of fishing on the ecosystem include results derived from research projects aimed at the study of trawling effects; effects on the ecosystem as a whole and burdens on vulnerable species such as mammals, turtles and cetaceans.

Chapter VI provides information on modern methods of fisheries' management and presents the advantages from their application. At the same time, an effort is made to examine their complimentarity and their contribution to the aims and provisions of the Common Fishery Policy. Towards this goal, the establishment of MPAs, appropriate indicators and the adoption of a precautionary approach to fisheries management in Hellas are addressed.

Chapter VII includes scientific papers which either describe the research developments or attempt to contribute to better knowledge of various fisheries issues such as stock assessment, selectivity of fishing gears, use of Geographical Information Systems and satellite imagery in fisheries management, use of innovative fishing methods (i.e. FADs), fishing in over exploited fishing grounds.

The editors adopted the rules of ELOT (Hellenic Organisation of Standardisation) for writing-translating the names of localities. (Hellas is written as Hellas throughout this volume). Exceptions are the transliteration of Aigaio and Kritikon which are named as Aegean and Cretan Sea, respectively.

ACKNOWLEDGMENTS

This report has been prepared with the collaboration of individualsfrom research institutes and universities in Hellas. Their contribution is highly acknowledged.

The editors would like to thank all the contributors to this publication; without their help the report would certainly be poorer. In particular, special thanks are due to a plethora of colleagues from the Hellenic Centre for Marine Research who, although they are not referred to as co-authors in the chapters, have contributed significantly to the realization of the report.

Thanks are also due to our colleagues from the educational institutes of our country for supporting this effort.

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- The NGOs: Mom (*Monachus monachus*); Pelagos Cetacean Research Institute; Sea Turtle Protection Society

The editors would also like to thank Mrs Erietta Tzovara for the layout of the report and her devotion in the preparation of the publication; Mrs Linda Kiousi for the linguistic improvements. Thanks are also due Mr Giannis Dokos and Mrs Panayiota Kosmopoulou for the preparation of maps.

CHAPTER 1

ENVIRONMENTAL FACTORS AFFECTING THE STRUCTURE AND PRODUCTIVITY OF FISHERY RESOURCES

CHAPTER I - ENVIRONMENTAL FACTORS AFFECTING THE STRUCTURE AND PRODUCTIVITY OF FISHERY RESOURCES

INTRODUCTION

The coastline of Hellas is more than 18 000 km in length and has a variety of coastal landforms, such as cliffs and rocky shores, beaches and deltaic coasts. The coasts form fragile natural systems and they have economical, social and cultural significance for mankind. Morphological features and bathymetry as well changes of the coastline of Hellas, are presented in detail in SoHelME 2005. Considering the significance of the sea floor as a fishery ground, this chapter reports on the geomorphology of the Hellenic Seas which consist of the Aegean (North, Central and South) and the Ionian Sea. It also reports on the development of the Hellenic Trench and the major gulfs.

The marine environment of Hellas is predominantly a temperate one. Hence fish stocks of the region are typically temperate, in keeping with the coastal water temperatures which range from 10°C to about 18°C in the winter, 14°C to 30°C in the summer (Table 1). The Hydrological and hydrodynamical features of the Hellenic coastal and open sea areas are presented in SoHelME, 2005.

Coasts are under pressures, facing complex development dilemmas. In the Hellenic coastal zone, urban effluents constitute a major land-based source (LBS) of pollution. Until the mid 1990s, most of the coastal area domestic wastes were discharged into the sea untreated. This practice resulted in increased nutrient concentrations, and metal accumulation in coastal ecosystems. Excess input of nutrients leads to eutrophication, which in turn triggers various physical, chemical and biological changes in plant and animal communities causing thus, a multi-link chain of events. Eutrophication is both beneficial and detrimental to Fisheries. This chapter presents data of chl α (a measure of assessing eutrophication) collected from the Aegean Sea and the Ionian Sea (open, offshore and inshore waters) during the last 15 years.

The most significant impacts of the clear, warm, low nutrient waters of the Aegean and Ionian Seas include high species' diversity, low biomass the distribution of temperate sea grasses that act

Table 1. Typical surface to bottom ranges of temperature and salinity in several coastal areas around Hellas in winter (February, March) and summer (August, September)

	Winter		Summer	
	Temperature °C (Surface-Bottom)	Salinity (Surface-Bottom)	Temperature °C (Surface-Bottom)	Salinity (Surface-Bottom)
Kerkyra	11-15	37-38	25-14	38-39
Ipeiros coasts	12-15 (at 50m)	37-38 (at 50m)	23-16 (at 50m)	37.5-38.8 (at 50m)
Amvrakikos G.	10-15	26-38	30-14	26-38
Patraikos G.	12.5-12.5 (at 50m)	38.5-38.5 (at 50m)	25.5-15.2 (at 50m)	38.4-38.5 (at 50m)
W. Peloponnisos	15-15	38.5-38.5 (at 50m)	25-20 (at 30m)	38.7-38.8 (at 30m)
Thermaikos G.	9-14	29-38	29-15	35-38
Strymonikos G.	11-15	24-28	27-15	24-38
Pagasitikos G.	12.5-13.5 (at 50m)	37-38 (at 50m)	25-14 (at 50m)	37.5-38.2 (at 50m)
Maliakos G,	11.5-12 (at 20m)	35-37.5 (at 20m)	23-22 (at 20m)	36.8-36.8 (at 20m)
N. Evvoikos G.	13-12 (at 100m)	36.8-37.5 (at 100m)	28-14 (at 100m)	37.6-37.8 (at 100m)
Petalioi G.	11-14 (at 200m)	38-39 (at 200m)	24-13 (at 200m)	37[5]-39 (at 200m)
Saronikos G.[1]	12[2]-15	38-39	28[3]-13[4]	38-39
Kalloni G. (Lesvos)	11-9	36.2-38.2	26-17	41-39.2
Rodos coasts	17.7-16.9 (at 50m)	39.1-39.2 (at 50m)	27-19.5 (at 50m)	39.3-39 (at 50m)
Kriti (Herakleion Bay)	14.5-14.7 (at 100m)	38.8-39 (at 100m)	24.9-14.8 (at 100m)	39.2-38.9 (at 100m)
Standard Deviaition	2-1.5	0.4-0.4	3-3	0.6-0.6

Source data: KONTOYIANNIS *et al.*, 2005 in SoHelME, 2005

Notes: 1: Including Elefsis Bay and the deep (450m) west sub-basin, 2-3: In Elefsis Bay, 4: In the west sub-basin, 5: Due to occasional inflow of Black Sea water.

as major nursery areas for many fish species. Description of the pelagic and benthic ecosystem in both coastal and open sea areas in Hellas is given in SoHelME, 2005.

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I.1. GEOMORPHOLOGY OF THE HELLENIC SEA-FLOOR

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INTRODUCTION

The sea-floor of the Hellenic Seas displays a complex geomorphology which reflects the complexity of the geological and geodynamic processes and the tectonic movements which are related with the active deformation of the Aegean crust (Figure 1). The Aegean Sea, between continental Hellas and Asia Minor, has been formed as a back-arc basin behind the southwards migrating orogenic arc and hosts the active volcanic arc.

The southernmost Aegean islands (Kythira, Kriti, Karpathos, Rodos) form the southern limit of the Aegean Sea towards the Eastern Mediterranean and the Ionian Sea. The Ionian Sea, located west of continental Hellas, and the Hellenic Trench, which surrounds the southernmost Hellenic territories from the south, host the deepest basins of the Mediterranean Sea. Their sea-floor relief is strongly controlled by active faulting and is thus very irregular. Most of the gulfs which dissect the

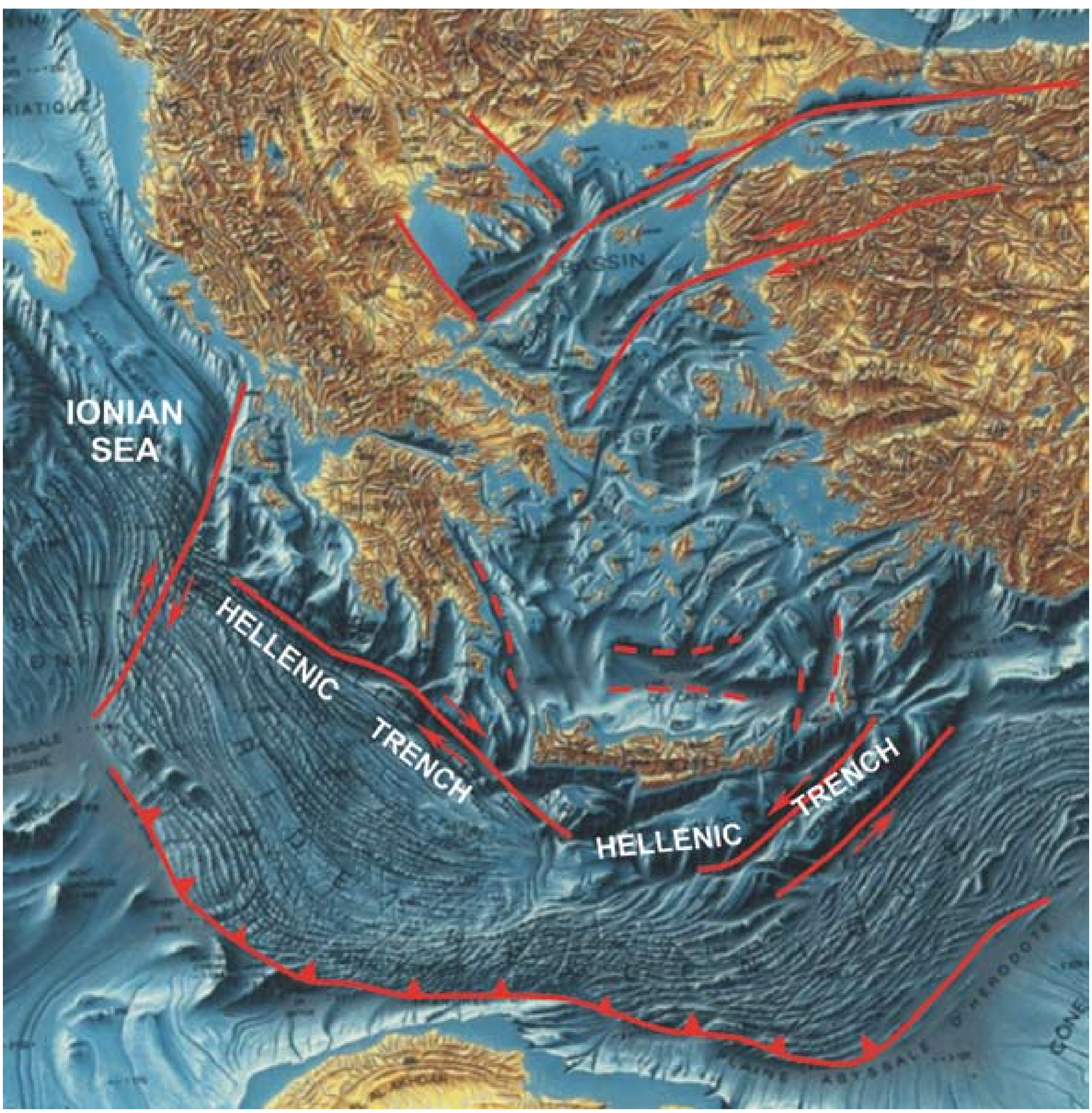

Figure 1: Morphological relief map and main tectonic lines of the Aegean - Ionian region.

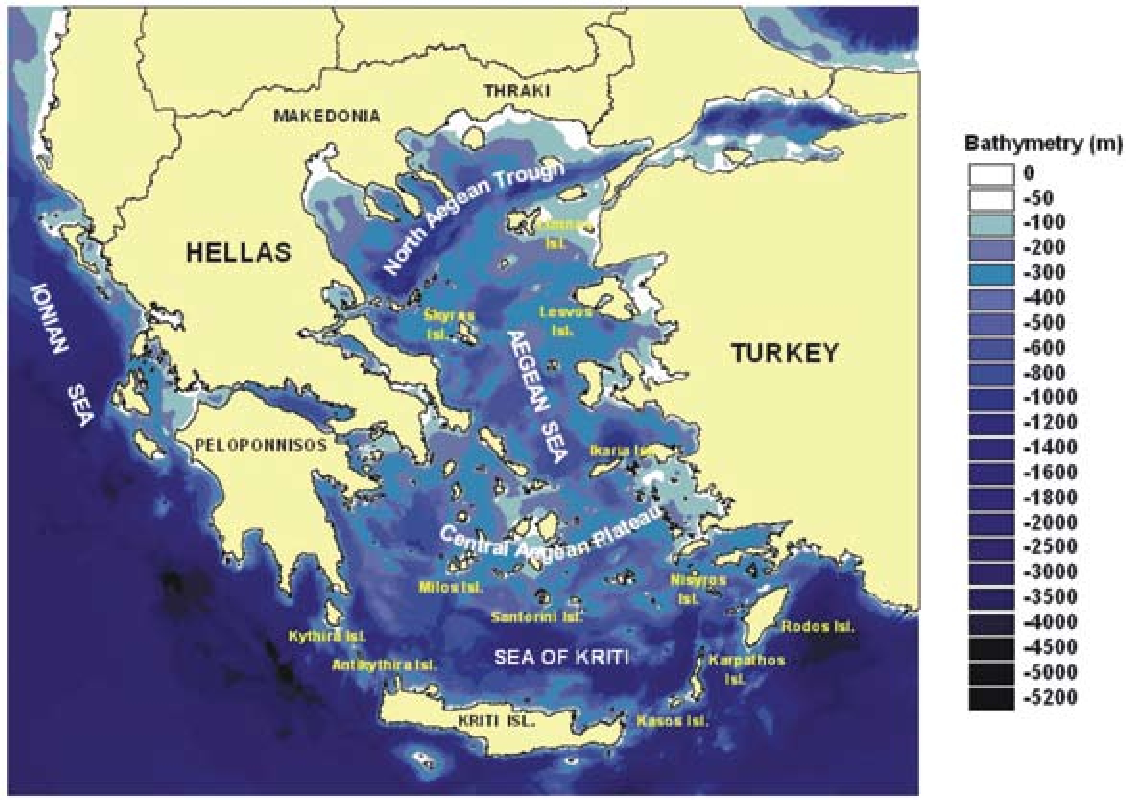

Figure 2: Bathymetric map of the Hellenic Seas (depths in metres) and location of major morphological features.

coastline of the Aegean and the Ionian Seas are also of tectonic origin.

AEGEAN SEA

The Aegean Sea can be divided into three distinct regions (Figure 2) with different morphological characteristics: the northern, the central and the southern part.

North Aegean

North Aegean Shelf: The northern margin of the Trough is composed of shallow platforms, which are dissected into NW-SE trending wide gulfs, like the Thermaikos and Strymonikos Gulfs. A wide shallow platform, with the Thassos and Samothraki Islands on it, extends between the Strymonikos and Saros Gulf for many kilometres off the coastline up to the 120 m depth contour. The North Aegean Shelf represents the offshore continuation of the alluvial planes of Northern Hellas and Eastern Thraki. Most of these planes have been formed in Upper Miocene – Lower Pliocene as continental basins filled up by lacustrine and fluvial Plio-Pleistocene deposits (LYBERIS, 1984). They are being drained by large rivers, which feed the shelf and the trough with terrigenous clastic material.

North Aegean Trough: The dominant morphological feature in the Northern Aegean Sea is the homonymous Trough (NAT), which has developed along the trace of the Northern Anatolian Fault (NAF) (Figure 3) (LYBERIS, 1984; PAPANIKOLAOU *et al.*, 2002). The North Aegean Trough comprises of a series of three main elongated depressions, separated from each other by morphological highs (Figure 2). The eastern depression is a narrow, N70E striking and up to 1 400 m deep basin, which extends from Limnos Island to the Gulf of Saros. The second depression, with an average depth of 1 200 m, is located to the SE of the Chalkidiki peninsula and indicates a progressive widening and shift of the Trough axis to N50E. The western depression corresponds to the 1 500 m deep and wide Sporades basin. Sedimentation in the North Aegean Trough comprises mainly of hemipelagic mud, turbidites and gravity driven deposits originating in the outer shelf and upper slopes of the trough.

Sporades-Limnos Plateau: The southern slopes of the North Aegean Trough are delineated by steep fault scarps, which represent the sharp contact with the 100-300 m shallow platform extending

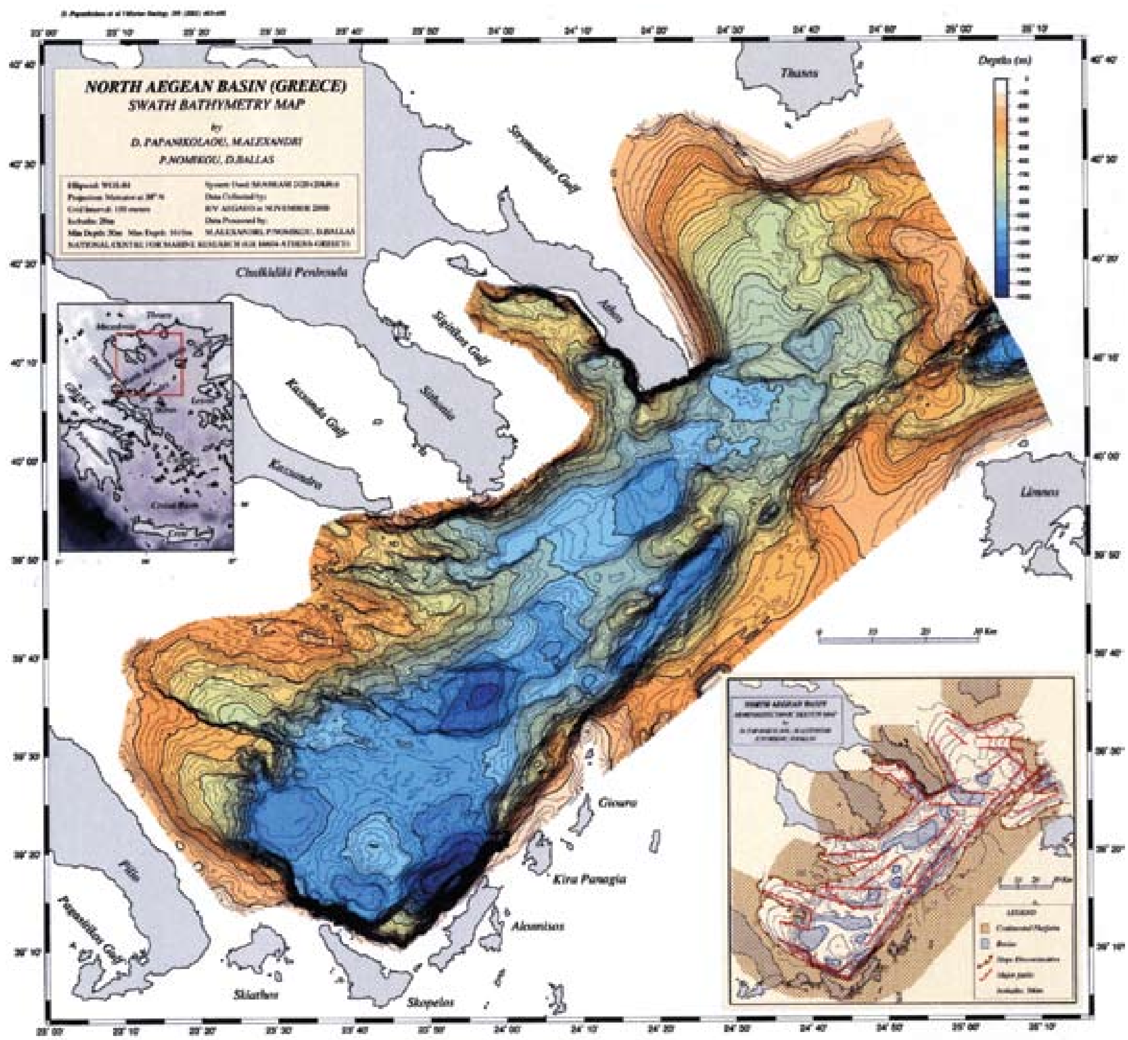

Figure 3: Swath bathymetry map of the North Aegean Trough. After PAPANIKOLAOU *et al.* (2002). Main fault traces are shown on the inset map.

between the Sporades Islands in the west and the Limnos and Imvros Islands in the east.

Various basins: Secondary strike slip faults, running parallel to the North Anatolian Fault, together with normal faults, are responsible for the formation of narrow but deep, small basins in the region between the North Aegean Trough and the Central Aegean Plateau (MASCLE & MARTIN, 1990). The 1 000 m *deep Skopelos basin,* the 800 m *deep Kymi basin,* the 800 m deep *S. Skyros basin,* the 1 000 m deep *N. Skyros basin,* the 800 m deep *Psara basin* represent isolated morphological depressions separated from each other by 200-400 m shallow platforms. The 800-1 000 m deep *Ikaria basin* constitutes the southernmost deep basin of the Northern Aegean region, before the shallow Central Aegean Plateau. All the above mentioned basins are of tectonic origin, since active faulting controls their subsidence, and they are surrounded by steep slopes.

Central Aegean

The Central Aegean Plateau (Kyklades plateau) represents a shallow platform of about 200 m mean depth, which forms the morphological link between the Attiki peninsula and the S. Evvoia Island to the west, and the Menderes region in Asia Minor to the east. The theoretical line, which passes over the islands of Andros, Tinos, Mykonos, Ikaria and Samos, constitutes the northern limit of the shallow plateau. The shallow limit of the Central Aegean Plateau coincides with the Volcanic Arc, to which the islands of Nisyros, Santorini, Milos, Poros and Aigina along with smaller islets and submarine volcanic centres belong.

The curved shape of the Central Aegean shallow

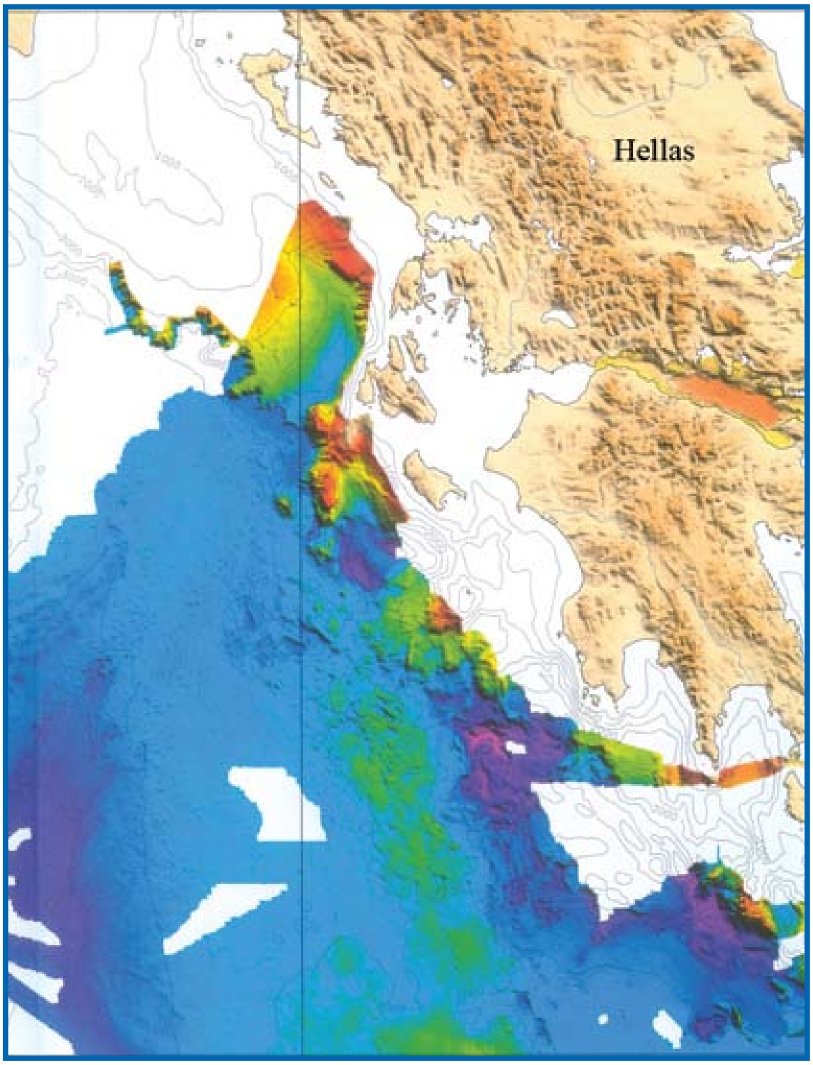

Figure 4: Swath bathymetry map of the Ionian Sea. (extracted from: Medimap Group 2005, Morpho- Bathymetry of the Mediterranean Sea, CIESM/IFREMER).

plateau follows the general shape of the Hellenic Arc and Trench System and is the result of stretching of the Aegean microplate in a NNE-SSW direction (LEPICHON & ANGELIER, 1981; MASCLE & MARTIN, 1990). The gentle submarine morphology of the Central Aegean reflects the low seismic potential and the weak neotectonic activity and faulting of the region. Biogenic sedimentation prevails on the shallow platforms between the numerous islands and islets.

South Aegean

A series of elongated deep basins are distributed between the Volcanic Arc to the north and the Island Arc to the south. The South Aegean basins extend from the Argolikos Gulf, off the Eastern Peloponnisos, over the Cretan Sea, between the islands of Kriti and Santorini, and continue to the Sea of Karpathos, west of Karpathos Island.

The greatest depths of the Aegean Sea are to be found here. The N-S elongated *Karpathos basin* is 2 500 m deep and is bordered by a steep faulted slope towards Karpathos Island. A 1 300 m deep shallow ridge separates the Karpathos basin from the 2 200 m deep Kamilonisi basin. The latter is located between the northern coast of Eastern Kriti and the Kamilonisi Islet. Next to this and north of Central Kriti, the 1 800 m deep *Irakleio basin* occupies the central part of the Southern Aegean Sea. Further to the west, a shallower but long and narrow basin follows the shallow ridge, which connects Western Kriti with the islands of Antikythira and Kythira and the Eastern Peloponnisos.

The formation and distribution of the *Deep South Aegean basins* is the result of the geotectonic regime, which was active over the region during the last 5 million years. Nevertheless, the tectonic and seismic activity in the Southern Aegean is presently much lower in comparison to the Northern Aegean. Tectonic activity has migrated southwards and affects the Island Arc with faulting, which is responsible for uplift or subsidence of successive regions along the arc.

The tectonic fragmentation of the Island Arc has resulted in the formation of relatively shallow straits, west and east of Kriti, which allow water exchange between the Aegean Sea and the East Mediterranean.

IONIAN SEA

In the Ionian Sea (Figure 4) two different parts may be recognized: the northern and the southern one, with the boundary between them being marked by the Kefallonia strike-slip fault. The northern part can be seen as the southward prolongation of the Adriatic Sea. An extensive shelf, with Kerkyra Island being part of it, connected to a relatively flat basin by a steep slope characterizes the northern Ionian Sea.

The sea-floor morphology changes dramatically in the southern part of the Ionian Sea, and coincides with the high seismicity of the region. Normal active faults are responsible for the formation of deep gulfs, like the Messiniakos and Lakonikos Gulfs and valleys. The regional tectonics and fault movements are controlling the sedimentation in these areas. Turbidites and gravity driven deposits form the bulk sedimentary infill.

Deeply eroded submarine canyons dissect the shelf and the slope off the Ionian Islands and the

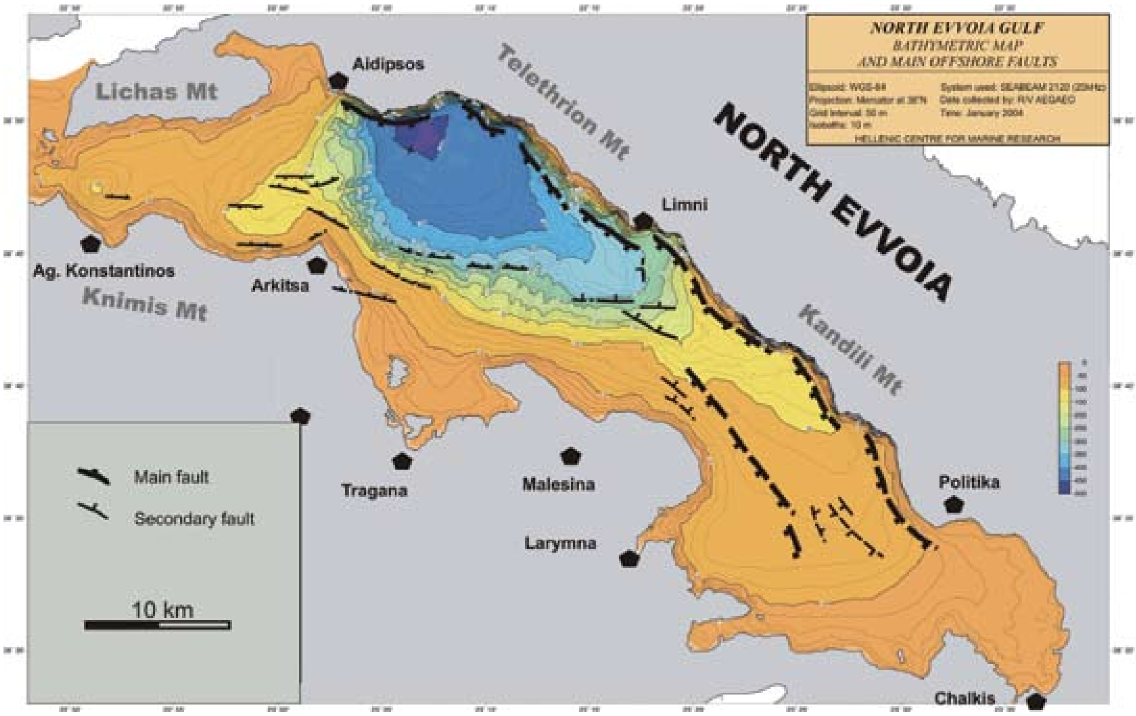

Figure 5: Swath bathymetry and main offshore active faults of the North Evvoia Gulf, modified after ALEXANDRI *et al.* (2005) and SAKELLARIOU *et al.* (2007).

Peloponnisos and terminate down-slope in small, deep, isolated basins at depths over 4 000 m. Note that the deepest basin (*Vavilov Deep*) in the Mediterranean Sea is located in this region, only 30 miles off the SW coast of the Peloponnisos and is over 5 100 m deep.

HELLENIC TRENCH

The succession of the deep basins along the foot of the submarine slope of the Ionian Sea constitutes the western branch of the Hellenic Trough (LEPICHON & ANGELIER, 1979). The Trough was considered previously as the boundary between the subducting East Mediterranean oceanic crust and the overriding Aegean continental crust. New data indicate that the segmented Trough constitutes the morphological expression of strike slip faulting between the thinned Aegean continental crust and the accretionary prism of the east Mediterranean Ridge.

The Hellenic Trough continues eastward, south of Kriti and further eastwards, southeast of the islands of Karpathos and Rodos. The Herodotus, Strabo and Pliny trenches form the central and eastern part of the Trough. These trenches have formed along significant strike slip faults, which undertake the lateral escape of the accretionary prism away from the southwards moving thinned Aegean continental crust. The Strabo and Pliny trenches terminate north-eastwards into the Rodos basin, a 4 000 m deep and relatively young basin within the Levantine Sea.

GULFS

Extensive faulting and vertical tectonic movements have resulted in the fracturing of the Hellenic mountain chains and the creation of deeply incised embayments and semi-enclosed basins.

Recent and active tectonics is the main driving mechanism, which generated and continues to regulate the morphology of Hellas. Intensive faulting resulted in the fragmentation of the upper crust into individual tectonic blocks, which undergo vertical or horizontal movements. These processes resulted in the formation of a complicated geomorphology of the Hellenic peninsula, which shows a mountainous relief with the main direction NW to SE (JACKSON & MCKENZIE, 1988; JACKSON, 1994). This morphotectonic regime has, as a consequence, the formation of a variety of drainage basins and drainage systems, including some very extended drainage areas as well as some smaller.

The Thermaikos and Strymonikos Gulfs, the two

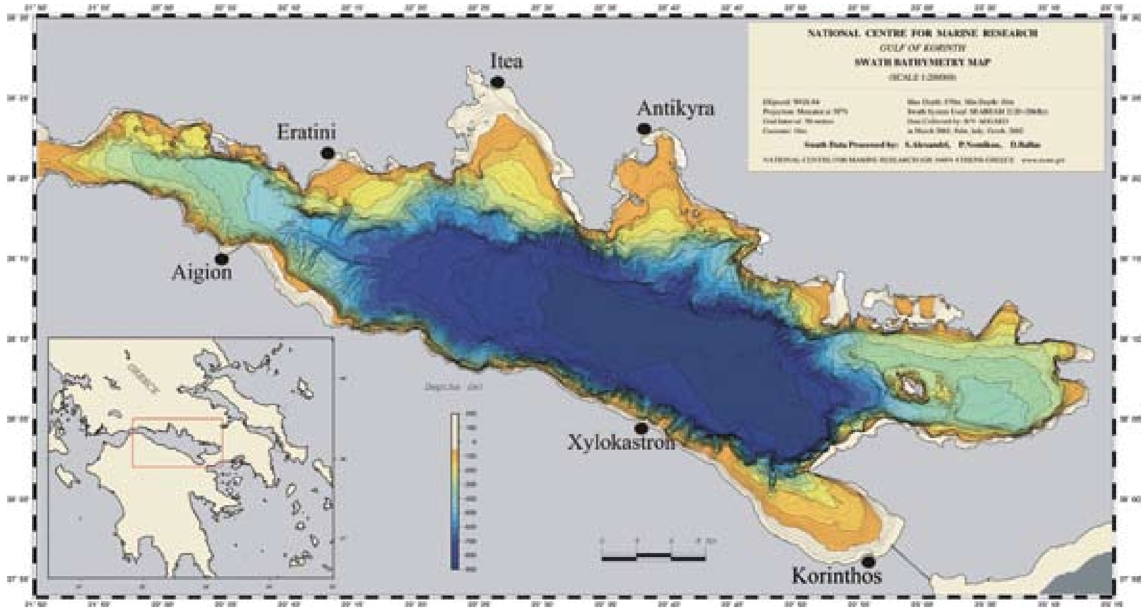

Figure 6: Swath bathymetry of the Gulf of Corinth (ALEXANDRI *et al.,* 2003).

most significant gulfs in the North Aegean, have developed on the northern shelf of the North Aegean Trough basin (Figure 3), and receive water and fertile material from large rivers.

The shallow Saronikos and S. Evvoikos Gulfs are located at the western edge of the Central Aegean plateau. Mainly biogenic sedimentation prevails on their seafloor.

On the other hand, the Lakonikos and Messiniakos Gulfs constitute two deeply incised, fault-controlled, steep submarine valleys between the three capes of the Southern Peloponnisos. They continue down-slope as canyons, which outflow into the deep basins of the Hellenic Trench.

Several semi-enclosed or isolated gulfs occur both along the eastern and the western side of Hellenic mainland. Among them, the Korinthiakos Gulf, with a maximum depth of about 900 m, has developed as a deep rupture between the Peloponnisos to the south and Central Hellas to the north (Figure 6). Together with the N. Evvoikos Gulf (Figure 5) they are considered as relatively young and tectonically active basins, formed in the frame of the extensional regime between the SW tip of the North Anatolian Fault and the NE tip of the Kefallonia Fault. The Pagasitikos and Amvrakikos Gulfs are shallower semi-enclosed basins on the Aegean and Ionian coasts, respectively.

All of the above isolated gulfs communicate with the open Aegean or Ionian Sea through shallow and narrow straits. This peculiar morphology was the main reason for the isolation from the open sea during the last low sea-level stage and their transformation into lakes. The timing of the flooding of the former isolated lakes by sea water was directly related to the depth of the respective shallow straits.

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1.2. THE DISTRIBUTION OF CHLOROPHYLL A IN THE AEGEAN AND IONIAN SEA

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Eutrophication is a serious environmental and economic problem in coastal and estuarine ecosystems that begins with the excess input of nutrients and organic matter in sea water and leads to increased production (growth) of phytoplankton. Any evaluation of the role of nutrients on eutrophication has to be carried out in a holistic perspective where (a) atmospheric deposition, (b) agricultural activities, (c) human sewage and business outfalls and (d) freshwater run-off, should be taken into consideration.

Eutrophication triggers various physical, chemical and biological changes in plant and animal communities causing thus, a multi-link chain of events.

Major consequences of eutrophication are:

1. Increases in suspended phytoplankton that are traditionally described as blooms. When blooms become dense the algae aggregate and sink into deeper water and to the bottom. Thus, eutrophication can result in increased vertical export, food supply to benthic organisms and increased oxygen consumption in bottom waters (which eventually can result in anoxia).
2. Eutrophication exerts a pressure of selection on algal populations allowing the growth of certain (dominant) species and extinguishing other species. The resulting decrease in spe-

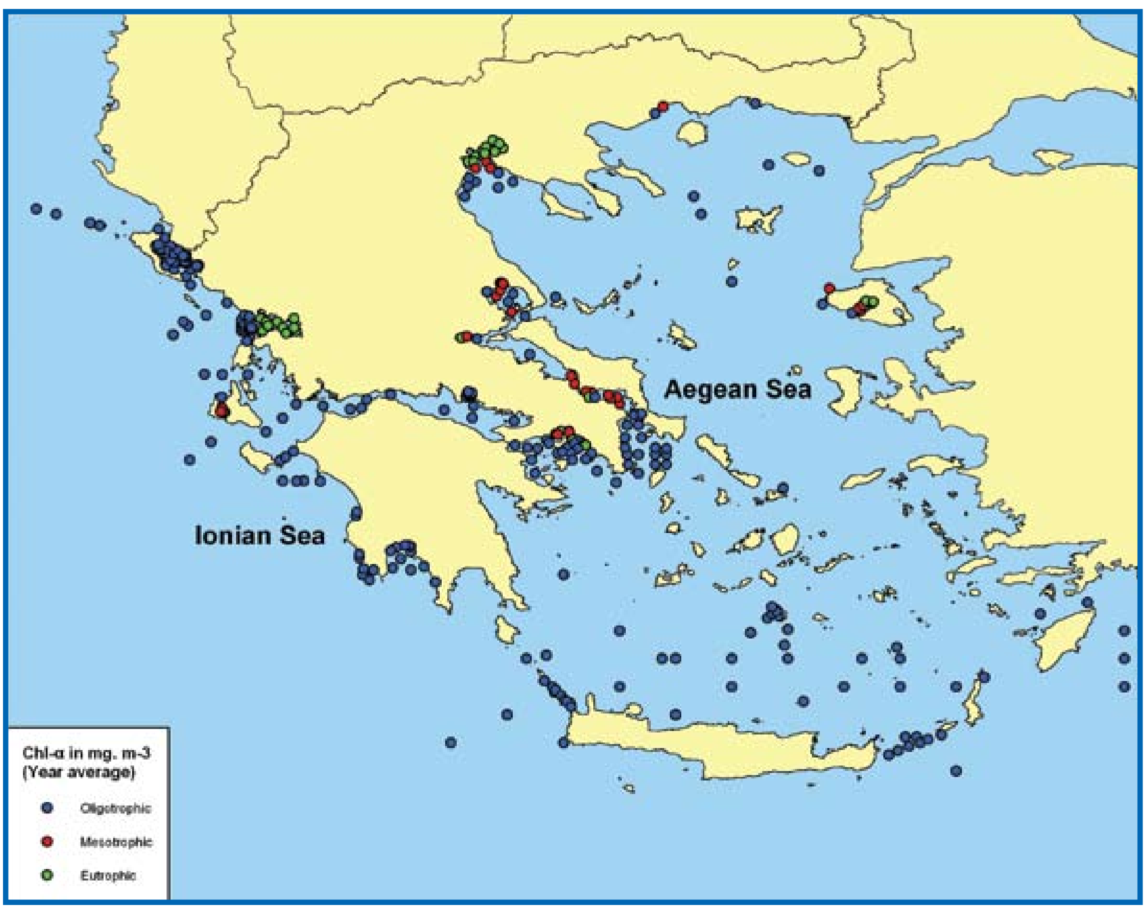

Figure 1: Mean annual values of chlorophyll α in the Aegean and Ionian Seas.
Source data: GOTSIS-SKRETAS *et al.*, 1991, 1996, 1997, 1999, 2003; ASSIMAKOPOULOU & GOTSIS-SKRETAS, 1997, 2000; GOTSIS-SKRETAS & ASSIMAKOPOULOU, 2000, 2001, 2007; IGNATIADES *et al.*, 2002, 2007; PSARRA *et al.*, 2004; KONTOYANNIS *et al.*, 2005; ASSIMAKOPOULOU & KONSTANTINOPOULOU, 2007.

Figure 2: Mean annual values of chlorophyll α in the Saronikos and South Evvoikos Gulf.
Source data: GOTSIS-SKRETAS & ASSIMAKOPOULOU, 1998; PAGOU & ASSIMAKOPOULOU, 1999; GOTSIS-SKRETAS *et al*., 2003a, b; IGNATIADES *et al*., 2007.

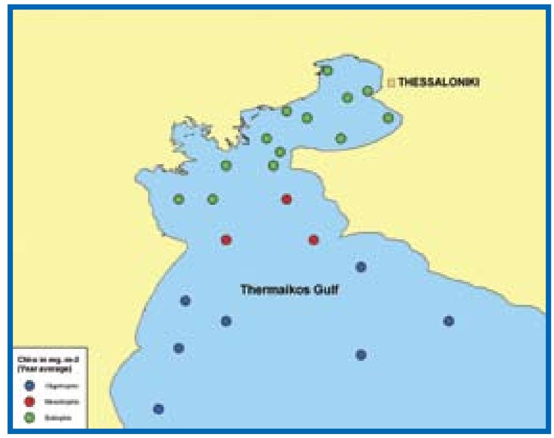

Figure 3: Mean annual values of chlorophyll α in the Thermaikos Gulf.
Source data: PAGOU & ASSIMAKOPOULOU, 1997, 2000; GOTSIS-SKRETAS *et al*., 2003a, b; IGNATIADES *et al*., 2007.

cies' diversity might have a dramatic impact on the nutritional status of the food-chain.

3. Some of the dominant species can release toxins into the water or be toxic themselves (red tides) thus creating problems in the marine ecosystem and to public health.
4. Algal blooms make the water turbid and block sunlight for macroalgae. Macroalgae, as well as flowering plants, in the coastal zone are essential for life in the sea. They provide a breeding ground, nursery, shelter, food store and feeding place for a large number of animals, including fish in their earliest stages. Macroalgae need sunlight, and when the water is turbid these algae are forced up to shallower depths. As a result, the macroalgal belts shrink and become narrower.
5. Eutrophication is both beneficial and detrimental to Fisheries. Increasing the phytoplankton growth (primary production) of a water body will generally increase overall fish production. However, changes in the phytoplankton species' composition due to eutrophication (growth of certain dominant species and loss of others) may change the quality of the algal-dependent fishery to favour those species that can feed on the available algal supply. The ability of grazing of carnivorous fish may also be reduced due to increased turbidity from increased amounts of phytoplankton as well as suspended sediment. Also, bottom fish appear to avoid the prevailing anoxic conditions in the deep layers of eutrophic environments and migrate to other grounds.

Figure 4: Mean annual values of chlorophyll α in the Amvrakikos Gulf.
Source data: PANAYOTIDIS *et al*., 1994, GOTSIS-SKRETAS *et al*., 2000 ; GOTSIS-SKRETAS & ASSIMAKOPOULOU, 2001.

This report presents data of chl α collected from the Aegean Sea and the Ionian Sea (open, offshore and inshore waters) during the last 15 years (see source data: Figures 1 - 4). The data are surface values that have been calculated as year averages per station and they have been classified with the use of scale: oligotrophic<mesotrophic<eutrophic defined as 0.5<(0.5-1.0)<1.0 mg.m^{-3} for chl α (IGNATIADES, 2005), and are presented analytically in Figures 1 - 4.
The total number of sampled stations, as well as, the number of oligotrophic, mesotrophic and eutrophic stations is given in Table 1. It is seen that the number of oligotrophic stations in both

Table 1. Total number of sampled stations and their trophic status.

Area	Stations	Oligotrophic	Mesotrophic	Eutrophic
Aegean Sea and adjacent Gulfs	178	118	31	29
Ionian Sea and adjacent Gulfs	134	119	5	10

Aegean and Ionian seas is much higher than the eutrophic ones.

From all areas, the Elefsis Bay in the western Saronikos Gulf (Figure 2), the inner Thermaikos Gulf (Figure 3), and the Amvrakikos Gulf (Figure 4) had the highest chl α values (>1 .0 $mg.m^{-3}$) and can be characterized as eutrophic areas. Also, some stations in the Maliakos, inner Pagassitikos and Kalloni gulfs exhibited high chl α concentrations. The offshore Hellenic waters (Figure 1) with chl α values <0.5 $mg.m^{-3}$ can be characterized as oligotrophic, while most coastal areas are mesotrophic. Generally, the chl α concentration is highest in estuaries and close to river mouths or big cities, reflecting the land-based inputs of nutrients.

Research on the effects of eutrophication on Fisheries in Hellenic eutrophic gulfs is scanty. One report (VASSILOPOULOU *et al.,* 2001) demonstrated that in the eutrophic Amvrakikos Gulf (Ionian Sea) the vast majority of red mullet could not reach sexual maturity, the length-at-age appeared to be smaller than in other areas of Hellas and the feeding intensity was reduced in the anoxic parts of the Gulf. It is obvious, therefore, that the fishery status in the eutrophic Stations (29 in the Aegean and 10 in the Ionian Sea) should be of high priority in future studies.

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CHAPTER II

DIVERSITY OF FISHERY RESOURCES

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INTRODUCTION

The marine living resources constitute a treasury of priceless assets for present and future generations of mankind. Despite the acknowledged value that these resources represent, relatively little is still known about them indeed, most species are unknown and whole new ecosystems have been discovered in the last two decades. Marine living resources and the benefits derived from them are under threat from several sources: fishery operations, chemical pollution, eutrophication, physical changes in habitats, and invasions of alien species. These threats were reviewed in "The State of the Hellenic Marine Environment" (SoHelME, 2005) which also gave an overview of the state of health of various oceanographic issues in the Hellenic Seas. However, issues concerning commercially exploited fish, crustaceans and mollusca were paid relatively little attention, although trend indications for these taxa have revealed that the productivity limits of the seas are being reached and often exceeded.

Biodiversity, the vast spectrum of life on this planet, includes variability within species (genetic), between species, at the community and ecosystem levels, as well as the processes that underlie ecosystem functioning. Biodiversity thus refers to the environmental life-support systems and natural resources on which we, as humans, depend.

This in turn has social and economic impacts since it affects productivity and the stability of fisheries, ecotourism opportunities and other types of industrial development. Global recognition of these problems and the fundamental link between biodiversity conservation and sustainable development is embodied in the United Nations Convention on Biological Diversity (1993).

Much pioneering work on marine habitats and their role in hosting myriads of species, some of which support fisheries, has been done in some EU countries. However, such research has just begun in Hellenic seas.

An essential step in ensuring marine biodiversity conservation in Hellas is the assessment of its current status, with regular updating thereafter so that problem areas are identified and addressed. The present chapter provides an evaluation of the current knowledge on the biodiversity of fishery resources in Hellas.

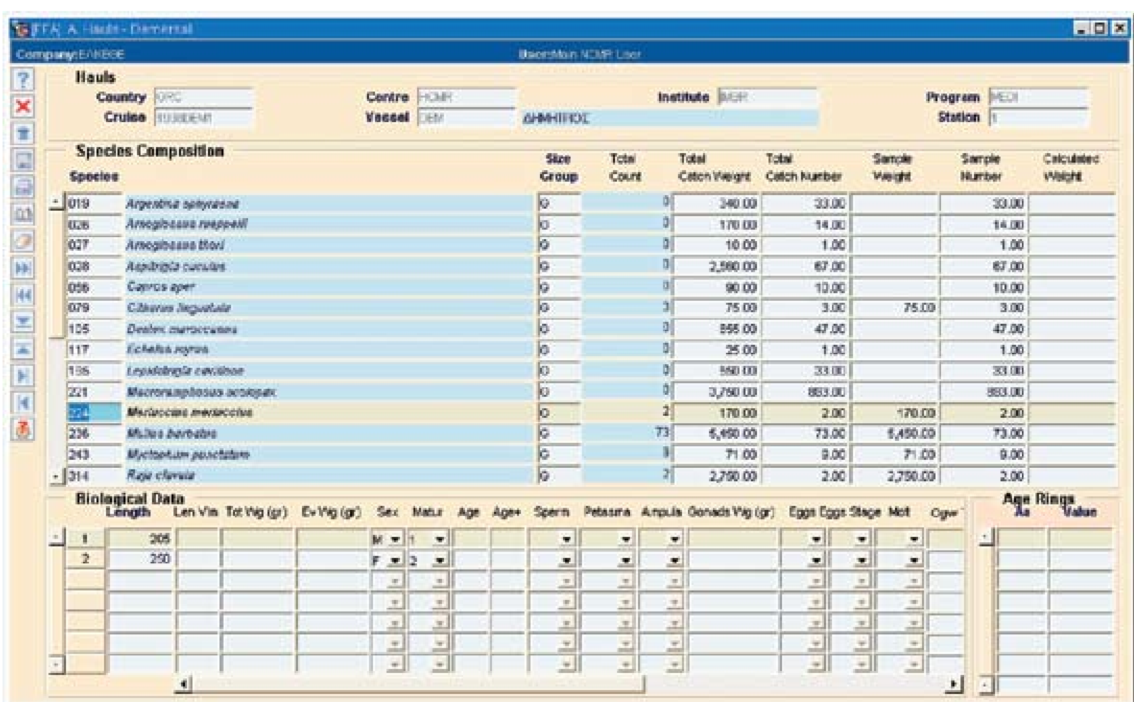

Figure 1: Entry form of the species diversity in a demersal haul. Source: IMAS - Fish, 2007.

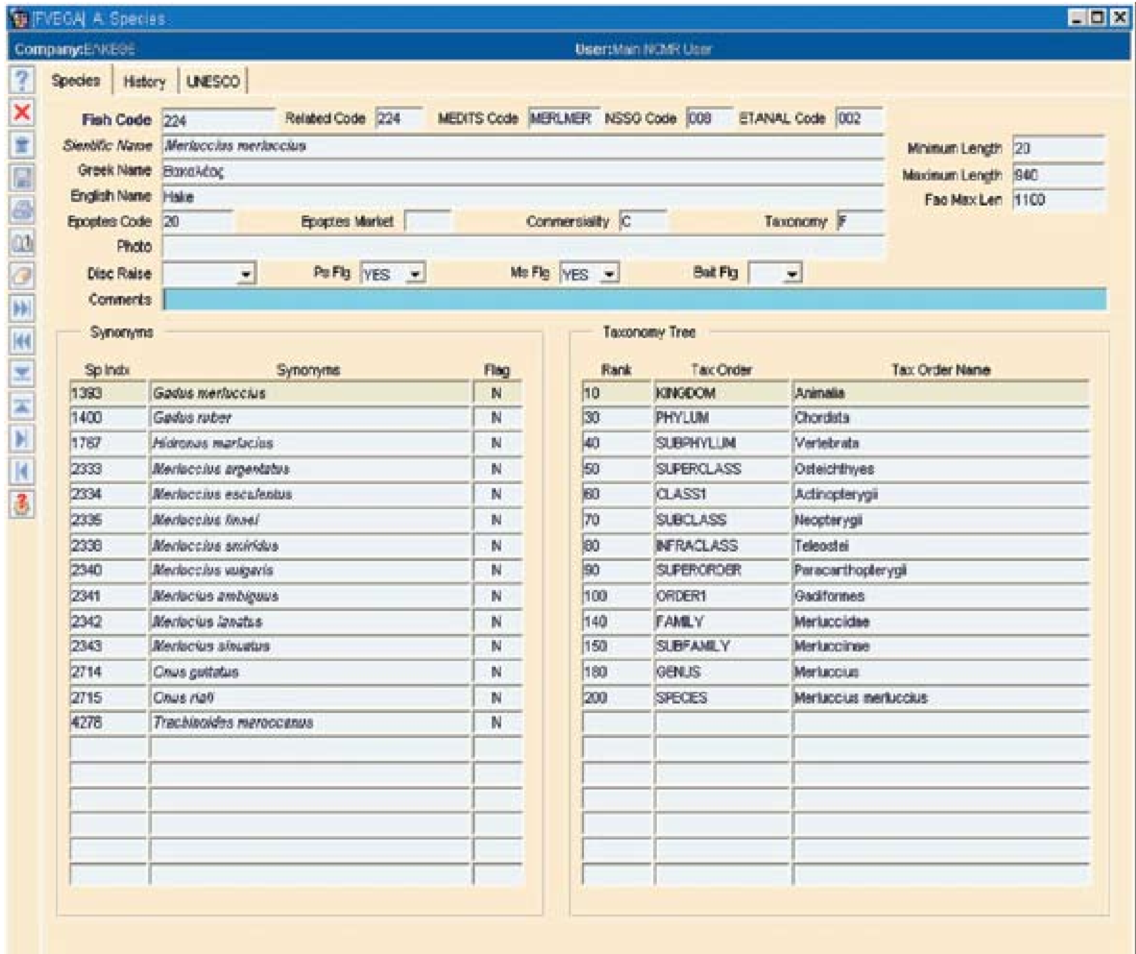

Figure 2: Entry form of a species (*Merluccius merluccius*) with full synonyms and taxonomic tree. Source: IMAS - Fish, 2007.

Much of the data presented here has been taken from the databank of the IMAS-Fish project, run by the Institute of Marine Biological Resources of HCMR. This project, which aims to develop a complete information system supporting the sustainable management of biological resources in Hellenic Seas, is funded by the Third European Support Framework – Business plan (Natural Environment and Sustainable Development). In the framework of the IMAS-Fish project, an integrated fisheries' databank has been constructed to support the data input and the statistical analysis of the collected data of the large-scale sample surveys. Examples of entry forms related to the diversity of fishery resources are presented in Figures 1 and 2. The IMAS fish databank integrates with a GIS system and the S-plus statistical package In addition to statistical analysis, it provides advanced modelling and predictions made with the help of GIS (Geographic Information Systems). A simple application of the project relevant to the diversity of marine species related to fisheries (data archived in the databank between 1988 and 2006) is presented in Figure 3.

The primary approach is to divide the spectrum of organisms into functional groups, each of which can be observed or, as appropriate, sampled at the same depth range. Representative groups are fish, mollusca and crustacean, possibly further divided into pelagic and demersal.

In all the afore-mentioned chapters, the species' diversity, depth distribution and role in fisheries are discussed.

Documenting the diversity of our biological resources is particularly timely and relevant given the importance of sustaining biodiversity and the ecosystem approach to fisheries management. Conservation of biodiversity is essential if long-term sustainability and stability in the fisheries are to be achieved.

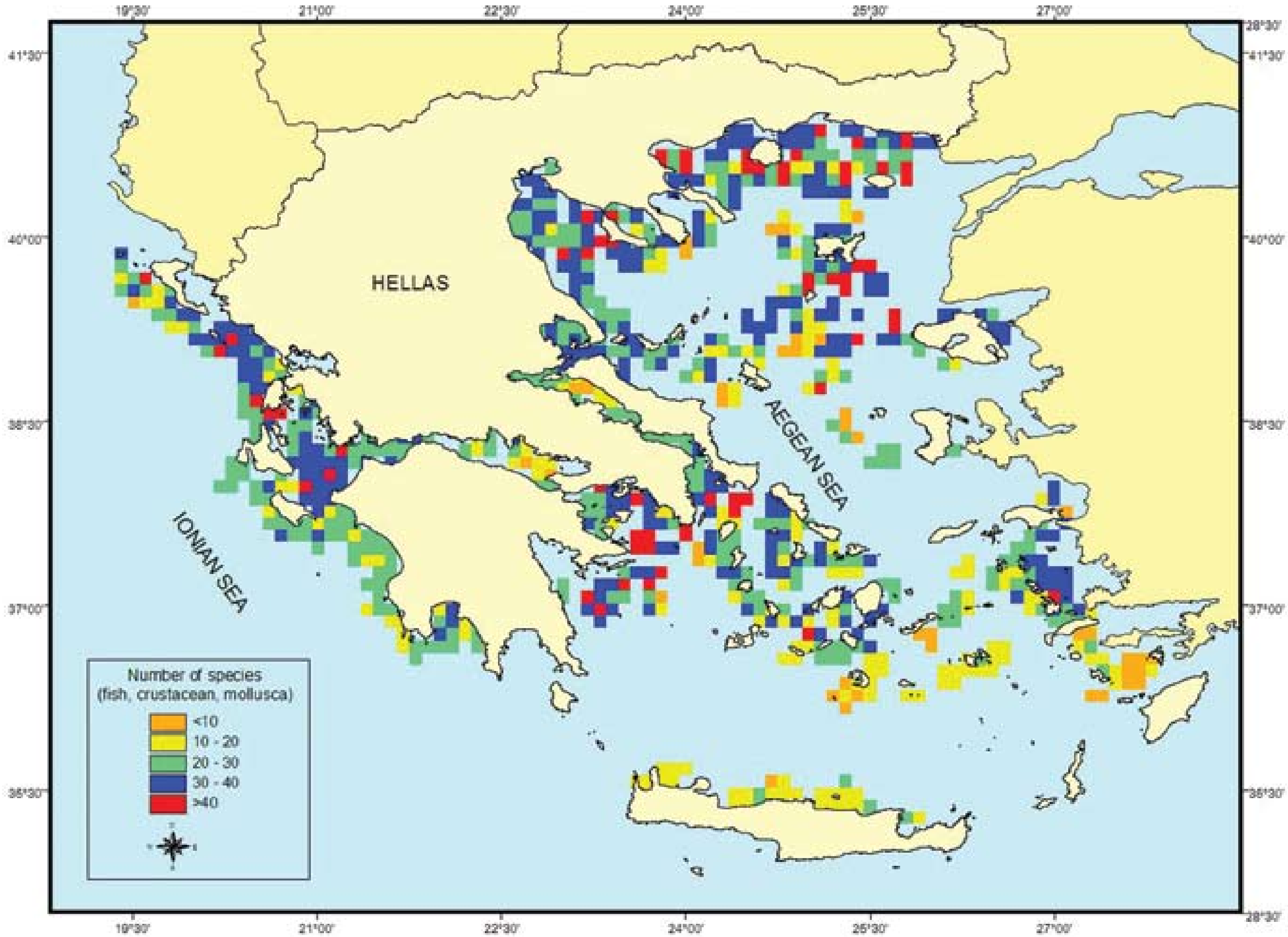

Figure 3: Distribution of selected species of interest to fisheries (crustacean, shell fish, squid and octopuses, sharks, rays and bony fish) based on various survey data. The number of species refer to the estimated mean per sampling operation.
Note: The low species number depicted in the Sea of Kriti could be an underestimation due to low sampling effort.

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II.1 FISH COMMUNITY STRUCTURE AND DIVERSITY OF DEMERSAL SPECIES

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INTRODUCTION

The Hellenic Seas are characterized by a thermophilic tropical and subtropical fish fauna originating from two different sources: i) relicts of the Tethys Sea and ii) immigrants of various origin arriving at different times from the Indian Ocean and the Red Sea (addressed in chap II.2. Corsini & Economidis, this volume). Overall, PAPACONSTANTINOU (1988) reported a total of 447 species, belonging to 129 families of which 283 species (63.3%) of Atlanto-Mediterranean origin, 21 (4.7%) are cosmopolitan species, 44 (9.8%) have a worldwide distribution and 86 (19.2%) are endemic in the Mediterranean Sea. According to the latest update the total number of recorded species is 467 (IMAS-Fish, 2007).

The Aegean Sea is separated into two sub-areas in respect of the distribution of fish fauna: (i) the northern Aegean Sea, roughly a rectangular basin, separated from the South Aegean by the archipelago of the Kyklades islands, characterized by cold water fauna, and (ii) the southern Aegean Sea characterized by more thermophilic species, as well as Lessepsian immigrants from the Red Sea PAPACONSTANTINOU, 1988).

Demersal fishes of the continental shelf and slope are subjected to an intensive fishery carried out by trawl, gill net and long line fleets. Long lines are selective gears targeting a small number of species, while gill nets and bottom trawls exploit a multi-species fishery targeting several demersal species. The results of experimental trawl fishing in the Hellenic Seas indicated that commercially important demersal and inshore stocks suffer from growth over-fishing. As a result, commercial catches consist mainly of young immature individuals and a variety of non-commercial species that are discarded (STERGIOU *et al*., 1997). Demersal and inshore assemblages from experimental and commercial sampling conducted during 1983-1994 in different fishing sub-areas, have been presented by STERGIOU *et al*. (1997) and PAPACONSTANTINOU & FARUGGIO (2000).

DEMERSAL SPECIES' DIVERSITY

The available data on the number of species and diversity patterns of soft bottom demersal fish assemblages in Hellenic waters are derived from experimental trawl surveys conducted on a seasonal basis (Table 1). The number of species is positively correlated with the number of hauls (Figure 1), increasing with latitude (Figure 2), though decreasing from west to east (Figure 3).

Based on the number of species caught during

Table 1. Summary table of the experimental hauls carried out by programme in the Hellenic Seas by HCMR.

PROGRAMME	CRUISES	HAULS	NO OF SPECIES	NO OF FISH SPECIES	MIN DATE	MAX DATE	MIN DEPTH	MAX DEPTH
North Aegean	8	216	180	150	1990	1992	25	546
Thermaikos - Thrakiko	8	288	200	170	1991	1993	16	416
Ionio - Patraikos	9	216	143	134	1980	1985	25	364
Evvoikos - Pagasitikos	8	246	145	142	1985	1988	15	346
Kyclades - Dodekanisa	4	161	210	171	1995	1996	30	633
Artificial Reefs	4	46	126	105	2004	2005	16	97
DEEP FISHERY	12	94	139	67	1996	1997	255	777
INTERREG	6	147	196	111	1999	2000	288	1192
MEDITS	30	1966	414	257	1994	2006	22	845
NECESSITY	2	8	56	47	2006	2006	84	540
Pagasitikos	4	38	93	73	1999	1999	21	94
Reshio	3	96	153	78	2000	2001	323	879

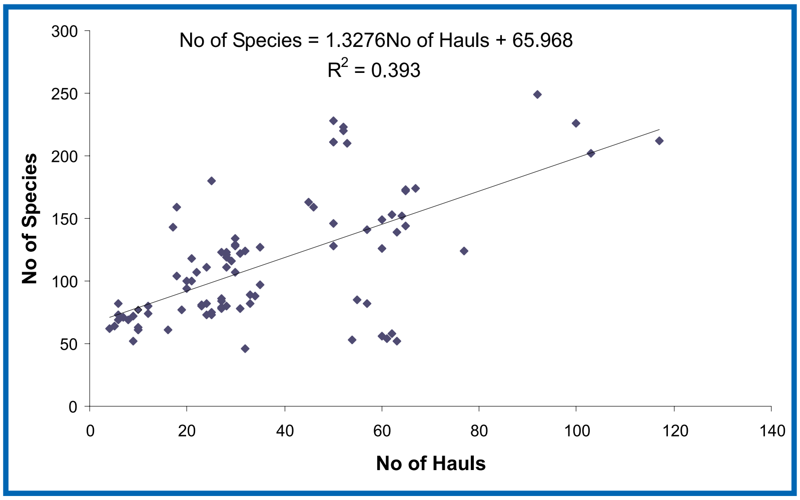

Figure 1: Relationship between number of fish species and number of hauls.

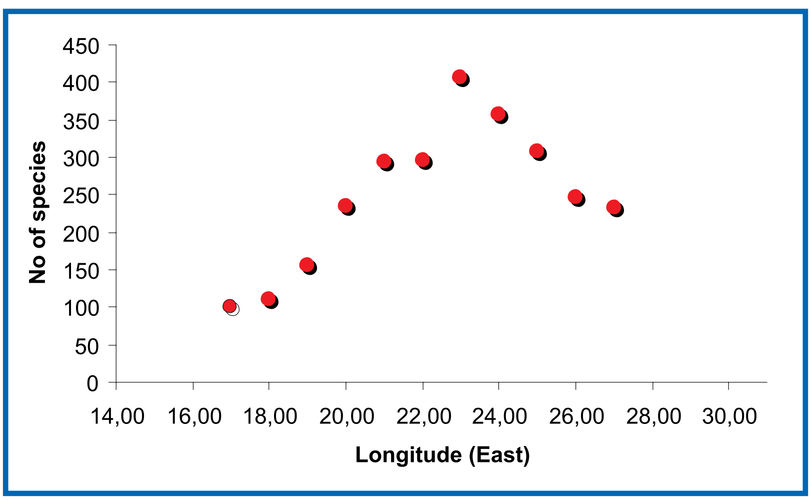

Figure 2: Relationship between number of fish species and latitude.

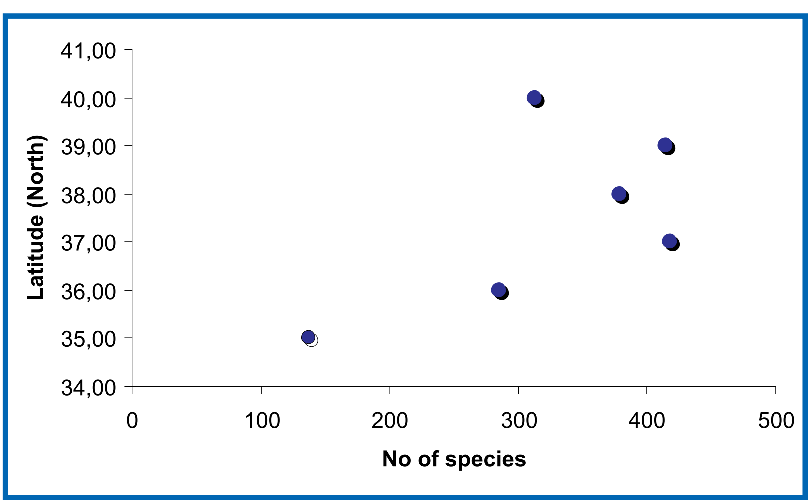

Figure 3: Relationship between number of fish species and longitude.

the experimental trawl surveys, the distribution of the number of fish species found is presented in Figure 4.

Analysis of the trawl catch data from the northern Aegean, Ionian, Thermaikos and Thracian Sea revealed that a total of 179 demersal fish species belonging to 61 families were collected from 717 trawls. In the northern Aegean Sea, 136 species were found over the continental shelf (<200 m), while the upper slope assemblage consisted of 109 species. In the Thracian Sea and Thermaikos Gulf, 150 species occurred at depths less than 200 m, as did 81 in the bathymetric range of 200-500 m. One hundred and seven species were found over the continental shelf in the Ionian Sea and 66 at depths between 200-400 m.

A feature of the presence-dominance structure of the demersal fish communities in the study area was the occurrence of a relatively small group of species that were common and abundant. Fifteen species dominated depths < 200 m (83.81% of the overall catch), while 10 (79.05%) dominated the upper slope in the northern Aegean Sea. In the Thracian Sea 23 species were most abundant on the continental shelf (89.02% of the overall catches), as were 12 species at depths below 200 m (97.36%). Similarly, 10 species made up 75.6% of the catches on the continental shelf of the Ionian Sea, with five dominating the upper slope (94.9%). The remaining species made up a small and inconstant proportion of the catches (Table 2).

DEPTH PATTERNS IN SPECIES' COMPOSITION

Classification and ordination of the trawl catch data from the northern Aegean, Ionian, Thermaikos and Thracian Sea, in terms of species abundance revealed the existence of four groups associated with the continental shelf and the upper slope. Groups I and II consisted entirely of samples taken from the shallow stations of the continental shelf (<100 m) in the northern Aegean, Thracian and Ionian Seas, respectively (Figure 5). Deeper stations on the shelf for each area (100-200 m) were subsequently classified in group III (Figure 6). All stations from the upper slope for each area were classified in group IV (Figures 7 & 8).

Dendograms indicated a high degree of similarity between samples corresponding to each group, suggesting well-defined spatial differences in species' composition for each area. Furthermore, the MDS stress values were < 0.09 in all cases verifying that the plots accurately represented the segregation of samples between groups. There did not appear to be any significant pattern of sea-

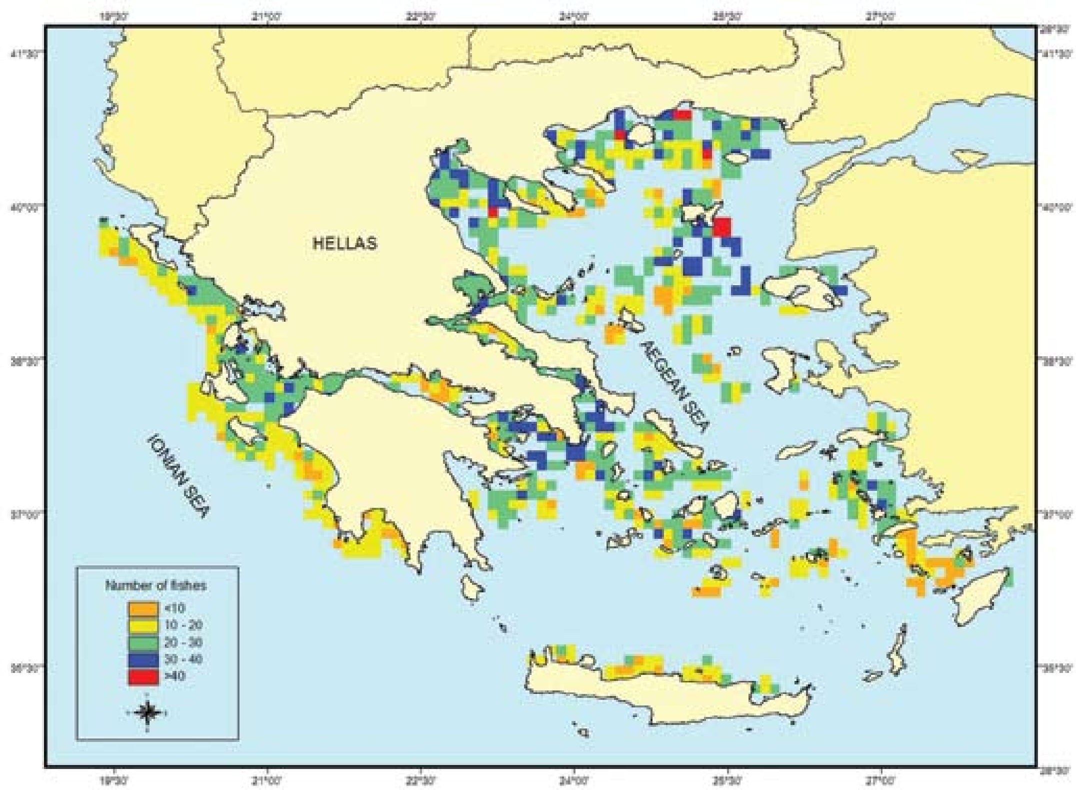

Figure 4: Distribution of the observed number of fish species in the Hellenic Seas.

sonal variation in the composition of the catches for any of the station-groups resulting from this analysis (LABROPOULOU & PAPACONSTANTINOU, 2000; LABROPOULOU & PAPACONSTANTINOU, 2003; LABROPOULOU & PAPACONSTANTINOU, 2004; LABROPOULOU & PAPACONSTANTINOU, 2005).

A relatively small number of species contributed most to the similarity of each group and area, though their relative abundances varied between adjacent groups (i.e. groups I-II, groups III-IV). Examination of the species that dominated each group and contributed highly to the similarity indicates that most species presented a wide distribution range and implies that species' differences between each group are quantitative rather than qualitative.

In each area demersal fish assemblage of the shelf differed in structure from the assemblage of the upper slope. However, no significant differences were detected between seasonal assemblages, suggesting that the abundance, distribution and association patterns of the species remained the same in time, for each area under study (LABROPOULOU & PAPACONSTANTINOU, 2004).

Differentiation between station-groups was evident by the graphical descriptors (*k*-dominance

Figure 5: Trawl catch composition at depths < 100 m.

Table 2. Dominant fish species in the northern Aegean, Ionian, Thermaikos and Thracian Sea, based on abundance rank for each station group identified by cluster analysis. Densities (%N) are averaged over all samples in each group. % Cum: average contribution to the similarity in each group. C indicates commercially important species. SD: Standard Deviation

Group III (16-28 m) average similarity: 67.8 SD: 4.9	% N	% Cum.		**Group I (30-90 m)** average similarity: 73.8 SD: 7.1	% N	% Cum.	
Arnoglossus laterna	13.55	12.37	C	**Serranus hepatus**	17.36	7.85	
Serranus hepatus	8.75	23.29		*Trisopterus minutus capelanus*	17.59	15.12	C
Diplodus annularis	4.24	32.27		*Mullus barbatus*	7.44	21.29	C
Gobius niger	6.74	40.72		*Arnoglossus laterna*	10.12	27.00	C
Mullus barbatus	30.75	48.11	C	*Merluccius merluccius*	3.21	32.08	C
Trisopterus minutus capelanus	1.21	53.63	C	*Spicara flexuosa*	6.92	37.10	
Spicara flexuosa	5.43	59.14		*Lepidotrigla cavillone*	2.75	41.71	
Trigla lucerna	1.61	64.48	C	*Cepola rubescens*	2.34	46.23	
Merlangius merlangus euxinus	3.54	69.45	C	*Deltentosteus quadrimaculatus*	5.35	50.73	
Scorpaena notata	0.45	74.15	C	*Callionymus maculatus*	3.40	55.06	
Merluccius merluccius	0.76	78.50	C	*Scyliorhinus canicula*	2.45	58.74	
Gobius paganellus	4.45	82.18		*Citharus linguatula*	1.67	62.33	C
Solea vulgaris	4.45	85.36	C	*Lophius budegassa*	0.90	65.76	C
Cepola rubescens	0.65	88.03		*Serranus cabrilla*	0.84	68.74	
				Symphurus ligulatus	0.58	71.51	
				Gaidropsarus sp.	0.42	74.05	
				Raja clavata	0.15	76.18	C
				Arnoglossus thori	0.75	78.27	C
Group II (100-190 m) average similarity: 73.6 SD=4.4	% N	% Cum.		**Group IV (200-500 m)** average similarity: 72.3 SD: 7.8	% N	% Cum.	
Trisopterus minutus capelanus	27.74	10.17	C	**Hymenocephalus italicus**	14.71	11.03	
Merluccius merluccius	10.16	18.29	C	*Gadiculus argenteus argenteus*	24.52	21.95	
Argentina sphyraena	2.04	23.95		*Lepidorhombus boscii*	5.30	31.81	C
Lophius budegassa	2.26	29.31	C	*Micromesistius poutassou*	26.42	40.85	C
Lepidorhombus boscii	1.38	34.50	C	*Coelorhynchus coelorhynchus*	2.41	47.97	
Arnoglossus laterna	2.46	39.37	C	*Phycis blennoides*	1.06	54.59	C
Scyliorhinus canicula	2.18	44.11		*Lophius budegassa*	1.14	61.12	C
Lepidotrigla cavillone	4.05	48.77		*Argentina sphyraena*	14.07	67.63	
Callionymus maculatus	2.54	53.41		*Merluccius merluccius*	6.88	74.03	C
Cepola rubescens	1.59	57.88		*Galeus melastomus*	0.50	78.95	
Serranus hepatus	6.99	62.10		*Trigla lyra*	0.37	82.62	C
Capros aper	0.88	66.07		*Capros aper*	0.16	86.12	
Phycis blennoides	0.31	69.75	C				
Aspitrigla cuculus	1.68	73.02	C				
Trigla lyra	0.33	76.27	C				
Mullus barbatus	4.53	79.52	C				

curves), for numerical abundance. Stations corresponding to groups II and III revealed more diversified and less dominated communities than those from the upper slope (group IV). The shallowest stations (group I) had an intermediate position. The curves were steeper and more elevated for group IV, suggesting that depths below 200 m were dominated by fewer species. The apparently high dominance curve for the upper slope of the Ionian Sea reflects the dominance of *Gadiculus argenteus*, corresponding to 86% of the total catch (LABROPOULOU & PAPACONSTANTINOU, 2003).

PATTERNS IN ABUNDANCE AND SPECIES' DIVERSITY WITH DEPTH

The number of hauls in each group resulting from cluster analysis was adequate to describe the different assemblages, as shown by the cumulative species' richness curves, since in all cases the curves were reaching their limits. The total number of species predicted by jack-knife estimation (S jack-knife) in all groups was higher than the actual number of species found in the respective surveys (Table 3).

Significant differences in mean species' abundance and diversity indices existed between the four depth zones for each area. The highest values of these parameters were found in samples from the continental shelf (30-100 m, group II) and decreased significantly for those from the upper slope. The reverse was true for dominance that increased significantly with depth with maximal values at depths > 200 m, except for the northern Aegean Sea, which was dominated by *Mullus barbatus* at shallow depths (25-32 m). However, ecological parameters appeared to be more or less uniform at depths between 30-195 m (i.e., groups II and III), since differences were not significant.

DETERMINING FACTORS

Four distinctive demersal fish assemblages were clearly associated with the topography of the study areas. A shallow assemblage is presented at about 30 m and represents coastal shallow bottom fauna of the continental shelf. Two assemblages corresponded to the middle (30-95 m) and deeper (100-200 m) parts of the continental shelf, and there was a deep assemblage which extended 200 m, representing the upper slope. The continental shelf assemblages exhibit greater abundance and contained species of larger size and commercial interest such as: *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus, Pagellus erythrinus,* and *Trisopterus minutus capelanus*. The upper slope assemblage was characterized by the presence of species such as *Gadiculus argenteus*, *Argentina sphyraena*, *Hymenocephalus italicus*, *Coelorhynchus coelorhynchus* and *Nezumia sclerorhynchus*, which are small and not commercially important. The main determining feature associated with the structure of the demersal fish assemblages is depth, as it reflects the changes from the continental shelf to the continental slope. However, other bottom and oceanographic characteristics also play a role, at least for structuring assemblages on the continental shelf between the three areas. Several factors appear to contribute to this geographical differentiation. These include the gradient in eutrophy, fresh/brackish water runoff, temperature and salinity differences along a NNW to SSE axis, and differences in the extent and the bottom type of the continental shelf. Neverthe-

Figure 6: Trawl catch composition at depths 100-200 m.

Figure 7: Trawl catch composition at depths 200-500 m.

Figure 8: Trawl catch composition at depths > 500 m.

Table 3. Ecological parameters by depth zone (mean ±SD) and summary of statistical tests for the demersal fish communities.

Group	Mean Depth (m)	Species (no/ km^{-2}) Mean ±SD		S (jack-knife)	Mean Richness (d)	Mean Diversity (H′)	Mean Evenness (J′)
		Min	Max				
I	22.5	25.3 (± 3.02)[a]		78.4	1.53 (± 0.57)[a]	1.55 (± 0.51)[a]	0.55 (± 0.13)[a]
	(16-28)	17	66				
II	57.3	33.8 (± 1.78)[b]		98.95	2.26 (± 0.46)[b]	1.96 (± 0.31)[b]	0.62 (± 0.09)[b]
	(30-90)	26	91				
III	122.1	33.2 (± 2.41)[b]		88.86	2.88 (± 0.90)[b]	2.19 (± 0.45)[b]	0.65 (± 0.10)[b]
	(100-190)	26	77				
IV	303.4	24.9 (± 1.17)[a]		86.65	1.63 (± 0.42)[a]	1.50 (± 0.36)[a]	0.53 (± 0.13)[a]
	(200-500)	19	69				
$F^{1}_{(3, 281)}$		50.20			54.23	41.43	14.45

[1] In all cases $P < 0.001$

less, the most important quantitative boundary for all areas was located around 200 m, a depth which separated the species of the continental shelf from those of the upper slope extending down to 500 m. Shifts in the abundance and occurrence of demersal fish species were associated with a depth gradient, even though the species were found over relatively broad depth ranges in each of the study areas. Abundances of species varied significantly with depth, but whenever the depth ranges of these species overlapped, the depth of maximum abundance changed. BROWN (1984) suggested that for ecologically similar species, those with the highest local population densities also tend to occur in a greater proportion of sampling sites and tend to have a wider spatial distribution. HECKER (1990) suggested that changes in species' composition between different megafaunal assemblages are due to the substitution of the dominant and subdominant species throughout the depth gradient by a continuous faunistic turnover.

The observed pattern of gradual species' replacement along the depth gradient is primarily based on the ontogenetic habitat shifts for some of the species and indicates that habitat selection may be based on the interaction between density-dependent food resources and density-independent environmental factors. Fish in the inshore zone tend to undertake an ontogenetic migration into deeper water (MACPHERSON & DUARTE, 1991; WARBURTON & BLABER, 1992; BLABER *et al*., 1995). CADDY (1993) hypothesized an offshore movement of older fish in several demersal species (e.g. sea breams, common pandora, mullets, etc.), possibly contributing to the continuing good recruitment in many areas, as well as to stock recovery.

Regardless of the actual balance between biotic and abiotic factors in determining the demersal fish assemblages, the occurrence of relatively homogeneous areas of species composition has some relevance to multispecies management. Mixed catches within the area of a given assemblage offer a redundancy in terms of species composition and relative abundances. Such information can be of value in dealing with by-catch and can be used to provide general guidelines for overall rational planning and management (GOMES *et al*., 1995).

The multivariate analyses did not detect any annual changes in the overall structure of the assemblages in each area. However, results suggest that changes in the assemblages' composition are weakly associated with seasonal changes. Therefore the demersal fish communities persisted over time and species rankings also remained constant, at least for the cruise dates of the study. Nonetheless, it should be noted that in order to detect temporal changes in groundfish assemblages, the length of the time-series must be considered. Some inferences are possible only with long-term data series. For example, in a study lasting from 1978 to 1991 on the Newfoundland continental shelf, GOMES *et al*. (1995) found that even though stock sizes had been declining steadily, changes in species assemblages could be detected only after several years of decline.

The number of species recorded in the present study represents 38.3% of the total marine ichthyofauna in Hellas. However, species' composition differs over the areas and depths examined. High species' richness and diversity characterized the continental shelf, but both variables decreased markedly with depth, while the reverse was true for species' dominance. On the other hand, evenness did not change with depth, indicating little variability in the numerical co-dominance of species over the depth range examined. The disparities in these general trends for group I in each area may be attributable to the more variable environments in shallow coastal waters. The *k*-dominance analysis suggested that the spatial trend in diversity and dominance was a strong feature of the species' assemblages under study, with dominance being the highest in group IV. BIANCHI *et al*. (2000), who investigated whether changes in diversity and dominance could be related to fishing, concluded that the largest changes in diversity appeared to be due to changes in evenness or species' richness, or both, often leading to an increase in diversity in response to heavy exploitation.

The overall structure of the demersal fish communities studied here stresses once more the multispecies character of the Hellenic fisheries. Management should take into account this diversity, since many fishing activities in these areas are not species' selective. Despite the enforcement of regulations for demersal and inshore fisheries in Hellenic waters (i.e. closed seasons and areas, limited issue of licenses, minimum legal landing size and mesh size regulations), the fishing effort in the northern Aegean, Ionian and Thracian Seas, as well as in the rest of the Hellenic waters, is very high (STERGIOU & POLLARD, 1994). Studies in other areas, based on extended time-series data during which major increases in fishing effort took place, indicate that fishing led to a decrease in catches and to increases in non-commercial species (OVERHOLTZ & TYLER, 1985; ROTHSCHILD, 1992). Furthermore, there is evidence that the size structure of demersal fish communities is affected by fishing. The overall trend is one of a reduction in large fish and a relative increase in small fish (BIANCHI *et al*., 2000; ZWANENBURG, 2000). Fish assemblages under consideration have suffered a long history of fishery exploitation. Therefore, over-fishing has affected the population structures and densities of the demersal fish communities, at least at depths up to 200 m, where most of the fishing activity is focused. It is possible that the organization of the demersal fish assemblages analysed is determined to a great extent by a unidirectional trend induced by fishing, bottom topography and oceanographic features of the study areas.

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II.2 ALIEN AND VAGRANT ICHTHYOFAUNA IN HELLENIC WATERS

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In a rather simplified scheme, which could also be adapted and used in the Hellenic seas, recent ichthyofauna of the Mediterranean is composed into four main groups of species:

(1) The endemics as compiled by QUIGNARD & TOMASINI (2000).
(2) The Atlantic, Boreal and Tropical including amphi-Atlantic species.
(3) The human introductions for aquaculture or aquarium purposes as well as via shipping.
(4) The Indo-Pacific/Red Sea immigrants introduced via the Suez Canal.

Several species of Atlantic origin, having a rare, maybe periodical, appearance could be eventually named *as "vagrants" or "visitors".* Others could be called "new colonizers", especially when their dispersal is favoured by special circumstances such as the Greenhouse Effect and a tendency of change in temperature and current regime in the NE Atlantic. The vagrants or visitors and the new colonizers' fish species of Atlantic origin are not easy to enumerate because their flux has continued for more than at least 10 000 years.

Concerning fish, the Indo-Pacific immigrants in the Mediterranean are *alien* species because they belong to another ecological status (thermophilous) and to a different bio-geographical zone (Indo-Pacific), and the Mediterranean is outside of their native distribution.

Among a number of about 500 native marine fish species in Hellenic waters, 41 non-native species have been recorded (Table 1) seven of which are not yet confirmed. These can be classified into three groups, namely (a) of Atlantic origin (b) Human introductions and (c) of Indo-Pacific origin.

ATLANTIC VAGRANT AND NEW COLONIZERS

A recent estimation of the fish species introduced into the Mediterranean via the Gibraltar Straits, gives more than 30 species up to 2006 (GOLANI *et al.*, 2002, 2006 on-line). Some of these could be eventually incorporated into the group of indigenous Atlanto-Mediterranean species. In Hellenic waters, the *Atlantic Vagrant* group comprises of four species originating from the Atlantic Ocean. Three species have been recorded from the Aegean: these are *Sphoeroides pachygaster*, well established in all the Mediterranean, *Enchelycore anatina* and *Seriola fasciata*. Consideration of *Gaidropsarus granti* as a non-indigenous Atlantic colonizer is questionable (Table 1).

Table 1. List of alien fishes in Hellenic waters. O: Origin (IP: Indo-Pacific, A: Atlantic, Aq: aquaculture). ES: Establishment success (E: Established, C: Casual, Q: Questionable), FR: Region of first record.

Fish	O	ES	FR	References*	World range**
Acipenser güldenstädtii	Aq	C	Evros estuaries	[1]	Black and Caspian seas estuaries and rivers
Acipenser stellatus [1]	Aq	C	Evros estuaries	[1]	Black & Caspian seas drainage, native in Evros
Acipenser sturio [1]	Aq	Q	Evros estuaries	[1]	European estuasries, native in Evros
Alepes djedaba [2]	IP	C	Aegean Sea	[2]	Indo-Pacific, Red Sea, E. Africa
Anguilla japonica ?	Aq	Q	Ionian Sea	this work	Pacific
Apogon pharaonis	IP	E	Rodos	[3]	Indo-Pacific. Red Sea, E. Africa coasts to Australia
Atherinomorus lacunosus	IP	C	Rodos	[4] [5]	Wide Indo-Pacific, Red Sea
Callionymus filamentosus	IP	C	Rodos	[6]	Indo-Pacific, Red Sea
Enchelycore anatina	A	C	Elafonissos	[7]	Eastern Atlantic
Etrumeus teres	IP	E	Rodos, Kyklades	[6] [8]	Red Sea to E. Africa, Indian Ocean to Australia
Fistularia commersonii	IP	E	Rodos	[9]	Wide Indo-Pacific, Central and South America

(continued)

Table 1. (continued)

Fish	O	ES	FR	References*	World range**
Gaidropsarus granti	A	Q	Rodos	[10]	Atlantic
Hemiramphus far	IP	E	Rodos	[11] [12] [13]	Wide Indo-Pacific, Red Sea
Huso huso	Aq	S	Evros estuaries	[1]	Black and Caspian seas drainage
Iniistius pavo	IP	C	Rodos	[14]	Wide Indo-Pacific, Red Sea included, and E. Pacific
Lagocephalus sceleratus	IP	E	Rodos	[14]	Indo-Pacific
Lagocephalus spadiceus	IP	E	Samos	[15]	Wide Indo-Pacific, Red Sea
Lagocephalus suezensis	IP	E	Rodos	[6]	Red Sea endemic
Leiognathus klunzingeri	IP	E	Rodos	[16]	Red Sea
Liza carinata ?	Aq	Q	Amvrakikos	this work	Western Indian, Red Sea
Liza haematocheila	Aq	E	Thracian Sea	[17]	Far eastern Asia from Russia to China
Micropterus salmonoides	Aq	Q	Ionian Sea	this work	Fresh Water, West Atlantic
Pagrus major ?	Aq	Q	?	this work	Northwest Pacific
Parexocoetus mento	IP	E	Rodos	[16]	Wide Indo-Pacific from Red Sea to Fiji
Pempheris vanicolensis	IP	E	Kastellorizo	[18]	Wide Indo-Pacific, Red Sea
Petroscirtes ancylodon	IP	C	Rodos	[6]	Red Sea to Arabian Gulf
Pteragogus pelycus	IP	E	Symi	[19]	Red Sea to E. Africa
Sargocentron rubrum	IP	E	Rodos	[20]	Indo-Pacific (E. Africa to Samoa and Japan)
Saurida undosquamis	IP	E	Naxos	[21]	Indo-Pacific to Australia and S. Japan
Seriola fasciata	A	C	Rodos	[14]	Eastern and Western Atlantic
Siganus luridus	IP	E	Tilos	[22]	Red Sea, E. Africa to Arabian Gulf
Siganus rivulatus	IP	E	Rodos	[23]	Red Sea and Gulf of Aden
Sphoeroides pachygaster	A	E	Rodos	[24]	Atlantic, Indian oceans
Sphyraena chrysotaenia	IP	E	Rodos	[19]	Indo-Pacific to China and N. Australia
Sphyraena flavicauda	IP	C	Rodos	[6]	Wide Indo-Pacific, Red Sea, E. Africa
Stephanolepis diaspros	IP	E	Rodos	[11] [12] [13]	Red Sea to the Arabian Gulf
Torquigener flavimaculosus	IP	C	Rodos	[25]	Red Sea, Arabian Gulf, E. Africa, Seychelles
Tylerius spinosissimus	IP	C	Rodos	[6]	Indo-West Pacific, Southeast Atlantic
Tylosyrus crocodilus	IP	C	Chalkidiki	[26]	Wide Indo-Pacific
Upeneus moluccensis	IP	E	Rodos	[27] [28]	Indo-Pacific
Upeneus pori	IP	C	Rodos	[6]	Red Sea, Gulf of Oman

([1]): As the species is considered as rare or extinct from its native range in Evros drainage, the new records may concern specimens from stocking (KOUTRAKIS & ECONOMIDIS, 2006).

([2]): The occurrence of *Alepes djedaba* in Hellenic waters is to be ascertained.

* [1] KOUTRAKIS & ECONOMIDIS, 2006; [2] BINI, 1960; [3] CORSINI FOKA *et al*., 2004; [4] QUIGNARD & PRAS, 1986; [5] CORSINI, 2004, new data; [6] CORSINI *et al*., 2005; [7] GOLANI *et al*., 2002; [8] KALLIANIOTIS & LEKKAS, 2005; [9] CORSINI *et al*., 2002; [10] ZACHARIOU-MAMALINGA, 1999; [11] TORTONESE, 1946, [12] TORTONESE, 1947a [13] TORTONESE, 1947 b; [14] CORSINI *et al*., 2006; [15] ANANIADIS, 1952; [16] KOSSWIG, 1950; [17] KOUTRAKIS & ECONOMIDIS, 2000; [18] PAPACONSTANTINOU & CARAGITSOU, 1987; [19] CORSINI & ECONOMIDIS, 1999; [20] LASKARIDIS, 1948a; [21] ONDRIAS, 1971; [22] KAVALLAKIS, 1968; [23] BRUNELLI & BINI, 1934; [24] ZACHARIOU-MAMALINGA & CORSINI, 1994; [25] CORSINI *et al*., 2006; [26] SINIS, 2005; [27] SERBETIS, 1947; [28] LASKARIDIS, 1948b.

** Based on: GOLANI *et al*., 2006 on-line; FROESE & PAULY, 2006.

The regular or rare appearance of "Atlantic" species in the Mediterranean is a more complicated phenomenon depending mainly on hydro-climatic long-term changes and short-term trophic relations among species. The active movement according to trophic availability concerns the errant large pelagic species such as sharks, various tunids, tetrapterids, swordfish, etc. Several such species are seasonal regular or rare vagrant visitors. In some other cases, such as the sea lamprey (*Petromyzon marinus*), the parasitic mode of life forces it to move faraway from its normal distribution. Therefore, the record of this last species in the North Aegean Sea (ECONOMIDIS *et al*., 1999), where there are no spawning grounds for permanent settlement, could be qualified as accidental and the species as "*vagrant*". A similar example would be given to any species of remoras, accompanying large marine animals, such as the *Remilegia australis* (synonym of *Remora australis*), signalled long ago in Hellenic waters (TORTONESE, 1946, 1947a), which, however, according to GOLANI *et al.* (2002) is very rare but it could be considered as a Mediterranean resident.

In several other cases, such as the Atlantic muraenid *Enchelycore anatina,* the spreading from the Atlantic to the Mediterranean, where there are only two records one of which is from Elafonissos (Peloponnisos coasts) (GOLANI *et al*., 2002), could be explained by passive dissemination of the leptocephali larvae and/or via transport in ship ballast.

HUMAN INTRODUCTIONS

There is no documented record that some alien fish species are introduced into the Hellenic Seas by ship ballast. But, on the other hand, uncontrolled and/or closed down aquacultures are responsible for releasing specimens in the wild from their reared stocks. In the Hellenic Seas such cases have already been observed. One of these may concern some mullet specimens, apparently *Liza carinata*, captured in several western Hellenic estuaries (unpubl. data). Such a species was introduced long ago as fry from Egypt to a fish farm near Arta (river Arachthos estuary in the Amvrakikos Gulf), which subsequently closed down. However, the species has also been recorded in the eastern Mediterranean (GOLANI *et al*., 2002) although its establishment seems to be rather problematic. It is known that around Hellenic and other European estuaries, among captured adult European eels (*Anguilla anguilla*) there are also some specimens of elvers of the Japanese eel (*Anguilla japonica*) as well as other alien eel species which have escaped from eel farms.

Another case concerns the largemouth bass, *Micropterus salmoides* which was captured near the estuaries of the Lessini Stream (PE ECONOMIDIS, unpubl. data). Very recent records concerning several sturgeons' species such as *Acipenser güldenständi*, *Huso huso* or various reared hybrids as well as *Acipenser sturio*, captured in the Thracian Sea, near the Evros River estuaries or in the river itself, strongly suggest that they originate from the release of fry or escapees from hatcheries lying in the Evros River catchment of Bulgaria and/or of Turkey, as there are no such installations in the Hellenic part of the river. With regard to Bulgaria, this information has been verified recently (KOUTRAKIS & ECONOMIDIS, 2006). Therefore, some previous records of *Acipenser stellatus* (ECONOMIDIS *et al*., 2000) maybe have had the same origin. Furthermore, there is unverified information that certain alien fish species (e.g. *Pagrus major*) or even fry of native Mediterranean fish such as *Dicentrarchus labrax* and *Sparus auratus*, and perhaps other species too, originating from distant areas (i.e. Spain), are used largely in marine hellenic fish farms. Consequently, very often these species of different genetic stock are released or escape as fry or adults into the wild. An example of human introductions is the Indo-Pacific native mullet, *Liza haematocheila* (*Mugil soiuy*), which was reared in Black Sea cage fish farms and following the closing down of many of these farms in the nineties was carelessly released into the Azov and Black Sea area (STARUSHENKO & KAZANSKY, 1996). Soon after having entered the Mediterranean, the species was observed in the Thracian Sea (KOUTRAKIS & ECONOMIDIS, 2000), where locally (e.g. Thracian lagoons) it has been exploited and thus appears frequently in the fish markets in northern Hellas (unpubl. data).

INDO-PACIFIC ALIENS

For the movement of various marine organisms from the Indo-Pacific and the Red Sea to the Mediterranean via the Suez Canal POR (1969) coined the term "Lessepsian migration", a term widely used in literature thereafter.

This third group includes the majority of alien species (27 species plus one uncertain, representing 79.4%). It is worth noting that the majority of these species have quite a slow process of spreading and settlement, underlining their thermophilous and stenohalous, tropical or sub-tropical, character. In the Mediterranean such environmental conditions are current in the eastern basin, mainly along the Asian coast. In the Aegean Sea a similar situation occurs in the SE corner around the Dodekanisos

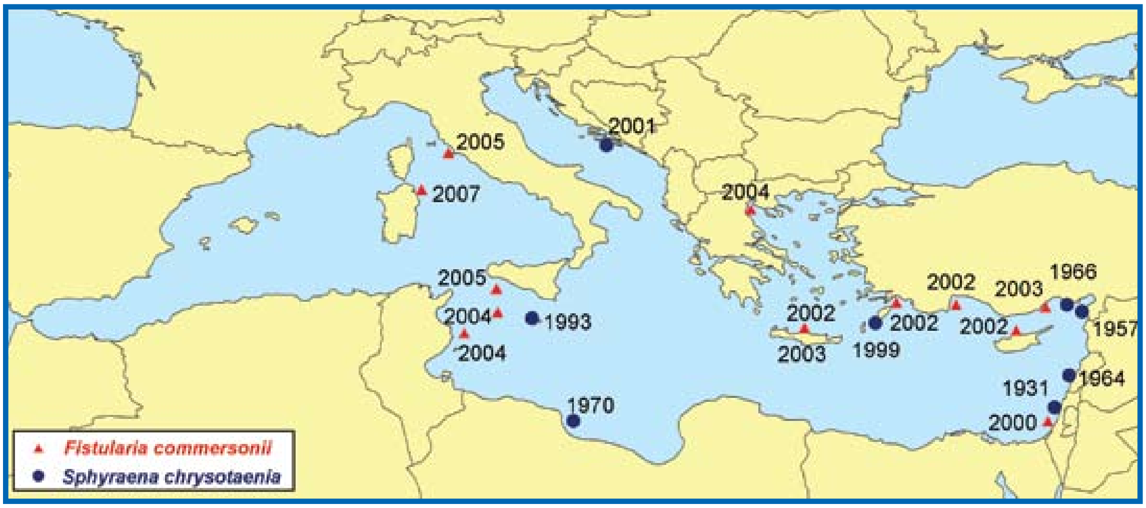

Figure 1: Chronicle of the establishment and spreading of *Fistularia commersonii* and *Sphyraena chrysotaenia* along the Mediterranean coasts (GOLANI *et al.*, 2006 on-line; ICES, 2006; PAIS *et al.*, 2007).

continental plateau. There is evidence that the contribution of the Indo-Pacific alien species into the Aegean Sea fish species' composition, and their population structure, is accelerating gradually, as many populations of these species have already created fishable stocks, as long ago *Upeneus* and *Siganus* species in the Dodekanisos islands and more recently *Fistularia commersonii* (CORSINI *et al.*, 2002; KALOGIROU *et al.*, 2007) and *Etrumeus teres* in the Kyklades (KALLIANIOTIS & LEKKAS, 2005).

Intensive research during recent years brought to light more alien species which might have been present but apparently in low densities and thus had escaped our attention (CORSINI & ECONOMIDIS, 1999). The flux of invaders appears to be continuous (STREFTARIS *et al.*, 2005) and furthermore, considering the spread of the distribution of these alien species, the need for continuous up-dating or a monitoring procedure is obvious (ZENETOS *et al.*, 2005; PANCUCCI-PAPADOPOULOU *et al.*, 2005).

ESTABLISHMENT SUCCESS

The older records of Lessepsian fishes in Hellenic waters until 1990 amounted to thirteen species (PAPACONSTANTINOU, 1987, 1990; see also References in Table 1). Among these the following can be mentioned: *Siganus rivulatus, Hemiramphus far, Stephanolepis diaspros*, *Upeneus moluccensis*, *Sargocentron rubrum* and *Lagocephalus spadiceus*. An increase of records has been evident in the last decade, when 15 other such species have been added. Altogether they represent about 41% of the Lessepsian teleosts introduced species, estimated today for the whole of the Mediterranean Sea.

CORSINI & ECONOMIDIS (1999) mentioned that several Indo-Pacific species were signalled almost simultaneously in the Dodekanisos and on the coast of Israel. Such is the case of *Siganus rivulatus*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Pteragogus pelycus* and *Fistularia commersonii*. In contrast, *Sphyraena chrysotaenia* (*pinguis*), *Apogon pharaonis*, *Etrumeus teres* and some others have been advancing slowly along the Anatolian coast. The latter immigrants have reached this area after a relatively long time, depending on the biotic and abiotic factors (GOLANI, 1998; CORSINI & ECONOMIDIS, 1999) (Table 1) (Figure 1). There is a direct relation between environmental conditions and the rate of spreading and adaptation of the new settler. In fact, species have to face a combination of unfavourable ecological conditions (water temperature, substratum, currents, trophic conditions, etc.) when following the narrow continental shelf of the South Anatolian coast as the main way for westward spreading, as the majority of such species are rather coastal. Consequently, once they reach the continental shelf of the Dodekanisos islands, usually they do not advance any further, while some of them are commercially exploited.

On the other hand, a large number of Lessepsian immigrants, being quite common in the Levantine, have not been recorded in the SE Aegean Sea.

It is obvious that several fish species already detected and established along the Levantine Turkish coasts are to be expected also in Hellenic waters. These especially are: *Dussumieria elopsoides*, *Herklotsichthys punctatus*, *Pelates quadrilineatus*, *Sillago sihama*, *Oxyurichthys petersi*, *Scomberomorus com-*

Table 2. Spreading of Lessepsian fishes in Hellenic waters out of the Dodekanisos continental shelf.

Species	North Aegean	South-Central Aegean	Ionian Sea	References*
Etrumeus teres		+		[1] [12]
Fistularia commersonii	+	+		[12] [2][3] [4]
Lagocephalus sceleratus	+	+		[5]
Lagocephalus spadiceus		+		[6]
Leiognathus klunzingeri	+	+		[3]
Parexocoetus mento		+	+	[3]
Pempheris vanicolensis		+		[4]
Saurida undosquamis		+	+	[7] [3] [8]
Siganus luridus		+	+	[3] [4]
Siganus rivulatus		+	+	[3] [4]
Stephanolepis diaspros		+	+	[3] [9] [12]
Tylosurus crocodilus	+			[10]
Upeneus moluccensis		+	+	[12] [11] [3]

* [1] KALLIANIOTIS & LEKKAS, 2005; [2] Chalkidiki, KARACHLÈ *et al.*, 2004; [3] GOLANI *et al.*, 2006 on-line; [4] Kriti, TINGILIS *et al.*, 2003; [5] Kriti, KASAPIDIS *et al.*, 2007; [6] Samos, ANANIADIS, 1952; [7] Naxos, ONDRIAS, 1971; [8] Kriti, TSIMENIDIS *et al.*, 1991; [9] Kriti, ECONOMIDIS & BAUCHOT, 1976; [10] Thermaikos, SINIS, 2005; [11] Patraikos, KASPIRIS, 1976. [12] Various areas, PERISTERAKI *et al.*, 2006.

merson and *Cynoglossus sinusarabici*.

Spreading: Lessepsian immigrants once having reached the Dodekanisos continental shelf (SE Aegean) seem to have difficulties for further spreading northwards to the north Aegean Sea, whereas their distribution is easier westwards (to the Ionian Sea). In fact, among the 28 Lessepsian fish species listed in Table 1, only four have been recorded in the North Aegean Sea (Table 2). Moreover, spreading to the south, central or the western Aegean and the Ionian Seas seems to have a low success, as only ten species have been recorded following this pathway (Table 2). The record of *Tylosurus crocodilus* in the Chalkidiki peninsula, based on a dead fish found on Gerakini beach (SINIS, 2005), needs a special mention as a record which merits further investigation. This is a first record for the Mediterranean and its derivation as a rejected specimen from undelivered foreign stock should also be contemplated.

This statement shows that some abiotic (water temperature, salinity, currents regime, size of continental shelf, etc.) and/or biotic factors (food quality and quantity, spawning facilities, etc.) are further impeding the spread of Lessepsian fish. In general, the species showing a wide distribution area (Table 1) are noticeably eurythermous as they are either true temperate species or they can adapt quite easily to temperate regions. The above-mentioned species which have spread out of the Dodekanisos area, fall into this category, as the majority of them are being eurythermous.

Although the continental shelf of Kriti, in the south Aegean Sea, is lying in a rather warm water zone, the colonization by Lessepsian immigrants presents some interesting particularities. Since these species are regarded as thermophilous, it would be expected that they would settle more easily in the coastal waters of Kriti. However, it is obvious that unfavourable factors seem to prohibit their large scale settlement there, as only eight fish species have been recorded from that area, two before 2002 (*Stephanolepis diaspros* and *Saurida undosquamis*), and six in the last four years: *Siganus luridus* and *Fistularia commersonii*, *Siganus rivulatus* and *Pempheris vanicolensis* and recently, *Lagocephalus sceleratus* and *Etrumeus teres* (Table 2). It is possible that these new records are the result of recent more intensive investigations, although the number of species remains low. This phenomenon could be attributed to the fact that although the continental shelf of Kriti is accessible to Lessepsian immigrants by the Kasos-Karpathos corridor, its colonization is low, mainly because this corridor is very narrow and surrounded by exceptionally deep water thus isolating the coastal zone of Kriti.

In conclusion, the westward spreading of Lessepsian species will proceed slowly, but may accelerate if the increase in water temerature continues. A rearrangement of the population structure is already appearing in the eastern basin and this could be an important factor for fishery management.

Habitat: At present most Indo-Pacific alien in-

Figure 2: The alien *Sphyraena flavicauda* (above) and the indigenous *Sphyraena viridensis* (below), caught in the same trawl (Trianda Bay, NW Rodos, 18 December 2006) (Photo: G. KONDILATOS).

vertebrates occupy the Mediterranean littoral and infralittoral zones to a depth of approximately 50 m, and are hardly found in deeper water (GALIL & ZENETOS, 2002). This is also true for the Lessepsian fish species, the majority of which are coastal species dwelling in rather shallow sandy or muddy habitats (GOLANI, 1993) or rocky shores, often covered by sea-grass.

In Rodos and other Dodekanisos coastal areas the majority of Lessepsian fishes are collected by trawlers at depths around 50 m, mostly on sandy-muddy bottoms, covered by well-developed Chlorophyceae beds (*Caulerpa prolifera* and *Caulerpa racemosa*) and Phanerogame beds, mainly *Posidonia oceanica* but also *Halophila stipulacea* (CORSINI & ECONOMIDIS, 1999; CORSINI *et al*., 2005, 2006). Other species such as *Pempheris vanicolensis*, *Sargocentron rubrum* and schools of juvenile *Shyraena chrysotaenia* are found on sandy-rocky bottom or in the case of *Iniistius pavo* on very shallow sandy areas. On the other hand, CORSINI *et al.* (2005) collected *Tylerius spinosissimus* at a depth of 80 m, which is less than that known for the species in tropical waters, but deeper than the average for Lessepsian immigrant fish found in the SE Aegean Sea. This probably indicates that there may be several unexplored niches in the region, suitable to the new colonizers. The first record of a young pufferfish in Rodos, found far away from the Suez Canal, indicates that a certain population of the species has already been established in the eastern Mediterranean, especially closer to Suez Canal areas, and spreading follows quite unusual ways. However, it is possible that other vectors (ship ballast, aquaculture or aquaria purposes transport), different from the natural pathway, may be responsible for the introduction of the Indo-Pacific species such as the spiny blaasop *Tylerius spinosissimus*, in common with other taxa also introduced in this way into Hellenic waters (PANCUCCI-PAPADOPOULOU *et al*., 2006).

Abundance and interactions: The abundance of some Lessepsian migrant fishes has already reached economic importance in the south-eastern Levantine and Anatolian fisheries.

Populations of Lessepsian fishes all over the coastal waters of the Dodekanisos continental shelf correspond generally to species that have been previously established there and they have been large enough to be commercially exploited (CORSINI *et al*., 2005). Among the established species listed in Table 1, the majority are caught regularly, but they cannot be considered as abundant. These are namely: *Hemiramphus far*, *Stephanolepis diaspros*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Saurida undosquamis*, *Atherinomorus lacunosus*, *Pempheris vanicolensis*, *Pteragogus pelycus* and *Apogon pharaonis*. On the other hand, some other species established successfully, are common and acquired commercial importance, i.e. *Siganus luridus*, *S. rivulatus* and *Sphyraena chrysotaenia*, the latter is normally confused with the two indigenous species *S. sphyhraena* and *S. viridensis* coexisting in the same coastal area (CORSINI & ECONOMIDIS, 1999), as well as with the recent Lessepsian colonizer *S. flavicauda* (Figure 2). The rapidly increasing population of the recent colonizer *Etrumeus teres* is already contributing to fishery resources of the Dodekanisos (CORSINI-FOKA, unpubl. data) and in the Kyklades Islands (KALLIANIOTIS & LEKKAS, 2005), as it has also been observed in Israel, Cyprus and the Turkish Mediterranean waters (GOLANI *et al*., 2006 on line).

Local indigenous fishes, especially the small-sized and the fry of many species are subjected to intense predation pressure. This fact presents the other side of the coin, maybe suggesting that several invaders as well as the native species are competing in this predation. Consequently, the impact on the local exploited populations by Lessepsian immigrants seems to be serious and accelerated in some cases. Thus a more detailed approach on this matter is needed.

The permanent establishment of a large population of a Lessepsian species in the area, and consequently how harmful this would be for the native species, is related to its reproductive success. In many cases such a successful breeding in combination with food availability and other favourable environmental factors very often lead to a population explosion. Such was the case of *Upeneus moluccensis* which during the 1940s showed a population explosion in the area (LASKARIDIS, 1948a), followed by a dramatic crash shortly after, so that nowadays this species is rarely found in the area (CORSINI & ECONOMIDIS, 1999).
Several Indo-Pacific invaders may have found vacant ecological niches and obviously they do not compete with local native species. Thus, *Siganus luridus* and *S. rivulatus* were well established in the entire Levantine basin initially and then invaded the central Mediterranean, their establishement was due to the presence of few herbivorous competitors and/or abundant available food. Furthermore, *Upeneus moluccensis* is present but it does not dominate *Mullus barbatus*. Also, *Apogon pharaonis* is regularly caught in trawl nets as well as its indigenous counterpart *Apogon imberbis*, while the small *Pteragogus pelycus* occurs with other labrid species of similar size (for example, *Symphodus* sp., *Coris julis*, *Thalassoma pavo*). Schools of Sphyraenidae are also noted, both belonging to the indigenous species *Sphyraena sphyraena* and *S. viridensis* but also to the Lessepsian *S. chrysotaenia and S. flavicauda* (see above). *Saurida undosquamis* is very rare compared to *Synodus saurus*. On the other hand, no local fish species disappeared in the Rodos waters.

Case study: *Fistularia commersonii*. In terms of impact, the blue cornetfish, *Fistularia commersonii*, a recent invader caught normally by trawl nets up to 50-60m depth, has developed an important population and is considered at the moment one of the worst invasive species (STREFTARIS & ZENETOS, 2006). This species presents a very fast expansion along the coasts of the Levantine basin (GOLANI, 2000; CORSINI *et al*., 2002) and recently up to the north Aegean Sea (Chalkidiki peninsula), to the northern coasts of Kriti and westward to the central Mediterranean and Tyrrhenian Sea (GOLANI *et al*., 2006 on line; PAIS *et al*., 2007) (Figure 1). The phenomenon is alarming because this fish reproduces and grows very rapidly, reaching a remarkably large size (Figure 3). Since its first appearance in 2001 in the Rodos marine area, the blue cornetfish actually occurs at a number of 5 to 20 specimens occasionally in a catch of any trawl nets' operation, mainly at 20-25 m depth, but also in very shallow waters at 20-30 cm of depth around the coasts.
Additionally, the species presents an extreme feeding activity and a clear aggressive behaviour when in schools. As a free-swimming carnivorous fish, it is merely dwelling over reefs and sea-grass beds. As it has no or a little commercial value, it is subjected to very low fishing pressure, being rather a "by catch" fish than a target. Consequently, it is free to form large populations which seriously

Figure 3: A large specimen of *Fistularia commersonii* (the man's height is 1.8m), caught along the SE Rodos coasts, 16 m depth, December 2005 (Photo: TH. FROUMIS).

Figure 4: A specimen of *Lagocephalus sceleratus* from Rodos coastal area (SL 376 mm) (Photo: G. KONDILATOS).

affect economical and ecological important native species not only in the limited area of SE Aegean Sea, but in all the occupied new habitats, such as the South Aegean Sea (unpublished data). It mainly feeds on fry and several exploited populations of economically valuable native fish, namely *Spicara smaris*, *Mullus* sp. and *Boops boops* (KALOGIROU *et al*., 2007).

Case study: *Lagocephalus sceleratus*

Among alien tetraodontids colonizers, the population of the large sized *L. sceleratus* (Figure 4), which is not marketable because it may be a source of food poisoning, is increasing rapidly in Aegean waters (CORSINI *et al*., 2006; BILECENOGLU *et al.*, 2006; PANCUCCI-PAPADOPOULOU *et al*., 2005; KASAPIDIS *et al*., 2007) and this fact is sustained also by very recent unpublished data which show the presence of a large number of juveniles in trawling activities along the coasts of Rodos Island.

CONCLUSIONS

Almost the entirety of alien fish species introduced for aquaculture and their presence in nature is based on unverified observations of free swimming specimens which strongly suggest careless release or escape from fish farms. The list of species is expected to gradually increase as the number of aquaculture installations in the Hellenic Seas and in the neighbouring areas has been increasing. Apparently, no serious precautions are undertaken in order to avoid any accidental escape from farm stocks.

Taking into account the increased interest of the scientific community in the Lessepsian invasion, an increase in the invading tropical fish of the Levantine coasts and their successful acclimatization there, confirms that "the littoral and infralittoral biota of the Levantine Sea is undergoing a profound change due to the influx of Erythrean invaders" (GALIL & ZENETOS, 2002). This provides further support to the theory of a tropicalization of the Mediterranean area.

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II.3. EARLY LIFE HISTORY OF FISH

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INTRODUCTION

Ichthyoplankton are the eggs and larvae of fish found mainly in the upper 200 meters of the water column. The eggs passively drift in the ocean carried along by the water currents. Ichthyoplankton are a relatively small but vital component of total zooplankton. They feed on smaller plankton and are prey themselves to larger animals. Investigations on these early life stages of fish are of paramount importance for fisheries science as follows:

- They advance the studies of fish taxonomy, diversity and biogeography
- They improve our understanding of fish reproductive strategies
- They provide knowledge on the location of spawning grounds and habitats of different fish species and the links with nursery areas
- Most importantly, they advance our understanding and ability to predict fluctuations in fisheries yields. Fished stocks are dependent on recruitment and the strength of recruitment is mainly determined during the vulnerable early life history stages. Mortality due to starvation, predation and offshore transport can be extremely high and the understanding of how abiotic and biotic factors interact in order to determine growth and survival of young fish is a 'hot' topic in fisheries science.

Since the early 1990s, several field investigations on the eggs and larvae of marine fish species have been carried out in Hellenic waters within the framework of various European and national programmes. The main methods and goals of these studies are outlined below.

SAMPLE PROCESSING AND IDENTIFICATION

Ichthyoplankton samples have been routinely taken during maximum egg production (DEPM), acoustic, and bottom trawl surveys have been carried out in the Hellenic Seas since the early 1990s (SIAPATIS *et al.*, 2000). The main objective was to determine spawning areas and seasons of fish species in the eastern Mediterranean in relation to principal characteristics of the water column. Equipment used for ichthyoplankton sampling are shown in Figure 1.

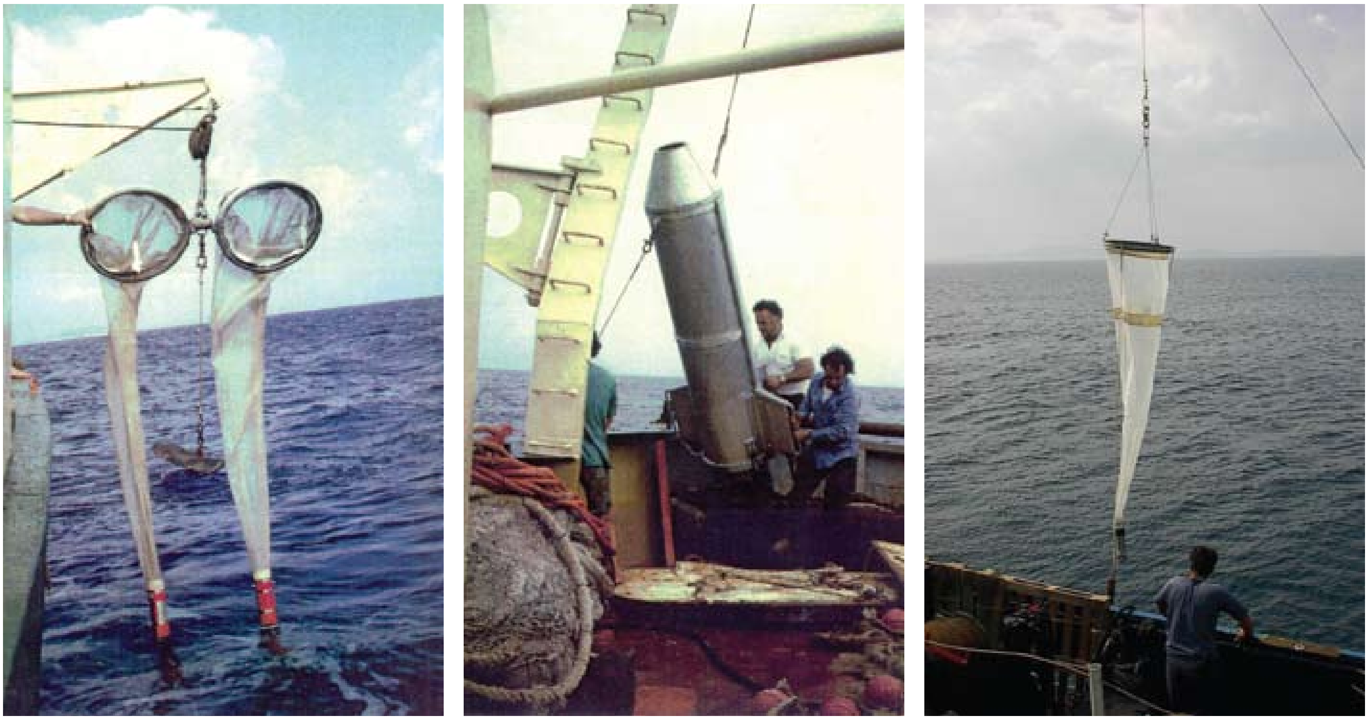

Figure 1: Different types of ichthyoplankton samplers.

In the laboratory, samples are sorted and fish eggs and larvae are being identified to the lowest possible taxonomic level. Larval species are counted and measured (notochord or standard length) in order to examine possible changes in distribution patterns with increasing size. The systematics of the Mediterranean Sea ichthyoplankton are not easy as identification of fish eggs and larvae is complicated by a large variety of species of different size, shape and pigmentation which change rapidly throughout their development. In an attempt to gather and record existing information, an ichthyoplankton database has been created at the HCMR including more than 2000 drawings and photos of different developmental phases of eggs, larvae, postlarvae and juveniles of over 250 fish species inhabiting the Hellenic Seas (SIAPATIS & CHILARI, 2003) (Figure 2).

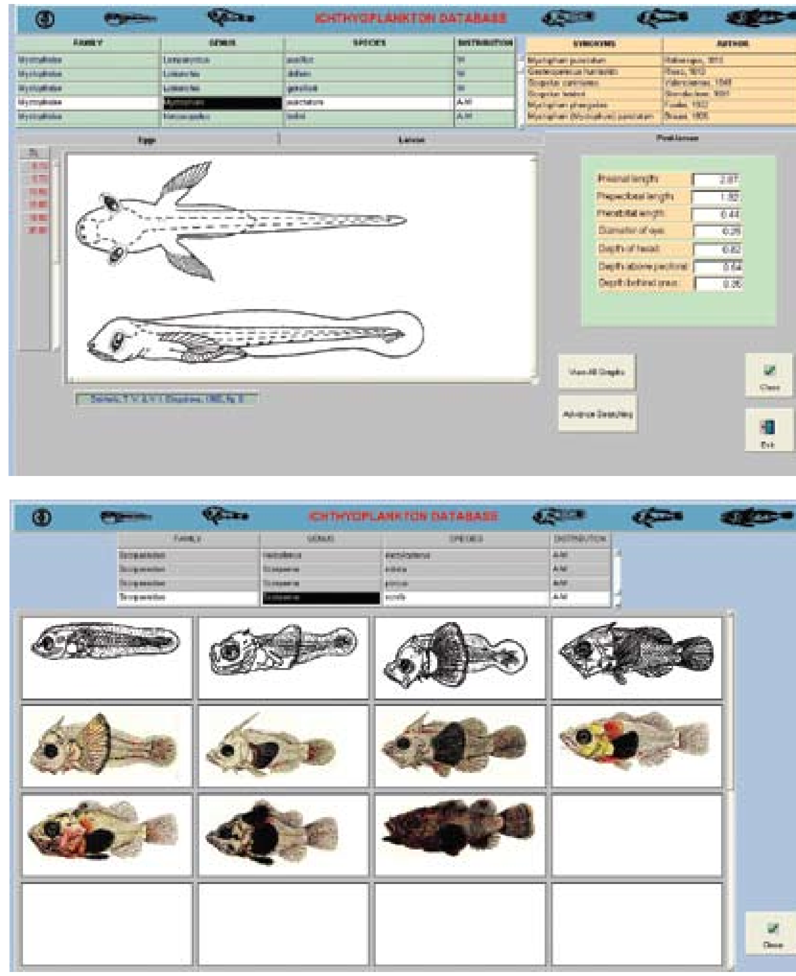

Figure 2: Forms of the ichthyoplankton database developed at HCMR showing different types of early life stages of fishes.

DIVERSITY, STRUCTURE AND DISTRIBUTION OF LARVAL FISH ASSEMBLAGES

Ichthyoplankton data have been analysed to study the distribution and abundance of larvae of different species in relation to topographic (bathymetry, distance from coast, longitude, latitude) and oceanographic conditions (temperature, salinity, currents, plankton concentration). However, most studies so far have shown that horizontal distribution and abundance patterns of ichthyoplankton reflect the spawning bathymetry of adults (SOMARAKIS *et al.,* 2002). Table 1 summarizes the spawning seasons of different fish species in the Aegean Sea, as determined by the presence of their larvae in the plankton (CARAGITSOU *et al.,* 1997, 2001).

Examining spatial and temporal patterns in distribution and abundance of ichthyoplankton in relation to oceanographic conditions may provide an insight into the adaptation of spawning strategies to the prevailing physical and biological processes as well as the effect of variability in these processes to year-class strength (SOMARAKIS *et al.* 2005, 2006). Most broad-scale multispecies ichthyoplankton investigations in the Hellenic Seas involved the definition of larval fish assemblages, their composition, the dominant or indicator species, the major distribution patterns, both across and along the continental shelves, and, where possible, the principal characteristics of the water column that control these patterns (e.g., CARAGITSOU *et al.*, 1997, SOMARAKIS, 1999; SOMARAKIS *et al.*, 2002, ISARI *et al.*, 2005). The largest differences have been generally found in the cross-shelf (onshore/offshore) location of sampling sites, the greatest contrast being roughly between the two sides of the shelf break at a depth of 150-200m. Spatial patterns observed mainly reflected the spawning localities of adults.

An important consideration in assemblage studies is whether larval fish associations are adaptive and result from similar responses among species to the pelagic environment ((FRANK & LEGGETT, 1983). For example, in a four-year study of larval fish assemblages in the NE Aegean in June (1993- 1996), SOMARAKIS (1999) (Figure 3) found a higher abundance of larvae of small-sized pelagic species (the anchovy *Engraulis encrasicolus* and mesopelagic species such as *Maurolicus muelleri* and *Hygophum benoiti*) in 1993 and 1995 (when waters were cooler, less saline and, most importantly, richer in zooplankton) than in 1994 and 1996 (when significantly higher temperature, higher salinity and lower mesozooplakton biovolumes were record-

Table 1. The spawning seasons of different fish species in the Aegean Sea, as determined by the presence of their larvae in the plankton (CARAGITSOU *et al.* 1997).

SPECIES	FAMILY	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Sardina pilchardus	Clupeidae	■	■	■	■	■	■						■
Sardinella aurita	Clupeidae							■	■	■	■		
Engraulis encrasicolus	Engraulidae						■	■	■	■	■	■	■
Cyclothone spp.	Gonostomatidae	■					■	■	■	■	■	■	■
Gonostoma denudatum	Gonostomatidae						■						
Argyropelecus hemigymnus	Sternoptychidae										■		
Maurolicus muelleri	Sternoptychidae	■	■	■	■	■	■				■	■	■
Ichthyococcus ovatus	Photichthyidae						■						
Vinciguerria spp.	Photichthyidae	■	■	■							■	■	■
Stomias boa	Stommidae			■	■			■					
Argentina sphyraena	Argentinidae				■								
Glossanodon leiglossus	Argentinidae			■	■	■	■						
Nansenia oblida	Argentinidae			■									
Synodus saurus	Synodontidae										■		
Chlorophthalmus agassizi	Chlorophthalmidae										■		
Benthosema glaciale	Myctophidae	■	■	■	■	■	■				■	■	■
Ceratoscopelus maderensis	Myctophidae	■					■	■	■	■	■	■	■
Diaphus spp.	Myctophidae	■	■	■	■	■	■	■	■	■	■	■	■
Hygophum spp.	Myctophidae	■	■	■	■	■	■	■	■	■	■	■	■
Lampanyctus crocodilus	Myctophidae	■	■	■	■	■	■				■	■	■
Lampanyctus pusillus	Myctophidae	■									■	■	■
Lobianchia sp.	Myctophidae	■	■	■	■	■	■	■	■	■	■	■	■
Myctophum punctatum	Myctophidae	■	■	■	■	■	■	■	■	■	■	■	■
Notoscopelus elongatus	Myctophidae			■	■								
Symbolophorus veranyi	Myctophidae	■	■	■	■	■	■				■	■	■
Lestidiops jayakari	Paralepididae	■	■	■	■						■	■	■
Lestidiops sphyrenoides	Paralepididae	■	■	■	■						■	■	■
Notolepis rissoi	Paralepididae										■		
Paralepis sp.	Paralepididae									■	■	■	■
Sudis hyalena	Paralepididae									■	■		
Nettastoma melanurum	Nettastomatidae	■								■	■	■	■
Gnathophis mystax	Congridae	■								■	■	■	■
Ophichthus rufus	Ophichithidae	■									■	■	■
Macroramphosus scolopax	Macroramphosidae						■	■	■	■			
Syngnathus sp.	Syngnathidae	■						■	■	■	■	■	■
Merluccius merluccius	Merlucciidae	■	■	■	■				■	■	■	■	■
Gadiculus argenteus	Gadidae			■	■								
Merlangius merlangus	Gadidae		■	■	■								
Micromesistius poutassou	Gadidae	■	■	■	■	■	■						■
Trisopterus minutus	Gadidae				■								
Gaidropsarus mediterraneus	Gadidae	■	■	■	■								■
Gaidropsarus vulgaris	Gadidae	■	■	■	■								■
Phycis blennoides	Gadidae	■	■	■	■								■
Trachipterus trachypterus	Trachipteridae			■									
Zeus faber	Zeidae							■	■	■	■	■	■
Capros aper	Caproidae			■				■		■			
Anthias anthias	Serranidae									■	■		
Callanthias ruber	Serranidae	■	■	■	■		■	■	■	■	■	■	■
Epinephelus alexandrinus	Serranidae									■	■		
Serranus cabrilla	Serranidae						■	■	■	■	■		
Serranus hepatus	Serranidae						■	■	■	■	■		

(Continued)

Table 1. (Continued)

SPECIES	FAMILY	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Serranus scriba	Serranidae									■	■		
Dicentrarchus labrax	Moronidae		■	■	■	■	■	■					
Apogon imberbis	Apogonidae									■	■		
Cepola macrophalma	Cepolidae						■	■	■	■	■	■	■
Trachurus mediterraneus	Carangidae						■	■	■	■	■	■	
Trachurus trachurus	Carangidae	■	■	■	■	■	■					■	■
Brama brama	Bramidae			■							■		
Mullus barbatus	Mullidae						■	■					
Mullus surmuletus	Mullidae						■	■	■	■	■		
Diplodus annularis	Sparidae						■	■					
Pagellus acarne	Sparidae						■	■	■	■	■		
Pagellus bogaraveo	Sparidae	■	■	■							■	■	■
Pagellus erythrinus	Sparidae						■						
Pagrus pagrus	Sparidae				■	■	■	■	■	■	■		
Chromis chromis	Pomacentridae							■	■	■	■		
Coris julis	Labridae						■	■	■	■	■	■	■
Sparisoma cretense	Scaridae	■											■
Gymnammodytes cicerelus	Ammodytidae	■	■	■	■								■
Trachinus draco	Trachinidae									■	■		
Lepidopus caudatus	Trichiuridae	■	■	■	■			■	■	■	■	■	■
Auxis rochei	Scombridae							■	■	■	■		
Euthynnus alleteratus	Scombridae								■	■	■		
Scomber japonicus	Scombridae							■	■	■	■		
Thunnus alalunga	Scombridae									■			
Xiphias gladius	Xiphiidae							■	■	■	■		
Gobiidae	Gobiidae	■	■	■	■	■	■	■	■	■	■	■	■
Callionymidae	Callionymidae	■	■	■	■	■	■	■	■	■	■	■	■
Blenniidae	Blenniidae	■	■	■	■	■	■	■	■	■	■	■	■
Bethocometes robustus	Ophidiidae										■		
Parophidion vassali	Ophidiidae									■	■		
Carapus acus	Carapidae	■	■	■	■	■	■				■	■	■
Centrolophus niger	Centrolophidae	■											■
Sphyraena sphyraena	Sphyraenidae					■	■	■					
Mugilidae	Mugilidae	■				■	■	■	■	■	■	■	■
Helicolenus dactylopterus	Scorpaenidae						■						
Scorpaena porcus	Scorpaenidae								■	■	■		
Scorpaena scrofa	Scorpaenidae								■	■	■		
Aspitrigla cuculus	Triglidae						■	■	■	■	■		
Lepidotrigla cavillone	Triglidae						■	■	■	■	■		
Citharus linguatula	Citharidae										■		
Lepidorhombus boscii	Scophthalmidae									■	■		
Scophthalmus rhombus	Scophthalmidae			■									
Arnoglossus spp.	Bothidae	■	■	■	■	■	■	■	■	■	■	■	■
Bothus podas	Bothidae									■	■		
Platichthys flesus	Pleuronectidae				■								
Buglossidium luteum	Soleidae	■	■	■	■						■	■	■
Microchirus ocellatus	Soleidae				■						■	■	
Microchirus variegatus	Soleidae						■	■	■	■	■		
Solea lascaris	Soleidae									■	■		
Solea vulgaris	Soleidae		■	■	■								
Symphurus nigrescens	Cynoglossidae	■								■	■	■	■
Diplecogaster bimaculata	Gobiesocidae										■		
Lepadogaster lepadogaster	Gobiesocidae										■		
Lophius budegassa	Lophiidae				■								

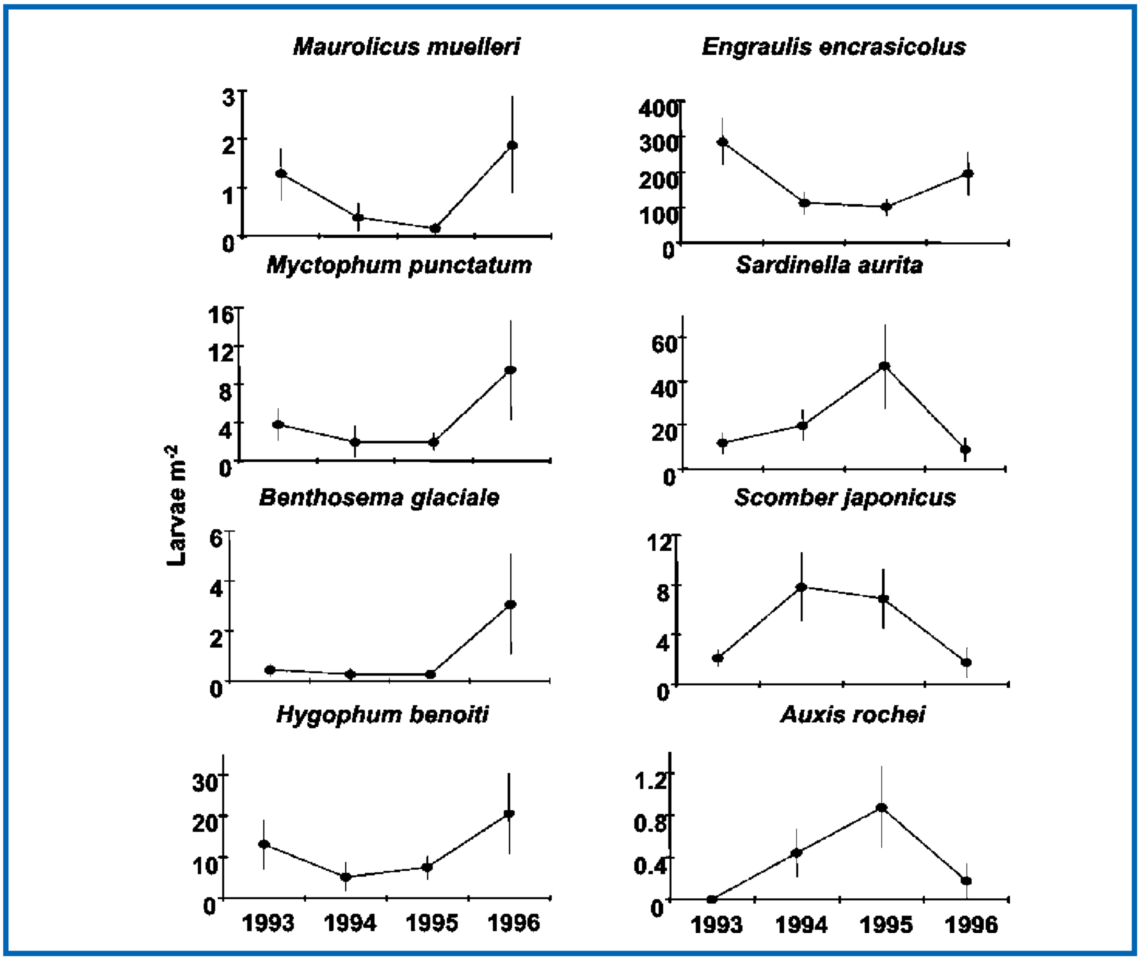

Figure 3: Mean abundance of selected epipelagic and mesopelagic species in the NE Aegean Sea during for four successive years (June 1993, 1994, 1995 and 1996).

ed). On the contrary larvae of the middle-sized pelagics (*Sardinella aurita*, *Scomber japonicus*, *Trachurus mediterraneus*, *Auxis rochei*) were more abundant in 1994 and 1995. These results were indicative of contrasting reproductive strategies among pelagic fishes in the area (SOMARAKIS *et al.,* 2000, SOMARAKIS & MARAVEYA, 2001).

UNDERSTANDING HOW OCEANOGRAPHIC FEATURES AFFECT THE ADVECTION OF EGGS AND LARVAE

Structure, integrity and recruitment of fish stocks may be linked to specific oceanographic features which can be elucidated by ichthyoplankton surveys (DRAKOPOULOS *et al.,* 2000). An example is given below for anchovy in the NE Aegean Sea (NEA) (Figure 4).

NEA is the major spawning ground for European anchovy in the eastern Mediterranean. In this area, Black Sea waters (BSW) inflow into the Mediterranean, enhancing local productivity and inducing high hydrographic complexity. We analyzed the distribution and abundance of anchovy eggs and larvae in the NEA from a bongo-net survey carried out during June 1995, in an effort to identify BSW effects. The northwestward movement of the BSW and its significant entrapment in the Samothraki gyre were the main factors influencing anchovy spawning and subsequent advection of the larvae. Both eggs and larvae were significantly associated with increased temperature, low salinity and high zooplankton values typically observed in the Samothraki gyre. The abundance of eggs was markedly higher over frontal areas in the periphery of this gyre. Larvae, especially larger ones (>6 mm), were particularly abundant within the Samothraki and another smaller anticyclone located in the western part of the island of Thasos. Thus, anticyclones, (especially the almost permanently present Samothraki gyre) favour larval retention with a potentially important role for the recruit-

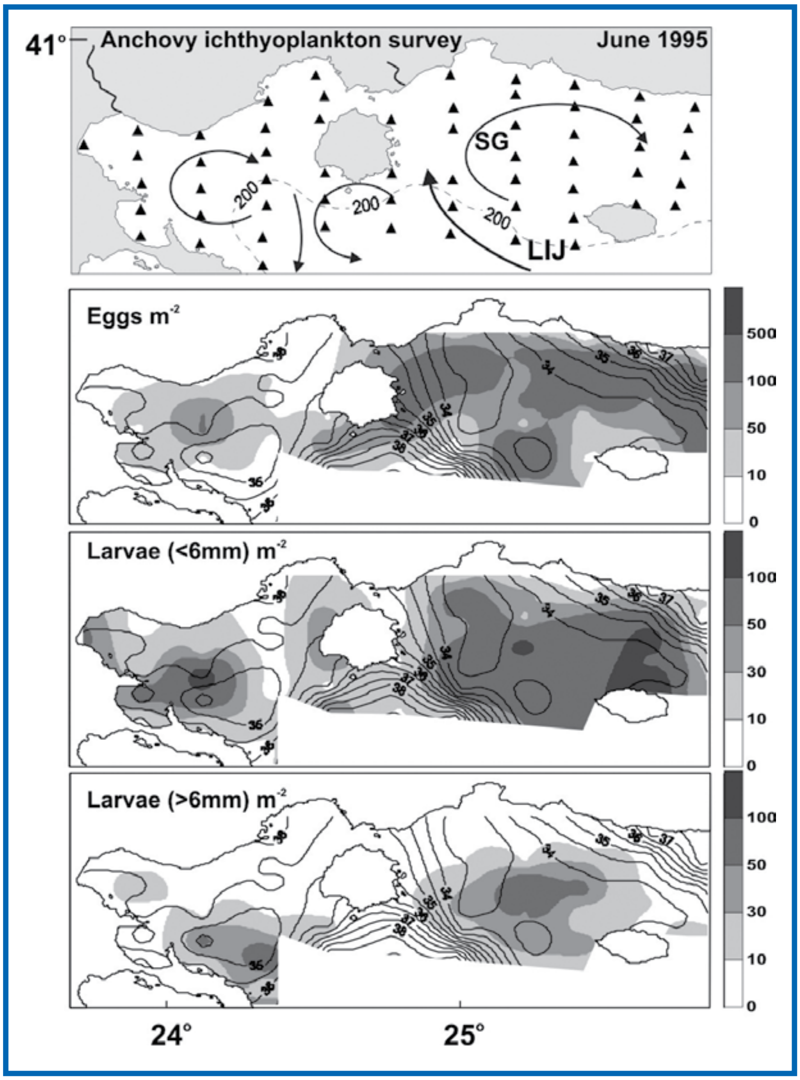

Figure 4: Contour map of the abundance of anchovy eggs, early larvae (<6 mm) and late larvae (>6 mm) in relation to surface salinity (isolines). Sampling stations and estimated baroclinic circulation is shown in the upper map. The Limnos-Imvros jet (LIJ) carrying Black Sea waters feeds the Samothraki Gyre (SG) where anchovy larvae are being entrapped.

ment of anchovy in the NE Aegean Sea (NIKOLIOUDAKIS *et al.,* 2005).

GROWTH AND MORTALITY OF FISH LARVAE

Small changes in the mortality rate or growth rate during the larval stage can cause large variations in recruitment (HEATH, 1992). Larvae that feed efficiently, and consequently grow faster, are subjected to lower cumulative mortality during the vulnerable larval stages.

The age and growth in larval fishes in the field is studied through otolith microstructure analysis (SOMARAKIS *et al.,* 1997a, b). Otoliths (ear bones) are microscopic structures that form daily rings. These can be used for the determination of age in young fish. The age-fish size data are subsequently used to estimate growth and mortality rates in the field (SOMARAKIS, 1999, SOMARAKIS *et al.,* 1998).

In comparing, estimated mortality rates for larval anchovy in the Mediterranean Sea, an interesting relationship emerges (Figure 5) suggesting that larval mortality rates increase with increasing egg production. However this empirical relationship requires further investigation.

Predation is probably an important source of mortality for ichthyoplankton. Important predators include juvenile and adult fish, jellyfishes (ctenophores and medusae), chaetognaths and euphausiids. *Mnemiopsis leidyi*, a lobate ctenophore, is considered as a "keystone predator" in pelagic ecosystems, which could cause significant changes in the structure of plankton communities and has the potential to be a major ichthyoplankton predator (MONTELEONE & DUGUAY, 1988) *M. leidyi* originating from eutrophic lagoons in North America was transported into the Black Sea during the early 1980s, possibly in the ballast waters of ships. This accidental introduction caused major changes in the Black Sea ecosystem as predation by *M. leidyi* on fish eggs and larvae (NIERMANN *et al.,* 1994) has been a major cause of ichthyoplankton mortality. In certain Black Sea areas, an-

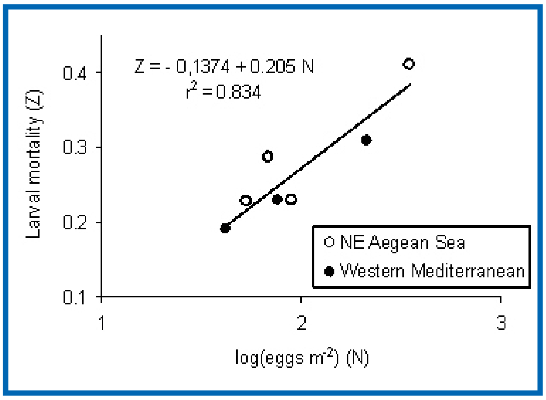

Figure 5: Empirical relationship between larval mortality and mean egg abundance of anchovy in the Mediterranean Sea.

chovy catches have almost collapsed for a period of more than two years. This collapse probably resulted from multiple factors, among which, overfishing, food competition between anchovy and the ctenophore and predation by *M. leidyi* on the early life stages of anchovy played the predominant roles. *M. leidyi* has been reported in the Aegean Sea during recent years. Its presence has been attributed to the transfer from the Black Sea by the surface current passing through the Dardanelles Strait (SHIGANOVA *et al.,* 2004). The continuous inflow of Black Sea waters from the Dardanelles and their advection into the Aegean Sea resulted in the spreading of *M. leidyi* populations in Hellenic waters. More targeted and comparative investigations are necessary to improve protection and management of the stocks of small pelagic fishes in the Aegean Sea, in order to increase their capacity to resist unforeseeable disturbances of the ecosystem caused by invaders such as *M. leidyi*.

FUTURE DIRECTIONS

Further development of investigations on the early life stages of fish in the Hellenic Seas will substantially improve current knowledge of the ecology of the stocks. Future intents are directed towards:

- the understanding of the mechanisms of advection of eggs and larvae and the oceanographic features involved
- the advancement of studies on the trophic ecology of marine fish larvae
- the study of prey-predator interactions and their links with larval growth and survival
- the characterization and mapping of spawning and larval habitats using GIS and advanced statistical models.

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II.4. REVIEW OF CEPHALOPOD FAUNA IN HELLENIC WATERS

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HISTORICAL DATA

Cephalopods comprise one of the older and more evolved classes in the phylum Mollusca. Drawings on ancient ceramics and ornaments (Figure 1) testify that they have been part of the daily life in Hellas since ancient times. Aristotle (384-322 B.C.) in his "Histories about animals" has given the earliest written descriptions for at least seven cephalopod species classifying them in 4 wider taxa: "polypod" corresponding to the current order of Octopoda, "sipia" corresponding to Sepioidea, "teuthos" and "teuthis" probably related to current families of Loliginidae and Ommastrephidae, respectively.

More recently, the first scientific literature on cephalopods of the Hellenic Seas came from FORBES (1844) who recorded three species from the Aegean Sea, followed by that of DEGNER (1926) referring to juveniles and paralarvae of nine cephalopod species collected during the Danish Oceanographical Expeditions of 1910. Until the mid 1980s cephalopod records were scanty and concerned only a small number of species (KOUTSOUBAS *et al.*, 2000). A complete list, including 24 species from the Ionian Sea, has been published by KASPIRIS & TSIAMBAOS (1986); however, systematic recording of cephalopod species began only in 1990 by the HCMR (formerly NCMR) in the framework of trawl surveys undertaking the assessment of commercially important species' stocks in the North Aegean Sea. During these surveys, carried out in collaboration with the Italian Institute of Zoology and Comparative Anatomy of the University of Bari, 17 new species for the Aegean Sea were identified from a total of 29 collected species (D' ONGIA *et al.*, 1996).

CURRENT COLLECTION OF CEPHALOPOD SAMPLES

Bottom trawl surveys carried out in the framework of national or international projects during the last fifteen-year period, by the NCMR, the Institute of Marine Biology of Crete (IMBC) and the Fisheries Research Institute in Kavala (FRI-NAGREF), contributed to the extensive collection of demersal cephalopod samples from almost the whole of trawlable bottoms of the Aegean and the Ionian Sea up to 800 m depths.

Apart from bottom trawl sampling, ichthyoplankton and mid-water sampling, stomach content analysis of marine predators, as well as incidental findings by fishermen, have constituted valuable sources of information, particularly for mid-water and epipelagic species that are in general rarely caught by conventional fishing gear and other sampling devices.

Figure 1: Mycenaean golden lamina having the shape and form of an octopus (top) and Minoan jug decorated with argonauts (bottom) dated to the 15th-13th centuries B.C.

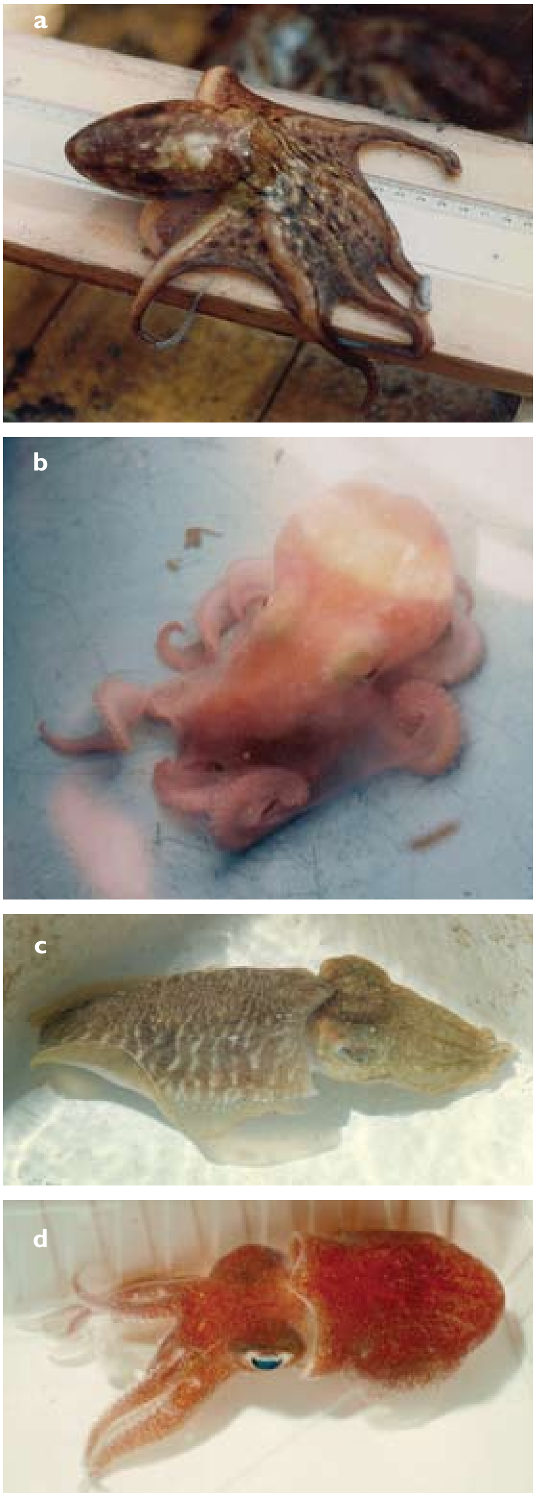

Figure 3: Robust octopods and cuttlefishes often arrive alive on deck from shallow but also from deep water trawling. (a) musky octopus *Eledone moschata*, (b) fourhorn octopus *Pteroctopus tetracirrhus*, (c) common cuttlefish *Sepia officinalis*, (d) stout bodtail *Rossia macrosoma.*

Records of cephalopods from the Hellenic Seas, reviewed by STERGIOU *et al.,* in 1997, included 38 species. In the latest review by LEFKADITOU (2006) they amounted to 45 species for the Aegean and 35 for the Ionian Sea. Evidence for the existence of *Abraliopsis pfefferi* in the Ionian Sea, based on the finding of its remains in the stomach content of a fish-predator caught in this region, has been also noted.

Some unpublished information concerning cephalopod species' diversity in different marine habitats of the Hellenic Seas is included in the present document, as well as an assessment of cephalopods' importance for human and marine predators' consumption.

SPECIES' COMPOSITION AND PREDATION

The 47 cephalopod species listed in Table I, are considered as verified records from the Hellenic Seas. They belong to 11 families of Teuthoidea, 2 families of Sepioidea and 4 families of Octopoda.

Demersal and benthic species constitute the majority of recorded cephalopods (Figure 2), among which there are some trawling resistant robust species of medium and large size (Figure 3). Open sea mid-water cephalopods, here noted as pelagic, usually with gelatinous or luminescent surface and numerous photophores (Figure 4), represent about one third of the total, whereas those occurring in near-surface waters, characterized as epipelagic (Table I), amount to a the minor fraction of the collected species.

Most of the species are widely distributed in the Ionian, the northern and the southern Aegean Seas and have been recorded repeatedly. The limited records and geographic range of some pelagic species, such as the pelagic teuthoids *Galiteuthis ar-*

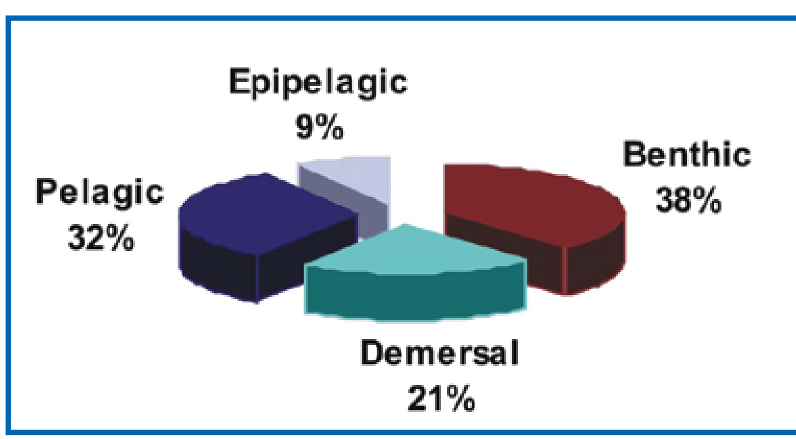

Figure 2: Proportion of benthic, demersal, epipelagic and pelagic species among cephalopods recorded from the Hellenic Seas.

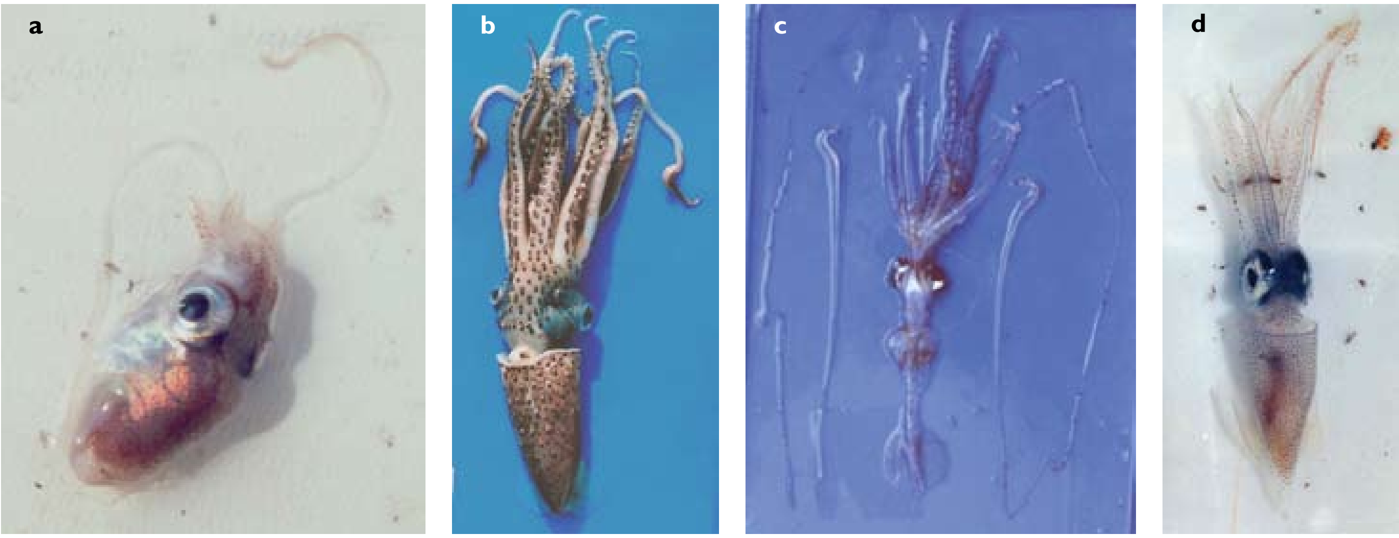

Figure 4: Pelagic cephalopod species: (a) odd bodtail *Heteroteuthis dispar*, (b) reverse jewell squid *Histioteuthis reversa*, (c) long-armed squid *Chiroteuthis veranyi*, (d) Verany's enope squid *Abralia veranyi.*

mata, Abraliopsis pfefferi, Ancistroteuthis lesueuri, Histioteuthis bonnellii, Ommastrephes bartami, Thysanoteuthis rhombus, Onychoteuthids or the epipelagic octopods *Ocythoe tuberculata, Tremoctopus violaceus* and *Argonauta argo*, should rather be attributed to the unsuitability of bottom trawl for the capture of pelagic species. The yearly use of an experimental bottom trawl with a relatively wider vertical opening, in the framework of the International Trawl Surveys in the Mediterranean (MEDITS) since 1994, as well as trawling in deeper waters has been shown to favour the capture of mesopelagic teuthoids (LEFKADITOU *et al.,* 2003a; 2003b). On the other hand, even limited studies in the Hellenic Seas concerning the contribution of cephalopod species to the diet of other marine organisms (Table 2), indicate the dominance of pelagic species, at the same time evidencing the abundance of these species.

Preference of particular hydrographic regimes by pelagic teuthoids should not, however, be ignored (LEFKADITOU *et al*., 2003a), as well as the effects of climatic and water-mass circulation changes on the species' geographical distribution. A good example is the bathy-benthic octopus *Bathypolypous sponsalis* that in the Mediterranean Sea extends from 120m to 1835 m, being more common at depths 400-700 m. Despite extensive deep-water trawling carried out in both the eastern and western part of the Ionian Sea during the last decade, it was found for the first time in 2003 east of Zakynthos Island (LEFKADITOU *et al*., 2004a). The recent increase of temperature and salinity in the intermediate layers (150-600 m) of the Ionian Sea (MANCA *et al*., 2002) is surmised to be the cause of its geographic expansion.

Small-sized species like the cuttlefishes *Sepiola affinis, Sepietta obscura* and *Sepietta neglecta*, are in general seldom recorded. Some uncertainty in the female specimen taxonomy of these species and/or their escape from trawl nets may be considered to be the most probable reasons for their infrequent findings.

Uncertainties in taxonomy have also been noted for the species *Alloteuthis subulata* (LAPTIKOVSKY *et al*., 2002), which was recorded in the north Aegean (D' ONGHIA *et al*., 1996) and the Ionian Sea (KASPIRIS & TSIAMBAOS, 1986), where as, the species *Sepiola robusta* and *Octopoteuthis megaptera* recorded in the eastern Aegean by SALMAN *et al.* (2002) have been most probably wrongly identified as explained in LEFKADITOU (2006).

The 47 species composing the cephalopod fauna of the Hellenic Seas show a wide geographic distribution in the Mediterranean Sea and the eastern Atlantic, with the exception of the species *Sepietta obscura, Sepiola affinis, Sepiola ligulata, Sepiola intermedia* and *Eledone moschata*, which are considered as endemic Mediterranean species. They reach 90,4% of the cephalopod species recorded in the eastern Mediterranean, excluding the above-mentioned doubtful records. *Sepiola steenstrupiana* and the lessepsian immigrants *Octopus cf. aegina, Octopus cyaneus, Sepia pharaonis* and *Sepioteuthis lessoniana* recorded in the Levant basin (SALMAN *et al*., 2002; MIENIS, 2004) have not yet been identified from the Hellenic Seas. Compared to the western Mediterranean the Cephalopod

Table I. List of cephalopod species collected from the Hellenic Seas by bottom trawl (+), only by midwater trawl or plankton nets (*), only by artisanal and sport fishermen (**) , or for which there is evidence of their occurrence only from remains found in the trawl catch (x),excluding *Alloteuthis subulata* doubtfully identified. (Characterisation of species as B: benthic, D: demersal, E: epipelagic, P: pelagic).

Order	Family	Species	N.Aegean (N>38°)	S.Aegean (N<38°)	Ionian	Main sources
TEUTHOIDEA	Brachioteuthidae	*Brachioteuthis riisei* (Steenstrup,1882) [P]		+		6, 9r
	Chiroteuthidae	*Chiroteuthis veranyi* (Ferussac, 1835) [P]	*	+	+	2, 3, 5r, 6, 9r
	Cranchiidae	*Galiteuthis armata* (Joubin, 1898) [P]		*	+	2, 7, 9r
	Ctenopterygidae	*Ctenopteryx sicula* (Verany, 1851) [P]		+	+	2, 6, 7, 9r
	Enoploteuthidae	*Abralia veranyi* (Ruppell, 1844) [P]	+	+	+	4, 5r, 6, 7, 8, 9
		Abraliopsis pfefferi (Verany, 1837) [P]		*		2, 6r, 9r
		Ancistrocheirus lesueuri (Orbigny, 1839) [P]	*			6r, 9r
		Pyroteuthis margaritifera (Ruppell, 1848) [P]	+	+	*	2, 4, 5r, 6, 9r
	Histioteuthidae	*Histioteuthis bonnellii* (Ferussac, 1835) [P]	+		+	3, 4, 5r, 6r, 7, 8, 9
		Histioteuthis reversa (Verrill,1880) [P]	+	+	+	4, 5r, 6, 7, 8, 9r
	Loliginidae	*Alloteuthis media* (Linnaeus, 1758) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Loligo forbesi (Steenstrup, 1856) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Loligo vulgaris (Lamarck, 1798) [D]	+	+	+	3, 4, 5r, 6, 8, 9
	Octopoteuthidae	*Octopoteuthis sicula* (Ruppel, 1844) [P]		+		2, 6, 9r
	Ommastrephidae	*Illex coindetii* (Verany, 1839) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Todarodes sagittatus (Lamarck, 1798) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Todaropsis eblanae (Ball, 1841) [D]	+	+	+	4, 5r, 6, 7, 8, 9
		Ommastrephes bartrami (LeSueur, 1821) [P]		+		6, UD
	Onychoteuthidae	*Ancistroteuthis lichtensteini* (Orbigny, 1839) [P]		+	+	6, 7, 9r
		Onychoteuthis banksi (Leach, 1817) [P]		*	+	2, 6r, 7, 9r
	Thysanoteuthidae	*Thysanoteuthis rhombus* (Troschel, 1857) [E]		**		5, 6r, 9r
SEPIOIDEA	Sepiidae	*Sepia elegans* (Blainville, 1827) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Sepia officinalis (Linnaeus, 1726) [D]	+	+	+	1, 3, 4, 5r, 6, 8, 9
		Sepia orbignyana (Ferussac, 1826) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
	Sepiolidae	*Heteroteuthis dispar* (Ruppell, 1844) [P]	*	+	+	2, 3, 5r, 6, 7, 9r
		Neorossia caroli (Joubin, 1902) [B]	+	+	+	4, 5r, 6, 7, 8, 9
		Rondeletiola minor (Naef, 1912) [D]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Rossia macrosoma (Delle Chiaje, 1830) [B]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Sepietta neglecta (Naef, 1916) [B]	+	+		5r, 6, 9
		Sepietta obscura (Naef, 1916) [B]		+		6, 9r
		Sepietta oweniana (Pfeffer, 1908) [B]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Sepiola affinis (Naef, 1912) [B]	+			4, 5r, 6r, 9
		Sepiola intermedia (Naef, 1912) [B]	+	+	+	3, 4, 5r, 6, 8, 9
		Sepiola ligulata (Naef, 1912) [B]	+	+	+	4, 5r, 6, 7, 8, 9
		Sepiola rondeleti (Steenstrup, 1856) [B]	+	+	+	1, 3, 4, 5r, 6, 8, 9

(continued)

species in the Eastern basin are fewer, due mainly to the absence of some pelagic teuthids and certain species of sepiolids, the records of which are particularly infrequent.

DEPTH DISTRIBUTION AND COMMUNITY STRUCTURE

The bathymetric distribution of the species, based on available data from the HCMR trawl surveys, reveals a wide depth range for most of the species (Figure 2), favoured by the diverse topography of the Hellenic Seas and in particular the generally steep waters of the southern Aegean and the Ionian Seas (Chapter 1.1). From the 39 species collected by bottom trawl, only two octopuses and five cuttlefishes are confined to the continental

Table 1. (continued)

Order	Family	Species	N.Aegean (N>38°)	S.Aegean (N<38°)	Ionian	Main sources
OCTOPODA	Argonautidae	*Argonauta argo* (Linnaeus, 1758) [E]	**	**	X	3, 5r, 6, 7, 9, UD
	Octopodidae	*Bathypolypous sponsalis* (Fischer, 1892) [B]	+	+	+	4, 5r, 6, 9
		Eledone cirrhosa (Lamarck, 1798) [B]	+	+	+	3, 4, 5r, 6, 7, 8, 9
		Eledone moschata (Lamarck, 1798) [B]	+	+	+	3, 4, 5r, 6, 8, 9
		Octopus defilippi (Verany 1851)			+	3, 5r, 9r
		Octopus macropus (Risso, 1826) [B]	**	+	+	3, 5r, 6r, 9
		Octopus salutii (Verany, 1839) [B]	+	+	+	4, 5r, 6, 7, 8, 9
		Octopus vulgaris (Cuvier, 1798) [B]	+	+	+	1, 3, 4, 5r, 6, 7, 8, 9
		Pteroctopus tetracirrhus (Delle Chiaje, 1830) [B]	+	+	+	4, 5r, 6, 7, 8, 9
		Scaeurgus unicirrhus (Orbigny, 1840) [B]	+	+	+	2, 3, 4, 5r, 6, 7, 8, 9
	Ocythoidae	*Ocythoe tuberculata* (Rafinesque, 1814) [E]	**	**		5r, 6r, 9r, UD
	Tremoctopidae	*Tremoctopus violaceus* (Delle Chiaje, 1829) [E]	*	**		5r, 6r, 9r, UD

1-FORBES (1844), 2-DEGNER (1926), 3-KASPIRIS & TSIABAOS (1986), 4-D' ONGHIA *et al.* (1996), 5-STERGIOU *et al.* (1997), 6-LEFKADITOU *et al.* (2003a), 7- LEFKADITOU *et al,* (2003b), 8-KRSTULOVIC-SIFNER *et al.* (2005), 9-LEFKADITOU (2006). (r: reviewed records only, UD: unpublished data).

Table 2: List of cephalopods species identified in the stomach content of different predators from the Hellenic Seas (compiled from LEFKADITOU & POULOPOULOS, 1998; MADURELL, 2003; ROBERTS, 2003; PERISTERAKI *et al.*, 2005; KAPIRIS & LEFKADITOU, 2006).

	Physeter macrocephalus	*Ziphius cavirostris*	*Xiphias gladius*	*Galeus melastomus*	*Etmopterus spinax*	*Helicolenus dactylopterus*	*Aristomorpha foliacea*
Chiroteuthis veranyi	+						
Abralia veranyi			+	++	+	++	++
Abraliopsis pfefferi				+	+	++	++
Ancistrocheirus lesueuri	+						
Pyroteuthis margaritifera				+	+		++
Histioteuthis bonnellii	++	++	+	+			+
Histioteuthis reversa	+		+		+		
Loligo vulgaris			+				
Octopoteuthis sicula	+	++				+	
Illex coindetii			++				
Todarodes sagittatus			++				+
Ancistroteuthis lichtensteini	+						
Onychoteuthis banksi	+						
Heteroteuthis dispar				++	++	++	
Argonauta argo			++				
Ocythoe tuberculata			+				
Octopus salutii							+

+ presence, ++ frequency >10% of cephalopod remains

shelf, although, as shown by the estimated center of gravity (COG), about one third of the species is more abundant at depths less than 100 m. Most of the pelagic teuthoids (Table I) have been caught exclusively in the middle and lower slope (>500 m). The species being more abundant in the shelf break zone (150-350 m) (i.e. *L. forbesi*, *I. coindetii*, *T. eblanae*, *T. sagittatus*, *A.veranyi*, *S. oweniana*, *R. minor*,

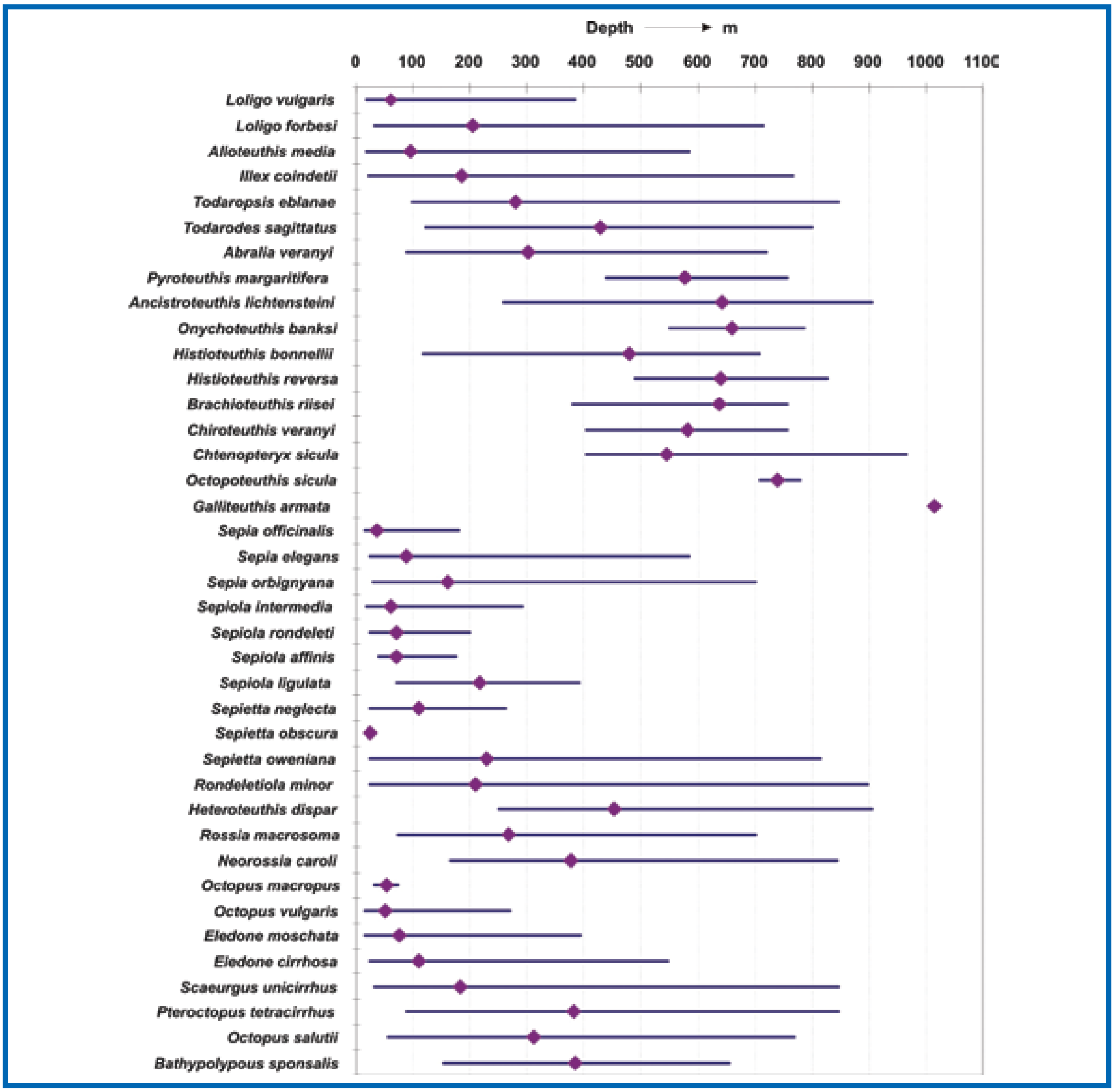

Figure 5. Depth range and gravic depth (represented by red rhombs) of cephalopod species catches by bottom trawl in the Hellenic Seas. Source data: HCMR trawl surveys.

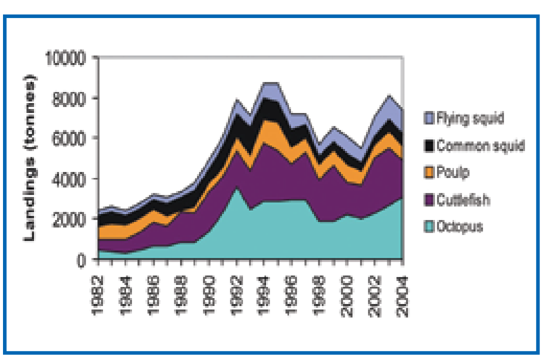

Figure 6: Cephalopod annual landings by species category in the Hellenic Seas, during the period 1982-2004. Source data: NSSG.

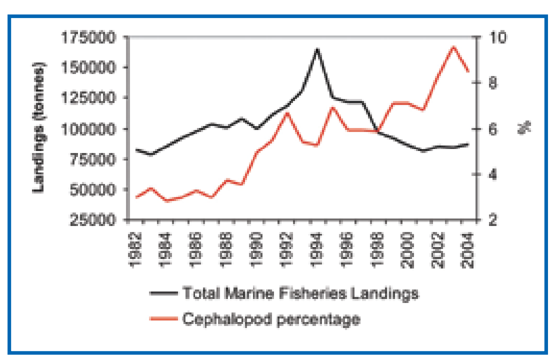

Figure 7: Variation of marine fisheries' total landings (including fish, crustacean and cephalopods) and cephalopod landings percentage, during the period 1982-2004. Source data: NSSG.

S. unicirrus, *O. salutii*, *P. tetracirrus*) are the most eurybathic.

Studies of the demersal cephalopod assemblages are available only from the Ionian Sea (LEFKADITOU *et al.,* 2003b; KRSTULOVIC-SIFNER *et al.,* 2005) and the northernmost part of the Aegean Sea (LEFKADITOU, 2006). *A. media*, *L. vulgaris*, *E. moschata*, *O. vulgaris* and *S. elegans* dominated catches on the upper shelf of both studied areas, with *S. officinalis* also showing very high abundance on the coastal shelf areas of the North Aegean Sea.

The lower shelf assemblage of the northern Aegean Sea, characterized by the highest abundance of *I. coindetii E. cirrhosa,* and *S. orbignyana*, is clearly distinguished from that of the upper slope, where *S. oweniana*, *B. sponsalis, N. caroli, R. macrosoma* and *O. salutii* were the most frequently caught species. In the eastern Adriatic and Ionian Seas KRSTULOVIC-SIFNER *et al.* (2005) have identified at lower shelf-upper slope an assemblage dominated by *I. coindetii, E. cirrhosa, A. media*, *L. vulgaris*, and *O. vulgaris,* whereas LEFKADITOU *et al.,* (2003b), analyzing catches only from the slope of the Ionian Sea, have found dominance of *S. oweniana, T. eblanae* and *L. forbesi* on the upper slope-shelf break zone (250-500) and *P. tetracirrus* as the most typical species occurring at greater depths.

HUMAN CONSUMPTION-FISHERIES' LANDINGS AND DISCARDS

In the Hellenic Seas there is a multi-gear exploitation of cephalopods, which are mainly caught as a bycatch. Directed fisheries by artisanal specific gears (fyke-nets, pots, trammel-nets) have been developed for the most commercially important species such as *Octopus vulgaris* and *Sepia officinalis,* which represent the major part of the cephalopod landings (LEFKADITOU *et al.*, 2002). The majority of demersal and benthic cephalopod species recorded in Hellenic waters are edible except for the octopus species *O. macropus, B. sponsalis* and *P. tetracirrus* that have a gelatinous flesh.

Landed species reported by the National Statistical Service of Greece (NSSG) since 1982, fall under the following five common names:

- Flying squid (ommastrephids mainly represented by *Illex coindetii*),
- Common squid (loliginids mainly represented by *Loligo vulgaris*),
- Cuttlefish (*Sepia officinalis*),
- Poulp (eledonids: *Eledone cirrhosa* and *Eledone moschata*) and
- Octopus (*Octopus vulgaris*).

Other species caught in relatively small quantities but consisting of a marketable fraction are *Loligo forbesi, Todaropsis eblanae, Todarodes sagittatus, Alloteuthis media, Scaeurgus unicirrhus, Sepia orbignyana, Sepia elegans, Rossia macrosoma, Neorossia caroli* and *Octopus salutii.* Cephalopod biomass being discarded has been estimated to range between 11% and 31%, depending on the season, the geographic area and the depth zone (MACHIAS *et al.,* 2001).

The analysis of the NSSG data for the period 1982-2004 shows that annual cephalopod landings reached their maximum value of 8682 tonnes in 1994 (Figure 5), following the trends of the total fishery landings. The considerable increase observed in cephalopod landings in the period 1989-1992, is due mainly to the increase in octopus and cuttlefish catches, the major part of which derives from the Thermaikos Gulf and the Thracian Sea (LEFKADITOU *et al.,* 2002). Likely causes for the important increase in cuttlefish and octopus catches could be due to the change in the fishery of these species using traditional fishing gears such as trammel nets, as well as the newly introduced (1980) specific gears targeting octopus (fyke-nets and plastic pots) and contributing to more than 80% of octopus coastal fishery landings in certain ports of the Thracian Sea (LEFKADITOU *et al.,* 2004b) (Figure 6). On the other hand, the percentage contribution of cephalopods to the total marine fisheries' landings is steadily increasing, reaching 9.6% in 2003 (Figure 7). The suggestion that short-living species like cephalopods could be subdominant predators, which would increase their biomass when longer-living finfish have been overexploited, has to be taken seriously into consideration, particularly for regions that are heavily exploited.

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II.5. BIVALVE AND GASTROPOD MOLLUSCS OF COMMERCIAL INTEREST FOR HUMAN CONSUMPTION IN THE HELLENIC SEAS

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HISTORICAL DATA AND PRESENT STATE

Gastropods and Bivalves consist of two of the older and more evolved classes in the phylum Mollusca. Aristotle (384-322 BC) in his 'Histories about animals' and 'Genesis of animals' has included gastropods and bivalves in the animals bearing 'shell' and termed 'shell skinned animals'. Aristotle was also the first who provided information on the morphology, reproduction and life-cycle characteristics for few mainly edible gastropod and bivalve species. Plenius (23-79 BC) was the first to introduce the term 'molia' (soft body) for these animals out of which the term Mollusca is derived. Plenius has also provided information for certain gastropod and bivalve species which were used by the ancient Romans either for food or for making jewelry.

A review of the relevant literature reveals that more than 1 100 gastropod and bivalve species have been recorded so far from the Hellenic Seas (KOUTSOUBAS, 1992; ZENETOS, 1996; KOUTSOUBAS *et al*., 1997, 2000; KOUTSOUBAS, 2005; DELAMOTTE & VARDALA-THEODOROU, 2001; ZENETOS *et al*., 2005). Twenty-one of these species (Table 1) have a commercial interest particularly in fisheries and aquaculture since they are collected and/or cultivated for human consumption. Fisheries of these species is regulated by the Ministry of Agriculture (General Directorate of Fisheries) and supported by the relative legislation (Presidential Degree 86/98 as it has been recently reformed 227/03). The minimum size allowed for fisheries and the closed fisheries period for selected species, according to the Presidential

Table 1. Molluscan species legally exploited covered by PD 86/98, PD 227/03 & EU Regulation 1967/2006.

Scientific name	Common Hellenic / English Names
BIVALVIA	
Arca noae	Kalognomi/Noah's ark
Barbatia barbata	Agriomydo/Hairy ark
Modiolus barbatus	Chavaro/Bearded horse mussel
Mytilus galloprovincialis	Mydi/Mediterranean mussel
Cerastoderma glaucum	Pourlida/Lagoon or olive green cockle
Donax trunculus	Telina, Fasolaki/Truncate Donax
Spisula subtruncata	Achivadaki/Subtruncate surf clam
Chlamys glabra	Gialistero chteni/Smooth scallop
Aequipecten opercularis	Chteni/Queen scallop
Pecten jacobaeus	Megalo chteni /Jacomb scallop
Ostrea edulis	Stridi/European flat oyster
Psammobia (=Gari) depressa	Esperos/Depressed sunset clam
Callista chione	Gyalisteri/Smooth callista
Chamelea gallina	Pseftokydono/ Stripped venus
Dosinia exoleta	Strogili achivada/Mature dosinia
Ruditapes (=Tapes) decussatus	Achivada/Grooved carpet shell
Venus verrucosa	Kydoni/Warty venus
GASTROPODA	
Haliotis tuberculata lamellosa	Afti tis thalassas/Lamellated haliotis
Hexaplex trunculus	Strobos/Banded murex
Bolinus brandaris	Agathotos Strobos/Spined murex
Stramonita (=Thais) haemastoma	Porphyra/Red-mouth purpura

Note: The baits are not included in the table

Table 2. Species of minor commercial interest including species illegally exploited.

Scientific name	Common Hellenic/ English Names
BIVALVIA	
Lithophaga lithophaga	Petrosolinas/European date mussel
Pteria hirundo	Fterostrido/European wing oyster
Pinctada radiata	Margaritoforo stride/Rayed pearl oyster
Donacilla cornea	Ammokochylo
Chlamys varia	Kalogria/Variegated scallop
Chlamys multistriata	Grammoto chteni/Little bay scallop
Spondylus gaederopus	Gaidouropodaro/European thorny oyster
Pholas dactylus	Daktilo, Folada/Common paddock
Solecurtus strigilatus	Samari/ Sandwich
Pinna nobilis	Pinna/Fun mussel
Crassostrea gigas	Stridi tou Eirinikou/Pacific oyster
GASTROPODA	
Patella caerulea	Petalida/Rayed Mediterranean limpet
Patella ferruginea	Sideropetalida/Ferreous limpet
Patella nigra	Mavri petalida/Black limpet
Patella lusitanica	Stiktopetalida/Ristic limpet
Patella ulyssiponensis	Agriopetalida/Rough limpet
Monodonta articulata	Arthrotos trochos/Articulate monodont
Monodonta turbinata	Trochos fraoula/Turbinate monodont
Bolma rugosa	Mati tis Panagias, Strovilos
Cerithium alucastrum	Skaltsini tou Aigeou/Spicate cerithe
Cerithium vulgatum	Skaltsini/Mediterranean cerithe
Strombus decorus	Konos tis Persias
Luria lurida	Gourounitsa/Cowry
Argobuccinum olearium	Agkathotritonas/Oil-vessel triton
Charonia tritonis variegata	Polychromos tritonas/Variegated triton
Charonia lampas	Tritonas/Knobed triton
Tonna galea	Bourou
Mitra zonata	Mitra/Zoned miter
Conus mediterraneus	Konos

Degree 227/03 and EU Regulation 1967/2006, is provided in Chapter III.7 (Management and legislation in the Hellenic fisheries). Additional species which have been either traditionally harvested as food resources, collected for use as fish baits (PD 109/02) or intentionally imported for culture during the last decades, although not mentioned in PD 227/03, are still exploited in certain coastal areas of Hellas. These are listed in Table 2.

SHELL PRODUCTION AND EXPLOITATION

The species of major commercial value in the Hellenic Seas (more than 90% of the total production) are the gastropod *Hexaplex trunculus* and the bivalves *Modiolus barbatus*, *Mytilus galloprovincialis* (both collected from natural banks and aquaculture units), *Arca noae*, *Cerastoderma glaucum*, *Donax trunculus*, *Chlamys glabra*, *Ostrea edulis* (most of the natural populations of this species located in the Thermaikos Gulf collapsed almost ten years ago due to overfishing and parasite infection), *Callista chione*, *Ruditapes decussatus* and *Venus verrucosa* (CHINTIROGLOU *et al.*, 2005).

Common fishing gears for the collection of the commercial molluscs in the Hellenic Seas are various types of dredges (mainly used for the collection of the species *Modiolus barbatus, Ostrea edulis, Chlamys glabra*) and hookah diving "nargiles" (mainly used for the collection of *Arca noae* and *Venus verrucosa*).

Although molluscs are harvested over all Hellenic coasts, most of the production is derived from three major areas i.e. the Thermaikos, Argo-Sa-

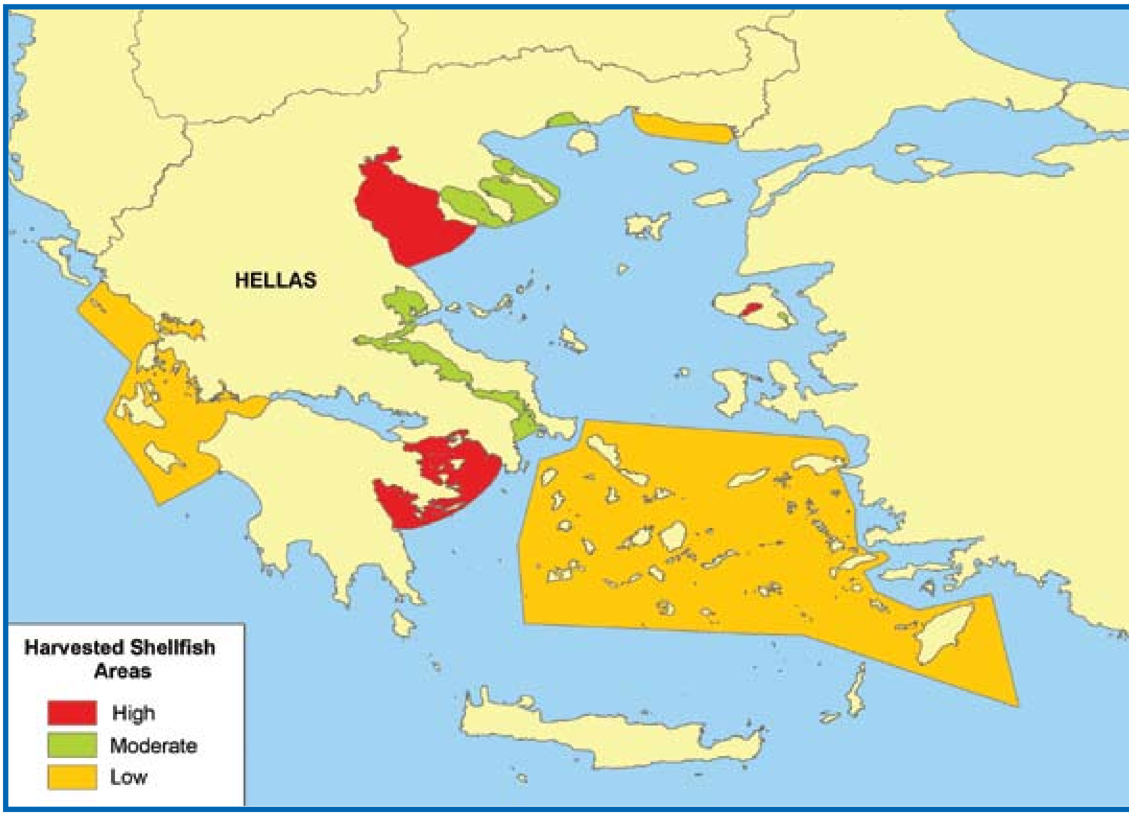

Figure 1: Map of the Hellenic Seas indicating areas with high, moderate and low production of shellfish (Source: HCMR based on NSSG data).

ronikos and Kalloni Gulfs which could be classified as "highly" exploited mollusc areas (Figure 1). The Chalkidiki Peninsula along with the Gulfs of Kavala, Evvoikos, Maliakos and Pagasitikos could be characterised as "moderately" exploited mollusc areas. Finally the Kyklades Plateau, Dodekanisos Islands and the Gulfs of Patras and Amvrakikos in the Ionian Sea could be considered as 'low' exploited mollusc areas (Figure 1).

Surprisingly and despite their commercial value, scientific information on life cycle characteristics (e.g. growth, reproduction, mortality rate and stock size) concerning the aforementioned species in the Hellenic Seas is rather scarce and is limited to very few species (e.g. *Callista chione, Cerastoderma glaucum, Venus verrucosa*). The production of each commercial species collected from Hellenic waters is difficult to estimate since in the available official data on the commercial species, as published by the National Statistical Service and ETANAL (a Company associated with the Hellenic Ministry of Agriculture and recording production from 12 different Fisheries' Auctions located in various areas of the Hellenic Seas) only a few are specifically reported (e.g. *Mytilus galloprovinciallis, Ostrea edulis, Callista chione* and *Venus verrucosa*), others are reported only under a generic name (e.g. *Chlamys* spp. in most cases is only *Chlamys glabra*), while the rest are usually reported as 'other shells'. Another major problem is the fact that for certain species, such as *Mytilus galloprovincialis*, which are collected both by fishermen from the natural populations and the aquaculture units, the origin is not clarified in the records kept. Figure 2 depicts trends of estimated bivalve production for the period 1980 to 2004 according to NSSG. A similar trend was apparent in the mollusc yield over time (1964-2004) in the N Aegean Sea (KALAITZI *et al*., 2007). It is well documented that the N Aegean Sea constitutes one of the most significant areas in the eastern Mediterranean Sea for bivalve production concerning both fishing and culture activities (more than 80% of the total Hellenic shellfish production is derived from this area). Analysis of data has revealed that the shellfish total annual yield fluctuated (although in low levels) up to the early 1990s when a great increase was observed due to the increasing demands for export to the European market. The high quantities of the shellfish production remained steady for the next years but a sharp decreasing trend appeared from the year 1997 onwards (Figure 2).

A similar declining trend was also evident during the last fifteen years when fishing vessels with a main license in shell fishing with dredges are condidered (Table 2). Although many other vessels may engage in shell fishing as a secondary or non-targeted activity, the declining trend in the number of vessels with a shell-fishing main license is indicative of the overall trend in shell fishing in Hellenic waters and is in accordance with the declining trend in production. Most shell fishing vessels operate in Thermaikos Gulf and Chalkidiki and markedly fewer vessels operate in Argolikos, Saronikos, and Evvoikos Gulfs, and in other areas (Table 3).

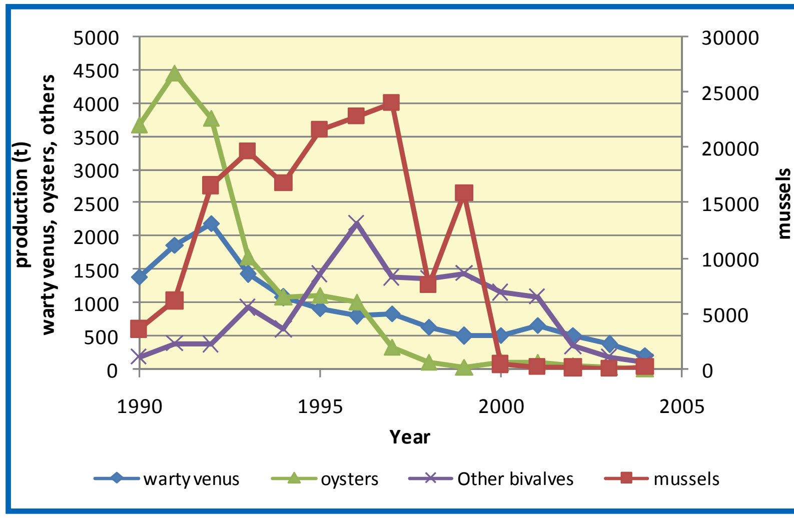

Figure 2: Time series of estimated bivalve production according to NSSG (extrapolated data based on sampling shell fishing vessels > 20HP). Source: IMAS-Fish, 2007.

SPECIES OF MAJOR COMMERCIAL INTEREST

The available existing scientific information along with data on the production for the species with major commercial value in the Hellenic Seas is presented below in detail.

- ***Hexaplex* (= *Murex* /*Phyllonotus*) *truncului* (Linnaeus, 1758)**

Hexaplex trunculus (Figure 3) is a very common gastropod species thriving in every type of substrate (sandy, muddy, hard bottoms and seagrass beds) and has a wide distribution in the eastern Atlantic Ocean and the Mediterranean Sea (KOUTSOUBAS, 1992; DELAMOTTE & VARDALA-THEODOROU, 2001). It is a carnivore and a scavenger feeding on bivalves, gastropods, barnacles, sea urchins, dead fish, etc. *Hexaplex trunculus* along with *Bolinus brandaris* and *Stramonita* (= *Thais*) *haemastoma* were heavily exploited during ancient and Roman times for the production of a deep purple dye (imperial purple) that was used to decorate royal garments; the dye was produced from the mucus of the hypobranchial gland of the three species. During spring and early summer, *H. trunculus* forms numerous aggregations that may reach hundreds of individuals and reproduces massively producing large egg masses that have the appearance of sponges (Figure 3). It is considered as an excellent sea food. However it is not collected in large quantities (less that 5ts/year) by divers or as a by-catch

Table 3. Distribution of vessels with a main license in shell fishing with dredges in NSSG areas during 1991–2006 Source: IMAS-Fish, 2007.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Kyparisiakos and Mesiniakos Gulfs	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Argolikos and Saronikos Gulfs	46	40	34	33	33	31	28	27	22	21	21	20	17	17	17	17
Korinthiakos Gulf	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Evvoikos Gulf	15	16	18	18	17	16	16	16	16	15	17	17	17	17	18	17
Pagasitikos Gulf	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2
Thermaikos Gulf and Chalkidiki	89	87	85	82	75	73	72	72	59	56	56	53	51	48	40	38
Strymonikos, Kavala, Thassos, Thracian Sea	14	14	11	11	11	10	10	10	10	10	10	9	9	9	8	7
Islands of Lesvos, Chios, Samos and Ikaria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dodekanissos	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0
Kyklades	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kriti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL	**175**	**168**	**157**	**152**	**144**	**138**	**134**	**133**	**115**	**110**	**112**	**106**	**100**	**97**	**89**	**85**

Figure 3: Shells of *Hexaplex trunculus* from the Hellenic Seas. In the right photo egg masses produced by the species and found on the coasts after strong storms. (Photos: D. KOUTSOUBAS).

from the bottom trawls. It is infrequently found in the fish markets in the Dodekanisos islands, the Evvoikos Gulf, the Thermaikos and Kavala Gulfs as well as in the islands of the NE Aegean.

- ***Arca noae* Linnaeus, 1758**

Arca noae (Figure 4) is an epifaunal bivalve of hard substratum whose distribution ranges from the eastern Atlantic Ocean, the Mediterranean and Black Seas to the West Indies. It lives attached with a solid byssus on rocks and shells occurring either solitarily or in clumps of conspecifics with the similarly byssally attached mytilid *Modiolus barbatus* at depths ranging from approximately low tide level to deeper than 100m. In some locations the species is commercially important as a seafood resource and natural populations are harvested by local fishermen and divers. On average it has a maximum length of 7cm, lives for as long as 16 years and may reach population densities of >12 ind m^{-2}.

It is very common in the Hellenic Seas and is mainly collected in the Evvoikos Gulf, the islands of the NE Aegean (especially Lesvos and Limnos), the continental shelf of the N Aegean (mainly the Thermaikos, Chalkidiki (Ierissos, Sithonia), Strymonikos and Kavala Gulfs) and the Ionian Sea. Its mean annual production over the last decade reached 10ts. *A. noae* is a major target species (mean annual production over 6ts for the fishing periods from 2000 to 2004) for the local fishermen in the Island of Lesvos (and in particular the Gulfs of Kalloni and Geras) where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005).

Figure 4: External and internal views of the bivalve shell of *Arca noae*. (Photo: D. KOUTSOUBAS)

- ***Modiolus barbatus* (Linnaeus, 1758)**

Modiolus barbatus is a commercially important mussel, distributed in the eastern Atlantic from the British Isles south to Mauritania, including the Mediterranean Sea and lives attached to rocky substrata by strong byssus threads from the lower midlittoral down to depths of approximately 110 m. It grows up to 6cm long, although individuals are usually smaller. The shell (Figure 5) has an elongated oval shape and the outer surface has a yellowish-white, light yellow or reddish-brown colour. Over the posterior half of the shell the periostracum bears long, flat bristles, each with a distinctly serrated edge, which is the reason for naming the species 'bearded horse mussel'. *M. barbatus* similarly to *A. noae* is a major target species (mean annual production over 200t for the fishing periods from 2000 to 2004) for the local fishermen on the Island of Lesvos (and in particular the Gulf of Kalloni), where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005). However, the species is not consumed locally and all the production is exported either to the northern parts of Hellas (mainly the markets of Thessaloniki and Kavala)

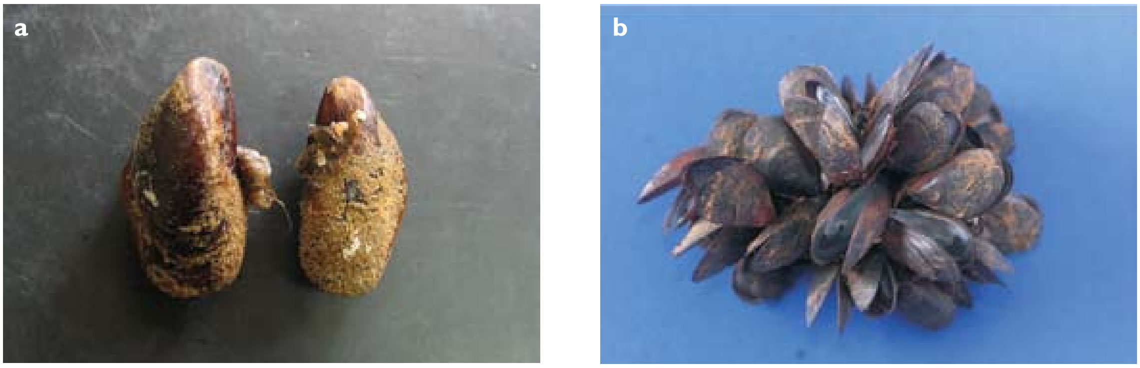

Figure 5: a) External view of the Bearded horse mussel *Modiolus barbatus* (Photo S. Galinou-Mitsoudi); b) Part of a mussel bed of *Mytillus galloprovincialis*. (Photo: D. KOUTSOUBAS).

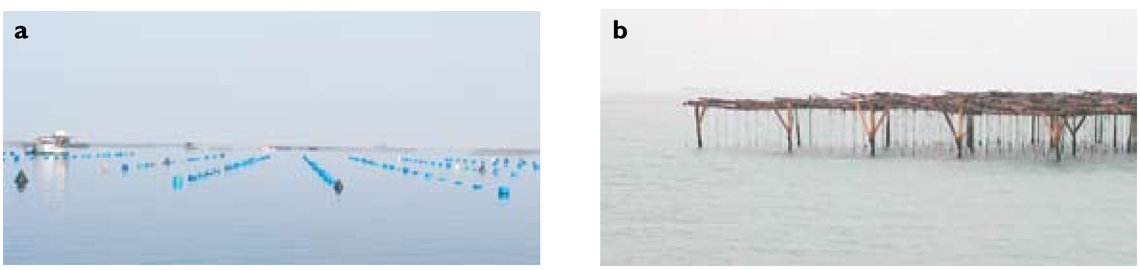

Figure 6: Mussel *Mytillus galloprovincialis* culture techniques (a) buoyed longline) and (b) rank-hanging in the Thermaikos Gulf. (Photos: S. GALINOU-MITSOUDI).

or abroad (Italy). The species is also exploited in the N Aegean (mainly the Thermaikos Gulf) where a mean annual production of 200t has been reported (GALINOU-MITSOUDI & PETRIDIS, 2000). Studies of the population in this area have revealed that the mean annual growth is 1.11 cm with a range of 0.3 - 1.9cm. The *M. barbatus* spatial distribution follows the contagious type including all ages which could be represented in each aggregation. This fact results in the discarding of undersized mussels (<5 cm) by the fishery which exceeds 90 % (GALINOU-MITSOUDI & SINIS, 2000). However, since 2002 fishing of *M. barbatus* is forbidden in the Thessaloniki Gulf due to the presence of high concentrations of heavy metals (Cd) detected in the edible part of the organism. This prohibition may lead to the recovery of the natural populations.

- ***Mytilus galloprovincialis* Lamarck, 1819**

Mytillus galloprovincialis is a Mediterranean species, whose exact range of distribution is not well defined due to the confusion with the very similar congeneric *M. edulis*. It is an intertidal species extending down to 40m depth and it may be found on all European coasts with hard substrata. It lives attached by byssus threads to rocks, piers and ropes within sheltered embayments, harbours, estuaries and on open rocky shores, while it may also form dense mussel beds directly on sandy-muddy bottoms in favourable sites (Figure 5b). The mean density in the most crowded beds may reach 24 000 mussels/m^2 (FAO, 2007). Intertidal specimens often remain small, rarely exceeding 6cm, while deep-water individuals often attain a length of 9cm and occasionally may reach even 15cm. Hellas along with Italy and Spain are the Mediterranean countries with the largest catches of *M. galloprovincialis* (FAO, 2007). Apart from natural populations, the species is also intensively cultured, mainly in coastal waters from the NE Atlantic (Galicia - NW Spain) to the northern shores of the Mediterranean Sea (FAO, 2007).

With regard to mussel culture, there are two systems employed (CONIDES & KEVREKIDIS, 2005); the traditional rack-hanging system installed in relatively shallow areas (-5m) and the more modern 'buoyed long-line' deployed offshore (Figure 6). Both use inland facilities. Mussels in both methods are stocked in special mesh netting, called 'socks', hanging from a wood or galvanized tube in the rack-hanging system or from the main horizontal rope in the long-line system. Mussel farming is based on natural settlement. Spat is commonly

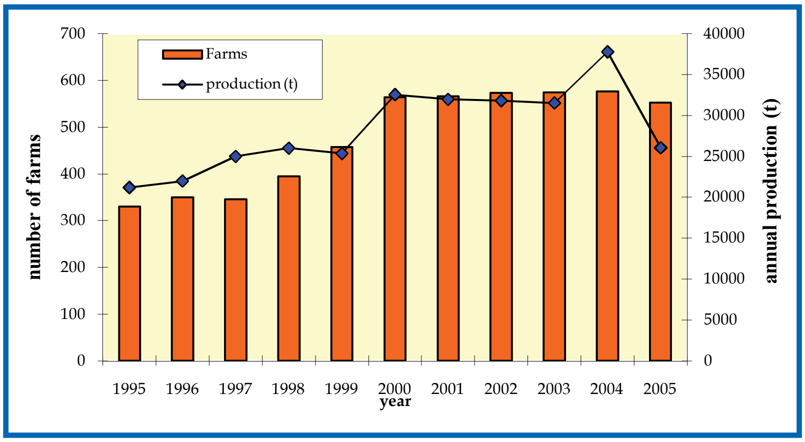

Figure 7: Trend in mussel farms and respective production in the Hellenic Seas over the last decade.

Figure 8: External and internal view of the shells of the Lagoon cockle *Cerastoderma glaucum.* (Photo: D. KOUTSOUBAS).

collected from vertical nets and ropes used as 'collectors' hanging in the water column during the two main reproductive peaks of the year (autumn, spring).

Mussel farming is one of the most dynamic sectors of Hellenic aquaculture and more than 550 mussel farms existed in 2005 (Figure 7) with the majority of those deployed in gulfs and bays of northern Hellas and especially the Thermaikos Gulf (88% of the farms are installed in this area). In this area, the presence of high concentrations of nutrients often leads to eutrophication, especially in the north-western part of the gulf, where mussel farming is concentrated, and a significant growth of mussels can be achieved in a relative short period of time [in a period of 7-8 months from spat collection, mussels reach commercial harvested size (5-6 cm in shell length)]. Mussel production has increased over the period 1995-2004 and came to approximately 37 000 t/year (Figure 7).

However, since 2001 harmful algal blooms and biotoxins affect the mussel farmers in this area. Furthermore, mussels produced are of a poor quality, with a tendency towards deterioration. This phenomenon has been attributed to the recent lower food availability in relation to the past, which subsequently leads to undernourishment of mussels (as evidenced by the low fullness of their stomachs - GALINOU-MITSOUDI unpubl. data).

- ***Cerastoderma glaucum*** **(Poiret, 1879)**

The lagoon cockle *Cerastoderma glaucum* is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy and muddy bottoms of the upper sublittoral zone in coastal areas and particularly various types of transitional water ecosystems such as estuaries, lagoons, saltmarshes and saltworks (LEONTARAKIS *et al.*, 2007). *C. glaucum* (Figure 8) is able to tolerate a wide salinity (5-38‰) and temperature range (0-25°C) and therefore, can be present in numerous populations (e.g. >368 cockles/m^2; LEONTARAKIS *et al.*, 2007). It is a characteristic species in many transitional ecosystems in the Hellenic Seas such as the Amvrakikos Gulf, the Gialova, Messolonghi, Nestos and Vistonis lagoons as well as the Evros Delta and the Maliakos Gulf (ZENETOS, 1996; KOUTSOUBAS *et al.*, 2000; NICOLAIDOU *et al.*, 2005). Studies from different Hellenic lagoons (GONTIKAKI *et al.*, 2003; LEONTARAKIS *et al.*, 2005; 2007) showed that each local lagoon cockle population has a characteristic strategy governing its physiological functions, affected by the local environmental conditions. It is collected by local fishermen in certain areas (e.g. Nestos and Vistonis lagoons – approximate production of 5 t) over a certain period of the year (such as before Easter) for human consumption.

- ***Donax trunculus*** **(Linnaeus, 1758)**

Donax trunculus (Figure 9) is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy bottoms of the upper sublittoral zone. On the coasts of the Thracian Sea where it is mainly harvested by dredging, it reaches a length of 4.2 cm and has a mean density of 37.5 indiv./m^2 (PSALTOPOULOU *et al.*, 2001). However, a decline in the annual production has been recently observed (Figure 9b), which has been attributed to fishing pressure (PSALTOPOULOU, 1999). The bivalve is not consumed in Hellas, therefore, the whole production is exported to Italy.

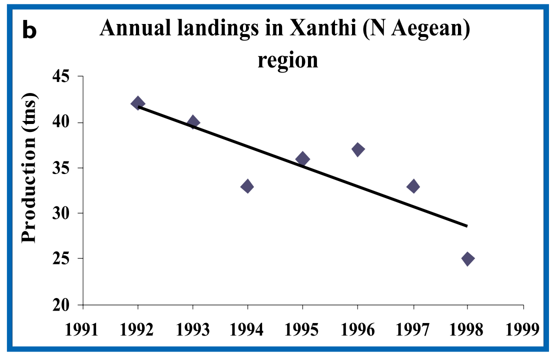

Figure 9: External and internal view of the shells of the Wedge shell *Donax trunculus* (left); Fisheries production of the *Donax trunculus* from the coasts of Thracian Sea (Xanthi) (PSALTOPOULOU, 1999).

Figure 10: a) Harvest of the Smooth scallop *Chlamys glabra* from the Kalloni Gulf (Lesvos isl, NE Aegean) b) traditional dredge gear "argalios"(Photos: D. KOUTSOUBAS).

- ***Chlamys (=Flexopecten) glabra* (Linnaeus, 1758)**

Chlamys glabra is a Mediterranean species living in detritic sand and biogenic sediments down to 40m depth. Shells living in the shallower waters often remain small, rarely exceeding 6cm, while in deeper waters shells may reach a length of 9 cm (KALATHAKI, 1992). In the Hellenic Seas it is mainly collected in the continental shelf of the N Aegean (mainly the Thermaikos Gulf), and the island of Lesvos in the NE Aegean (Figure 10). It is also found in the Patraikos, Korinthiakos and Evvoikos Gulfs (ZENETOS, 1996)

Chlamys glabra was a major target species (mean annual production over 20t between mid 1970s and late 1980s, 5 t from the late 1980s to 1990s) in the fishery of the Island of Lesvos (and in particular the Gulf of Kalloni being, along with sardines, the two most popular biological resources of this area) and it was collected either by a traditional dredge ('argalios' or 'lagamna': Figure 10) and/or by divers (PASPATIS & MARAGKOUDAKI, 2005). Unfortunately, smooth scallop stocks in the Gulf of Kalloni seem to have collapsed recently (from 2003 onwards) due to intensive harvesting and the lack of any rational management. Over the last three years most of the production of this bivalve (less than 10 t/year) is mainly derived from the thriving populations in the Thermaikos Gulf. However, the scallops fishery status in Thermaikos gulf since 2003 is similar with *M. barbatus* due to heavy metals in the scallops flesh.

- ***Pecten jacobaeus* (Linnaeus, 1758)**

Pecten jacobaeus (Figure 11) is endemic to the Mediterranean Sea. It is one of the largest Mediterranean bivalves, with a length that may reach 15 cm. It lives on sandy and muddy bottoms of the sublittoral zone and can actively swim to escape from predators by means of a form of jet propul-

Figure 11: *Pecten jacobaeus* (a); *Ostrea edulis (b)*. (Photos: S. KATSANEVAKIS).

sion. *P. jacobaeus* is edible but occurs in exploitable quantities only in the northern Adriatic Sea. In the Hellenic Seas, *P. jacobaeus* is widespread from the Ionian Sea and Sea of Kythira to the Aegean (ZENETOS, 1996), but its density is generally too low to support a cost-effective fishery. It is usually caught as a by catch by fishing trawls and dredges or collected by divers. The most dense scallop population reported in Hellenic waters is the one in the marine lake Vouliagmeni (Korinthiakos Gulf), with maximum density exceeding 50 scallops per 1 000 m^2, and a total estimated abundance exceeding 20 000 individuals (KATSANEVAKIS, 2005). However, shell fishing is prohibited in the lake, while due to its small size it could not support a substantial scallop fishery even if shell fishing was allowed.

- ***Ostrea edulis*** **Linnaeus, 1758**

The European flat oyster *Ostrea edulis* is the native species of oyster found throughout Europe (from Norway to Morocco, in the whole Mediterranean Basin and the Black Sea). Natural populations are also observed in eastern North America from Maine to Rhode Island, following introductions in the 1940s and 1950s (FAO, 2007). Ostrea edulis (Figure 11) has an oval or pear-shaped irregular shell with a rough, scaly surface and a distinct hooked beak, patterned with delicate foliation. The left shell is deeply concave and fixed to hard substratum, the right being flat with rougher edges and sitting inside the left acting as a lid. The flat oyster can reach large sizes (>20cm) and grow very old (>20 years).

It has been cultured for food since Roman times and used to be the basis for oyster production in many European countries. However, since the early 1970s, many flat oyster populations suffered massive mortalities due to infection by the pathogenic protozoan parasites *Marteilia refringens* and *Bonamia ostreae*. Similarly in Hellas, oyster stocks in the Thermaikos Gulf (mean annual production over 600t up to the late 1990s) collapsed (Figure 2), due to infection by *Marteilia* sp. (VIRVILIS & ANGELIDIS, 2006). Over-fishing has also been suggested as one of the major reasons for the collapse of the natural populations (GALINOU-MITSOUDI & SINIS, 2000). Recently an oyster culture unit has started on the coast of Argos (Peloponnisos, S Aegean) using the long-line cultivation system but production is directed only to the domestic market (CONIDES & KEVREKIDIS, 2005).

- ***Callista chione*** **Linnaeus, 1758**

Callista chione (Figure 12a) is a shallow-burrowing filter feeder, inhabiting the surface layers of fairly clean sandy sediments, from just offshore to a depth of about 130m. It occurs south of the Iberian Peninsula, into the Mediterranean, along the Atlantic coast of Morocco and up to the Canary Islands and the Azores. It is among the most abundant bivalve species inhabiting shallow soft-bottom Mediterranean shores (ZENETOS, 1996). Studies conducted in Hellenic waters (METAXATOS, 2004; LEONTARAKIS & RICHARDSON, 2005) have shown that *C. chione* is a slow-growing species that attains a shell height of about 6cm in 15-17 years.

C. chione reaches commercial size (4.5 cm) after 3-4 years. The natural mortality rate of the population in the N. Evvoikos Gulf was estimated at 0.271 y^{-1}. The species is gonochoristic, with multiple spawning all year round, capable of gonadal maturation after the second year of life (METAXATOS, 2004). The smooth Callista is economically important in several Mediterranean countries (Spain, Italy, Croatia and Hellas) where an extensive clam fishery is carried out by the artisanal fleet. In the western Mediterranean the most commonly used fishing method is dredging (GASPAR *et al.*, 1999),

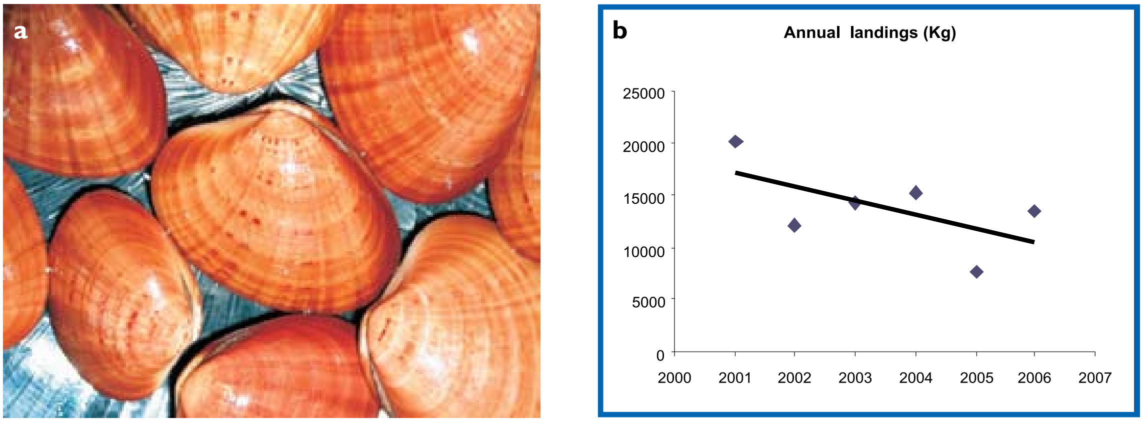

Figure 12: a) Individuals of the smooth clam *Callista chione* collected in the N Aegean Sea (left) (Photo: P. LEONTARAKIS); b) Fisheries' production of the Smooth clam *Callista chione* from the Hellenic Seas. Source data: ETANAL.

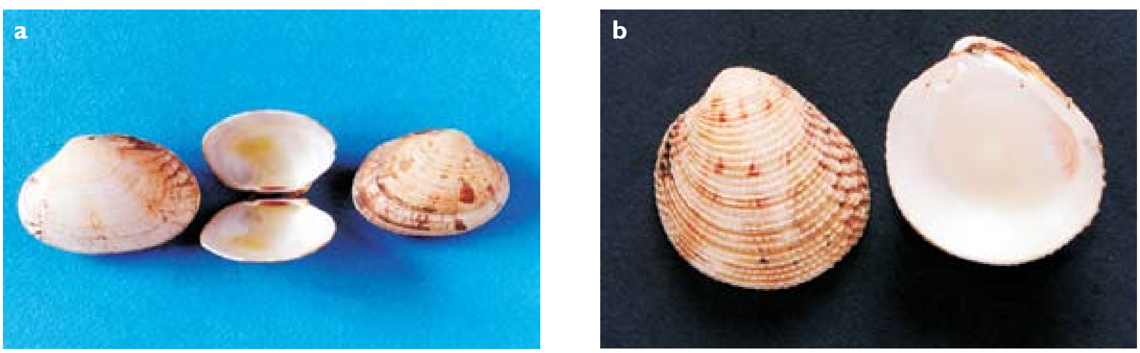

Figure 13: External and internal view of the shells of a) *Ruditapes decussatus* and b) *Venus verrucosa* (Photos: D. KOUTSOUBAS).

while in the coastal waters of the Aegean Sea it is mostly collected by divers (METAXATOS, 2004). Populations of *C. chione* in the Hellenic Seas are found in the Evvoikos, Saronikos and Thermaikos Gulfs as well as the Cretan Sea (DELAMOTTE & VARDALA-THEODOROU, 2001) and in the Gulf of Patras, Ionian Sea (ZENETOS, 1993). Despite the decline in the landings of *C. chione* in the fish markets as recorded by ETANAL over the last seven years (Figure 12b) the species still has a considerable production (over 10 t/year).

Studies on the population dynamics of the species in the N Evvoikos Gulf have revealed that overfishing pressure exists from divers who exploit the stocks, particularly on older and bigger clams while younger clams (<4 years old) are not selected (METAXATOS, 2004).

- ***Ruditapes (=Tapes/ Venerupis) decussatus* (Linnaeus, 1758)**

Ruditapes decussatus (Figure 13) is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy and muddy bottoms of the upper sublittoral zone in coastal areas and particularly various types of transitional ecosystems (e.g. estuaries, lagoons). It is collected by local fishermen in certain areas such as the Pylos and Nestos Lagoons and the Axios Delta (KOUTSOUBAS *et al*., 2000; NICOLAIDOU *et al*., 2005), the Evros and Vistonis Lagoons (LEONTARAKIS, unpubl. data) and the Papa Lagoon (CHRYSSANTHAKOPOULOU & KASPIRIS, 2001). In the latter lagoon *T. decussatus* reaches a size of about 5 cm in the fifth year of its life and has an approximate annual production of 10 ts (most of which is exported to Italy).

- ***Venus verrucosa* Linnaeus, 1758**

The warty venus, *Venus verrucosa* is found from Norway to Durban (South Africa) and is common in the Mediterranean on detritic sandy bottoms, sand bottoms scattered with coralline rhodoliths, gravel substrate as well as in *Posidonia oceanica* meadows, usually up to a depth of about 30 m

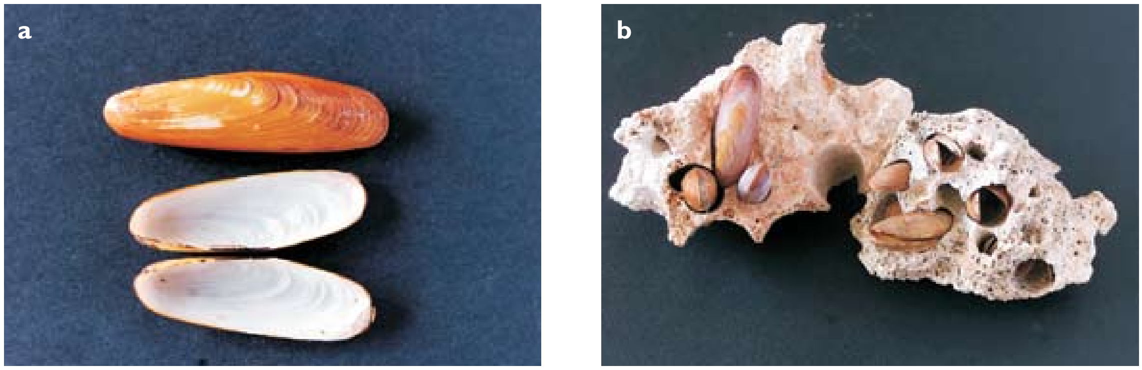

Figure 14: a) View of the external and internal part of the shells and b) of specimens in their natural habitat - calcified hard substrate of the European date mussel *Lithophaga lithophaga* (Photos: D. KOUTSOUBAS)

(ZENETOS, 1986). The species (Figure 13) which is very sensitive to extreme temperature and salinity variations (e.g. impact on growth, development of microbes), may attain a length of 6cm. It is fished intensively off the coasts of Normandy and Brittany and sustains commercial fisheries in some areas of the Mediterranean such as the southern Adriatic and the Aegean Sea (ARNERI *et al*., 1998).

In the Hellenic Seas it is mainly collected in the Evvoikos and Saronikos Gulfs, the islands of the NE Aegean (especially Lesvos and Limnos) and the continental shelf of the N Aegean (mainly the Thermaikos Gulf, Gulfs of Ierissos, Strymonikos and Kavala). *V. verrucosa* is a major target species (mean annual production over 15t for the fishing periods from 2000 to 2004) for the local fishermen on the Island of Lesvos (and in particular the Gulfs of Kalloni and Geras) where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005). Studies on reproductive aspects of *V. verrucosa* examined in the Thermaikos Gulf populations (GALINOU-MITSOUDI *et al*. 1997) have shown that sexes are separated, first reproduction occurring at a shell length greater than 1.9cm at the age of 1+ years. The gonads are at rest during the winter or at the beginning of gonad development during winter and spring. The maturity and release of gametes occurs during an extended period from May to November after the water temperature increase (>17.4 °C). Yields of warty venus from this part of the Hellenic Seas have stabilized at moderate quantities (~250 t/year) over the last years (Figure 2) while at the beginning of 1990s the annual yield was over 2 000 t.

SPECIES OF MINOR COMMERCIAL INTEREST

Among species of minor commercial interest (Table 1), there are species characterized as endangered or threatened and protected, not only by the Hellenic legislation but also by European and International laws (Bern Convention, Protocol Barcelona Convention, EC Habitats Directive 92/43), i.e. the tritons *Charonia tritonis variegata* and *Argobuccinum olearium*, the fan mussel *Pinna nobilis* and the European date mussel *Lithophaga lithophaga*. However, all these illegally collected species are caught only in small quantities and are not sold in fish markets but only sporadically in local small restaurants. The available existing scientific information for two of these species (i.e. *L. lithophaga* and *P. nobilis*) is presented below.

- ***Lithophaga lithophaga*** **(Linnaeus, 1758)**

The European date mussel *Lithophaga lithophaga* (Figure 14) is endemic to the Mediterranean Sea and is an inhabitant of hard substrata (calcified) communities in the midlittoral and upper sublittoral zones (GALINOU-MITSOUDI & SINIS, 1994). The autoecology (ecology, population dynamic, biology) of *L. lithophaga* has been extensively studied in the Evvoikos Gulf (GALINOU-MITSOUDI & SINIS, 1994, 1995). The population density of this species which seems to be dependent on the substratum type (limestones), the presence of other organisms (e.g. endolithic), predation and environmental conditions is higher in the N. Evvoikos (36 indiv./dm^3). The age of the first reproduction is 2+ years and the reproductive activity is annual and continuous. The main reproductive period is during the summer and autumn in water temperatures > 14°C. *L. lithophaga* is a long-lived species (> 54+ years) and its growth rate is one of the slowest among bivalves. The highest growth rate is observed at the end of spring and early summer. Annual productivity of *L. lithophaga* is 1659.6 g/m^2. The annual turnover ratio (P/B) was 0.845 in the

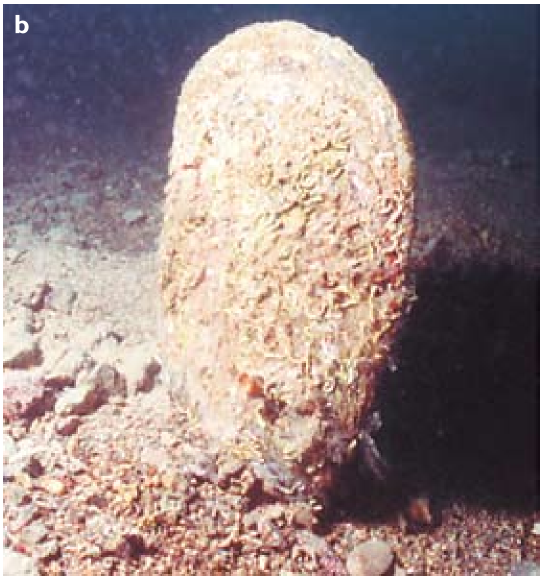

Figure 15: Photos of live specimens of the fan mussel *Pinna nobilis* in its natural habitats a) *Posidonia* meadows (Photo: D. Koutsoubas); b) sandy bottoms (Photo: S. KATSANEVAKIS).

Evvoikos' population and among the lowest values reported in the literature. Besides the Evvoikos Gulf, populations of the species are also found in the Ionian islands, Ipeiros coasts, Korinthiakos Gulf, Sea of Kythira, N Sporades Islands, Dodekanisos, Kriti, Lesvos isl., Maliakos, Argolikos, Chalkidiki (ZENETOS 1986; 1996; GALINOU-MITSOUDI & SINIS, 1994, 1997a; GEROVASILEIOU *et al*., 2007) and are still sporadically exploited (however, with a reduced frequency due to existing legislation) by divers as a food resource.

- ***Pinna nobilis* (Linnaeus, 1758)**

The fan mussel *Pinna nobilis* (Figure 15) is endemic to the Mediterranean Sea and occurs at depths between 0.5 and 60 m, mostly in soft-bottom areas overgrown by seagrass (mostly *Posidonia* meadows) but also in unvegetated sandy bottoms (KATSANEVAKIS 2006, 2007a). It is the largest Mediterranean bivalve and one of the largest in the world, attaining lengths up to 120 cm. *P. nobilis* is long-lived and may live over 20 years (GALINOU-MITSOUDI *et al*., 2006). Fan mussels live partially buried (usually >35 % of their length) by the anterior portion of the shell and attached by their byssus to the substratum.

Reproduction of *P. nobilis* takes place by means of external fertilization and its success depends on the proximity of other individuals spawning synchronously. When a population becomes sparse (as is the case for most fan mussel populations in the Mediterranean) failure of fertilization becomes a critical issue for the survival of the species. The planktonic period is short, hence populations (especially in closed embayments) which are relatively isolated are not easily recolonised if depleted. The global population of *P. nobilis* has been greatly reduced over the past few decades as a result of recreational and commercial fishing for food, the use of its shell for decorative purposes, and incidental mortality by trawlers, bottom nets, or anchoring. Although *P. nobilis* has become rare in many parts of the Mediterranean, important local populations still exist in the Hellenic Seas (HAMES *et al.,* 2001; GALINOU-MITSOUDI *et al*. 2006; KATSANEVAKIS 2006, 2007a; GEROVASILEIOU *et al*., 2007) especially in the Korinthiakos, Evvoikos, and Thermaikos Gulfs, the islands of Chios and Lesvos (NE Aegean), NW Kriti as well as the Ionian Sea (ZENETOS 1986; 1996).

Despite being a protected species, in certain areas fishing mortality greatly exceeds natural mortality and is a critical determinant of the spatial distribution of the species. In Vouliagmeni Lake a marked zonation of *P. nobilis* individuals occurred with the species being restricted in the shallow peripheral zone at depths <22 m, with a major peak at depths between 12 and 13 m and was attributed to mortality due to illegal fishing by free divers (KATSANEVAKIS, 2007b). Natural mortality in this population was strikingly size dependent and *P. nobilis* suffered high natural mortality during the first year of life; the probability of death by natural causes quickly diminished as the fan mussels grew in size. Growth rates had a seasonal pattern, with an extended period of very slow growth between late autumn and early spring and a peak in growth rates during late spring - early summer, probably related to an optimum combination of temperature and food availability (KATSANEVAKIS, 2007b). The abundance of *P. nobilis* in lake Vouliagmeni was estimated between 5 450 – 8 400 individuals (KATSANEVAKIS, 2007a). The mean fan mussel populations' density in Chios Island was found to be 0.06 inds/m^2 with a range of 0.05 - 0.07 inds/m^2 (GALINOU-MITSOUDI, unpubl. data), while the mean density from Kefallonia Island (Ionian Sea) was 0.05 inds/m^2 with a range of 0.02-0.08 inds/m^2 (HAMES *et al.,* 2001). Recently, an undisturbed *P. nobilis* population was found in very shallow depths (2-3m) on the eastern coast (north of the Epanomi port) of the Thermaikos Gulf (GALINOU-MITSOUDI *et al.* 2006). The population density of *P. nobilis* in this area reached 1.3 inds/m^2, which is the highest reported value in the Hellenic Seas and among the highest in the Mediterranean. The fan mussels in the Thermaikos Gulf reached an age of 27 years, which is the highest reported value in the Mediterranean.

CONCLUSIONS

Despite their commercial value, scientific information concerning exploited molluscan species in the Hellenic Seas is rather scarce and limited to very few species such as *Callista chione, Cerastoderma glaucum* and *Venus verrucosa*. Similarily, the distribution, degree of exploitation and the status of populations have not been assessed for other molluscs that are not commercially exploited as a food resource but are collected for other uses (e.g. fishing bait, drug production, cosmetics, jewellery, shell collections, etc.).

Based on archived data from the ETANAL and the National Statistical Service, it appears that the shellfish production which peaked in the early 90's, has declined or even collapsed followed by an analogous decline of the vessels with a main license in shell fishing. These indicate that the respective legislation (PD 86/98 and PD 227/03) had a rather poor effect on molluscs' natural population sustainability. It is evident that assessment of exploited stocks is urgently needed towards a rational management of these biological resources in the Hellenic Seas.

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II.6. DECAPOD CRUSTACEANS: AN ACCOUNT ON SPECIES OCCURRENCE AND EXPLOITATION IN HELLENIC WATERS

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INTRODUCTION

In a recent assessment of the decapod fauna of Hellenic waters (KITSOS; *et al.,* 2006), a total of 250 species was recorded. The most diverse, in terms of species number, are the true crabs (brachyurans) followed by caridean shrimps and anomurans (hermit crabs, squat lobsters). Dendrobranchiate shrimps and macrurans (lobsters and relatives) contribute to a lesser extent to the decapod species diversity. Decapods can be found in Hellenic waters from the supralittoral habitats, such as the rock crab *Pachygrapsus marmoratus* (Figure 1), to the deepest bottoms explored so far.

Figure 1: The rock crab *Pachygrapsus marmoratus* (Photo: S. KATSANEVAKIS).

They exhibit a variety of feeding modes being filter, plant and deposit feeders as well as active predators or scavengers. Nevertheless, predation seems to be the commonest feeding type. Thus, they play a significant role in marine food webs. The great majority of decapods are found in, on or near the sea bottom (benthic or nektobenthic). Only some shrimp species are pelagic (12 species, most of them also occurring near the bottom), while a single genus is only represented in the plankton.

As a result of the size spectrum covered by different species, information on the contribution of decapods to marine communities comes from two different research fields. Small, endo- or epibenthic species (macrofauna) can be collected by benthic sampling gear, while larger species (megafauna) are found in the catches of towed gear (dredges and trawls) or nets (benthic, nektobenthic or pelagic).

OCCURRENCE OF DECAPODS IN HELLENIC WATERS

Although a comprehensive analysis of decapod overall occurrence in the Hellenic marine environment has not yet been undertaken, a relatively large amount of information has been accumulated until now thanks to benthic and fisheries' research conducted in recent years. Here, we shall consider some interesting aspects regarding decapod ecology and depth distribution (based on personal observations and relevant studies, mainly ABELLÓ *et al.,* 2002; CHILARI *et al.,* 2005; COMPANY *et al.,* 2004; DOUNAS & KOUKOURAS, 1989. D'ONGHIA *et al.,* 2003; KOUKOURAS, 2000; KOUKOURAS *et al.,* 2000; KOUKOURAS & DOUNAS, 2000; MYTILINEOU *et al.,* 2006; PAPASPYROU *et al.,* 2004; POLITOU *et al.,* 1998; 2003; 2005; UDEKEM D' ACOZ, 1999 and references therein; VAFIDIS *et al.,* 2005); then, we shall briefly present the species of importance to the Hellenic fisheries.

Shallow shelf (0-50 m)

Due to the variety of habitats encountered in this zone, decapod species' richness is considerably greater than in deeper waters. In fact, most of the records of species occurrence in Hellenic waters come from this depth zone. Nevertheless, with some exceptions mentioned below, macrofaunal decapod species richness, abundance and biomass are much lower in comparison with other benthic groups such as polychaetes or molluscs. Usually macrofaunal decapods are not commonly included in the most dominant species of soft bottom macrofaunal communities of the continental shelf and slope.

Hard bottoms covered by photophilous algae –a characteristic Mediterranean habitat structured mainly by species of the brown alga *Cystoseira*- host a variety of small decapods as well as other crustaceans such as cumaceans, isopods and amphipods. Mostly abundant among decapods are some crabs (*Acanthonyx lunulatus*, *Pilumnus hirtellus, Pirimela denticulata*) and anomurans (i.e.*Clibanarius erythropus, Pisidia* spp). Shrimps such as *Stenopus spinosus* (Figure 2), *Eualus cranchii* and *Hippolyte* spp. also find refuge there.

Megafaunal crabs such as *Macropipus depurator, Goneplax rhomboides Medorippe lanata* and *Calappa*

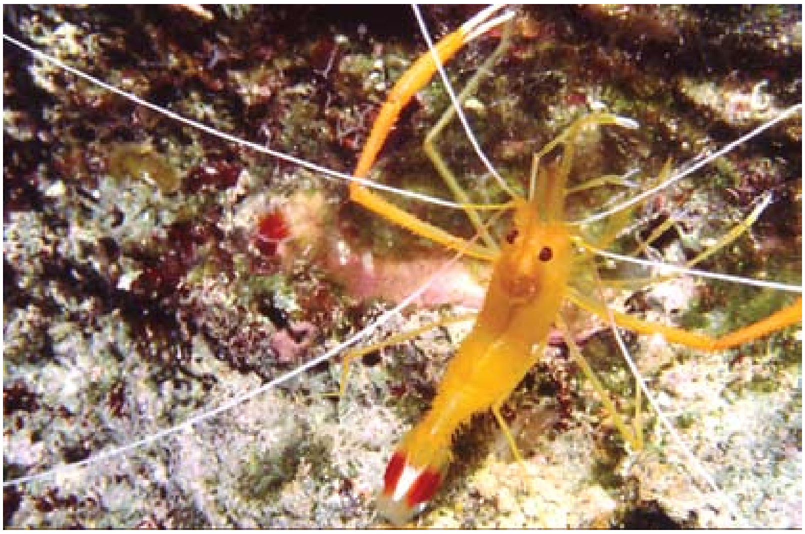

Figure 2: The orange shrimp *Stenopus spinosus* lives in caves and hard bottoms. (Photo: S. KATSANEVAKIS).

Figure 3: The ghost shrimp *Pestarella tyrrhena.* (Photo: A.TRICHAS).

granulata are dwelling on soft bottoms. They are extremely eurybathic, showing persistence in occurrence all along the entire shelf muddy bottoms, some of them even reaching the upper slope. Other smaller crabs (i.e. *Inachus thoracicus* and *Pilumnus spinifer*), inhabit the shallow soft bottoms together with a variety of small caridean shrimps (paleamonids, processids, hippolytids and crangonids), while various crabs belonging to the genus *Xantho* inhabit pebbly bottoms. In areas bordering estuaries, the dendrobranchiate caramote prawn *Melicertus kerathurus* thrives and constitutes a valuable fishery resource. In addition, burrowing thalassinid shrimps, represented by sixteen species, play an important role in sediment metabolism. Some of the thalassinids such as the mud shrimp *Upogebia pusilla* and the ghost shrimp *Pestarella tyrrhena* (Figure 3) can attain very large populations in shallow, sheltered areas (estuaries, bays) and are highly esteemed as fishing bait. On very shallow muddy bottoms of lagoons and sheltered areas the Mediterranean shore crab *Carcinus aestuarii* and the shrimps *Crangon crangon* and *Palaemon adspersus* can also be found in high abundances.

From the quantitative point of view, decapods -together with amphipods- are the most abundant macrofaunal group in sea grass meadows, mainly those of *Posidonia*. They are represented by an important number of relatively small species, especially during the night, when many species come to the meadow from adjacent biotopes. They belong to brachyuran crabs (i.e. *Achaeus gracilis*), caridean shrimps and anomurans (i.e. *Cestopagurus timidus, Pagurus* spp.). Nevertheless, the caridean shrimps such as *Hippolyte* spp., *Palaemon* spp., *Thoralus cranchii and Athanas nitescens,* are usually the most abundant numerically.

Middle Shelf (50-100)

Here, in addition to the above mentioned megafaunal crabs of the soft bottoms, other smaller crab species are encountered such as *Macropodia tenuirostris* and *Inachus parvirostris*. In this depth range, the deep-water pink shrimp *Parapenaeus longirostris* starts to appear (see section on commercial decapods). Among other decapod groups, the burrowing shrimps *Calianassa subterranea* and *Jaxea nocturna* are found in muddy bottoms.

Lower shelf (100-200 m)

To the megafaunal species mentioned in the previous shelf sections, other species (the crabs *Homola barbata*, *Latreillia elegans* and the green shrimp *Chlorotocus crassicornis*), mainly present at this depth zone, are added. Other megafaunal decapods, whose depth distribution extends to the slope, appear in this zone: the crab *Macropipus tuberculatus,* the Norway lobster *Nephrops norvegicus* (Figure 4), and the shrimps *Solenocera membranacea, Plesionika heterocarpus* and *Lysmata olavoi.* Thus, the large decapods encountered in this depth zone seem to form a transitional assemblage between shelf and slope.

Upper slope (200-500 m)

In the upper slope of the Ionian Sea, thirty species of megafaunal decapods have been reported from trawl catches. Most abundant are shrimps already mentioned in the lower part of the shelf region, i.e. *P. longirostris* and *P. heterocarpus*. A variety of other *Plesionika* species dwell in these depths (*P. antigai, P. acanthonotus, P. gigliolii, P. edwardsii* and *P. martia*) together with a variety of other benthic, nektobenthic or pelagic shrimps e.g. the giant red shrimp *Aristaeomorpha foliacea, Aegaeon lacazei, Pasiphaea sivado, Sergia robusta, Pandalina profunda*. Here, the main Hellenic fishing grounds of the Norway lobster *N. norvegicus* are located (see section on commercial decapods).

Middle slope 500-1500 m

In the 500-700 m zone, the giant red shrimp *A. foliacea* and the pandalid shrimp *Plesionika martia* predominate in the experimental catches of the Ionian Sea. The former species and the blue and red shrimp *Aristeus antennatus* are the dominant decapods found in the 700-900 m zone. Finally, the 900-1200 m zone is dominated by *S. robusta* together with the common blind lobster *Polycheles typhlops*. Deep water shrimps such as *Acanthephyra eximia*, *Acanthephyra pelagica* and *Gennadas elegans* are also present. The deep-water crab *Geryon longipes* mainly inhabits this depth zone.

Deeper than 1500 m

From these depths, seven megafaunal species have been reported. Among them, *A. eximia* is very common, while *P. typhlops, A. antennatus, G. elegans* and *S. robusta* are still present. The shrimp *Nematocarcinus exilis* and the Mediterranean endemic crab *Chaceon mediterraneus* are found only at these depths. The latter has been recorded at a depth range of 2250 to about 3000 m.

As is the rule for other megafaunal groups worldwide, slope species diversity, abundance and biomass decrease with depth. Nevertheless, in this depth range, decapod –mainly shrimp- abundance usually overwhelms that of fishes. This high relative importance of deep water decapods is attributed to the increased oligotrophy of the eastern Mediterranean, in which the decapod species concerned are able to persist due to their low levels of food requirements.

ALIEN DECAPODS IN HELLENIC WATERS

According to data compiled in GALIL *et al.* (2006), 63 alien decapod crustaceans are present in the Mediterranean. The great majority (73%) are of Indo-Pacific origin, with only 15% of tropical Atlantic origin. As a result of its geographic position, the great majority of the 15 alien decapod species recorded so far from Hellas (Table 1) are of Indo-Pacific origin having arrived in the Mediterranean via the Suez Canal.

Among alien species, ten belong to crabs, four are penaeid shrimps, and one is a caridean shrimp. As in other animal groups, most alien decapods are encountered only in S.E. Hellenic waters, their occurrence decreasing significantly northwards and westwards. The alien decapod recording rate has recently accelerated, with 5 species being added in the past two years; among them the highly invasive crab *Percnon gibbesi* (Figure 5) has already shown to be established (PANCUCCI-PAPADOPOULOU *et al.,* 2005; THESSALOU-LEGAKI *et al.,* 2006; KIRMITZOGLOU et al., 2006).

Figure 4: *In situ* photograph of the Norway lobster *Nephrops norvegicus* emerging from its burrow www.hcmr.gr

Figure 5: *Percnon gibessi* from Rodos (Photo: M. CORSINI-FOKA).

Table 1. List of alien decapods reported in Hellas

Alpheus rapacida	*Metapenaeopsis aegyptia*
Calappa pelii	*Metapenaeopsis mogiensis consobrina*
Callinectes sapidus	**Myra subgranulata*
Charybdis (Goniohellenus) longicollis	**Percnon gibbesi*
* *Charybdis hellerii*	*Portunus pelagicus*
Ixa monodi	*Thalamita poissonii*
**Leucosia signata*	*Trachysalambria palaestinensis*
Marsupenaeus japonicus	

*Alien species recently (2005-6) added to the list of Hellenic decapod fauna.

Figure 6: The caramote prawn *Melicertus kerathurus* (Photo: K. KEVREKIDIS)

SPECIES OF COMMERCIAL IMPORTANCE

In Hellenic waters, important target shrimps for the bottom trawlers are restricted to two dendrobranchiates: the caramote prawn *Melicertus kerathurus* (Figure 6) and the deep-water pink shrimp *Parapenaeus longirostris*.

The caramote prawn lives in coastal marine or brackish waters on muddy sand or sand, usually at depths between 5 and 50 m. It prefers areas in the vicinity of estuaries where its nursery grounds are located (i.e. Amvrakikos and Thermaikos Gulfs and the coastal areas of the N. Aegean). The shrimp is fished both by trawlers and the artisanal fleet. Trawl catches in theThermaikos Gulf vary greatly inter- and intra-annually, with maximum catches of up to 7.5 kg/h occurring at the beginning of the fishing season (KEVREKIDIS & THESSALOU-LEGAKI, 2006). In the Amvrakikos Gulf, only coastal boats fish the caramote prawn but the resource is considered to be under severe threat (CONIDES *et al.,* 2006).

The most profitable fishing grounds (in terms of biomass) for the deep-water pink shrimp *P. longirostris* are found mainly on the lower continental shelf of the Argosaronikos and the upper continental slope (200-500 m) of the Ionian and the S. Aegean. In the N. Aegean, the important grounds extend from middle shelf to 500 m (ABELLÓ *et al.,* 2002; SOBRINO *et al.,* 2005).
Due to the fact that trawling in Hellenic waters is mainly conducted on grounds shallower than 400-500 m, and because of their patchy distribution, the deep-water dendrobranchiate red shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* are only occasional targeted by Hellenic trawlers (PAPACONSTANTINOU & KAPIRIS, 2001, 2003). Nevertheless, in the Ionian Sea *A. foliacea* is the most important commercial species trawled experimentally at depths between 500 and 700 m (11-14 kg/h; 17-23% of the total catch) and shows substantial yields (4.8-7.4 Kg/h) in deeper waters (700-900 m). In the latter depth range, *A. antennatus* shows also a relatively high biomass (1.4-1.9 kg/h) (MYTILINEOU *et al.,* 2006). The above figures suggest the possibility for the development of deep-water fishery targeting for red shrimps, although, due to the vulnerability to fishing pressure of both the bathyal environment and *A. foliacea*, this prospect merits special attention. Biological and fishery data on *A. foliacea, A. antennatus, M. kerathurus* and *P. longirostris are provided in chapter 7:* Research on shrimps.
In the Dodecanese Islands, a traditional trap fishery exists, targeting the pandalid shrimp *Plesionika narval* (Figure 7) (THESSALOU-LEGAKI *et al.,* 1989). The fishery exploits the bottoms around the islands of Symi, Rodos and Halki. Another caridean exploited locally is *Palaemon adspersus* in the Messologhi lagoon (KLAOUDATOS & TSEVIS, 1987).
The highly valued Norway lobster *Nephrops norvegicus* shows the most profitable catches, in terms of biomass, at the upper slope (200-500 m) of the N Aegean and the Ionian Sea, while yields from the

Argosaronikos and the S. Aegean are significantly lower (ABELLÓ *et al.,* 2002; KALLIANIOTIS *et al.,* 2004). Experimental trawling in the S. Aegean showed that the species is present in the lower shelf down to 800 m (TSERPES *et al.,* 1999) but it is not reported at all in the catches from the continental margin of Kriti (KALLIANIOTIS *et al.,* 2000). Exceptionally high densities found in shallow depths have been observed in the enclosed Pagasitikos Bay where trawlers are not allowed to operate (SMITH & PAPADOPOULOU, 2003). Other lobsters such as the spiny lobster *Palinurus elephas* (Figure 8) and the European lobster *Homarus gammarus* are fished mainly by the coastal artisanal fleet on rocky bottoms up to about 50 m, from where, more rarely, the Mediterranean slipper lobster *Scyllarides latus* (Figure 9) is also collected.

Finally, some other crustaceans of secondary importance to the Hellenic fishery, marketable only locally when fished in sufficient quantities, can be mentioned. They include the crabs *Calappa granulata*, *Macropipus tuberculatus, Maja squinado,* the pandalid shrimp *Plesionika edwardsii* and the stomatopod *Squilla mantis*. Many species of decapods are totally discarded by trawlers; more than half of about 50 species recorded in commercial catches belong to brachyurans followed by caridean shrimps and anomurans. In general, the discarded crustacean fraction in the total catch is the highest in comparison to fish or cephalopods discarded, and ranges from 39 to 91% in terms of biomass (MACHIAS *et al.,* 2001).

IMPORTANCE OF DECAPODS TO FISH FEEDING

Although commercial decapod species are few, we should take into consideration an important indirect effect this animal group has on the sustainability of Hellenic fisheries. Decapods play a fundamental role as prey for predatory fish. Here, we shall give some examples from relevant research in Hellenic waters.

In the shallow waters of Kriti, decapods clearly dominate the diets of the red mullet *Mullus surmuletus* and the brown comber *Serranus hepatus* forming 89 and 67% by weight of their total diet, respectively. Most important is the mud shrimp *Upogebia tipica,* but a variety of caridean shrimps and crabs are also present in stomach contents (LABROPOULOU & ELEFTHERIOU, 1997). The same preference to decapod prey is shown by the red porgy *Pagrus pagrus,* primarily for *Upogebia* and also for the crab *Liocarcinus maculatus* (LABROPOULOU *et al.,* 1999).

Figure 7: The unicorn shrimp *Plesionika narval*. (Photo: S. KATSANEVAKIS).

Figure 8: The spiny lobster *Palinurus elephas*. www.faocopemed.org

Figure 9: The Mediterranean slipper lobster *Scyllarides latus*. (Photo: S. KATSANEVAKIS).

The Mediterranean poor cod *Trisopterus minutus capelanus* depends primarily on decapods for food, while fish are second in importance. Although the shrimp *Alpheus glaber* is the most frequent food item in its diet, a variety of other carideans (paleamonids and processids), brachyurans as well as of other decapod groups are also exploited (POLITOU & PAPACONSTANTINOU, 1994)

The four-spotted megrim *Lepidorhombus boscii* preys mainly upon caridean shrimps (*Alpheus glaber* and *Processa canaliculata*) in the sandy or muddy bottoms of the N. Aegean (200-400 m) (VASSILOPOULOU, 2000).

The mesopelagic shrimps *Pasiphaea sivado* and *Sergestes arcticus* are the most important prey of the bathyal demersal fishes such as *Chlorophthalmus agassizi* and *Hoplostethus mediterraneus* on the upper slope of the Ionian Sea, where, an important correlation exists between fish predator abundance and prey availability (MADURELL *et al.,* 2004).

Finally, decapods contribute to the diet of the commercially important decapod species. For example, the pink shrimp *P. longirostris* feeds on other decapods such as shrimps and crabs (LABROPOULOU & KOSTIKAS, 1999; KAPIRIS, 2004).

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CHAPTER III

CURRENT STATE OF THE FISHERIES SECTOR

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INTRODUCTION

Fishery in Hellas constitutes an important sector of the primary production and has always been both a professional and a leisure activity, closely related to a community's social structure and tradition, contributing in a small or a greater proportion to the economy of each particular area. Due to certain geomorphological and biological characteristics of the Hellenic Seas, and mainly the extended and complicated coastline, the narrow continental shelf, the low productive capacity of the waters, the complex multi-species nature of the ecosystem, as well as the prevailing socio-economic structures, a significant development of the small-scale multi-gear fisheries was favoured.

The Hellenic fisheries sector underwent rapid changes during the last 25 years mainly because of the participation of Hellas in the European Union. Despite the modernization of the fleet and the fisheries regulations under both the CFP and the national fisheries policy, landings are consistently declining, affected by the recent crisis of the industry all over Europe: scarcity of natural resources, pressure on fishing stocks and intense market competition worldwide. Falling catches across EU waters highlight the fishing of stocks beyond maximum sustainable yield, despite constant efforts to regulate fisheries. This failure has been analyzed in depth during the last decade by the scientific community, which has repeatedly recommended substantial changes in incentives and governance, as well as adjustments in the way that fisheries research and monitoring are conducted and expertise is deployed. The situation is even more complex in the Mediterranean, due to the poorly developed fishery data collection systems and the lack of historic long-term time-series, which make knowledge of the current state of the fisheries far below what it ought to be. Recently, however, the establishment of a Community framework for the collection and management of fishery data was adopted by all EU members, and may radically contribute to the evaluation and improvement of the situation of the fishery resources and the fisheries sector.

The current chapter aims to give the readers a clear understanding of some of the key issues involved in giving shape to the contemporary state of the Hellenic commercial fisheries sector. Information contained within the chapter has been gathered from a number of different sources including legislation, official documents, scientific publications and research project reports. A compilation of ten papers provide information on a variety of topics including an explicit description of the sector by presenting the fishing gears and methods used, the landings that are produced, the existing data recording systems, the management of fleets and resources as defined by both EU and national legislation, and certain socio-economic features of professional fishermen. In some cases there are strong links between papers and when these occur references are made within the text. However, there are also more subtle links between chapters, so if the readers wish to improve their understanding of the different issues of the sector, including how it has evolved to what is in place today, they need also to consider related sections in different chapters.

Vassiliki F. Vassilopoulou

III.1. THE FISHERIES IN THE MEDITERRANEAN SEA

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INTRODUCTION

The Mediterranean Sea is the largest of the semi-enclosed European Seas. It is surrounded by 18 countries and has shores on three continents (Europe, Africa and Asia) with a coast-line of 46 000 km, where some 129 million people live. It has an average depth of 1.5 km, and more than 20% of the total area is covered by water less than 200 m deep (UNEP, 1989). The sea consists of two major basins, the eastern and the western. There are also smaller regional seas within the Mediterranean such as the Ligurian, Tyrrhenian, Adriatic, Aegean seas. It is linked to the Atlantic by the Straits of Gibraltar, with the Black Sea and Sea of Azov by the Dardanelles, the Sea of Marmara and the Bosphorus, and with the Red Sea through the Suez Canal. The Mediterranean Sea is characterized by low precipitation, high evaporation, high salinity, low tidal action and relatively low nutrient concentrations outside the inner coastal zone and parts of some regional seas.

GENERAL DESCRIPTION OF FISHERIES IN THE MEDITERRANEAN SEA

Mediterranean fishery represents about 23% of the total Community fleet expressed in tonnage and 35% in engine power. In numbers, it represents about 48% of Community fishing vessels. On average, fishing vessels in the Mediterranean are smaller than in the rest of the Community. More than 34 000 vessels, around 80% of the Mediterranean vessels, are smaller than 12 m in length, giving the Mediterranean fleet its characteristics of a small scale artisanal fishery, although a large proportion of the catches is taken by larger, non artisanal vessels[1]. The landings in volume in the Mediterranean represent a relatively modest share of about 12% of total Community landings.

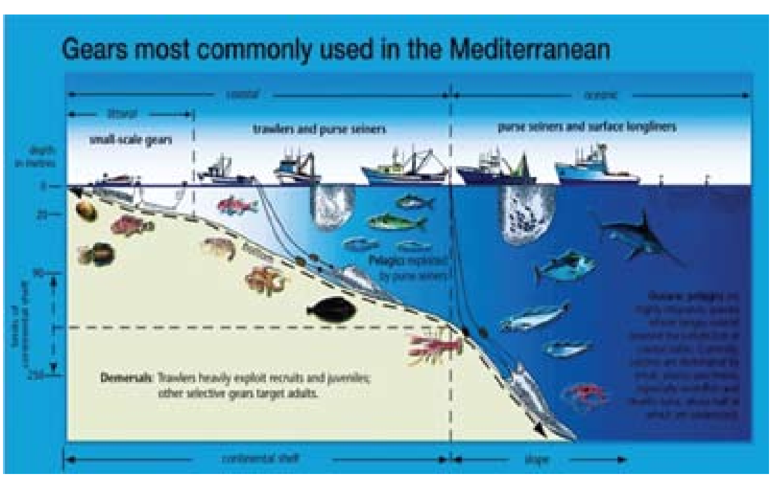

Figure 1: Most commonly used gears in the Mediterranean Sea. Source: www.fao.org.

The fishing fleet

The Mediterranean fisheries can be broken down into three main categories: small scale fisheries, trawling and seining fisheries (Figures 1 and 2). The term "small-scale fisheries", attempting to integrate aspects of the "coastal" and "artisanal" fisheries and to avoid the vagueness, inconsistencies and differences of previous definitions, is virtually absent from the official terminology of most Mediterranean countries. This term was introduced initially in 1990 by the European Commission, when the Commission presented a proposal[2] to amend Regulation 4028/86 on measures to improve and adapt structures in the fisheries and aquaculture sector (Anonymous, 1990).

Most of the trawlers could be considered as semi-industrial or industrial vessels, taking into account the international practice. Trawls are widely used in the Mediterranean and there are two main types: (a) bottom, and (b) pelagic trawlers. Seine nets (purse seines) are one of the main types of fishing gear used in the Mediterranean. The Community Mediterranean fleet represents about 22% of the total Community fleet expressed in tonnage and 34% expressed in engine power. In numbers, it represents about 46% of Community fishing vessels. On average, fishing vessels in the Mediterranean are smaller than in the rest of the Community. More than 32 950 vessels, i.e. around 80% of the Mediterranean vessels, are smaller than 12 m in length, giving the Mediterranean fleet its

1 Fisheries Yearbook 1993-2002, Office for the Official Publication of the European Communities, 2003, ISBN: 92-894-6338-4

2 COM(90) 358 final of 7 September 1990

Figure 2: Commercial fishing activities conducted by different fishing vessels: a) artisanal fishery boat, b) trawler. Source: S. GLYKOKKOKALOS.

characteristics of a small-scale artisanal fishery, although a large proportion of the catches is taken by larger, non-artisanal vessels[3].

The fish production

Fishing has a long tradition in Mediterranean countries, and many methods of exploitation of this resource have developed there from ancient times. This historical and cultural background is the reason for the diversity of gears in use, and the significance of so many small-scale fisheries that are found along the Mediterranean seashore.

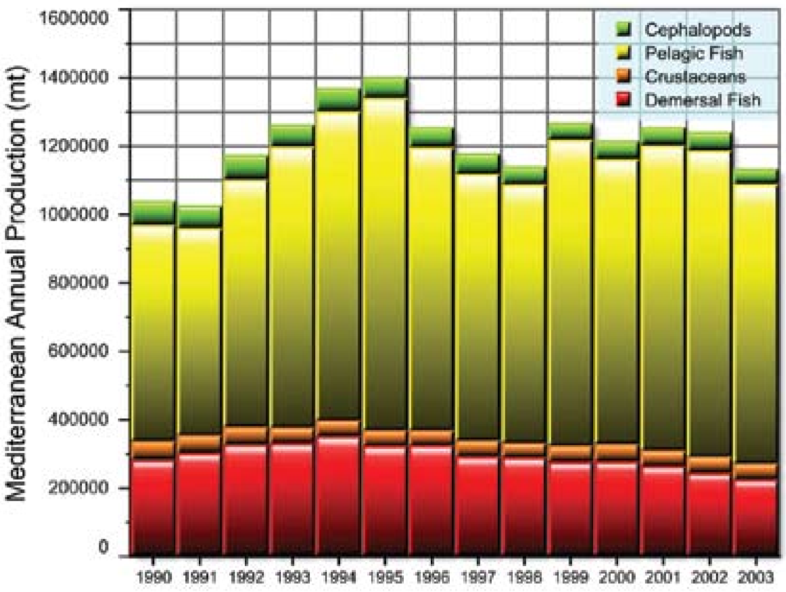

Figure 3: Total annual production of Mediterranean countries. Source data: FAO FISHSTAT database

The total production of capture fisheries in the Mediterranean (all countries included) is illustrated in Figure 3. It can be seen that the cephalopod and crustacean production is almost stable the last 15 years. The demersal fish production shows a decline during the last 10 years probably showing the effects from over-fishing from the medium fishery sector (trawlers and purse seiners). Pelagic fisheries show a fluctuation during the last 15 years and form the largest component of the Mediterranean landings.

The exploited depth range for demersal fisheries in the Mediterranean is usually from 10 to 800 m, but is mainly within 400m for shallower shelf species such as coastal species, e.g. grey mullets, sea breams, sea bass, some shrimps (*Crangon crangon*), and many molluscs. Continental shelf fisheries are usually dominated by red mullets (*Mullus barbatus, Mullus surmuletus*), sole (*Solea solea*), gurnards (*Trigla* sp.), poor cod (*Trisopterus minutus capelanus*), Black Sea whiting (*Merlangius merlangus euxinus*), common spiny lobster (*Palinurus elephas*) and the karamote prawn (*Melicertus kerathurus*). On the continental slope, however, there are many species of economic interest. Thus on the upper slope (200 - 400m) there are hake (*Merluccius merluccius*), flatfishes (*Lepidorhombus boscii, Citharus linguatula*), Norway lobster (*Nephrops norvegicus*) etc., and various shrimps (e.g. *Penaeus longirostris*). In the deeper waters, from 400 to 600m, the dominant species are the greater forkbread (*Phycis blennoides*), the blue whiting (*Micromesistius poutassou*) and the red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*).

3 European Union fleet register

THE STATE OF THE RESOURCES

Demersal and pelagic resources

Mediterranean resources have a long history of biological research (FARRUGIO *et al.,* 1993), but for many countries it is only relatively recently that research has been carried out specifically in support of management of fish populations, and the level of application of research recommendations in the management of marine fisheries is still generally low. Less information on the state of stocks is available for species in the Mediterranean, and fishery landings' trends often provide the only indication of changes that have occurred in the past.

The depletion of inshore resources occurred very quickly after the Second World War, during which stocks in the northern Mediterranean, which had been heavily fished before the war, had recovered in biomass and individual size, due to a reduction of fishing pressure during the period of hostilities. A similar situation was reported in 1993 for the hake populations along the coasts of Croatia during the recent civil wars. These examples also have a hopeful aspect as it suggests that stock levels can recover, once effort levels are reduced, and that a reduction of fishing effort would lead to a rebuilding of stocks.

Periodical updating of the research activities dealing mainly with demersal and small pelagic Mediterranean living resources and fisheries have been realized by the General Fisheries Council for the Mediterranean (GFCM) since 1970, during working group occasions and technical consultations at a regional level. OLIVER (1983) reviewed the fisheries' resources and activities in the western Mediterranean giving information on the state of the stocks, the production, the landings, etc. The scientific knowledge of large pelagic stocks and fisheries is annually updated for more than 20 years by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Furthermore, a detailed review has been prepared for the EU Diplomatic Conference on Fisheries' Management, held in Kriti in 1994 (CADDY, 1999) and in Venice two years later, in 1996 (FARRUGIO, 1996; TSIMENIDES, 1997; PAPACONSTANTINOU AND FARRUGIO, 2000), as well as in the meeting held at Kriti for the Coordination of Fishery Research in the Eastern Mediterranean (OLIVER *et al.,* 1997). On the other hand, the FAO fisheries' statistics database has now been updated until 1994 (FAO, 1995). All these allow a fairly complete panoramic synthesis of the situation to be drawn. LLEONART (2002) describing the fisheries' assessment methodology applied in the Mediterranean concluded that most fisheries' research projects have a local contingency. The only exception is the MEDITS programme (BERTRAND *et al.,* 2002), funded by EU and France, Hellas, Italy and Spain and extending along the north coasts of the Mediterranean Sea, including Albania, Croatia and Slovenia since 1994, and Tunisia and Morocco later. Of 36 assessments of the hake in the Mediterranean, 28 concluded that it is over-fished and 7 that it is fully exploited. Of 32 red mullet assessments, 18 found it over-fished. Most of the targeted demersal fish stocks and the large pelagic stocks are considered either fully exploited or even over-fished. For the small pelagic the picture was more diverse, with only 2 of 14 assessments of the anchovy stocks rating it as over-fished and the sardine stocks rated as within safe limits.

Time-series of fishery landings can provide important indications for changes in a fishery, or changes to the underlying environment (CADDY, 1990). Often, as in the case of Mediterranean fisheries, this is essential in the absence of complete or independent information such as on the fishing intensity or fishing mortality affecting the stock. Fishery landings' trends can provide the only indication about important changes that might have occurred in the past. FIORENTINI *et al.,* (1997) based on the 45-year time-series of landings gave a general view of the catches in the Mediterranean:

(a) Despite some significant differences, the overall pictures from the west and the east Mediterranean are not strikingly different.

(b) From the study of catch trends, a high proportion of species or species groups in both the west and east Mediterranean showed increases in landings over the whole time period until the late 1990s.

(c) From the perspective of stock assessment, very few time-series showed stable yield levels, suggesting a considerable dynamism caused by environmental and/or trophic or fishery-related impacts in the fisheries of the sub-region.

Catch statistics on demersal and small pelagic species show a negative trend in the 1990s for the most important species or groups of species (FIORENTINI *et al.,* 1997). Daily catch rates per vessel have fallen dramatically when compared to catch rates of some decades ago, despite the fact that the power and efficiency of fishing vessels has increased in recent times. Also the catch quality, both in terms of species and size composition, has been changing over time. Long life-span species and bigger sized specimens have practically disappeared from demersal catches in several areas and fisheries. The current evaluation of demersal, small and large pelagic fisheries, carried out within the GFCM and ICCAT frameworks, confirm this picture of over exploitation of several resources and highlights the need to reduce the mortality of juveniles and the overall current fishing effort by about 15-30% for those fisheries catching some over exploited stocks[4]. Despite the recognized over exploitation of several resources, there are few scientifically reported cases of stocks at risk of collapse.

Deep fish resources

The exploitation of deep waters for fisheries is probably a new perspective for the development of fisheries in the Mediterranean Sea. Deep fisheries in the area are developed mainly in the western Mediterranean and in some areas of the central region (Italian coast of the Ionian Sea) at depths extending down to 800-1 000 m, while recently this fishery is under development in the Aegean Sea. The most important stocks are those of the two species of red shrimps: *Aristaeomorpha foliacea* and *Aristeus antennatus*, and of lesser importance the hake and the red fishes. Fishing activity is carried out mainly by trawlers and secondly by netters or long liners adapted accordingly for fishing in deep waters. The condition of the red shrimps stocks along the coasts of Spain and Hellas is considered satisfactory regarding over-fishing, while along the Italian coasts the stocks are over-fished. The extension of bottom trawl fishing activities in deep waters would take the pressure off the shallow water species and would provide the fish market with new products. However, this could involve the danger of disturbing the deep-water ecosystem which is more fragile, and where the recovery of the depleted stocks will require more time and complicated management interventions as related with other shallow water stocks. Therefore, knowledge on the biology and on the inter-specific relationships of the deep-waters species is needed in order to plan a reasonable managing design.

THE CONSERVATION POLICY OF MEDITERRANEAN FISHERIES' RESOURCES

Fisheries' management in the Mediterranean is, in general, at a relatively early stage of development, judging by the criteria of North Atlantic fisheries. Quota systems are generally not applied, mesh-size regulations usually are set at low levels relative to scientific advice, and effort limitation is not usually applied or, if it is, is not always based on a formal resource assessment (ANONYMOUS, 2001).

The importance of Mediterranean fisheries was fully recognised by the adoption, in October 2002, of an ambitious Action Plan[4] to ensure the sustainability of fisheries in the Mediterranean. The measures foreseen in the Action Plan include: a concerted approach to declaring fisheries' protection zones, the use of fishing effort as the main instrument in fisheries' management, improving fishing techniques so as to reduce the adverse impact on stocks and the marine ecosystem and promoting international co-operation.

Moreover, in the Mediterranean there are two regional fisheries' organizations, ICCAT and GFCM, which have different degrees of development and activity. ICCAT plays and should maintain an essential role in the management of highly migratory species in the region. EU is committed to this organization at both management and scientific levels, and it has been in the forefront in pressing the on-going work within that organization for the establishment of a control and enforcement scheme. GFCM, which is the most appropriate forum for the management of demersal and small pelagic fisheries in the Mediterranean, has made considerable strides in recent years, essentially due to initiatives which have been taken by the EU and Member States.

On a national level, the fisheries' legislation of the different Mediterranean countries contains a great variety of conservation/management measures which can be broadly separated into two major categories: those aiming to keep the fishing effort under control and those aiming to make the exploitation patterns more rational. The first set of measures is based on restrictions imposed on the number or fishing capacity of the vessels, rather than on catch limits and control of discards and by-catches, upon which the fisheries' policy in the Atlantic mostly relies. The second set of measures is based on provisions concerning gear specification, gear deployment, fishing practices or techniques, fishing seasons or areas and resource exploitation patterns, and are commonly known as technical measures.

Mesh sizes is an important item to manage fishery and especially the trawl fishery. The smallest sizes for trawls in the world are found in the Mediterranean (CADDY, 1990). The goal of a 40 mm mesh size proposed by the GFCM and adopted recently by EU member states[5] is still far from realistic in many Mediterranean countries. The relatively high

4 COM/(2002), 535 final. 09.10.2002

5 EU Council Regulation No 1967/2006

price of small fish, the existence of some small species that would not be caught, and the short-term losses that would occur as a result of increasing mesh size, are the main reasons which would make this measure difficult to apply. Furthermore, the control and surveillance of actual mesh sizes entails the difficulties involved in the individual examination of vessels at sea. Another type of regulation which is adopted in the recent EU regulation is the use of square nets in order to improve selectivity of trawls.

Apart from the main target of a management policy, which is the conservation of fisheries' resources, the establishment of a common fisheries' policy in the Mediterranean should also take into account the political and socio-economic aspects of the Mediterranean nations that share in the exploitation of these resources. A number of technical measures have already been woven into the national laws of all FAO/GFCM Member States (TSIMENIDES, 1994).

Following extensive discussions in the early 1990s on the general principles of a conservation and management policy specifically for the Mediterranean, the Council adopted Regulation (EC) No. 1626/94 laying down certain technical measures for the conservation of fishery resources in the Mediterranean. This particular regulation was never accepted and applied by the member states. Many provisions of this regulation were never applied. Following the approval of the new reformed Common Fishery Policy in December 2002, discussions were initiated to change this regulation. From these discussions it became obvious the need for a serious re-evaluation of the mesh-sizes of some gears, the landing sizes of some commercial species, the legal distance from coast to practice fishing, the least depth of use of the various gears, etc. The new regulation for the management of the Mediterranean fisheries was approved finally following extensive discussions with the participation of fishermen (especially the representatives of trawler and purse seiner fleet segments).

The GFCM has attempted to harmonize, on a Mediterranean level, some of those technical measures. The need for a reduction in overall fishing effort, particularly in inshore waters, remains the main priority for management action. So far, few Mediterranean countries have taken management action to control increases in fishing effort, in spite of repeated recommendations by the GFCM. For the Mediterranean countries, members of the EU, a limitation in total fleet capacity and horsepower are in effect.

SOME PROBLEMS IN THE MANAGEMENT OF THE MEDITERRANEAN RESOURCES

All the Mediterranean fisheries' research institutes have scientific teams capable of studying the biological and dynamic parameters of the most important stocks, as well as the fleets' dynamics and interactions. The existence of good quality and quantity catch and effort statistics remain, however, a weak point. Official statistics are not fully accurate in the Mediterranean countries and so they are not reliable; in several countries suggestions have been made to improve those data, but the majority of the statistical data are still often very far from reflecting the reality. The lack of reliable official statistics is a considerable handicap for researchers who must devote a significant proportion of their resources estimating the corrective factors to apply to official statistics.

As for the inventory of the fleets, it leaves much to be desired in most countries. The statistics do not sufficiently describe the structure and capacity of the fleets, which depends on heterogeneous factors such as the depth of the fishing grounds, the type of fishing activity, the economic level of the fishermen, the shipbuilding, traditions, etc. Particularly, as regards the small-scale fleets, the files available in the national administrations are generally quite incomplete. An underestimation of about 50% compared to the real figures is not rare and of course, it can introduce important biases in the analyses. To avoid this situation, the latest works in the area have focused on improving sampling and assessment strategies, essentially based on the installation of networks of samplers on the coasts, which particularly apply to Mediterranean fisheries.

Another important point is that, despite the apparent very complex situation which the multi-specificity of the Mediterranean catches seems to show, some 'target species' can be identified as main indicators of the status of composite stocks and thus there is a possibility of reducing the assessment tasks to a relative level very similar to what it is in other parts of the world. For example, as noted during the EU Meeting on Mediterranean Fisheries (Ancona, Italy, 1992) it can be defined, for the north-western Mediterranean fisheries, a group of 13 species which constitute the 'basic production'. Even if imperfect, the landing statistics show that this group represents more or less 50% of the overall demersal production of the European fleets (ANONYMOUS, 1992).

Additionally, another problem of fisheries' manage-

Figure 4: Illegal fishing techniques like blast fishing and the use of home-made illegal gears is still a problem for Mediterranean coastal and artisanal fisheries due to limited man-power of law enforcement agencies.

ment in the Mediterranean is the lack of effective surveillance/enforcement by authorities, which is due to the extended coastline and the numerous landing sites making it difficult to detect illegal fishing (Figure 4). In fact the GFCM has put forward a scheme aiming to ensure a high degree of compliance with relevant conservation measures, and legal certainty and security for the vessel concerned, indicating a number of principles that an effective Control and Enforcement Scheme should embody (GFCM, 2007).

REQUIRED ACTIONS AT INTERNATIONAL LEVEL

Improvement of scientific advice through research activities

As regards scientific research in general, most of the findings of the research projects in recent years have proved to be useful to support scientific work within the scientific bodies of the Regional Fisheries Organizations and of the FAO sub-regional projects e.g. ADRIAMED, COPEMED, MED-SUD-MED, EAST-MED. However, initiatives still need to be taken by the EU to support the scientific work carried out within the Mediterranean regional fisheries' organizations and to strengthen their role to stimulate scientific and technical activities among their parties.

Harmonization of measures in the Mediterranean Basin

Although the EU have taken the initiative on fisheries' management regardless of whether other countries of the region will follow, it is obvious that there is an interest in ensuring harmonization of the management measures applied in the region. The Net should pursue the discussion and adoption of Mediterranean-wide management .measures, particularly within GFCM, to ensure as much consistency as possible between the EU initiative and the management carried out by other countries of the Mediterranean basin.

Co-operation among States and among industries

The Mediterranean Sea is characterized by a high number of coastal states with little tradition and means to ensure fisheries' management. A multilateral fisheries' policy in the region should have an active co-operation policy as a fundamental element. This co-operation should be focused, most notably, on enhancing the coastal States' capability to carry out their international obligations. Data collection, basic research and monitoring and control of fishing activities are some of the possible actions to be favoured in this context. Therefore, the development of a Mediterranean-wide co-operation programme, using scientific experience and the existing financial frameworks as much as possible must be promoted.

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III.2. COMMON FISHERIES' POLICY (CFP) A TOOL FOR THE MANAGEMENT OF EUROPEAN FISHERIES' SECTOR

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OVERVIEW AND HISTORY OF CFP

Fishing and aquaculture are important economic activities in the European Union. While the fishing sector's contribution to the gross national product of Member States is generally less than 1%, its impact is highly significant as a source of employment in areas where there are often few alternatives. In addition, it helps to supply fish products to the European Union market, one of the biggest in the world. With a production of over 7 million tonnes of fish, in 2003, from fisheries (Figure 1). and aquaculture, the European Union is the world's second largest fishing power after China

The European Union's fleet comprises more than 91 000 vessels which vary greatly in size and fishing capacity or potential catching power. Fleet capacity has declined over the past few years because it was too large for the available fish and had become uneconomic. The jobs provided by fishing are varied. The number of fishermen has been declining over the years. Between full-time and part-time jobs, approximately 260 000 fishermen are directly employed in catching fish. Their activities generate more jobs in processing, packing, transportation and marketing on the production side and in shipyards, fishing gear manufacturing, chandlers and maintenance on the servicing side.

The European Union organisation is based on setting the common markets between the member states. A similar situation was established for the fisheries' sector (this term signifies the marine and inland capture fisheries and aquaculture).

Until 2002, the CFP was based on the initial agreement of 1983. The main axes of management were:

- Management and protection of the resources and stocks.
- Structural policy and supporting instruments.
- Common organisation of the market, stabilisation of the market and support of the provision of goods.
- Relationships with third countries.
- Enforcing of legislation and regulations, establishment of control structures.

In 1992, the term 'sustainable use' of resources was introduced in the CFP foundations since research showed that most stocks were over-fished and the European fleet was very large and over-capitalised in relation to the stock biomass and state.

In 2000, the CFP was reformed following Regulation EC/104/2000 so that particular attention was shown to:

- Market stabilisation.
- Stabilisation of the provision of the market of fisheries' products.
- Stabilisation of market prices within acceptable limits.
- Support of the fishermen's income.

The realization of the CFP was based on 4 multi-annual guidance programmes (MAGP) between 1983 and 2001. MAGP I (1983-1986) focused on

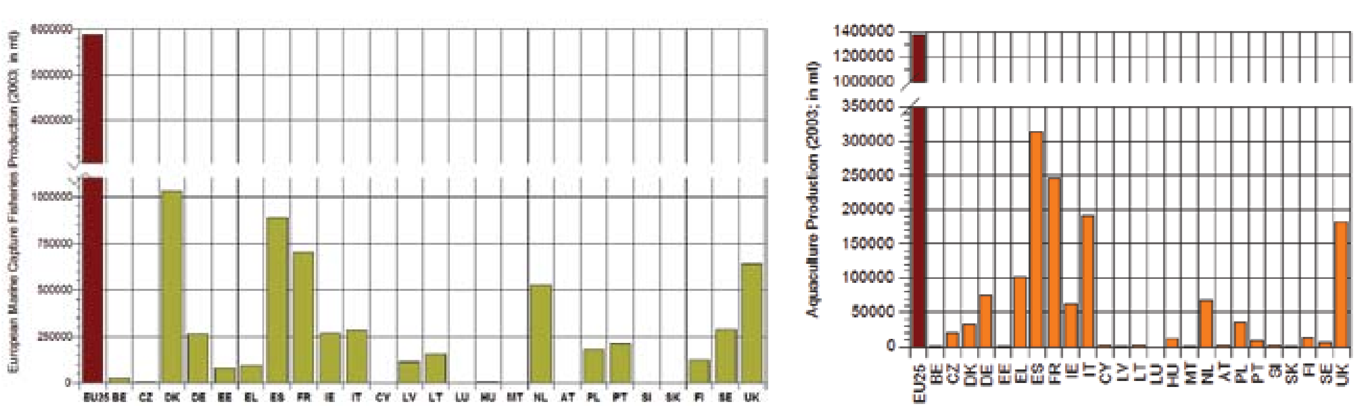

Figure 1: European fisheries' production (in 2003) (left), European aquaculture production (right) Source data: *EUROSTAT.*

the stabilization of the European fleet in terms of number and capacity. MAGP II (1987-1991) focused on the reduction of the fleet in terms of number. MAGP III (1992-1996) focused on the reduction of the fleet in terms of reduction of fishing effort and in particular 30% reduction of effort on demersal stocks and 20% reduction of the effort on the benthic stocks. MAGP IV (1997-2001) was based on the fact that even after three MAGP programmes, the European stocks still receive more fishing pressure than the research results showed and focused on the further reduction of fishing effort by 30% on the stocks which are at the point of collapse and by 20% on the stocks which are over-fished.

Around 2000-2002 and before the elaboration of the CFP Regulation EC/2371/2002, the European Commission initiated a procedure to reform the CFP. The reasons for the reform were:

- The old CFP included many goals difficult to achieve.
- The enforcement of the policies was limited.
- There is a lack or scarcity of research and statistical data regarding the state of the stocks and the effectiveness of the management measures.

According to the Green Bible which was published by the European Commission (European Commission 2001, 2002) the basis for the reform of the CFP were the following:

- Improvement of the management policies.
- Application of technical measures for the better application of the legislation.
- Access to stocks and fishing grounds (common and transboundary).
- Monitoring of fisheries' statistics, monitoring of the vessels' operation and fisheries' data collection.
- Multi-annual programmes of fisheries' management.
- Broaden participation of stakeholders in the fisheries' sector.
- Use of the research results.
- Strengthening of the socio-economic side of the CFP including the vessels' decommissioning policies and the re-orientation of fishermen.
- Improvement of external relationships.
- Provide special attention to the management of the Mediterranean fisheries due to its special nature and in particular, the fact that Mediterranean fisheries are traditional, multi-gear and multi-species and therefore, common measures do not apply or do not have the same applicability as in the other European waters. It also includes the support of the Mediterranean councils G.F.C.M. and ICCAT.
- Support of research.
- Establishment for the first time of the RACs (Regional Advisory Councils).

NEW DEVELOPMENTS AND CFP REFORM

Following the reform process, Regulation EC/2371/2002 (12 December 2002) was enforced. This regulation is referred to as the Common Fisheries' Policy. A main characteristic of this regulation was that it did not include any measures for the Mediterranean. A new parallel process for the elaboration of a common policy focused on the Mediterranean was initiated in 2003 [COM(2003)-589].

The basic changes were:

- Long-term approach: until now measures concerning fishing opportunities and related measures have been taken annually. They have often resulted in fluctuations which not only have prevented fishermen from planning ahead but have also failed to conserve fish stocks. Under the new CFP, long-term objectives for attaining and/or maintaining safe levels of adult fish in European Union stocks will be set as well as the measures needed to reach these levels.
- A new policy for the fleets: the reform has responded to the challenge posed by the chronic overcapacity of the European Union fleet by providing two sets of measures:
    - o a simpler fleet policy that puts responsibility for matching fishing capacity to fishing possibilities with the Member States;
    - o a phasing out of public aid to private investors to help them renew or modernise fishing vessels, while keeping aid to improve security and working conditions on board.
- Better application of the rules: The diversity of national control systems and sanctions for rule breakers undermines the effectiveness of enforcement. This is why measures will be taken to develop cooperation among the various authorities concerned and to strengthen the uniformity of control and sanctions throughout the European Union. These measures will help establish the level playing field that fishermen have been calling for.
- Stakeholders' involvement: stakeholders, particularly fishermen, need to take a greater part in the CFP management process. It is important that fishermen and scientists share their

expertise. Regional advisory councils (RACs) will be created to enable them to work together to identify ways of achieving sustainable fisheries in the areas of interest to the RAC concerned.

The main action plans within the new CFP are:

- For the first time ever, a strategy for the sustainable development of European aquaculture. This strategy is designed to strengthen the role of aquaculture in providing jobs and in supplying quality fisheries' products in a way that does not harm the environment.
- The integration of environmental protection requirements into the CFP.
- The eradication of illegal fishing in order to ensure sustainable fisheries beyond European Union waters.
- Measures to counter the social, economic and regional consequences of fleet restructuring. In addition to the measures already in place under the Structural Funds, the proposed actions mainly concern the reprogramming of structural aid in favour of reduction of fleet capacity and social measures, the improvement of the image of the sector and support for sustainable coastal development.
- The reduction of discards of fish by tackling the causes of discarding. The measures proposed aim to prevent catches of unwanted fish, particularly immature fish and to remove incentives for discarding.
- The creation of a single inspection structure to ensure the pooling of Community and national inspection and monitoring resources.

In accordance to the reformed CFP article 1, the measures included in the new common policy refer to:

- Management of resources and environment: Fish stocks are moving freely within the territorial waters of the member-states and thus, they are shared to some extent. State governments have agreed that exclusive economic zones should extend to 200 nautical miles from their coasts. This agreement has allowed for the exploitation of natural resources such as oil and gas in grounds where deposits were discovered. This agreement has also created the need for the management of the common stocks and resources. Policies must, therefore, be devised to regulate the amount of fishing, as well as the types of fishing techniques and gear used in fish capture, if this heritage is to be passed on to future generations.
- Control and enforcement: With the reform of the Common Fisheries' Policy measures have been taken to strengthen the quality and effectiveness in which CFP rules are enforced throughout the European Union. Cooperation between Member States is vital in a sector where fishing vessels operate in the waters under the jurisdiction of several Member States. The creation of a Community Fisheries' Control Agency is especially important in this respect as it will allow Member States to pool their resources with the aim of achieving commonly agreed goals. Transparency has been reinforced. The yearly publication of the scoreboard provides a useful tool to measure the enforcement record of Member States, indicate where the shortcomings in the application of the rules are located as well as put pressure on those with unsatisfactory records to improve. Sanctions imposed on those caught infringing the rules of the CFP continue to vary between Member States of the European Union. The detection of the same infringement may result in a simple warning in one Member State while in another the outcome may be a heavy fine. To ensure a level playing field in the violation of CFP rules, a catalogue of sanctions to be applied by Member States for serious infringements is to be established by the Council. The increased use of modern technologies is also critical in bringing about effective monitoring of fishing activities. For example, satellite based applications for positioning and navigation are crucial for ensuring the main objectives of the Common Fisheries' Policy. To this end, the satellite vessel monitoring system (VMS) has become mandatory for vessels of over 15 metres, as of 1 January 2005.
- Structural measures: Structural policy in the fisheries' sector has to combine two objectives: it must contribute to the aims of the common fisheries' policy while playing its part in strengthening economic and social cohesion. On the one hand, the role of structural policy is to adapt and manage the development of infrastructures in the industry concerned. On the other hand, one of the European Union's main objectives has been, and remains, the strengthening of economic and social cohesion, or solidarity, across its regions. To help in this task, various Funds have been created in order to target financial help in the areas, persons and industrial categories which need it most. These include, among others, the Financial Instrument for Fisheries' Guidance

(FIFG). Structural aid from the FIFG has been available to the fisheries' sector for the period 1994-1999 and again from 2000 to 2006. On 1 January 2007, the FIFG will be replaced by the European Fisheries' Fund which will cover the period 2007-2013.

- Market policy: The common organisation of the markets (COM) in fishery and aquaculture products was the first element of the common fisheries' policy to be put in place by the Council of Ministers in 1970. Its original aims were to provide market stability and guarantee a fair income for fish producers. The current market organisation originates from the early COM but the market organisation measures now cover an area that extends to 25 countries and among which there are significant disparities in distribution chains, consumer habits and prices. In addition, fisheries' resources have become increasingly scarce and the COM has had to react accordingly by introducing measures to avoid waste and ensure an optimal match between supply and demand. Since 1970, every revision of the COM has been made with these objectives in mind. Producers' organisations (PO) are now the favoured medium through which the changes have been applied. The market organisation contributes towards the CFP's general objective of seeking to guarantee sustainable fisheries and secure the future of the fisheries' sector. Price stability, an appropriate balance between supply and demand and preference for EU production without damaging the growing demands of the processing industry have been the key goals of the COM over the past few decades. To achieve these aims, the main instruments have been:
  - o Establishing common marketing standards;
  - o Setting up producers' organisations;
  - o Introducing a price support system based on intervention mechanisms;
  - o Constructing a trade regime with non-member countries.
- A reform of the COM was undertaken in late 1999 with a view to achieving a better match between supply and demand, strengthening the competitiveness of the processing industry and improving information to consumers about the fish products available on the market.
- External relations: A large part of the European fleet relies on access to non-Community fish resources either in waters under the jurisdiction of third countries with which the European Community has fisheries' agreements, or in international waters. Due to its exclusive competence for fisheries, the European Union is entitled to enter into international fisheries' obligations with third countries or with other international organisations. Accordingly, the European Commission, acting on behalf of the Union, negotiates bilateral fisheries' agreements with third countries and takes part in different Regional Fisheries' Organisations (RFO). Bilateral fisheries' agreements between the European Union and third countries establish the general framework for access of Community fleets to the waters of these countries. A protocol attached to each lays down the specific conditions (technical, financial, type of resources, etc.) for implementation of the agreement.
- Regional Fisheries' Organisations (RFOs) are created by international agreements. They provide a framework within which the representatives of governments agree on ways of managing the fish resources of the open seas and straddling stocks. They are meant to strengthen regional cooperation to guarantee both conservation and the sustainable exploitation of fish resources. These organisations issue recommendations on management and conservation measures based on the best scientific advice available. Aquaculture and processing: Both the aquaculture and processing sectors in the European Union are growing industries. In addition to being important sources of fishery products to European consumers, they also provide substantial employment opportunities in areas dependent on fishing. The aquaculture industry of the enlarged Union (EU-25) produces a total of 1.3 million tonnes of fishery products a year at a value of about €3 billion which represents about 33% of the total value of European Union fishery production and about 20% of its volume. The value of the processing sector's production (€18 billion) largely exceeds that of both landings and aquaculture.
- Governance: The European Commission believes that it is essential to engage in dialogue with the fisheries' industry and other groups affected by the Common Fisheries' Policy. Real dialogue is a prerequisite for successful policies as it generates an exchange of views with fishermen and other stakeholders and provides the Commission with better knowledge

Figure 2: Traditional fisheries are common in the Mediterranean area. (Photo: A. CONIDES)

about their problems and expectations which, in turn, can be taken into consideration when proposals for fisheries' rules are drafted by the Commission. The industry is also more likely to accept and implement CFP rules if it has been involved in the formulation of these rules. This action aims at the strengthening of the dialogue with the sector through the following actions: (1) Reinforcement of European trade organisations to allow them to better carry out their tasks, and (2) Improve communication to ensure that stakeholders are better informed about the CFP legislative proposals in the pipeline, scientific advice as well as other aspects related to the CFP. The Commission proposed to create a network of Regional Advisory Councils (RACs) involving fishermen, scientists and other stakeholders on a regional level. On the basis of the Commission proposal, the Council adopted in July 2004 a common framework for RACs which foresees the establishment of 7 RACs covering 5 geographical areas as well as pelagic stocks and the high seas fleet.

- Research: Research and technological development (RTD) activities are essential elements in the functioning of industrialised countries. In general terms, the quality and relevance of RTD contributes to the individual and collective well-being of citizens. It fosters company competitiveness and employment and is essential in promoting consumer and environmental protection. High level research is increasingly complex, interdisciplinary and costly. This is why the role of the European Union in promoting research activities is vital in that it can mobilise sufficient human and financial resources. Research projects financed at European Union level are supported by Framework Research Programmes with a view to foster innovation, diversity and competitiveness in a sector faced with diminishing fisheries' resources.

EFFECTS OF THE CFP REFORM ON THE HELLENIC FISHERIES' SECTOR

The Hellenic fishing fleet is characterised by its enormous share of small-scale coastal vessels: out of approximately 18 000 units more than 17 000 are smaller than 12 meters. Over 21% of vessels of the Community fleet are registered in Hellas, but represent only 5% in tonnage and 8% in power. These characteristics also explain the main activities of this fleet, which are targeting coastal stocks around and between the numerous islands and some other stocks in the Mediterranean. Only a small group of Hellenic fishing vessels (about 35 accounting for ~12 000 GT and 23 000 kW) is active in international waters. The average age of the Hellenic fleet is 24.5 years. In 2005, there were 18 276 vessels from which 94% use passive gears (mostly coastal vessels) and 6% use towed gears (trawlers, purse seiners and shore-seiners). The average tonnage was 29 GT per vessel and the average engine power is 5 kW/vessel. The evolution of the Hellenic fishing fleet is presented in detail in the chapter 3. perspective from the National Statistical data. The application of the CFP policies on the Hellenic fisheries' sector is expected to affect both the fishing gears and the stocks (Figure 2).

Effects of fishing gears use

Even though there is limited knowledge of the essential habitats for most of the species living in the Hellenic seas, it is obvious that prohibition of fishing in protected ecosystems such as the *Posidonia* meadows or areas that are essential habitats for the stocks, such as river deltas and lagoons, as well as enforcement of limitation in mesh sizes and minimum landing sizes for various species will substantially decrease the expected landings.

Significant problems will arise in closed areas and gulfs such as the Korinthiakos Gulf, North and South Evvoikos Gulfs, Pagasitikos Gulf, Middle Thermaikos Gulf, Middle Strymonikos Gulf and various straights. Considering the distribution of the fleet along the Hellenic coastline, a large segment of the fleet will be required to double or even triple the duration of their fleet in order to reach fishing grounds where fishing is legal and this is expected to increase the cost of fishing substantially considering, at the same time, the international oil prices.

Effects on the resources

The application of the CFP policies is expected to enhance the state of the stocks by protecting the essential habitats of the species and, at the same time, strengthen the controlling mechanisms and structures. The policies which are especially important are:

- The creation of protected areas for reproduction.
- The protection of zones of species recruitment.
- The technological upgrading of fishing gears, the use of selective gears which will enable the substantial reduction of by-catches and discards and the decrease of the maximum mesh sizes.

Effects on landings

The expected increase of the minimum mesh sizes as well as the increase of minimum landing sizes of species are expected to reduce the annual landings. Already the annual production of Hellas has been declining during the last 10 years, from being stable at around 160 000 tonnes to 92 000 tonnes approximately today (2005). As an example, by comparing the minimum landing sizes already provided in Regulation EC/1626 with research data the following reduction of landings is possible (values depend on the geographic area, HCMR 2003): Bogue by 0-4%; anchovy by 9-42%; hake by 60-90%; red mullet by 8-70%; Norway lobster by 0-5%; sardine by 0-90%; swordfish by 20-60%; picarel by 0-75%. Obviously highest values are expected in closed gulfs and sensitive ecosystems.

In any case, the above will affect the Hellenic fisheries only if law enforcement is appropriate.

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III.3. FISHERIES STATISTICS IN HELLAS: DATA COLLECTION AND PROCESSING

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INTRODUCTION

At present, two entities are routinely engaged in collecting and processing data concerning the primary phase of the fishing industry in Hellas: The National Statistical Service of Greece (NSSG) and the Fisheries Development Company (ETANAL). A third entity, the Ministry of Agriculture (MA), cooperates with NSSG and conducts periodical surveys and/or investigations on specific subjects to cover the existing statistical needs in the fields of management and long-term planning of the fisheries' policy. Moreover, the Ministry of Mercantile Marine (MMM) has established a register of fishing vessels since 1988 which is continuously updated. The type of information collected on the various segments of the Hellenic fishing industry is presented below.

- FISHING FLEET
  NSSG: a) Motorized fishing vessels ≥20HP: registered - yearly, b) motorized fishing vessels ≤19HP and professional rowing boats: operational - yearly.
  MMM: Register of fishing vessels - fisheries census 1988, updated every 3 months.
- PRODUCTION
  NSSG: a) Motorized fishing vessels ≥20HP: monthly - basic statistics, b) motorized fishing vessels ≤19HP and professional rowing boats: yearly - indications.
  ETANAL: Partial coverage: monthly - fish and fisheries' products landed / traded at eleven official fishing ports.
- EMPLOYMENT
  NSSG: a) Motorized fishing vessels ≥20HP: monthly - total, full time, part time, b) motorized fishing vessels ≤19HP and professional rowing boats: yearly - total.
- FISH PROCESSING
  NSSG: a) Inventory information based on census survey conducted every four years, b) yearly production of processed fish and fisheries' production (type - quality).
- INTERNAL TRADE
  NSSG: Inventory information based on census survey conducted every four years (number of employees - wholesale, retail outlets).
- EXTERNAL TRADE
  NSSG: Yearly statistics of imports / exports (collected through taxation offices and customs offices).
- CONSUMPTION
  NSSG: Data collected through household expenditure sample surveys (conducted every five years).
- PRICES
  NSSG: Wholesale and retail prices within the context for the construction of monthly wholesale and retail price indices.
  ETANAL: Monthly average prices by species for the quantities of fish traded at the eleven official fishing ports.
- AQUACULTURE
  NSSG: Monthly census survey of inventory and production characteristics of aquaculture and fish - farming units.

In the paper, the survey systems, methods of data collection and processing procedures of the two entities are described. Also the quality profiles of the produced statistics are presented.

A. THE NATIONAL STATISTICAL SERVICE OF GREECE (NSSG)

This is the official state authority for the collection and compilation of statistical data from various fields of the national economy, including fisheries. In order to obtain fisheries' data, the NSSG uses a nationwide data collection system and cooperates with the Ministry of Mercantile Marine, Ministry of Agriculture, the port authorities, the local customs offices and correspondents in municipalities and communities. The primary objective is to provide catch and employment statistics, but fishing fleet statistics are used to estimate production. The NSSG classification criteria of vessels takes into account the fishing area and the gear used. The fishing area is perceived as the area in which the fishing vessel operates and the where greatest quantity of fish is caught. In total, 16 fishing areas have been delineated in the Hellenic territory and 2 fishing areas outside territorial waters of Hellas (Figure 1). Regarding fishing gear, they are divided into four basic categories: trawl-nets, ring-nets (purse-seines), seine-nets (beach-seines) and others (set-nets, bottom and drift long lines, dredges, small ring nets, sponge-fishing gear, etc.).

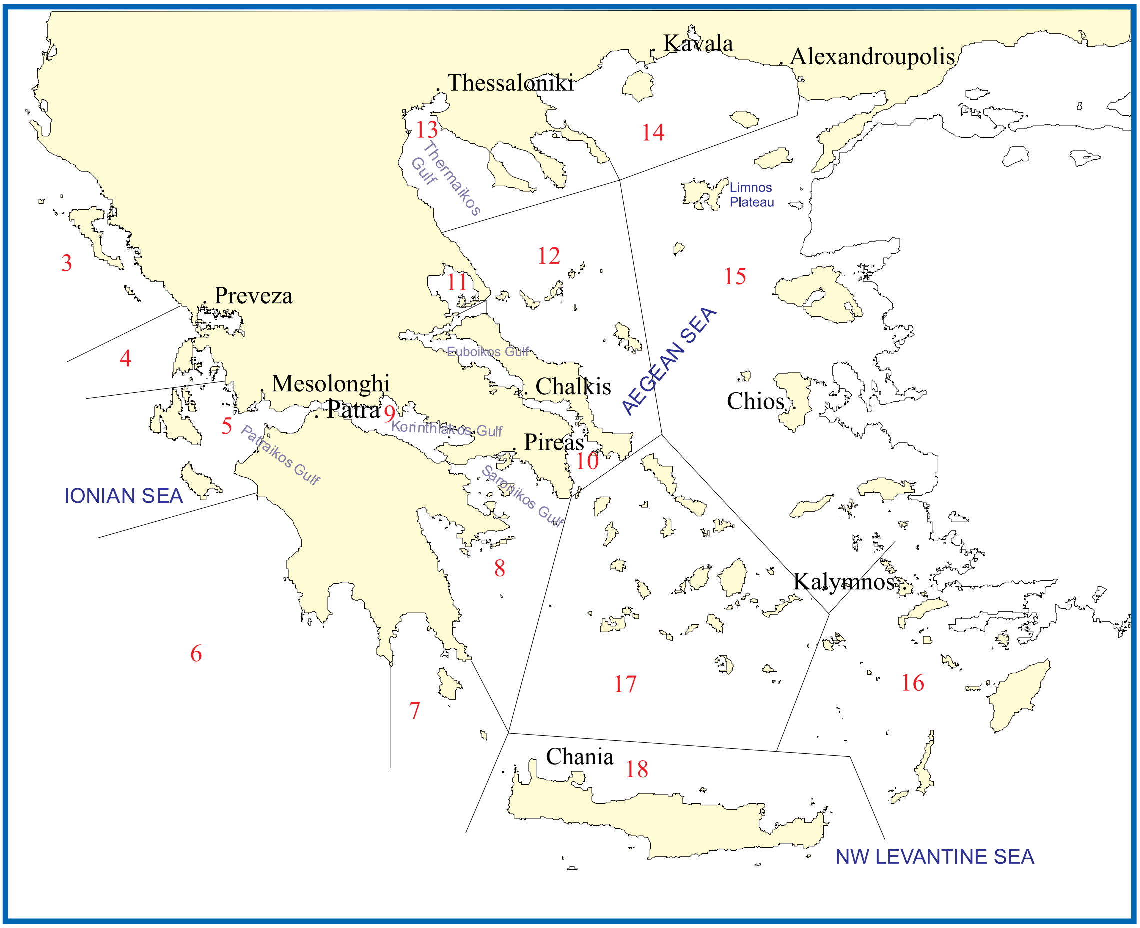

Figure 1: The NSSG fishing areas ([3] Coasts of Ipeiros and Kerkyra, [4] Amvrakikos Gulf and coasts of Lefkada island, [5] Coasts of Kefallonia, Zakynthos and Gulf of Patras, [6] Gulf of Kyparissia and Gulf of Messinia, [7] Gulf of Lakonia, [8] Gulf of Argolida and Saronikos Gulf, [9] Gulf of Korinthia, [10] Gulf of S. and N. Evvoia-Gulf of Lamia, [11] Pagasitikos Gulf, [12] Eastern coasts of Evvoia and Sporades islands, [13] Thermaikos Gulf and Gulf of Chalkidiki, [14] Strymonikos, Gulf of Kavala, Thassos, Thracian Sea, [15] Islands of Lesvos, Chios, Samos and Ikaria, [16] Dodekanisos, [17] Kyklades, [18] Kriti) and the ETANAL fishing port markets

Based on these criteria, fisheries are divided into three categories: a) overseas fisheries, which is operated by trawlers fishing on the coasts of N. Africa and the Atlantic Ocean b) open sea fisheries, which is operated by bottom trawlers and purse-seiners fishing in Hellenic waters, and c) inshore fisheries, which is operated by beach-seiners and vessels of the "others" fishing gear category in coastal waters. With regard to fisheries' production, the products are classified into four major biological groups: fish, cephalopods, crustaceans and pelecypoda. Each group is further divided into species or groups of related species. Furthermore, the products have three quality categories: "first", "second" and "third". In respect of employment, only data concerning the number of persons actively involved in fishing are collected, without a distinction between employers and employees and without reference to sex, age or other social parameters.

Four independent statistical surveys are conducted, each of which is focusing on the particular portion of the fleet:

Sea Fisheries' Survey for Motorized Vessels ≥20 HP (SFS-1): This is a census-type survey conducted on a monthly basis and covers the activities of marine fishing vessels operating in Hellenic waters with an engine power of 20 HP or higher (the survey started in 1964 and up to 1969 it covered the activities of all professional motorized vessels). The following parameters are investigated: fleet characteristics (number, engine power and tonnage of vessels), production (volume and value) and employment.

Fleet statistics are not the immediate concern. Actually, the NSSG does not monitor directly the fleet parameters, but keeps a register of fishing vessels (RFV), mainly for the purpose of deriving raising factors for computing the national production from the catch data of individual vessels. The initial information was based on the results of the fisheries' census, which was conducted in 1962. A new register of fishing vessels has been established and is continuously updated by the Ministry of Mercantile Marine.

For collecting data, the "reporting" measurement approach has been adopted according to which information referring to the quantity of fish caught, the area fished, the personnel employed and the number of working days is provided directly by the fishermen. Practically, the "sampling" survey method was adopted, under the rough assumption that the respondents constitute a random sample of the target population. Using appropriate raising factors derived from the RFVs, the catch and employment data of the respondents were utilized to assess the total fisheries' production by fisheries' sector, gear, geographical area, month of fishing, biological category, quality class and value, and also provide employment data by the fisheries' sector. The fishermen are asked to complete a monthly statistical questionnaire, or to indicate that their vessel did not work. The questionnaire provides information on the characteristics of the vessel, the labour force, the fishing area, the number of working days or states the reasons for inactivity, the fish landed and the average sale price by category of fish. Code numbers are allocated to the individual species and groups of species within the established biological categories. The completed questionnaires are forwarded to the local offices. Each customs office represents a number of fishing ports and landing places, where the active fishing vessels are located. The collected questionnaires are submitted directly to the NSSG for editing and further processing. The results of the survey are published in the annual bulletin under the title "Sea fishery by motor vessels". The time lag between data collection and publication of the results is 2-3 years. Output tables are given below:

Part one, Yearly summary comparative tables

I. Number, horsepower and tonnage of motor-propelled fishing vessels, by categories.
II. Quantity and value of catch, by categories and kind of fishery.
III. Quantity and value of catch, by categories and kind of fishing tools.
IV. Quantity of fish landed, by principal species.
V. Quantity of fish landed, by fishing areas.
VI. Annual average employment, quantity landed and value of catch, by kind of fishing tools.

Part two, Analytical tables

A.1: Distribution of motor fishing vessels, by categories and horsepower groups.
A.2: Distribution of overseas and open sea fishing vessels, by tonnage groups.
B.1: Quantity and value of catch, by categories and kind of fishery.
B.2: Quantity and value of catch, by categories and kind of fishing tools.
B.3: Quantity of catch, by principal species and kind of fishing tools.
B.4: Quantity of catch, by principal species.
B.5: Quantity of catch, by fishing areas and kind of fishing tools.
B.6: Quantity of catch, by principal species and fishing areas.
C.1: Number of persons employed, by kind of fishing tools.
D.1: Quantity, value and average price of catch distributed by fish-pier, by main species (from 1999 and afterwards).

Quality profile of SFS-1

From the methodological and operational aspects of statistics produced by the NSSG, conclusions can be drawn on the quality of the information provided and the various sources of bias introduced during the sampling design and planning, data collection, processing and tabulation processes.

As regards sampling and planning operations, the following problems are identified: a) Due to the huge scale of the field and processing operations, the census method with a monthly frequency, is subject to serious systematic errors and provides no measure for the margin of error to which the data are subject, b) no provision was made during the design process to produce the appropriate mapping material showing the statistical units under the coverage of each customs office. The consequence may be omissions and duplications, c) the accuracy of the RFV is low and becomes a source of bias in the estimation of the raising factors for inferring population values from sample catch data, d) the criteria for the classification of the catch in quality categories are not defined, and in practice the fishermen use their own classification criteria.

With regard to the measurement procedure, the main problem is the response bias associated with the method in data collection. The reporting approach for data collection is highly subjective, since it is not based on actual measurements of landings or logbooks, but on information provided by the fishermen. The acceptance procedures are not defined and there is no procedure to clear up difficulties, check answers and ensure completeness. This situation introduces several response errors during the data collection process, such as: a) provision of distorted answers by the fishermen, b) possible cheating concerning the economic data, c) introduction of a memory error resulting from the length of the reference period.

Further to the biased nature of the obtained sample data, the procedures employed in data collection introduce several measurement errors arising from: a) lack of training and briefing of the staff of the customs offices, b) lack of written instructions, c) lack of field observation, d) lack of standardization of the work performed in data collection.

At the processing stage, all operations preceding computer processing are essentially reading through the questionnaires with no quality control or checking error techniques at the processing stage.

Regarding the final output of the survey, the established tabulation system is incomplete, in the sense that it utilizes only a portion of the spectrum of information obtained in the survey. One of the major drawbacks is that the results of the production statistics are presented only by fishing area, which make a sense from the management point of view, but does not satisfy the needs of many potential statistic users. Classification of the fleet and catch data on a prefecture basis, which is the official administrative unit, is certainly required. In addition, there is a real need to broaden the scope of the tabulation programme by including additional characteristics concerning: a) operational statistics on fishing effort (number of fishing days and reasons for inactivity), b) Quantity of catch, by principal species, kind of fishing tools and fishing areas, c) Number, horsepower and tonnage of motor-propelled fishing vessels, by categories and by prefecture/fishing areas.

Sea Fisheries Survey of Motorized Vessels ≤19 HP (SFS-2): This survey started in 1970 and covers the "inshore" component of the fisheries which is operated by motorized vessels with an engine power of 19 HP or less. The number of operational vessels and the quantities of fisheries' products landed during the previous year are investigated. Production is not directly measured, but is estimated by multiplying the number of vessels by the annual average total catch per fishing vessel. For this purpose old catch data per fishing vessels are utilized. The annual catch per vessel has been assumed stable and is kept fixed over time (~2 tons/vessel/year).

Quality profile of SFS-2

Both the procedures and methodology used for obtaining and processing data suffer from certain drawbacks, which reduce the validity of the results. The main factors which adversely affect the quality of the statistics are: a) poor coverage of important statistical items (seasonality of fishing, species composition of the catch, value indications, part-time employment), b) the inappropriateness of the persons responsible for data collection (secretariats of the municipalities and communities), c) the very subjective method used for estimating the annual catch per vessel, d) poor quality control and error-checking procedures.

Sea Fisheries Survey of rowing boats (SFS-3): This survey which started in 1962 essentially investigates the number of operated rowing boats. Information is collected from the secretariats of the coastal municipalities and communities who are asked once a year to fill in relevant statistical questionnaires referring to the items of interest.

The results of SFS-2 and SFS-3 surveys are published in the annual bulletin "Yearly Agricultural and Livestock Production" along with the results of the statistical surveys on other branches of the Agricultural Economy.

Overseas Fisheries Survey (SFS-4): This is a monthly survey addressed to vessels operating in the Atlantic Ocean and on the coasts of N. Africa. The survey is based on the census method and uses the reporting approach (fishing companies report data on production and employment directly to the NSSG). Essentially the survey covers the same characteristics as the SFS-1 survey. No data are compiled on the number of trips of each fishing vessel and the number of hours spent fishing. The results are tabulated in a manner similar to the results of the SFS-1 survey and appear together in the annual issues of the bulletin "Sea fishery by motor vessels".

Quality profile of SFS-4

Due to the low number of overseas fishing vessels and the efficiency of their respective companies, the response rate to the questionnaire is high, and therefore, the census type survey is appropriate for the statistical investigation of this fisheries' branch. The actual number of operating fishing vessels calls for a specific investigation.

B. THE FISHERIES DEVELOPMENT COMPANY (ETANAL)

The fisheries' development company ETANAL S.A. has provided the general framework and methodology of the system of measurement of landings in the fishing port markets but is not directly involved in the collection and processing of data. This is the responsibility of the individual fishing port markets, which have their own administration. ETANAL simply acts as a coordinating body.
Data are obtained on a daily basis by recording the quantities and prices of the transacted products. Data collection started in 1969 and initially covered only six fishing port markets. Gradually, with the addition of new fishing port markets, the data collection network was extended, and it now covers 11 fishing ports (Figure 1).

The Transportation, Transaction and Marketing Methods
A census survey was conducted with the assistance of ETANAL with the overall objective to assemble information on the transportation, transaction and marketing methods, the controls exercised and the documents used for data collection in the individual fishing port markets.
For the collection of the required information a precodified Recording Schedule (RS) was designed. The variants which are included in the Recording Schedule provide, on the one hand, detailed information on the methods and practices followed in each fishing port market, and on the other hand, can be used to produce the needed indicators which would best discriminate between fishing port markets.

a. <u>Transportation</u>
The two main transportation methods of Hellenic marine fisheries' products used in the individual fishing port markets are: a) direct landings of marine fishing vessels and b) inland transportation. The relative importance of these two transportation methods, expressed by their percentage contribution to the total inflow of Hellenic marine fisheries' products in the individual fishing port markets, is given in Table 1.

b. <u>Marketing</u>
The census results provided, among other things, two kinds of information on the transportation of products: The Movement Network System of products between fishing port markets, and the Transportation System of products in the fishing port markets from other fishing ports. It should be noted that the states of the Movement Network System and the Transportation System are not constant on a monthly basis and depend on a seasonal pattern.
As a result, out of the total of 11 fishing port markets, the 8 fishing port markets (01, 02, 03, 04, 05, 06, 10, 11), are "mixed fishing port markets" in the sense that they receive products from other fishing port markets and dispatch products to other fishing port markets. The remaining 3 fishing port mar-

Table 1. The relative importance of various transportation methods of marine fisheries' products in individual fishing port markets, expressed by their percentage contribution to the total inflow quantities.

Fishing port markets	Transportation methods		
	1. Fishing vessels	2. Inland transportion	3. Other (sea transportation)
01. PIRAIAS	25%	75%	
02. THESSALONIKI		100%	
03. KAVALA	75%	25%	
04. PATRA	40%	60%	
05. CHALKIS	40%	60%	
06. CHIOS	70%	30%	
07. ALEXANDROUPOLIS	90%	10%	
08. MESSOLONGHI	20%	80%	
09. KALYMNOS	20%	30%	50%
10. PREVEZA		100%	
11. CHANIA	100%		

kets (07, 08, 09) are "dispatching fishing port markets" in the sense that they only dispatch products to other fishing port markets. The mixed fishing port markets with heavy movement of products are Peiraias (01) and Thessaloniki (02), followed by Kavala (03), Patras (04) and Chalkis (05).

c. <u>Transactions</u>

There are significant differences between fishing port markets concerning the forms of transaction. The two extreme cases are the fishing port market of Kavala (03) where four forms of transactions are utilised (fish-producers and fish-traders, fishermen's Associations and fish-traders, fish-brokers and wholesalers, fish-brokers and retailers), and the fishing port market of Preveza (10) where only one form of transaction is employed (fish-producers and retailers).

In all the fishing port markets both the pre-auctioning arrangements and auctioning transactions are conducted independently by the persons concerned. Controls are exercised only in the fishing port markets of Chalkis (05), Messolongi (08) and Preveza (10). In the auction procedures, a variety of administrative controls are exercised within the fishing port markets of Peiraias (01), Thessaloniki (02), Kavala (03), Chalkis (05), Chios (06), Alexandroupolis (07) and Messolongi (08). Controls are not exercised at all in the fishing port markets of Patras (04), Kalymnos (09), and Preveza (10).

There are also significant differences between the fishing port markets concerning the controls exercised at the exit of the transacted fisheries' products from the fishing port.

The Existing Administrative Fisheries Statistics

The system of data collection has been adjusted to the adopted method of auction sales carried out in the fishing port markets. In particular, the quantities and prices of the sold products are recorded when the buyer is called to present an invoice or other relevant document at the exit from the fishing port market in order to be charged with a percentage of the value of the transacted products for port expenses.

Although all fishing port markets follow to some degree the above method, there are marked differences between fishing port markets regarding the controls exercised during the auctioning and data recording procedures. These procedures have not been standardized. It can be said that each port has established its own methodology which suits the means available and the local conditions of marketing. Inevitably, the statistics produced differ between ports regarding coverage, completeness and reliability.

A detailed investigation of the kind of information provided by different fishing port markets revealed that two major groups of fisheries' statistics are available: a) Basic fisheries' statistics which are produced by all fishing port markets and meets the requirements set up by ETANAL and, b) additional statistics which are available in some fishing port markets.

The basic fisheries' statistics consist of three parts, which cover the following: 1) Transacted inflow quantities (number of fish boxes and weight in Kgs) and value (gross total value, average sale price and range of prices) of individual species fished in Hellenic marine waters, along with their code numbers, classified by major biological group (fish, cephalopods, crustaceans and mollusks), individual species from inland water fisheries, individual species from overseas fisheries, imported species which are transacted through the fishing port markets. These species are not given code numbers. 2) Summary of basic survey items and additional information concerning products imported and products transferred from the fishing port market in question to other fishing port markets: a) Total of marine and freshwater products grouped by major biological categories (total quantity and value of fishes, cephalopods, crustaceans and mollusks), b) total quantity and value of imported fisheries' products (fresh, frozen), c) total quantity, value and average price of products classified by quality (A-class, B-class, C-class), d) quantity of products transferred from the given fishing port market to other fishing port markets. 3) Detailed information on the quantity, value, average sale price and range of prices of the 19 commercially most important species classified by freshness and size category (this information is collected since 1989).

Additional administrative fisheries' statistics are available in a number of fishing port markets: 1) For a number of years the biggest fishing port markets (Peiraias, Thessaloniki and Kavala) collect information on a daily, bi-weekly and monthly basis on the three species particularly important to the processing industry (sardine, anchovy and mackerel). The data items collected cover landed quantities, average sale prices and quantities sold for human consumption, quantities sold for processing and quantities withdrawn. 2) The fishing port markets of Thessaloniki, Kavala and Patras collect monthly information on the quantity, value and average sale price of products classified according to their origin, as follows: a) Medium Fisheries products, further subdivided by type of fishing vessel (trawlers, day purse-seiners, night purse-seiners and beach seiners). The number of Medium Fisheries vessels landing in the port in question during the previous month is also given, b) coastal fisheries and aquaculture products (including lagoon farming), c) Inland water fisheries' products, d) imported products, d) the fishing port market of Thessaloniki provides assessments of labour force (number of fishing workers) and productivity, expressed in production per vessel and production per fisherman, for the Medium Fisheries, based on the assumption of a fixed number of crew members employed by the vessels of each fisheries' branch.

Neither the Basic nor the Additional Administrative Fisheries Statistics are published. The results of the Basic Administrative Fisheries Statistics are tabulated by each fishing port market in the form of a monthly statistical leaflet which is common for all fishing port markets and is distributed to relevant authorities and interested bodies. Each statistical leaflet provides information on the transacted products during the previous month. The same tabulation format is used by all fishing ports, but the degree of coverage and completeness may differ between ports.

Yearly statistical leaflets are produced by adding up the monthly data. ETANAL tabulates the information obtained from the annual statistical leaflets of fishing port markets to produce a similarly structured annual statistical leaflet which refers to the yearly total transacted fisheries' products in all fishing port markets of the country.

Monthly and annual leaflets providing additional administrative fisheries' statistics are also prepared by the fishing port markets.

From 1999 and thereafter, a table showing the quantity, value and average price of catch distributed by fish-pier, by main species and by month. has been incorporated in the annual publication of NSSG leaflet titled "Sea fishery by motor vessels"

Improvement of the Operational Aspects of the System

For the improvement of the operational aspects of the system, actions should be taken in the following two fields of interest. The first concerns the improvement of the quality of species' classifications. The second concerns the introduction into the system of a procedure for checking the accuracy (=validity) of the produced statistics on a current basis (=monthly).

<u>The problem of species misclassifications</u>: Due to the fact that Hellenic common names are used, the same common name is used in different locations for different species, and different species may appear under the same name.

A Check Sample Survey (CSS) is proposed to be executed aiming to provide the needed information for assessing the magnitude of the problem, estimations of the size and direction of the measurement bias inherent in the calculated estimates on a species basis, and computer de-biasing methods. The same information will also be used for the revision of the existing list of species.

A "matching scheme" is proposed to be used in the questionnaire design of CSS for obtaining the required multiple items of information for quality checking. Survey data in CSS will be collected from a sample of purchasers/invoices basis (=survey units) at the exit of the sample fishing port markets. The "matching scheme" consists of two parts. These will be completed simultaneously on a sample survey unit basis at the measurement process of CSS: Part-A (AFS): is used for recording the species' Hellenic common names and the respective transacted quantities (number of fish boxes, Kgs) as they appear in the purchase invoice (sample). Part-B (CCS): is used for recording the respective fresh correct information on the survey characteristics concerning the true species' names and quantities.

The statistical matching of the parallel records appearing in parts A and B of the matching scheme will provide the needed sample data for assessing the magnitude of the problem of species' misclassifications, the estimation of the size and direction of the measurement bias inherent in the calculated estimates on a species basis, and the development of the computer methods for their de-biasing. Also, the same sample information will be used for the revision of the existing list of species.

For the sampling design of CSS, the method of "Two-stage sample in space and time" is proposed. In the sampling scheme, the first-stage sampling units (=Primary Sampling Units, PSUs) are the survey fishing port markets, and the Secondary Sampling Units (SSUs) are the survey units (purchaser/invoice).

For the area sample of CSS, the five fishing port markets in which controls are exercised at the exit of their transacted fisheries' products are (01. Peiraias, 02. Thessaloniki, 03. Kavala, 05. Chalkis, 06. Chios) and the important fishing port market of Patras (04) - without exit control - can be selected.

For minimizing the cost of CSS, "sampling in time" will be introduced into the sampling design of the survey. Specifically, by taking into account the transaction seasonality pattern of Hellenic marine fisheries' products in the survey fishing port markets, time-strata (=seasons) can be introduced into the system and two sample weeks will be randomly selected within each time-stratum. Within the sample weeks, daily data will be collected from pre-determined samples of SSUs by using the method of a simple systematic sample with a random starting point.

The proposed CSS is an efficient sampling design and will yield a high precision of the required multiple survey characteristics at a low cost.

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III.4. COMMERCIAL FISHING GEARS AND METHODS USED IN HELLAS

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INTRODUCTION

Since humans began fishing at least 90 000 years ago, fishing technology has evolved from simple harpoons and hooks to industrial factory trawlers in the 20th century (KENNELLY & BROADHURST, 2002). The first known use of fishing gears by humans is reported by YELLEN *et al.*, (1995) and refers to the use of harpoons to catch catfish. The use of hand lines, nets and fish pots is mentioned in the scripts of many 'classical' writers (e.g. Aristotle, Homer, Oppianos). The use of an early type of beam trawl in the river Thames in the 14th century and the discards that were produced caused the first attempt to enforce regulations for the operation of a fishing gear (DYSON, 1977). The introduction of more active fishing methods like the use of purse seines in the USA in 1826, the invention of a Danish seine in 1848 and the first use of modern otter trawls in England and Ireland around 1860, indicate the rapid progress in fishing gear technology as well as the commercialization of the fisheries.

The purpose of this chapter is to describe briefly but as clearly as possible the main types of commercial fishing gears and methods currently in use in Hellenic marine fisheries. The chapter includes both the gears used in coastal fisheries and open sea fisheries. The classification and terminology followed is according to the FAO Fishing Gear Classification (NEDELEC & PRADO, 1990). The way that the gears operate and their demands on the operating vessel are also considered (SAINSBURY, 1996). So, they are cited as follows:

- Towed and dragged gears (bottom trawl, boat seine, dredges)
- Encircling gears (day and night purse seine, small surrounding net)
- Static gears (nets, long lines, pots)

The technical characteristics, according to official records of the gears throughout Hellas (FILLIPOUSIS *et al.,* 1989, 1991; ANASTASIADOU *et al.,* 1990, 1992; KARLOU *et al.,* 2006), the way of operation and the target species are reported for each gear. However, all the gears mentioned occur in great variety in Hellenic ports determined by the local conditions, thus the more representative types are described herein. The legislative provisions concerning the different gear types are provided in Chapter III. 7 (Management and legislation in Hellenic fisheries).

TOWED AND DRAGGED GEARS

Bottom trawl

The traditional bottom trawl gear used in Hellas is a low opening gear that consists of many rectangular pieces of netting connected side by side, with numerous selvages, forming a big funnel-type net. The netting is made of multifilament twine, knotted and knotless, with diamond meshes. This type of trawl gear is relatively the same irrespective of the species that is mainly targeted each time. Minor modifications that are made to the gear by the fishermen, are usually associated with the fishing grounds or other local demands and do not significantly change the main structure of the gear. The main sections of the Hellenic bottom trawl gear are the wings, the main trawl body or shoulders, the extension piece and the cod-end (Figure 1).

Wings are made of two half sections that consist of 1-4 pieces of net each, are about 11-12 m long and the netting stretched mesh size is mainly 90 mm. The main body comprises of an equal number (usually 4-6) of rectangular pieces of netting, each 100 meshes wide, placed at the right and left side of the central triangle located at the upper (tselo) and lower (boukos) part of the trawl body, respectively. The length of the main body is about 20 m and the netting stretched mesh size ranges from 40 to 70 mm. The extension piece consists of 5-7 pieces of net of 100 meshes wide each. It is about 19 m long and the netting stretched mesh size is mostly 40 mm. The last part of the net, the cod-end, consists of 1-6 pieces of net. The cod-end is about 7 m long, its overall width is mostly 300 meshes, which is the same lengthwise, and the netting stretched mesh size is 40 mm. It is usually covered by a strengthening piece of netting. A single rope of PA (elastic polyamide) is tied around the cod-end to close it. (Figure 1).

The entire length of the trawl net is usually 58 m and the mouth circumference (stretched circumference at the fishing line) is about 61 m. The vertical opening of the gear is 1.3 m (0.7 to 1.6 m) and the horizontal opening (at spreaders) is 14.4 m (9 to 15 m), according to measurements made to three 1:8 scale models of representative Hellenic bottom trawl gears that were tested at the North Sea Center flume tank (Hirtshals, Denmark) (ADAMIDOU & KALLIANIOTIS, 1997).

Regarding the ropes where the net is mounted, the float line is about 32 m long, 18–28 mm thick and is made of PA or MAN (Manila fiber); the ground rope is about 48 m long, 40 mm thick and is made of PA+Fe or PP (polypropylene) and Fe. The trawl net has no spreading wires; the net is joined directly to the spreaders. The sweeps are made of PA+Fe or MAN+Fe; their length ranges from 180 m to 280 m and their thickness from 24 to 50 mm. The otter boards of the traditional trawl are oval or rectangular and weigh 200 to 400 kg depending on their material. Every time that a tow takes place only one trawl net is towed.

Bottom trawl fisheries in Hellas are multi-species fisheries. The main target species or group of species are closely related to the season, depth (POLITOU *et al.*, 2003) and substrate while the geomorphology of the bottom is an important ruling factor (KALLIANIOTIS *et al.*, 2004). However, the most important species in terms of both landings and value are *Merluccius merluccius, Mullus barbatus, Parapenaeus longirostris, Nephrops norvegicus*.

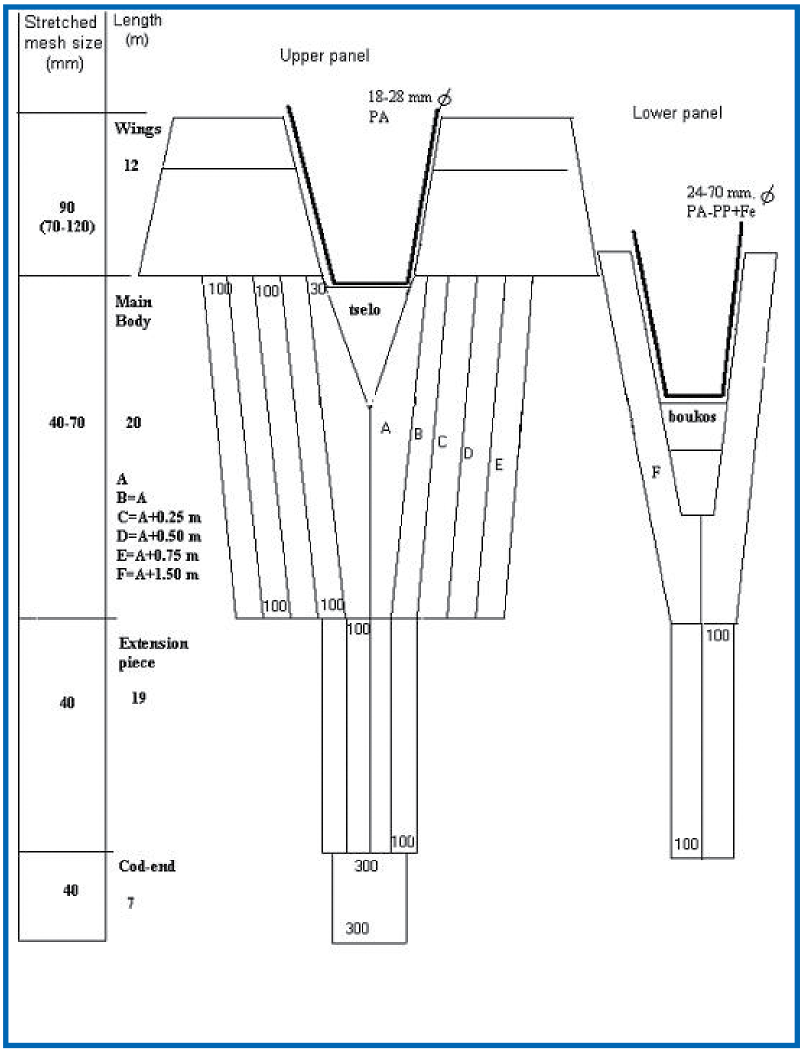

Figure 1: Design and technical characteristics of traditional greek trawlnet (Photo: A.ADAMIDOU).

Boat Seine

A commercial boat seine net operating in Hellenic waters consists of four main sections: the cod-end, the bag, the main body or shoulders and the relatively long wings (Figure 2a). The total length of the net ranges from 200 to 440 m and the stretched circumference of the mouth opening is 36 - 129 m. The bag is the central part of the net. It is 13-40 m long and the netting stretched mesh size is 20-28 mm. It consists of 8-16 rectangular pieces of netting of the same mesh size and twine thickness. The rearmost part of the bag is the cod-end, which is 1-7 m long, and the netting stretched mesh size is 16-20 mm. Shoulders are made of two half sections. The length of the shoulders varies from 11 to 70 m and the stretched mesh size from 24 to 60 mm. They consist of 2-10 rectangular pieces of netting with different mesh sizes and twine thickness. The wings are the longest part of the net representing 75% of the total length of the gear. They are also made of two half sections. They have a length of 144 to 400 m and a stretched mesh size of at least 600 mm. At the wings and shoulders there is a strengthening piece of enforced netting that is used to join the main netting with the headline and the ground rope and to prevent damage to the main netting. A spreader is used at the end of each wing to attach the netting to the hauling ropes. The headline and ground rope are made of braided PA or PP rope and have a thickness of 6-12 mm and a length of about 600 m with the ground rope being slightly longer. The rigging of the gear is strongly related to the species targeted and the geomorphology of the fishing area. Oval and cylindrical floats are usually used in the headline for buoyancy and lead weights are used in the ground rope for weighing down. Floats and weights increase progressively from the wings to the bag. An important component for the capture efficiency of boat seines is the long hauling ropes, of maximum length 700 m, extending from the wings, which are used to encircle a large area. No doors are used for the operation of the gear. The technical details of a typical boat seine net are illustrated in Figure 2a.

The boat seine operates close to the coastline fishing grounds (< 0.5 mile) at depths < 50 m fol-

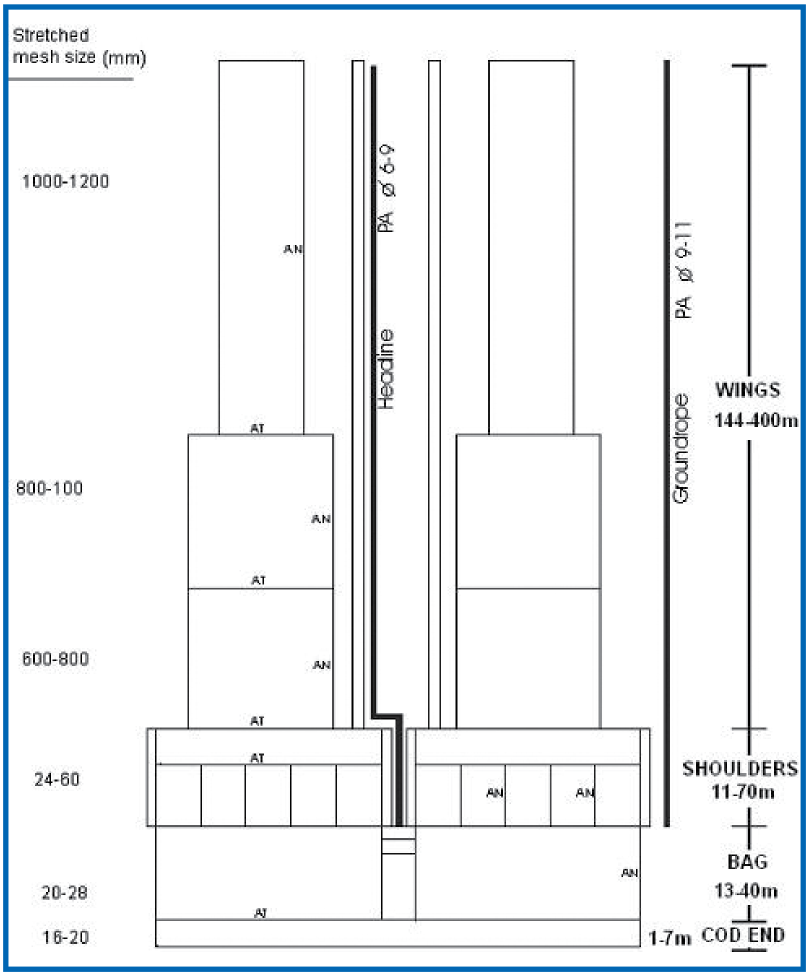

Figure 2(a): Design and technical details of a typical boat seine net (by A. ADAMIDOU).

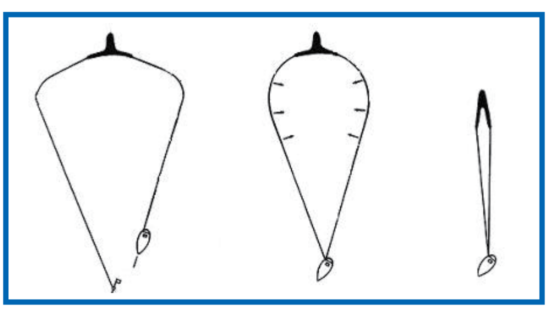

Figure 2(b): A plan of the operation of the boat seine gear (from SAINSBURY, 1996).

lowing more or less pre-defined hauls. The vessel carries out one-day trips, starting shooting one hour before sunrise until one hour after sunset. The shooting of the gear begins by setting an anchored buoy within 70 m from the coast. The vessel steams in slowly with approximately 5m/min. The hauling ropes of one side are laid out, the net follows and equal number of ropes for the other side is then laid out. In this way the gear encircles a relative large area in more or less a triangular pattern. The vessel courses back and when it reaches the anchored buoy, the first and the last ropes are hauled in slowly by the winch to guide the fish into the net. When the aft part of the bag comes to the surface it is pulled on to the boat by hand (Figure 2b) (ARMENI-AGIOBLASSITI, & ADAMIDOU, 1997). The gear activity strongly depends on the weather conditions and on the geomorphology of the fishing area. It is most efficient on flat bottoms with a smooth inclination where long ropes can be used (a 10 m depth difference between the mooring and the fishing place is required). Boat seines are also used in rougher grounds, but then with shorter ropes while they cannot operate on rocky bottoms since the net can be damaged very easily (LEFKADITOU & ADAMIDOU, 1997).

The target species for the boat seine fishery considered in general for Hellenic Seas are: *Spicara smaris* as the primary target species, while *Sardina pilchardus*, *Boops boops*, *Mullus barbatus*, *Loligo vulgaris* and *Pagellus erythrinus* as the secondary target species. (KARLOU-RIGA *et al.,* 1997; FISHERIES LABORATORY, 2001; PETRAKIS *et al.,* 2001, KALLIANIOTIS *et al.,* 2000).

Dredges

Dredging is not a widespread fishing method in Hellenic coastal fisheries. The related fishing gears are small and light and are used mainly for harvesting bivalve molluscs and sponges. Two dredge types are used, one for bivalve molluscs which is called "argaleios", and another for sponge-fishing called "gagava".

Bivalve dredge or "Argaleios"

The "argaleios" consists of a triangular metal frame up to 0.2 cm thick that has the sidebars curved at the end (Figure 3). The lower bar of the frame is up to 1.2 m long and may have a raking bar with or without teeth. A twine netting bag is attached behind the frame to collect the catch. The netting bag is up to 1.5 m long and the mesh size is over 70 mm (stretched mesh). The overall weight of the gear cannot surpass 12 kg. The "argaleios" can be towed either by hand or from a vessel by a towing rope tied to the eyelet at the top of the triangular frame. It is used on even seabeds at depths from 1 to 20 m and the target species are the smooth scallop (*Chlamis glabra*) and the smooth clam (*Callista chione*), (*Modiolus barbatus*). The gear is mainly

Figure 3: A typical bivalve dredge or Argaleios (Photo: A. ADAMIDOU).

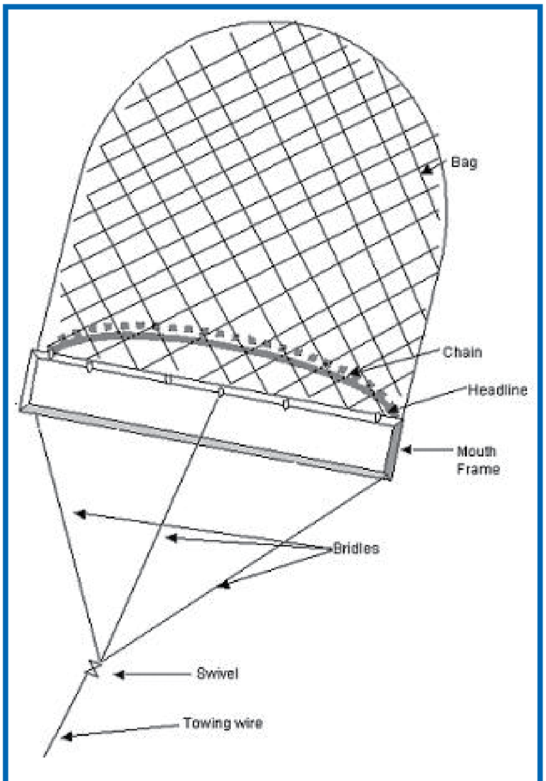

Figure 4: A rough drawing of a sponge dredge or gagava (by A. ADAMIDOU).

used in the Thermaikos Gulf and to a lesser extent in the Saronikos and the Pagasitikos Gulfs.

Sponge dredge or "Gagava"

A rectangular mouth frame made of wood or metal tubing, to which a holding bag of twine netting is attached, constitutes the "gagava" (Figure 4). The frame is about 2 m wide, 0.5 m high and 2.5-3 cm thick. The holding bag has a constant width proportional to the frame, its length is 4 to 8 m and the mesh size is 300-340 mm (stretched mesh). It is tied directly to the upper and side part of the frame while, at the lower part, a chain of 2.5-2.6 m is connected and the bag is attached to the chain. The bag is emptied either by loosening the end line or by lifting it from the rear to drop the catch from the mouth. The overall weight of the gear is up to 50-60 kg. The "gagava" is dragged along the seabed by a towing wire that is linked to the frame by three ropes (two at the lower and one at the upper part of the frame), using a motorised winch with a towing speed of 2 knots/h. It is used mainly in sponge fishing at depths from 10-50 m on an even seabed. The gear is traditional and very famous in sponge fishing in the south-eastern Aegean Sea (Dodekanisos area) but nowadays its use is limited.

ENCIRCLING GEARS

Purse seines

Purse seining is one of the oldest fishing methods activated all around the world mainly on the coast until 1950 (HAYES *et al*., 1996, LOVE, 2006). After that period, the introduction of synthetic fibres in nets' manufacture, the modernisation of ships and their equipment and the use of electronic systems to detect fish catch, made the fishery more dynamic, and it moved also to the open sea. In the Mediterranean all the countries use purse seining intensively. The fishery is realised either during the night with the use of artificial light, which is also the most usual method, or during the day mainly in seasonal passages of migratory fishes. The differentiation between the two kinds of fishery consists of the characteristics of the gear used, the target species, the season, the fishing grounds and the legislation. The philosophy of purse seining is to gather species that usually form schools, surround them by a long wall of netting, purse the netting through the purse line creating a net open at the top and closed at the bottom trapping the fish.

Night purse seine

Commercial night purse seine gear operating in the Hellenic waters consists of two main sections: the main body and the cod-end. An auxiliary piece of netting is attached to the two ends of the main body to help the hauling of the gear. The main body of the night purse seine gear consists of 8-20 oblong pieces of netting ("ferses" in Hellenic), each being 400 meshes wide and joined one below the other. The netting stretched mesh size of the main body is 14 -28 mm. However, the two upper and two lower oblong pieces usually have a

Figure 5(a): Lamp rafts at the deck of a purse seiner (Photo: A. CHRISTIDIS).

Figure 5(b): The large rowing net boat holding one end of night purse seine net during the setting of the gear (Photo: A. CHRISTIDIS).

Figure 6: The hauling of the night purse seine net (Photo: A. CHRISTIDIS).

bigger mesh size (32 -90 mm stretched mesh) and are narrower compared to the pieces of the main body and are made of thicker twine. The cod-end consists of 4-19 pieces, is placed either at the centre of the main body or at the side and is made of thicker twine compared to the main body netting. The length of the gear ranges from 450 to 760 m (mounted), the stretched height from 80 to 120 m and the hanging ratio of the headline to the main body netting is 5-33%. The headline and the lead line are usually made of PA or PP, are 10-16 mm thick and the lead line is usually 5-15% longer than headline. A large number of plastic floats placed at close intervals on the float line ensure that the upper part of the net will always be at the water's surface. At the lead line rustproof metallic rings are connected at equal distances by small ropes of 0.5-2.5 m long. The number of rings is determined by the length of the gear (usually 60-135 rings). A wire cable -the purse line- passes through the rings and closes the bottom of the purse seine at the end of the gear operation.

The operation of the night purse seine in Hellenic waters comprises one "mother vessel", one large rowing net boat and several lamp rafts (Figure 5a) as this type of fishery relies on light attraction. When a school of fish is detected, usually by the echosounder, the lamp rafts are released on to sea to concentrate the fish. Afterwards, when the concentration of fish under the lamp rafts becomes adequate, the large rowing boat holds one end of the net (Figure 5 b), the "mother vessel" encircles the fish with the net and returns to the point where the large rowing boat waits to take the other end of the net. The "mother vessel" begins to winch in the purse line, closing the bottom of the seine and forming a bag-like net around the fish. The other lines are also winched in, reducing the space inside the net, which is then brought alongside the "mother vessel" (Figure 6). Using dip nets, scoops or other appropriate tools the crew take the fish on board the ship and place them in large ice basins.

The main catch of night purse seines consists of sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicholus*), chub mackerel (*Scomber colias japonicus*), horse mackerel (*Trachurus* spp.) and bogue (*Boops boops*) (VIDORIS *et al*., 2001)

Day purse seine

A small number of recordings exist for the day purse seine gear. It consists also of the main body, the cod-end and the auxiliary piece of netting used for the hauling of the gear. The main body consists of oblong pieces of netting each being 400 mesh-

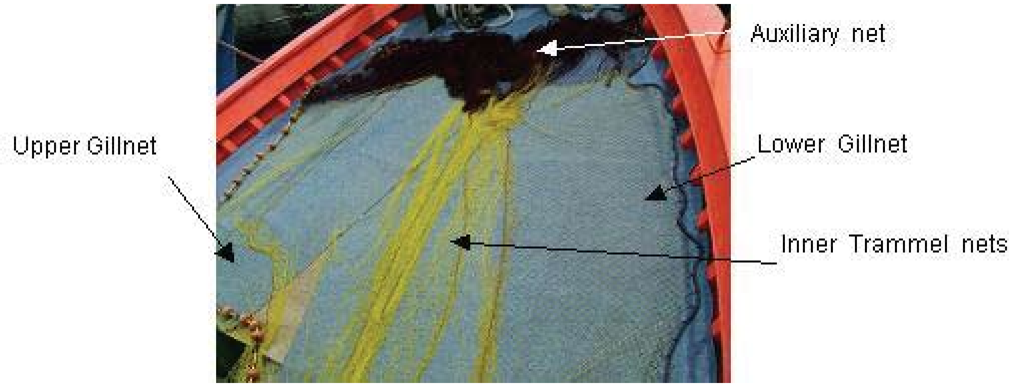

Figure 7: A part of a small surrounding net (Photo: A. ADAMIDOU).

es wide, joined one below the other but a fewer pieces than the night purse seine; they are usually 5-9 which makes the gear shorter. The netting stretched mesh size of the main body is 40 mm and the netting twine is thicker. The two upper and two lower oblong pieces are narrower compared to the pieces of main body, are made of thicker twine and have the same or a bigger mesh size (72 mm stretched mesh). The cod-end consists of 5-7 pieces, is placed usually at one side of the main body and is made of thicker twine compared to main body netting. The length of the gear is up to 800 m (mounted), the stretched height up to 120 m but most commonly 70-80 m and the hanging ratio of the headline to the main body netting is 15%. The headline and the lead line, usually made of PA or PP, are 10-16 mm thick. The flotation, the sinking as well as the purse rings and purse line follows the same strategy as for the night purse seine.

The operation of the day purse seine is the same as the night purse seine without the use of the lamp rafts. The main catch consists of species such as: *Sarda sarda, Euthynnus alletteratus, Katsuwonus pelamis, Auxis rochei, Orcynopsis unicolor, Pomatomus saltator, Seriola dumerilii, Argyrosomus regius, Coryphaena hyppurus*.

Small surrounding net

The small surrounding nets used in Hellas named 'kouloura' are constituted from 1 to 9 oblong nets ("ferses" or "kanatia" in Hellenic) that are connected vertically. The nets can be all gill nets, or all trammel nets or a combination of these (gill nets for the first and last net; trammel nets the inner ones) (Figure 7). The stretched mesh size ranges from 44 to 72 mm. The length of the nets ranges from 250 to 500 m and can be equal or increased from the upper to the lower net. The nets are connected through lacing ropes. On each lacing rope the last part of the previous and the first part of the next net are rigged. The length of the lacing ropes is equal or little longer than the nets that are connected. The first and last oblong net is connected to the headline and lead line, respectively. An auxiliary piece of netting exists at the two sides of the surrounding net to facilitate the hauling of the gear. At the headline, a sufficient number of floats are placed with increased frequency providing the adequate buoyancy to maintain the upper part of the net at the water's surface during the fishery. The lead line is supplied with weights to ensure the vertical position of the net in the water.

The small surrounding net is used mainly for pelagic and semi-pelagic species that are shoaling (*Sarpa salpa, Mugil* spp., *Sarda sarda, Katsuwonus pelamis, Pomatomus saltatrix*) however, when it is used at depths lower than the height of the gear it fishes also demersal species. When the target species is detected, an anchored buoy is set in the water with the one end of the net attached to it. The ship, following a circular course, leaves the rest of the net, surrounds the school of fishes and returns to its initial place. Then, the net is gathered simultaneously from the two ends. Thus, the fishes are trapped in a space that is continually reduced. The fishing operation lasts half to one hour and the depth of fishery ranges from 4 to 65 m with 4-30 m being more usual. The gear is used mainly in the northern and central Aegean Sea.

STATIC GEARS

Nets

Fishing with nets is one of the most widespread fishing techniques used in ancient times. Fish may be caught in nets gilled (mesh behind opercula), wedged (mesh around the body) or tangled (by external protrusions without the body penetrat-

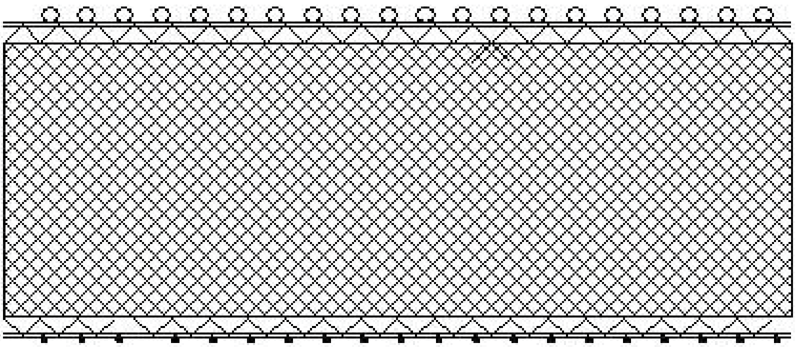

Figure 8(b): A rough drawing of a gillnet (by A. ADAMIDOU).

Figure 8(a): The upper part of a gillnet (Photo A. ADAMIDOU).

ing the mesh) (HAMLEY, 1975). The way that a fish can be caught depends on the mesh size and the tightness of the netting that is closely related to the hanging ratio (length of float line or lead line divided by the length of unmounted, stretched net). Fishing with set nets is well developed in Hellas since nearly all vessels of small-scale fishery use them for several fisheries (drift nets are prohibited by national legislation). The types of set-nets used mostly are: gill nets, trammel nets and combined nets.

Gill nets

A gill net is a single, rectangular sheet of netting hanging on a rope along its upper and lower part (on float line and lead line, respectively) (Figure 8). Sometimes, side cords are attached to each side end. The net is held vertically in the water owing to the combined action of floats and weights. A gill net can be used singly or most usually several nets are joined in fleets. It can be set in many ways depending on the target species and the type of seabed. The most frequent ways are: at or below surface, on the seabed, or in mid-water.

Concerning gill nets that are used in Hellas, the webbing is made of multifilament twine (monofilament twine is not allowed in Hellenic fishery). The length of each mounted gill net ranges mainly from 40 to 220 m; the depth ranges from 50 to 100 meshes when it targets demersal species while for pelagic and semi-pelagic species it ranges from 200 to 400 meshes. The hanging ratio can vary from a loose 0.25 (for lobster) to a tight 0.75 (for bogue, picarel, mackerel) while 0.5 is the most common for demersal species (mullets, hake, sea breams). The mesh size varies widely depending on the size and species being targeted. Floats of expanded PVC having a ring, cylindrical or egg shape are attached to the headline to maintain the buoyancy. Weights, usually steel, with a ring or cylindrical shape are attached to the lead line to ensure bottom contact even though lead-core lead lines have become more popular to avoid the catching on obstructions. The size and the frequency of the floats depend on the mesh size – they need to be slightly larger than mesh opening- and the depth at which the net is used. The surface gill nets need more floats and fewer weights while the opposite is necessary in bottom gill nets. Suitable mooring (usually stones) is used to fix the net to the bottom and plastic buoys to give lift and mark the position of the net.

Gill nets are used all around the Hellenic coasts with a high level of differentiation among them concerning the features of the gear, the target species and the way of deployment. However, the most common types (metiers) in gill net fishery that take place all over the Hellas are the ones targeting: red mullets (*Mullus* spp.), hake (*Merluccius merluccius*) and/or mackerel (*Scomber* spp), bogue (*Boops boops*) or picarel (*Spicara smaris*). The most important characteristics of these fisheries are as follows:

Gill nets for red mullets are usually 50-100 m long, 40-60 meshes deep and the mesh size ranges from 32 to 52 mm (stretched mesh). *Mullus surmuletus* is caught at bottoms enclosed between rocks and seagrass meadows, between 5 and 30 m depth while *Mullus barbatus* are caught mostly on seagrass meadows, muddy and sandy bottoms at 10-60 m depth. Nets are set once or twice a day, before sunrise and/or after sunset and stay in the water for 2-3 hours. The fishing period is from June to November.

Gill nets for hake and mackerel are usually 100-250 m long, 60-100 meshes deep and the mesh size ranges from 52 to 72 mm (stretched mesh). Nets are set on muddy, seabeds at 60-400 m depth. They are set before sunset and hauled before sunrise and stay in the water for 10-12 hours. The fishing period is from April to September.

Gill nets for bogue or picarel are usually 100-250 m long, 60-300 meshes deep and the mesh size ranges from 36 to 52 mm (stretched mesh). Nets are set on sandy seabeds and on seagrass meadows at 20-100 m depth. They are set once or twice a day, before sunrise and/or after sunset and stay in the water for 2-3 hours. The fishing period is mainly from May to October.

Trammel nets

Trammel nets are made of three rectangular sheets of netting in parallel order, that hang jointly on a single float line and lead line along their upper and lower part, respectively (Figure 9). The inner sheet has smaller mesh size than the outer ones and larger height to be loose enough. Thus, when a fish confronts the net it goes through the large mesh of the outer sheet, pushes the loose inner sheet, which consequently forms a pocket through the large mesh of the next outer sheet, and traps the fish. Floats and lead weights of appropriate size and frequency ensure the vertical position of the net in the water and the requested depth regarding the species targeted. Proper ballast is attached to each terminal end to fix the net on the bottom and a single line with a plastic buoy to mark its position in the sea.

Concerning the trammel nets used in Hellas, they are all bottom-set nets targeting demersal species. Their webbing is made of multifilament twine; their mounted length ranges mostly from 40 to 220 m; the depth of the outer panels ranges from 0.60 to 1.6 m with the inner sheet being 1.6 times deeper. The mesh size of the inner sheet varies widely depending on the size and species being targeted and is usually 5 times less than that of the mesh size of the outer sheets. The floats and weights are of the same types as those used in gill nets as well as those used for mooring and the buoy. They are set singly or in fleets in various configurations depending on the current conditions, type of seabed and target species.

Trammel nets are the most popular fishing gear in the Hellenic small-scale fishery. They are used all around Hellas, with many differences in the technical characteristics of the gear and the target species. Trammel nets usually target a group of species. The most common trammel net fisheries (metiers) in Hellas are the ones targeting: cuttlefish (*Sepia officinalis*), shrimps (*Melicertus kerathurus*), lobsters (*Palinurus elephas*) and common dentex (*Dentex dentex*), red mullet (*Mullus spp*.), common sole (*Solea solea*), large species of Sparidae family (*Pagellus erythrinus, Diplodus sargus, Pagrus pagrus, Sparus aurata*). The most important

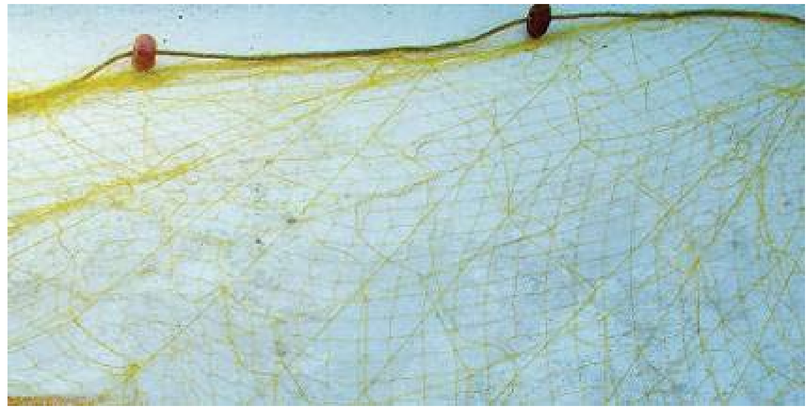

Figure 9: The upper part of a trammel net (Photo: A. ADAMIDOU).

characteristics of the trammel nets used in these fisheries are as follows:

The trammel nets for cuttlefish are usually 50-100 m long, the depth of the inner sheet is 50-60 meshes and of the outer ones 6.5-7.5 mesh. The most common mesh sizes are 60-72mm and 300-360 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.5. Nets are set on muddy seabeds and seagrass meadows at depths from 5-30 m more often. They are set before sunset and hauled before sunrise staying in the water for 12-14 hours. The fishing period is from February to May. They are used all around Hellas.

The trammel nets for red mullets are usually 100-220 m long, the depth of the inner sheet most frequently is 60 meshes and of the outer ones 7.5 mesh. The most common mesh sizes are 40-48mm and 200-240 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.5. Nets are set on nearly all types of seabed at depths from 20-200 m. They are set once or twice a day, before sunrise and/or after sunset and stay in the water for 2-3 hours. The fishing period is from April to September. They are used all around Hellas.

The trammel nets for large species of the Sparidae family are usually 100-350 m long, the depth of the inner sheet most frequently is 60 meshes and of the outer ones 7.5 mesh. The most common mesh sizes are 60-80 mm and 300-400 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.5-0.6. Nets are set on any type of seabed at depths from 30-300 m. They may be set once, before sunset and hauled before sunrise staying in the water for 12-14 hours or twice a day, before sunrise and/or after sunset and

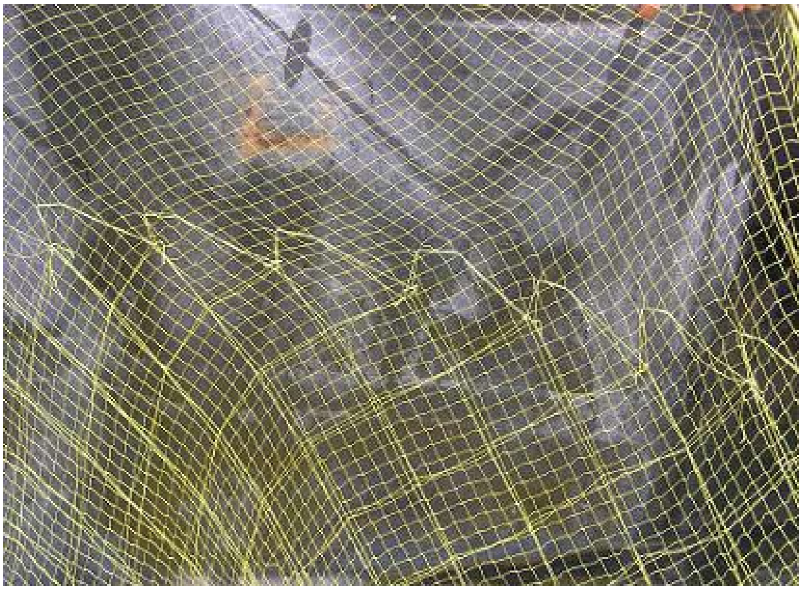

Figure 10: The join of a gillnet and a trammel net at a combined net (Photo: A. ADAMIDOU).

stay in the water for 3-4 hours. The fishing period is almost all the year except for winter. They are used all around Hellas.

The trammel nets for lobster and common dentex are usually 100-220 m long, the depth of the inner sheet most frequently is 50-60 meshes and of the outer ones 7.5 mesh. The most common mesh sizes are 60-90 mm and 300-400 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.4-0.5. Nets are set on rocky and mäerl seabeds at depths from 30-150 m. The soaking type is 10-24 hours. The fishing period is from May to September. They are used mainly in the central and southern Aegean Sea and in the Ionian Sea.

The trammel nets for shrimps are usually 50-100 m long, the depth of the inner sheet most frequently is 60 meshes and of the outer ones 4.5-6.5 mesh. The most common mesh sizes are 40-48mm and 200-240 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.5. Nets are set on muddy seabeds at depths from 5-30 m. They are set once or twice a day and stay in the water for 3-8 hours. The fishing period is from April to June and from September to November. They are used mainly in the northern and central Aegean Sea and in the Ionian Sea.

The trammel nets for common sole are usually 50-100 m long, the depth of the inner sheet is 40-60 meshes and of the outer ones 4.5-5.5 mesh. The most common mesh sizes are 68-90 mm and 330-420 mm (stretched mesh) for the inner and outer sheets, respectively. The hanging ratio is usually 0.4-0.5 (ADAMIDOU *et al.*, 2004). Nets are set on sandy and muddy seabeds at depths from 10-70 m more often. They are set before sunset and hauled before sunrise staying in the water for 12-14 hours. The fishing period is from October to April. They are used mainly in the northern and central Aegean Sea and in the Ionian Sea.

Combined nets

A combined net is made up of a gill net at its upper part and a trammel net at the lower. Concerning its structure, it can be either (A): a gill net having at its lower part two sheets of netting with large mesh size attached to the opposite sides (Figure 10); or (B): two separate nets, a gill net and a trammel net, that hang vertically one after the other connected to a common rope. In the second case, the net has three mounting ropes, a float line (where the gill net hangs), a lead line (where the trammel net is attached) and a connection line in between where both nets are attached. The combined nets target species in the whole water column, pelagic and semi-pelagic that may be caught by a gill net and demersal species caught by a trammel net. They maintain their vertical position in the water by means of floats and weights as in the other set-nets. The floats and weights are of the same types as those used in the other set nets as well as those used for mooring and buoyancy.

The combined nets used in Hellas are usually constructed according to the first of the aforementioned ways; their mounted length is 100-300 m for the majority of the nets and the depth is 100-300 meshes. The depth of the nets joined in a fleet is often not the same, but increases gradually from the first to the last net. The trammel net may cover 20-50% of the entire depth of the net. The mesh size varies mostly from 40 to 64 mm (stretched mesh). Floats and sinkers are of the same types used in all set-nets but are placed with greater frequency on the respective ropes. An auxiliary rope is connected to the lead line to support it on rough bottoms. Combined nets are set usually singly or in small fleets, on any type of seabed, at depths from 10-100 m. They are often arranged around rocky areas or vertical to the shoreline forming a half circle targeting species that are travelling along the shore, or across known fish movement paths. Bogue (*Boops boops*), picarel (*Spicara* spp.), Atlantic bonito (*Sarda sarda*), saddled sea bream (*Oblada melanoura*), red mullets (*Mullus* spp.), gilthead sea bream (*Sparus aurata*) are the main target species. The gear is very com-

Figure 11(a): Circle hook with a big eye (Photo: A. ADAMIDOU).

Figure 11(b): Basket with hooks hung at its mouth (Photo: A. ADAMIDOU).

Figure 11(c): Reflectors used to enable the localization of the surface purse seine (Photo: V. LEKKAS).

mon in the central and the southern Aegean Sea and in the Ionian Sea.

Long lines

Long lines, as the name implies, is a fishing gear that consists of a main line of long length to which many branch lines are attached at equal intervals. Each branch line has a baited hook at its end. The length of the branch lines, the distance among them and the size of the hook depends on the target species. The main line and the branch lines are monofilament twines made by PA with the main line being thicker than the branch lines. In certain cases, the mainline is made of a woven rope of varied thickness while the branch lines from wire. The branch line may be tied to the main line or connected to it by a swivel or a swivel plus a snap-on connector. The hook is characterized by a number that decreases as the size of the hook increases. The shape of the hook also varies; it may be a "J" type that is the most common one, a circle hook or circular hook with a big eye (Figure 11a). The choice of bait also has a direct relation to the target species. Many fish species, like mackerel and sardine, round sardinella, squid, octopus, mussels, sand worms are used (the entire fish or pieces of them) fresh, frozen or salted. For easier storage and use of the gear, the main line is placed in a coil in plastic baskets while the hooks are hung on cork at the mouth of baskets (Figure 11b). Each basket allocates a certain number of hooks. Long lines are distinguished into two main categories: a) surface long lines b) bottom long lines. Surface long lines are also divided into drifting and set while bottom long lines are always set.

Surface long lines

The surface long lines are used at or near the surface of the sea and are separated into drifting and set. They are mainly used for the fishery of big pelagic species (swordfish and thunnidae), therefore, the main line is very long and thick and the branch lines are usually double. The intervals between the branch lines are also large. The hooks are big usually circular ones with an eye.

<u>Drifting surface long lines</u>

The drifting long lines do not have any stabilisation equipment, they are left to drift with the sea currents. Their localization is usually electronic (by GPS) with the help of reflectors. The main line is 1.5-2.5 mm thick, the branch lines 1-2 mm thick and the space between them is 20-45 m. The nominal number of hooks is 3-6. At appropriate intervals (every 5-10 hooks) plastic buoys of 5-10 l (litres) are connected to the main line, while at the two ends and in the middle of the main line large buoys of 20 l, joined to black flags and reflectors, are connected to enable the localization (Figure11c).

Set surface long lines

The set surface long lines have stabilisation equipment (weights) at one or even both ends. The main line is 1.5-3 mm thick, the branch lines 1-2 mm thick and the space between them is 20-45 m. The nominal number of hooks is 3-6. At appropriate intervals (every 5-15 hooks) plastic buoys of 1.5-3 l are connected to the main line and weights of 0.5 kg; while at the two ends and in the middle of the main line large buoys of 20 l and weighing 5-10 kg are also connected. Flags and reflectors at the ends of the long line enable the localization (Figure 11c).

Bottom long lines

The bottom long lines are always set. They consist of the main line with suitable weights (usually stones) to fix the long line to the bottom and plastic buoys to give lift and mark the position of the long line at both ends. Smaller weights are also placed at regular intervals along the main line, which keep it on the seabed. Sometimes floats are also placed at regular intervals in the interspaces of the weights. Thus, the main line becomes meandering. According to the size of hook, they are divided to small, medium and large ones.

Small bottom long lines.

The nominal number of hooks is 12-16. The main line is 0.5-1 mm thick, the branch lines, 0.2-0.6 mm thick and the space between them is 2.5-5 m. They fish at depths from 20 to 100 m for large species of the Sparidae family (*Pagellus erythrinus, Diplodus sargus, Pagrus pagrus, Sparus aurata*).

Medium bottom long lines.

The nominal number of hooks is 8-12. The main line is 0.5-1.2 mm thick, the branch lines, 0.4-0.8 mm thick and the space between them is 5-8 m. They fish at depths from 80 to 180 m for larger species of the Sparidae family (*Pagellus erythrinus, Diplodus sargus, Pagrus pagrus, Sparus aurata*), dusky grouper (*Epinephelus marginatus*) and white grouper (*Epinephelus aeneus*).

Large bottom long lines

The nominal number of hooks is 3-7. The main line is 1-2.5 mm thick, the branch lines, 0.5-0.1 mm thick, sometimes made of wire, and the space between them is 8-11 m. They fish at depths from 200 to 700 m for hake (*Merluccius merluccius*), dentex (*Dentex dentex*), dusky grouper (*Epinephelus marginatus*), white grouper (*Epinephelus aeneus*), wreckfish (*Polyprion americanus),*greater amberjack (*Seriola dumerili*),blacktip grouper (*Epinephelus fasciatus*), and some species of Elasmobranchii.

Pots -Traps

Pots or traps are fishing gears in the form of cages, baskets or funnels that are set on the seabed, baited or not, for the capture of fish, cephalopods and crustaceans. Their shape may be cylindrical, rectangular or spherical with one or more entrances. They have a steel, wood or plastic frame covered by twine, plastic or wire netting and set out singly or in fleets. Pots are marked at the surface by a line with a buoy at each end. Ballast is used mainly at each end when pots are set in fleets. The basic principle of pots' operation is to attract the target species that enter the pot either for sheltering or for feeding, enabling their entrance into the pot and obstructing their escape. The pots may be hauled either by hand (in shallow waters or when a small number is used) or with lines (in deep waters) or using hydraulic haulers when pots are in fleets. The depth of hauling and the type of seabed depend on the target species. Pots are used by small-scale fishery; the amount of pots that will be used is determined by the size of the vessel and the number of crew. The soaking time varies from 10 hours to10 days. The most common types of pots used in Hellas are presented below.

Fyke net

A fyke net is a cylindrical trap with a cone-shaped end that consists of 2-5 metallic hoops covered with twine netting (Figure 12). Its length varies between 1.2 and 6.2 m. The hoops are made of galvanized steel wire with an external plastic coating, slightly flattened at the bottom in order to sit on the seabed. The diameter of the hoops range from 0.38 m to 0.60 m and their thickness is between 12 and 15 mm. A rectangular piece of netting of 40-44mm stretched mesh size, covers the hoops, is mounted on them and is tied up on one side forming a cone-shaped holding chamber. One or more netting funnels are placed inside the trap, mounted on the 1st and 2nd or 3rd hoop with direction from the mouth to the rear end of the fyke net. In this way the fish that enter the fyke net cannot escape and remains trapped in the holding chamber from where it is removed by the fishermen. A gill net of 6-8 m long and 15-20 meshes high is placed vertically at the entrance of the fyke net and leads the fish towards the 1st netting funnel. Fyke nets are usually used in pairs, being linked on the two sides of the guiding panel. They are set out in fleets of 20-50 pairs, either by hand or using a winch, in muddy bottoms and in seagrass meadows, at depths from 5 to 30 m. A single line with a plastic buoy is attached to each side of the fleet to mark its position in the sea and ballast to fix the fleet on the bottom. Depending on the vessel's size, from 100 to 1 500 pairs of fyke nets are fished, with several fleets being deployed. They are left to fish from one to seven days depending on the fishing conditions. Afterwards they are retrieved, emptied and reset. The main target species of the fyke net is the common octopus (*Octopus vulgaris*) (northern Aegean Sea) (KALLIANIOTIS *et al*., 2001; LEFKADITOU *et al*., 2003), the European eel (*Anquilla anquilla*) (western Hellas) and other smaller fishes (mainly Gobiidae and Sparidae).

Figure 12: A typical fyke net (Photo: A. ADAMIDOU).

Fish pot

A fish pot has an ellipsoid shape with a flat bottom in order to sit on the seabed (Figure 13). The diameter at the wider end of the pot is 0.5-0.8m, the height is 0.5-0.8 m and the weight about 2 kg. It is made of galvanised steel wire 2.5-3 mm thick that is woven to form a mesh of 0.6-0.7 cm (bar length). The fish pot has a funnel-shaped entrance at its upper side. The opening of the entrance is reduced gradually as it goes down inside the pot, to allow fish to enter, but not to escape, unless they are smaller than the wire mesh size. Fish pots are baited and hauled, usually independently one from the other, at depths from 15m to 70 m on muddy or sandy bottoms or close to rocks. The bait is usually salted fish, cheese or yeast. A single line with a plastic buoy is attached to each fish pot to mark its position. Depending on vessel size, 30 to 100 pots are used. The soaking time is 12-24 hours. The pots are retrieved individually, by pulling up the buoy line with a hooked pole. The pot is emptied, re-baited and reset. The fish pots are used mainly in the south-eastern Aegean Sea (Dodekanisos area) and the main target species are: white sea bream (*Diplodus sargus*), black sea bream (*Spondyliosoma cantharus*), sharp snout sea bream (*Diplodus puntazo)* and groupers (*Epinephelus* spp.)

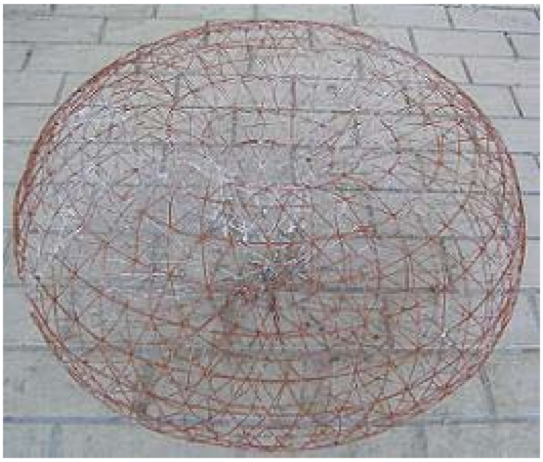

Figure 13: A typical fish pot (Photo: A. ADAMIDOU).

Crustacean pots

The Crustacean pots may be rectangular with a rounded or flat upper part or barrel-shaped. The rectangular pots are made of a frame of steel rods that is covered by twine netting of stretched mesh size 16-24 mm when it targets shrimps, 40 mm for crayfish and 60-80 mm for lobster (Figure 14). The barrel-shaped pots are made of horizontal slats fixed on 3-4 PVC hoops. The opposite sides are covered by twine netting of 48-80 mm (stretched mesh). A plastic funnel with a 20-40 cm opening at the upper part leads crustaceans inside the pots where the bait is placed. Small-sized fish or pieces of fish are the most common bait. Fishing for shrimps and lobsters is carried out at depths ranging from 70-130 m, on muddy (shrimp) or rocky (lobster) bottoms while for crayfish from 200-520 m. Crustacean pots are set in fleets. The soaking time ranges from 4 hours (crayfish) to 1 day (lobster). The number of pots used varies from 50 to 200 depending on the length of the vessel and the number of crew. The Crustacean pots are used mainly in the south-eastern Aegean Sea (Dodekanisos area) and in the central Aegean Sea.

Octopus pots

They are of the oldest type of pots, traditionally made of clay. Nowadays, lighter and more long-lasting materials are used such as plastic buckets

Figure 14(a): Crustacean pots for lobsters (Photo: A. ADAMIDOU).

Figure 14(b): Crustacean pots for shrimps (Photo: A. ADAMIDOU).

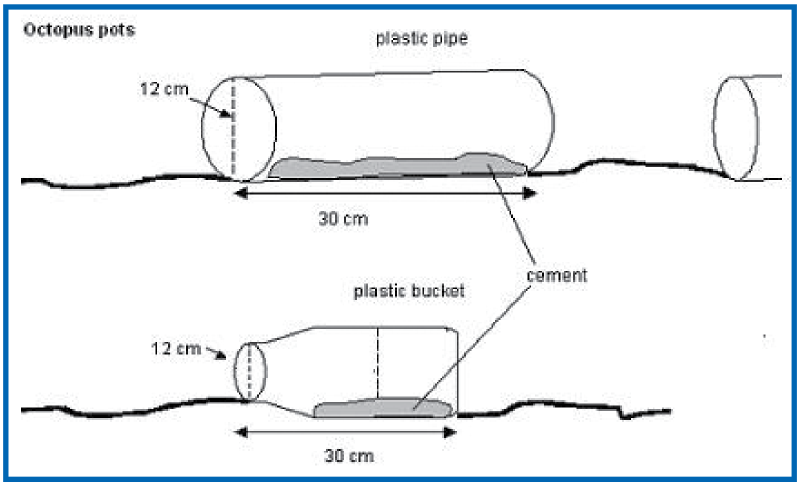

Figure 15: A rough drawing of octopus pots (by A. ADAMIDOU).

or pipes (Figure 15). Their length is about 30 cm and their diameter 12 cm. A small amount of cement is placed inside the plastic pots at the side that is adjacent to the seabed to keep the pot on the bottom. Octopus pots are not baited and are set always in fleets of 50-100. They are set at depths of 10-70 m and the soaking time is 5-10 days. They are used in the northern and eastern Aegean Sea targeting the common octopus (*Octopus vulgaris*).

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III.5. HELLENIC MARINE FISHERIES: A GENERAL PERSPECTIVE FROM THE NATIONAL STATISTICAL SERVICE DATA

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INTRODUCTION

The vast majority of Hellenic landings are fished in Hellenic marine waters (FAO 2004) that include part of the Ionian and NW Levantine Seas and the entire Aegean Sea. The Ionian is mainly fished by Italy, Malta, Hellas, Albania, Tunisia and Libya. In the Hellenic Ionian Sea only the deep fish stocks are partly exploited by the Italian fisheries fleet. The mean Hellenic Ionian landings represented less than 10% of the total Ionian landings in the late 1980s (STERGIOU & POLLARD, 1994) and around 5% in 2004 (based on GFCM/FishStat data for 2004). The Levantine Sea is mainly fished by Lebanon, Turkey, Israel, Syria, Cyprus, Egypt and Palestine. The mean Hellenic Levantine landings, which are mainly composed of large pelagic fish, represent less than 1% of the total Levantine landings. In contrast, the Aegean Sea is exploited only by the Hellenic and Turkish fleets. The Turkish fleet exploits the eastern Aegean coastal zone and part of the central Aegean international waters. The Turkish Aegean landings increased from about 20% of the mean total Aegean landings for the period 1982-1987 (STERGIOU & POLLARD, 1994) to 33% for 2004 (based on GFCM/FishStat data for 2004). This is attributed to the modernization of the Turkish fishing fleet over the last two decades. Overall, Hellenic marine fisheries and aquaculture production is inadequate to support local demand and thus a net amount of 115600 t was imported in 2005 (imports: 213000 t, exports: 97400 t; EUROSTAT 2006).

STERGIOU *et al.* (1997) reviews the marine fisheries' landings and effort for 1964-1987, whereas PAPACONSTANTINOU (2002) overviews the Hellenic fisheries and their regulations. In addition, TSIKLIRAS *et al.* (2007) reconstruct the total Hellenic landings, including those of small-scale fisheries which are not recorded by various authorities, based on recent data. The increase in Hellenic marine landings from 1985 to 1994 and the subsequent decline to almost half of the previous values (TSIKLIRAS *et al.*, 2007) might suggest overexploitation of the resources. However, this peak in the mid 1990s coincided chronologically with the fishing fleet registration (according to the EU requirements), suggesting that this increase is probably biased because of extrapolation and conversion issues. The Hellenic marine fisheries' sector underwent rapid socio-economic changes during the last 25 years mainly because of the participation of Hellas in the European Union. As a result, subsidies, management regulations and fisheries research have been enforced and this has certainly affected fishing capacity, resource management and stock assessment. Thus, the updated landings and effort series are important for the evaluation of the state and management of the Hellenic marine fisheries.

In the present work, the major socio-economic and operational aspects of the Hellenic marine fisheries are examined for the period 1964-2003. In particular, the following aspects are analysed and presented: (a) long-term changes in fishing effort, landings and wholesale value of landings; and (b) landing species' composition per main fishery (i.e. fishing gear used).

SOURCES OF MARINE FISHERIES' STATISTICS

Marine fisheries landings (in metric tons, t) of the Hellenic fleet have been recorded and published in yearly bulletins since January 1964 by the National Statistical Service of Hellas (NSSG Bulletins, 1964-2003). Landings' data are collected directly from a sample of fishing vessels that are surveyed by local customs authorities as described in Chapter III.3. NSSG data are the best figures available with respect to length of time, spatial and temporal resolution, consistency, degree of subjectivity, and statistical design of data collection (ANONYMOUS, 1994; STERGIOU *et al.*, 1997; PAPACONSTANTINOU, 2002).

The Hellenic fishing fleet includes: (a) fishing vessels operating in distant waters (of no concern to the present study); (b) trawlers; (c) purse seiners; (d) beach seiners operating along the coasts; and (e) 'other coastal boats' (including trammel and gill netters, drifters, long-liners, traps, etc.) operating along the coasts. There are also a few vessels, termed 'mixed vessels', which are licensed to operate both as trawlers (mainly in the wintertime) and purse seiners (mainly in the summertime).

For the period 1964-1981, separate landings' statistics are available for 23 taxa and since 1982 for 66 taxa of fishes, cephalopods, crustaceans and bivalves. Overall, the following types of data are available for 1964-2003: (a) total annual landings per taxon and fishery (monthly commercial landings of taxa per fishery and fishing subarea are not available); (b) monthly landings per taxon; (c) total annual and monthly landings and wholesale value of landings per fishery (data pertinent to the annual/monthly wholesale value of landings per tax-

Table 1. Total annual fishing effort (engine horsepower, HP; boat tonnage, GRT; number of boats; number of fishers), marine fisheries landings (in metric tons) and wholesale value of landings (in million €), Hellenic waters 1964-2003. The mean and standard deviation (SD) are also given.

Year	Fishing effort				Landings	Value (×10^6)
	HP	GRT	No of boats	No of fishers	t	€
1964	118833	21206	6800	14427	53598	1.55
1965	123363	21369	7124	14478	53460	1.82
1966	131559	21373	7283	14376	52756	1.98
1967	143562	22106	7345	14554	53495	2.04
1968	168977	21523	8399	15201	55944	2.27
1969	179247	20153	8149	14550	60769	2.48
1970	161473	20412	2343	7612	45656	1.83
1971	173730	20242	2431	7366	47178	2.03
1972	173781	22012	2329	7583	54421	2.34
1973	225721	26715	2728	7840	61998	3.16
1974	250189	29690	2823	7053	56819	3.68
1975	285359	31006	3050	7345	62666	4.56
1976	307727	33597	3196	8159	71842	6.44
1977	333613	32021	3544	8402	70220	7.45
1978	371547	33708	3880	8812	74517	9.82
1979	397661	34869	4133	8840	75744	11.62
1980	430656	36727	4426	9385	73140	18.38
1981	467334	38620	4839	10191	75916	23.17
1982	502138	39211	5184	11089	84268	29.67
1983	539556	41381	5586	11213	80925	35.86
1984	567917	43517	5976	11579	88082	44.37
1985	580980	41676	6163	12304	93969	59.55
1986	618131	43728	6480	13285	101397	92.15
1987	653471	45433	6815	14367	106717	96.80
1988	790533	41125	8981	15238	104012	117.68
1989	805196	40248	9089	18960	112549	147.87
1990	823411	41969	9234	19173	112192	174.89
1991	830239	42837	9308	21425	123783	204.26
1992	823388	41969	9232	20035	141352	223.17
1993	819864	41989	9172	19293	155211	247.33
1994	805037	41659	9002	19798	181675	296.70
1995	805446	41552	9026	19162	150187	277.98
1996	815435	41490	9166	18847	148759	278.41
1997	711543	39181	6976	19109	147735	288.21
1998	715901	36146	8128	16952	106988	225.41
1999	678573	35132	7699	16310	109556	246.01
2000	661282	34398	7595	16184	88116	221.04
2001	666033	33779	7676	15738	83259	219.30
2002	636977	33742	7353	15563	85460	233.46
2003	609904	34703	6996	14547	85155	257.92
Mean	**498169**	**31366**	**6392**	**13659**	**89787**	**103.12**
SD	**254314**	**7702**	**2327**	**4361**	**34376**	**110.44**

on is not available); (d) total annual fishing effort per fishery; (e) total annual and monthly number of fishers per fishery (data concerning number of fishers per fishing subarea is not available). It must be pointed out that fishing effort is expressed in engine horsepower (HP), number of boats and boat tonnage (measured in gross registered tons, GRT). Data concerning boat tonnage is not available for beach seiners and 'other coastal boats'. In addition, data concerning monthly fishing effort or annual/monthly fishing effort per fishing subarea is not available.

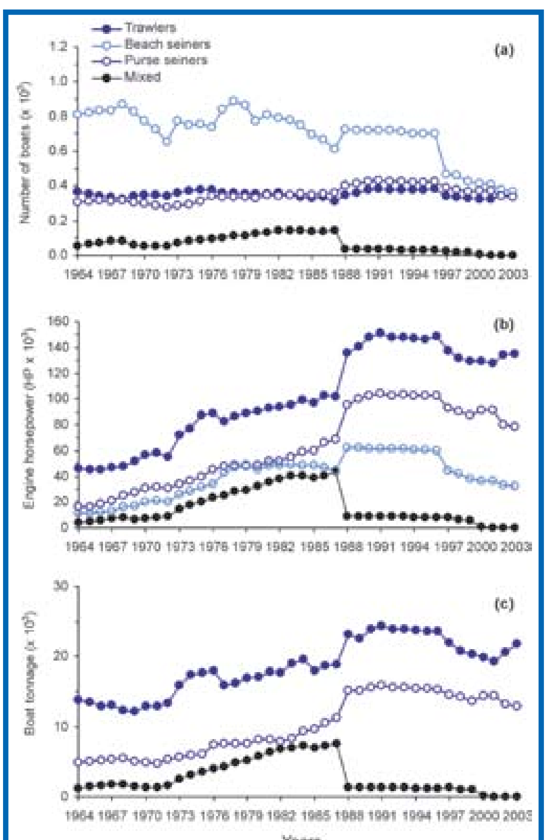
TOTAL FISHING EFFORT AND VALUE OF LANDINGS

The total annual landings, fishing effort (in terms of number of boats, HP, GRT and number of fishers) and the wholesale value (in euros, €) of the total landings for 1964-2003 are shown in Table 1. Total landings increased from 53 598 t, in 1964, to 85 155 t, in 2003, reaching a peak in 1994 (181 675 t). The total fishing effort increased from 6 800 boats, 118 833 HP and 21 206 GRT, in 1964, to 6 996 boats, 609 904 HP and 34 703 GRT, in 2003 (Table 1). The wholesale value of the landings also increased from 1.55 million €, in 1964, to 257.9 million €, in 2003 (Table 1).

The above-mentioned figures do not include those concerning small coastal boats (i.e. engine <19 HP) and boats operating in distant waters. The total number of the small coastal boats is estimated at 14 000 each catching 300-350 kg/month (NSSG 1998; TSIKLIRAS *et al.*, 2007). Thus, the total annual landings of the small coastal boats range from 50 400 to 58 800 t (average: 55 000 t per year). These figures refer only to the period following 1995. For the period 1970-1994 the average estimated catches of the small coastal boats were 25 000 t per year. The capacity of the distant water fleet in 2003 was 22 boats, 16 829 HP and 3 910 GRT, the total landings 4,566 t and the total wholesale value of the landings 17 million € (NSSG, 2006). Hence, considering that during the last 20 years both the number of fish farms and their production were increased (from 4 farms producing 200 t in 1988, to about 270 farms producing 97 000 in 2004 and 106 000 t in 2005) (AGRICULTURE BANK OF GREECE, 1998; EUROSTAT, 2006), the total Hellenic marine captured and aquaculture production probably ranges between 230 000 and 250 000 t. The latter is true based on the marine captured production (landings) provided by NSSG.

FISHING EFFORT PER FISHERY

The annual number of boats, HP, GRT (except for 'other coastal boats') and number of fishers per fishery for 1964-2003 are shown in Figures



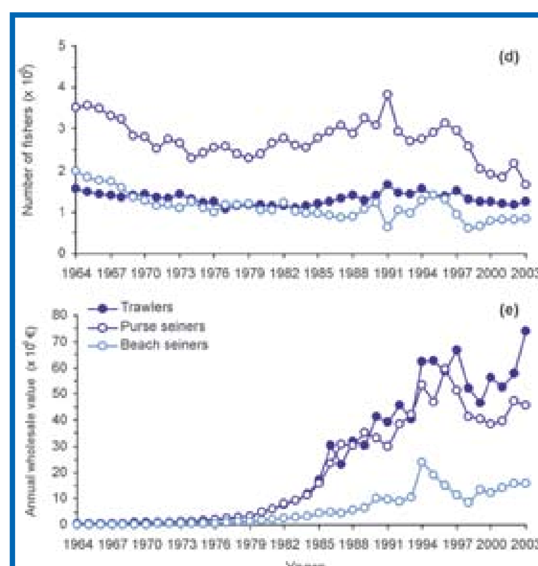


Figure 1: Annual number of boats (a), engine horsepower (in HP) (b), boat tonnage (in GRT) (c), fishers per boat (d) and wholesale value (in €) of landings (e), for trawlers, purse-seiners, beach seiners and 'mixed vessels' operating in Hellenic Seas, 1964-2003.

1 and 2. Although the number of trawlers and purse-seiners did not change considerably between 1964 and 2003 (Figure 1a), this was not true for beach-seiners and 'other coastal boats' (Figures 1a and 2a). Beach-seiners consistently declined since 1964, whereas 'other coastal boats' showed two patterns of change; an exponential increase between 1970 and 1988 and a smooth decline thereafter (Figure 2a). The number of 'mixed vessels' decreased after 1987 (Figure 1b).

The HP and GRT both increased till the late 1980s and thereafter remained more or less constant, fluctuating around a mean of 135 217 HP and 21 778 GRT for trawlers, and 78 229 HP and 12 925 GRT for purse-seiners (Figures 1b and 1c). The capacity of beach-seiners steadily increased over the 1964-2003 period (Figures 1b and 1c), despite the efforts of the Hellenic State since 1979 and those of EU since 1994 to reduce them by advancing measures supporting their withdrawal and/or fully prohibiting renewal/modernisation licences. In contrast, 'other coastal boats' after a sharp decline in 1970, showed an increase till 1988, and then remained in a plateau until 1995 and declined thereafter (Figure 2b). The capacity of 'mixed vessels', i.e. those licensed to operate both as trawlers and purse-seiners, decreased from 1964 to 2003 (Figures 1b and 1c).

The number of fishers remained rather stable for trawlers, purse-seiners and beach-seiners (Figure 1d), whereas for "other coastal boats" increased exponentially between 1970 and 1991 and declined thereafter (Figure 2c). The sharp decline in the number of boats and fishers involved in the 'other coastal boats' fishery in 1970 is attributed to the fact that since 1969 the coastal boats with engine <19HP are no longer recorded by the local customs authorities.

Wholesale value increased exponentially for trawlers up to around 75 million € (in 2003) during the study period (Figure 1e). The mean wholesale value also increased exponentially for purse-seiners and beach-seiners up to the mid 1990s (up to 60 million € for purse-seiners and more than

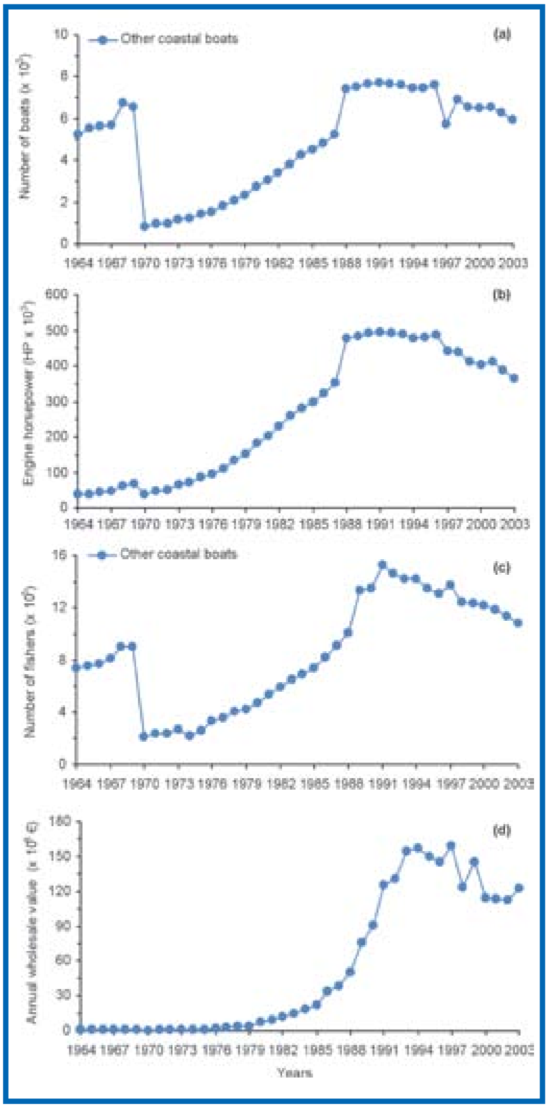


Figure 2: Annual number of boats (a), engine horsepower (in HP) (b), boat tonnage (in GRT) (c), fishers per boat (d) and wholesale value (in €) of landings (e), for other coastal boats operating in Hellenic Seas, 1964-2003.

Table 2. Percentage (%) contribution of the major fisheries to the total fishing effort (expressed as engine horsepower, HP; number of boats; number of fishers) and wholesale value of landings, Hellenic waters 1964-2003.

	Fishing effort			Value
Fishery	HP	No of boats	No of fishers	
Trawlers	21.0	5.6	9.7	23.0
Purse seiners	13.0	5.6	20.1	19.4
Mixed vessels	3.3	1.1	-	-
Beach seiners	8.3	11.1	8.2	5.6
'other coastal boats'	54.4	76.6	62.0	52.0

20 million € for beach-seiners) whereas thereafter declined to lower levels (Figure 1e). As far as the ‘other coastal boats’ are concerned, the wholesale value of their landings increased exponentially to about 160 million € in the mid 1990s and declined thereafter (Figure 2d).

The socio-economic importance of the ‘other coastal boats’ is higher when compared with those of the remaining fisheries (Table 2). Thus, the ‘other coastal boats’ contributed 54.4%, 76.6%, 62.0% and 52.0% to the mean total HP, number of boats, number of fishers and wholesale value of landings over the 1964-2003 period, respectively (Table 2).

The HP/boat ratio for trawlers, purse-seiners and beach-seiners showed a linear increase between 1964 and 1988, whereas thereafter remained relatively constant fluctuating around a mean value (Figure 3a). In contrast, HP/boat for ‘other coastal boats’ remained constant since 1970 (Figure 3a). With respect to GRT/boat, this remained constant for trawlers and purse-seiners from 1964 to 1988, then shifted to a higher value and remained constant thereafter (Figure 3b). The fishers/boat ratio showed a stable pattern for trawlers, beach-seiners and ‘other coastal boats’ over the entire period, whereas for purse-seiners it decreased (Figure 3c). Finally, the HP/fisher ratio increased for each fishery till the mid 1980s, whereas thereafter fluctuated around 95-120 HP/fisher for trawlers, 30-50 HP/fisher for purse-seiners, 40-95 HP/fisher for beach-seiners, and 30-50 HP/fisher for ‘other coastal boats’.

The mean fishers/boat, HP/boat, and HP/fisher ratios all differed significantly (ANOVA, $P<0.005$) among fisheries (Table 3). The mean fishers/boat was higher for the purse-seiners while the HP/boat and HP/fisher ratios were higher for trawlers (Table 3).

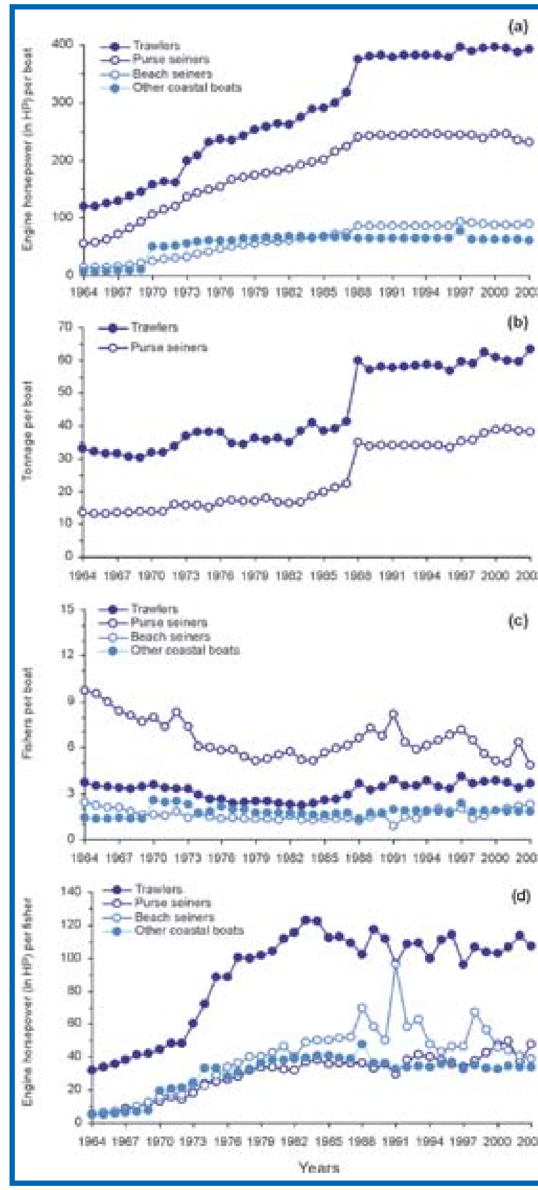


Figure 3: (a) HP per boat, (b) GRT per boat, (c) fisher per boat and (d) HP per fisher, for each fishery operating in Hellenic Seas, 1964-2003.

Table 3. Mean Fishers/boat, HP/boat, HP/fisher, Landings/Boat, Landings/HP, Landings/Fisher, Value/Kg, and Value/fisher ratios for each fishery (trawlers, purse-seiners, beach-seiners and ‘other coastal boats’), Hellenic waters 1964-2003. Values with the same exponent (a, b, c and d) do not differ significantly between each fishery.

Ratios	Mean ± Standard Error			
	Trawlers	Purse-seiners	Beach-seiners	Other-coastal
Fishers/boat	3.19^{a} ±0.54	6.56^{b} ±1.30	1.63^{c} ±0.35	1.82^{d} ± 0.31
HP/boat	282.20^{a} ±98.78	182.81^{b} ±63.71	60.62^{c} ±27.37	54.91^{c} ±20.32
HP/fisher	90.04^{a} ±29.50	29.75^{b} ±12.36	39.56^{c} ±20.05	29.91^{b} ±11.48
Value/fisher	17.76×10^{3a} ±18.40	7.82×10^{3b} ± 8.30	6.17×10^{3b} ± 6.80	4.47×10^{3b} ± 4.50
Value/kg	1.10×10^{3a} ± 1.10	0.53×10^{3b} ± 0.53	0.82×10^{3c} ± 0.86	1.24×10^{3a} ± 1.23
Landings/Boat	43.98^{a} ±14.78	81.35^{b} ±15.74	10.29^{c} ± 3.18	6.31^{c} ± 2.34
Landings /HP	0.16^{a} ± 0.03	0.50^{b} ± 0.20	0.21^{c} ± 0.13	0.14^{a} ± 0.07
Landings /Fisher	13.77^{a} ± 3.48	12.87^{a} ± 3.39	6.48^{b} ± 1.83	3.42^{c} ± 1.06

ANNUAL LANDINGS AND VALUES

The annual landings of 'other coastal boats' increased exponentially from 1964 to 1994, followed by a decline (Figure 4a). A general linear increase was also apparent for the remaining fisheries up to 1994, followed by a decline thereafter (Figure 4a). Landings per HP (i.e. catch per unit of fishing effort) declined for all fisheries but the rate of decline was higher for the purse-seiners (Figure 4b). In addition, the wholesale value per fisher ratio (i.e. annual income) and the wholesale value per landings both increased exponentially during the total period for all fisheries (Figure 5).

The mean value/fisher and the mean value/kg ratios both differed significantly (ANOVA, P<0.05) among fisheries. The mean value/fisher was higher for trawlers and the mean value/kg was higher for trawlers and 'other coastal boats' (Table 3). The mean landings/boat, landings/HP and landings/fisher all differed also significantly (ANOVA, P<0.001) among fisheries; the mean landings/boat and landings/HP were higher for purse-seiners, whereas the mean landings/fisher were higher for trawlers and purse-seiners (Table 3).

OVERALL SPECIES COMPOSITION OF LANDINGS

Overall, the two pelagic species European anchovy (*Engraulis encrasicolus*) and European sardine (*Sardina pilchardus*) dominated the fisheries landings, comprising 14.6% and 14.1% of the mean total, respectively, over the 1982-2003 period (Figure 6). In addition, seven other taxa (bogue, *Boops boops*; Mediterranean horse mackerel, *Trachurus mediterraneus*; picarel, *Spicara smaris*; Atlantic mackerel, *Scomber japonicus*; European hake, *Merluccius merluccius*; grey mullets, Mugilidae; red mullet, *Mullus barbatus*) each contributed from 2.1% to 7% (Figure 6).

SPECIES' COMPOSITION OF LANDINGS PER FISHERY

The composition of the mean landings per fishery over the1982-2003 period is shown in Figure 7. In particular, more than 30% of the mean trawl landings was dominated by five species (*M. merluccius*, *M. barbatus*, *T. mediterraneus*, *S. smaris*, and *Micromesistius poutassou*) (Figure 7a). For purse-seiners, five species (*E. encrasicolus* and *S. pilchardus* and, to a lesser extent, *T. mediterraneus*, *B. boops* and *S. japonicus*) cumulatively contributed more than 84% of the mean total landings (Figure 7b). For beach-seiners, more than 60% of the landings was comprised mainly by *S. smaris*, *S. pilchardus* and *B. boops* (Figure 7c). Finally, only 30% of the mean

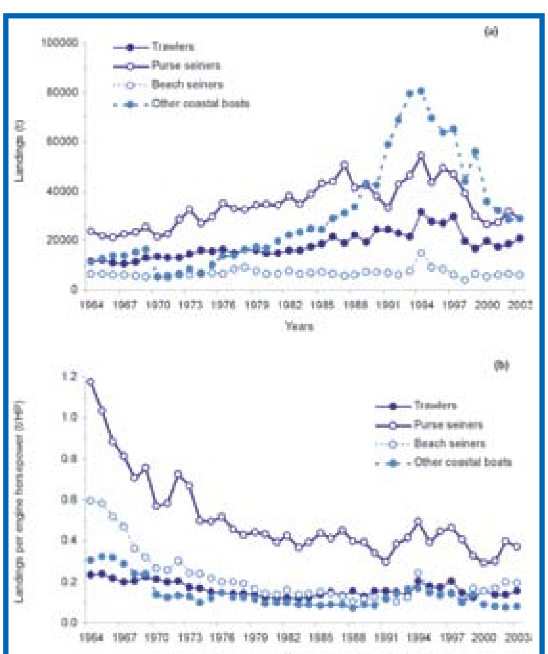


Figure 4: (a) Annual total landings (in t) and (b) landing per unit of fishing effort (expressed as engine horsepower, HP), for each fishery operating in Hellenic Seas, 1964-2003.

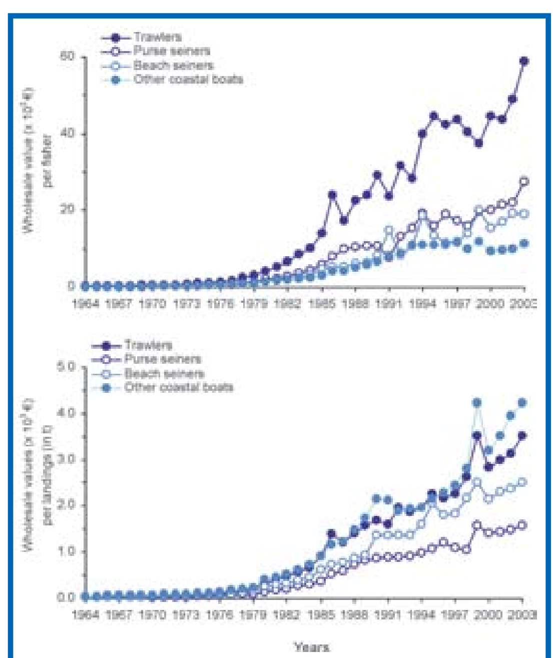


Figure 5: (a) Wholesale value per fisher and (b) value per landings, for each fishery operating in Hellenic Seas, 1964-2003.

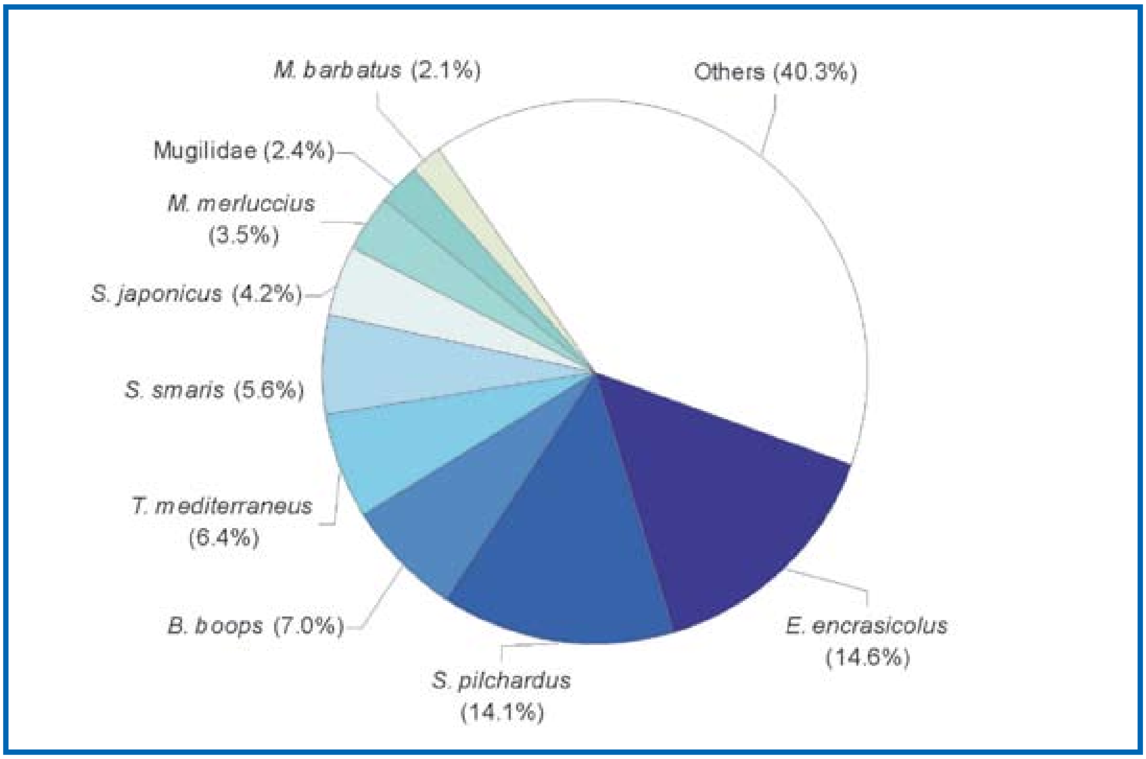


Figure 6: Species' composition of the mean fisheries landings from Hellenic Seas, 1964-2003.

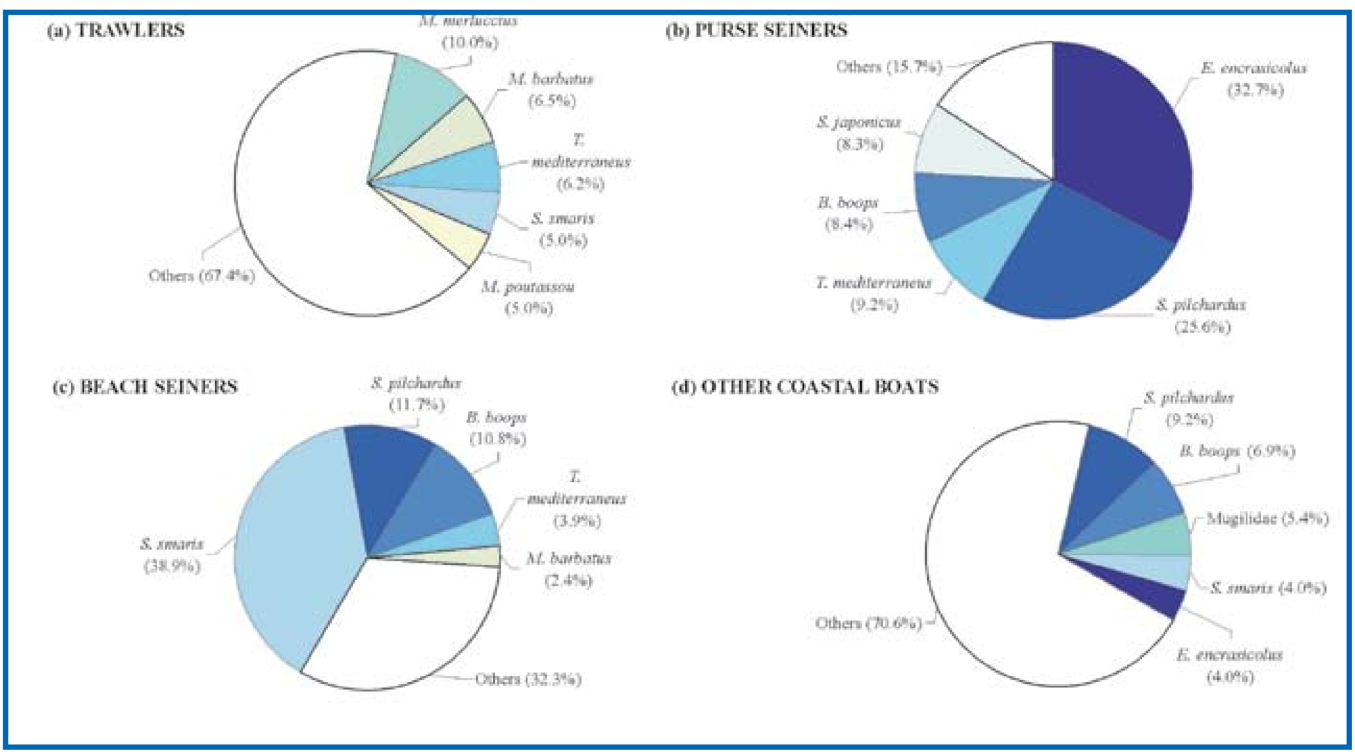


Figure 7: Species' composition of the mean fisheries landings for each fishery operating in Hellenic Seas, 1964-2003: (a) trawlers, (b) purse-seiners, (c) beach-seiners and (d) 'other coastal boats'.

'other coastal boats' landings was comprised of five taxa (*S. pilchardus*, *B. boops*, Mugilidae, *S. smaris* and *E. encrasicolus*) (Figure 7d).

CONCLUSIONS

Our findings showed that the Hellenic marine fisheries are characterized by a large number of species caught per main fishing gear (i.e. multi-species fisheries) as well as by a variety of species that are exploited concurrently by different fishing gears (i.e. multi-gear fisheries). These aspects agree with the findings of various previous studies in Hellenic waters (TSIMENIDES, 1994; STERGIOU & POLLARD, 1994; STERGIOU *et al.*, 1997; KAPANTAGAKIS *et al.*, 2001; PAPACONSTANTINOU, 2002; STERGIOU *et al.*, 2004; STERGIOU *et al.*, this volume). The patterns and propensities of marine fisheries' landings presented in this chapter are based on the NSSG data that are subjected to certain biases and limitations. These can be remedied once the reconstructed dataset (TSIKLIRAS *et al.*, 2007) is adopted.

Hellas, being a member of the European Union since 1981, led to the adoption of new fisheries' management regulations and policies for the Mediterranean (EU Reg. 1626/94, EU Reg. 1967/2006). In addition, Hellenic fisheries have also greatly benefited through the five-year developing programmes, by subsidies which undoubtedly led to the modernization of the fishing fleets and the geographic and vertical expansion of the fisheries. Thus, the increasing trends in effort during 1964-1987 were mainly unregulated, whereas in 1988 the consensus of the Hellenic effort changed and from then onwards it has been regulated and remained constant up to 1997 followed by a slight decline, following the EU regulations. In addition, the decrease in the number of beach seiners for the years following 1997 is attributed to the fact that fishers have been subsidised for retreating their vessels (EU Reg 3699/93), because beach seiners are considered to be harmful for the stocks and habitats.

The increase in the HP/boat and GRT/boat ratios during 1964-2003 for all fisheries (Figures 3a and b), with the exception of the 'other coastal boats' fishery for which the rate of increase was much smoother, clearly indicates, when combined with the fact that the number of boats per fishery did not change considerably during that period (Figure 1), the modernisation of the Hellenic fishing fleet. For trawlers, the sharp increase in the HP/boat and GRT/boat ratios in 1988 is attributed to the fact that during 1985-1988 boat owners were subsidised by EU to modernise their boats (EU Reg. 4028/86). Also, such a modernisation brought about an increase in the fishers/boat ratio for trawlers during 1985-1997 (Figure 3c). This can be attributed partly to the aforementioned modernization but also to the fact that they operate on a 24 h basis, with increased personnel, exploiting various fishing grounds. Proportionate change was observed in the number of purse seiners, though at a steady rate. In contrast, for purse-seiners, the fishers/boat ratio is decreasing. This is attributed to the adoption of hydraulic winches and nylon nets, as opposed to cotton ones, until the end of the 1970s, whereas the increase at the end of the 1980s may be due to the replacement of older boats by new ones of higher capacity (larger tonnage and engine HP) due to EU subsidies (Figure 3c).

Despite the modernization of the Hellenic fisheries' sector and the fisheries' regulations currently enforced for pelagic and demersal fisheries (i.e. closed seasons, limited issue of new licenses, minimum legal landing sizes, mesh size regulations, banning of pelagic trawl, prohibiting the fishing of small pelagics with bottom trawl or with electric light (P.D. 244/21-6-91; EU Reg. 1626/94), increase of mesh size of codend in 40 mm stretched (EU Reg. 2550/2000)), fisheries' landings per effort are consistently declining. This fact reveals the inadequacy of the current management regulations, most of which are of technical and non-scientific practices (STERGIOU *et al.*, 1997). The situation gets more complicated due to multi-species and multi-gear nature of the fisheries which pose certain difficulties in using traditional fisheries models. New measures are thus required in order to complement the existing ones. One such measure is the adoption of marine protected areas (TSIKLIRAS & STERGIOU, this volume), which are also consistent with the current trends in fisheries management (i.e. ecosystem-based management: BROWMAN & STERGIOU, 2004).

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III.6. SPATIAL AND TEMPORAL VARIABILITY IN HELLENIC MARINE FISHERIES LANDINGS

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INTRODUCTION

Unlike the well studied Atlantic and Pacific ecosystems for which scientific surveys and records date back many centuries (e.g. KLYASHTORIN, 1998), the Mediterranean fisheries are characterised by a poorly developed data collection system and, with few exceptions (FROMENTIN, 2001), a lack of historic scientific data especially on long-term data-series across trophic levels (CIESM, 2000, 2003). Such data deficiencies in fisheries may complicate the examination of past landings' variability, the comparison with present conditions and predictions for the future (DAYTON *et al.*, 2000). Fisheries landings' time series are useful for forecasting (e.g. STERGIOU *et al.*, 1997; LLORET *et al.*, 2001), defining management zones (e.g. TSIKLIRAS & STERGIOU, 2007) and targeted species (STERGIOU *et al.*, 2003), and for development of ecological models and testing ecological hypotheses (e.g. WATSON & PAULY, 2001).

In Hellas, long-term studies on fisheries' ecology and population dynamics were mainly based on the data-series published by the National Statistical Service of Greece, NSSH (STERGIOU & CHRISTOU, 1996; STERGIOU *et al.*, 1997). These data, which have been reported since 1964 on a species' (or groups of species) basis for different fishing subareas of the Hellenic Seas, have been consistent and useful in examining ecological hypotheses (STERGIOU *et al.*, 1997; TSIKLIRAS *et al.*, 2007). Although the NSSH landings form the basis for the dataset of FAO (Food and Agricultural Organisation), various biases are known, notably with respect to the data collection and misreporting of catches (PAPACONSTANTINOU, 2002).

In this chapter, we identify spatial heterogeneity and temporal variability patterns in total NSSH landings per Hellenic fishing subarea and annual and monthly fisheries landings per taxon and fishery over the 1964-2003 period.

DATA SOURCES

The annual landings of the Hellenic commercial fishing fleet have been recorded since 1964 by the National Statistical Service of Greece for 16 fishing subareas (A3 to A18). Subareas 1 and 2 are outside Hellenic waters (Atlantic Ocean and North African Mediterranean coast, respectively). Landings' data refer to the legal and reported large- and small-scale fisheries, excluding recreational or sport fishing (TSIKLIRAS *et al.*, 2007). The taxonomic resolution of the recorded landings changed in 1982. For 1964-1981, 23 species or groups of species (henceforth called taxa) had been recorded and as from 1982, 66 taxa are being recorded. In our analysis we excluded bivalves that are largely derived from aquaculture.

DATA ANALYSIS

Multivariate analyses (cluster and multidimensional scaling) and time series techniques (simple regression and trend analysis) were used in order to identify spatial and temporal patterns in Hellenic marine fisheries landings. To assess whether groups revealed by multivariate analysis differed, we conducted one-way analysis of similarities (ANalysis Of SIMilarities test: CLARKE & GORLEY, 2001). Finally, we used SIMPER analysis (SIMilarity PERcentages: CLARKE & GORLEY, 2001) to identify the contribution (cumulative percentage) of each taxon to the average Bray-Curtis similarity within and among the groups revealed by multivariate analysis. Time-varying regressions (trend analysis) were fitted to all landings time series. Regressions and slopes that were significantly ($P<0.05$) different from 0 were identified. A detailed account of trend analysis for commercial fisheries is given in STERGIOU & CHRISTOU (1996) and STERGIOU *et al.* (1997).

TEMPORAL VARIABILITY

Annual landings

The annual total (fishes, cephalopods and crustaceans) marine landings generally increased exponentially between 1964 and 1994 and declined thereafter (Fig. 1a) thus overall exhibiting a quadratic trend. This trend mirrors global catches that have fallen steadily since 1994 after the correction of the China effect was applied (WATSON & PAULY, 2001). More specifically, fish landings, which made up the main part of the total landings (92%), increased exponentially from 47 000 t in 1964 to a peak of around 152 000 t in 1994 and then sharply declined to less than 75 000 t in 2003 (Figure 1b). The increase in cephalopod landings was exponential reaching around 9000 t (Figure 1c) while

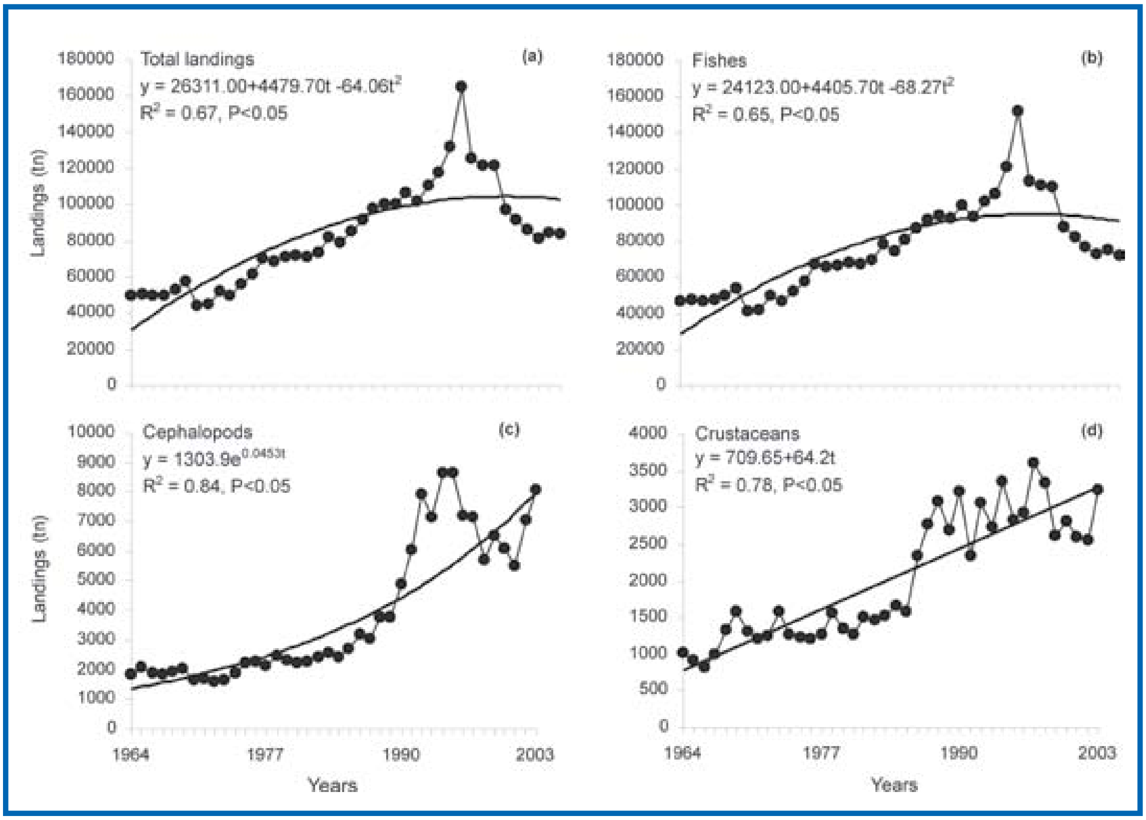


Figure 1: Annual landing (in metric tons, t) trends for: (a) all landings combined, (b) fishes, (c) cephalopods, and (d) crustaceans in Hellenic Seas, 1964-2003. Trend lines with slope significantly different from zero (P<0.05) are also shown.

that of crustaceans was linear, with high variability for 1994-2003 period (Figure 1d).

Apart from the general quadratic trend, the fish, cephalopod and crustacean annual landings in the 16 subareas (A3 to A18) exhibited various trends (Figure 2): (a) almost stable low landings for >15-20 years, followed by short-term increasing trends, <10 years (e.g. subarea A3 and A14), (b) increasing (e.g. cephalopods in A13) or decreasing (e.g. fishes in A11) linear or exponential trends during the entire study period, (c) quadratic trends (e.g. fishes in A13), (d) drastic changes (increase or decrease of landings) occurring during short time periods (<5 years) with obvious restoration (e.g. fishes and cephalopods in A17) and (e) high variability of landings fluctuated around a mean value (e.g. cephalopods in A15). The patterns (d) and (e) were more pronounced in cephalopod and crustacean landings due to their lower landings when compared with fishes (Figure 2). Finally, short-term periodicity of landings is evident for the vast majority of the time-series.

Annual landing trends for the most abundant taxa displayed significant (P<0.05) quadratic trends (i.e. an increase in landings up to around 1994 that was followed by a sharp decline) for most cases (Figures 3a to 3r). Contrary to the quadratic trend, the European sardine (*Sardina pilchardus*) displayed a long-term linear trend fluctuating around a mean value, followed by a sharp increase in 1992 and a linear decline after 1998 (Figure 3m). *Spicara smaris* and *Thunnus* spp. landings showed a linear decline since 1982 (Figures 3g and 3o, respectively), while the round sardinella (*Sardinella aurita*) landings remained constant for 1982-1989 and increased exponentially since 1990 (Figure 3r). Finally, the landings of *Trachurus trachurus* (Figure 3p) and *Sarda sarda* (Figure 3q) displayed a long-term periodicity (>12 years). Short-term variability was apparent in all landing series.

The increasing landing trends up to 1994 might be attributed to the modernization of the fishing fleet, as indicated by the increasing trends in boat tonnage and engine horsepower (STERGIOU *et al.,* this volume). Fleet modernization led to an increase in the number of days at sea, especially

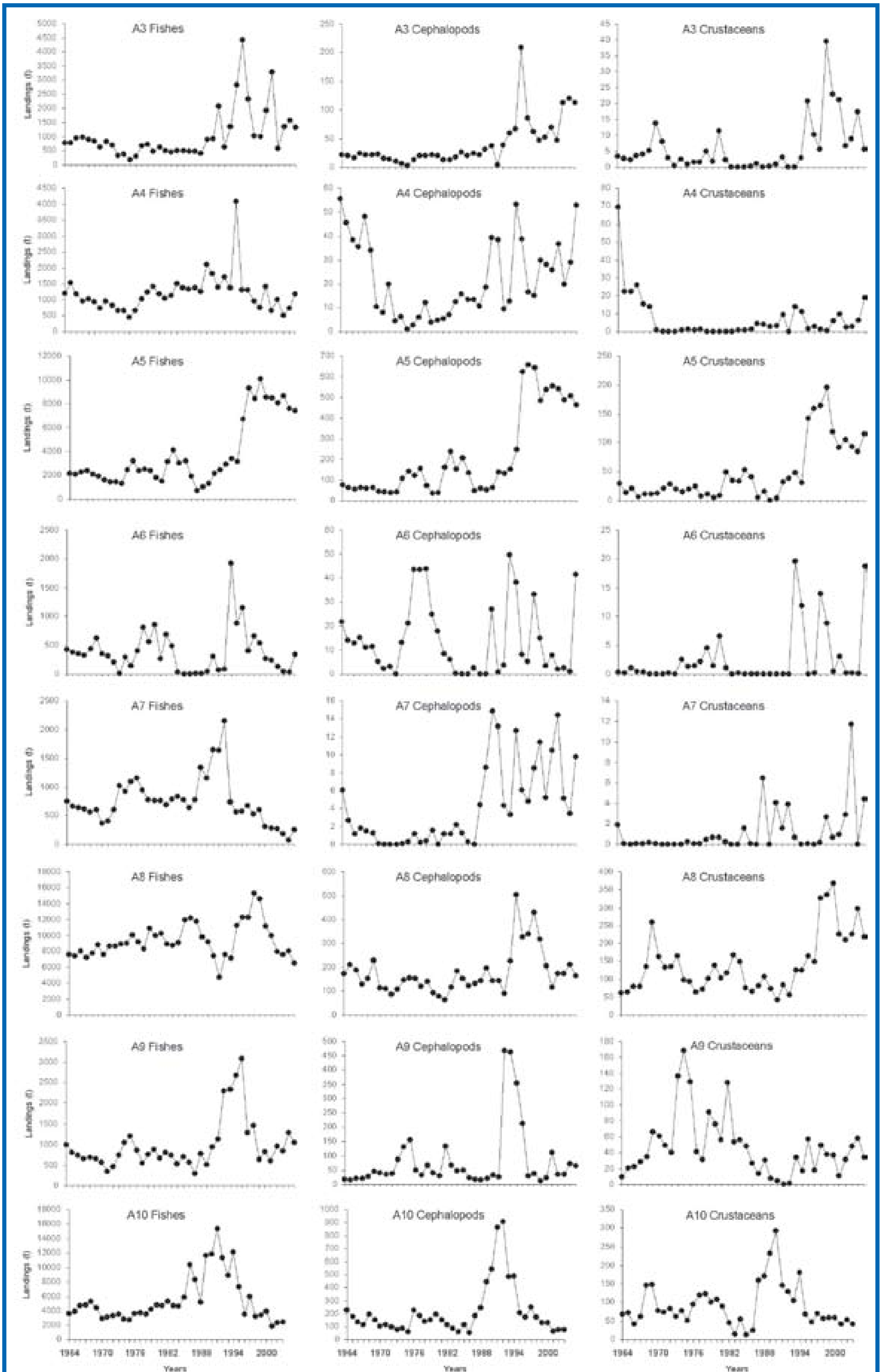
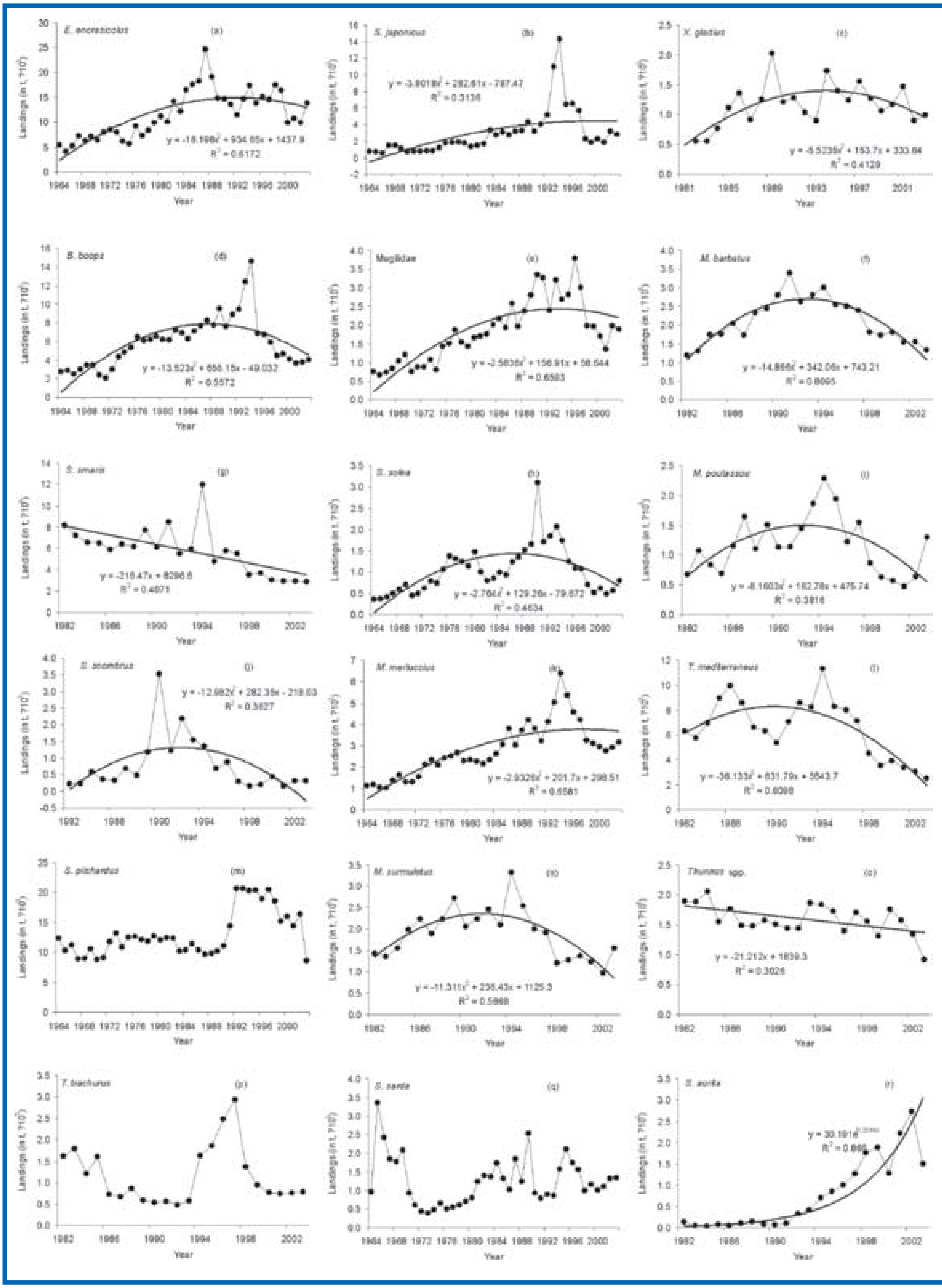


Figure 2: Annual landings (in metric tons, t) for fishes, cephalopods and crustaceans for each fishing sub-area in Hellenic Seas, 1964-2003.

Figure 3: Annual landings (in metric tons, t) of the 18 most abundant taxa in Hellenic Seas, 1964-2003. Note that some taxa are recorded only since 1982 and *X. gladius* since 1981.



for the small-scale coastal vessels, to the spatial expansion of trawling to deeper water resources and to the exploitation of new species (KAPANTAGAKIS *et al.*, 2001). In contrast, the decline of fisheries landings during the last decade is an indication that Hellenic fisheries resources and especially the Aegean ones (STERGIOU & KOULOURIS, 2000) are not sustainable, showing signs of becoming fully- or over- exploited (STERGIOU *et al.*, 1997; TSIKLIRAS & STERGIOU, 2007). Interannual variability, which adds to long-term trends, might be due to the synergetic effect of micro-

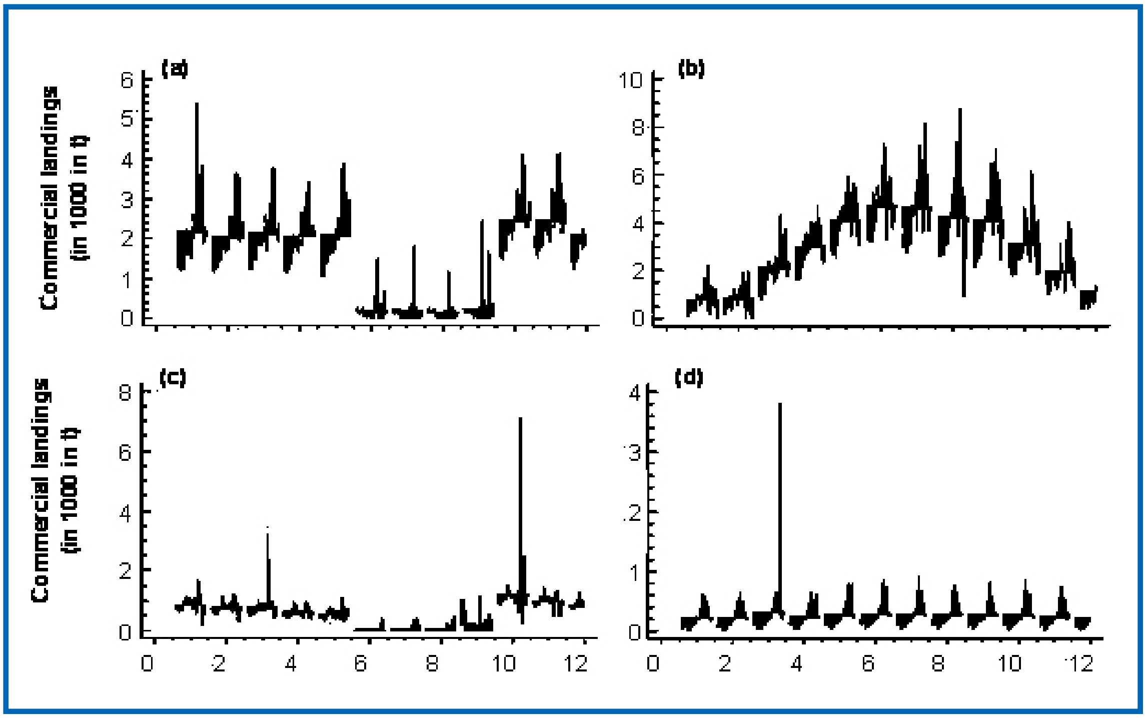


Figure 4: Seasonal sub-series plot of monthly commercial landings per fishery operating in Hellenic Seas, 1964-2003 (a: trawlers, b: purse seiners, c: beach-seiners, d: 'other coastal boats'). Horizontal lines represent monthly averages in 1964-2003 period and vertical lines are actual monthly landings for each year during the same period.

economic factors and climate variability (STERGIOU & CHRISTOU, 1996; STERGIOU *et al.*, this volume). Short-term periodicity might be related to climate changes (STERGIOU & LASCARATOS, 1997). The exponential increase in *S. aurita* landings (Figure 3r) is also the result of temperature increase in the northern Aegean which allowed for the northwards expansion of round sardinella distribution and the establishment of large population densities that are reflected in landings (TSIKLIRAS & STERGIOU, 2006).

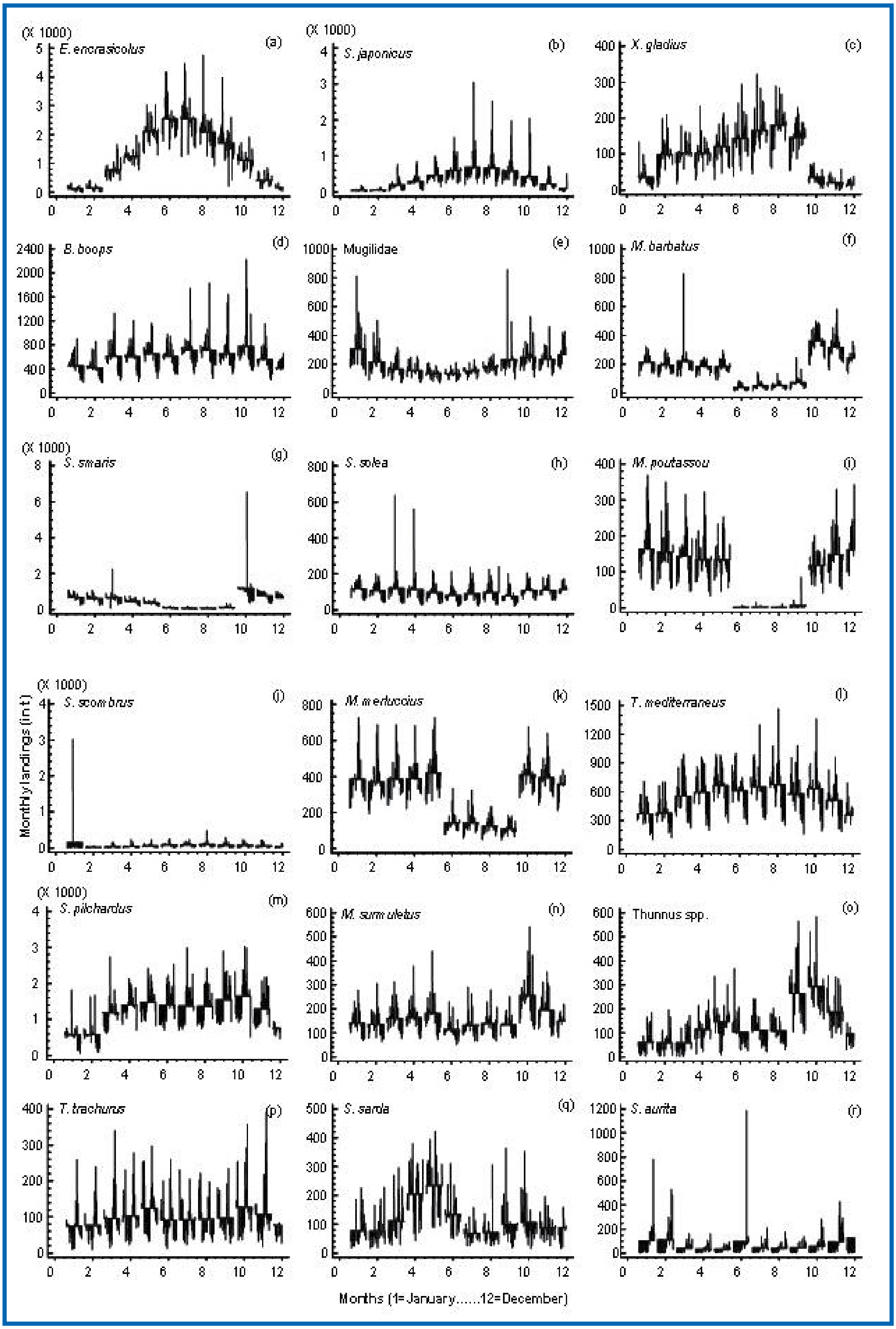
Monthly landings

The monthly total landings per fishery exhibited a pronounced seasonal cycle (Figure 4). Trawl and beach-seine landings were consistently very low between June and September (Figures 4a and 4c) when trawling and beach-seining are prohibited by law. In contrast, the landings of purse-seiners increased from a minimum in January to a maximum in June and declined thereafter (Figure 4b). This is related to the prohibition of the purse seine fishery from 1st December to the end of February, the spawning of the main targeted species, such as European anchovy (*Engraulis encrasicolus*), round sardinella (*Sardinella aurita*) and Atlantic horse mackerel (*Trachurus trachurus*) in the summer months and the favourable weather conditions in summer which increase the number of fishing days (KAPANTAGAKIS *et al.*, 2001). In contrast, no seasonality was observed in the landings of 'other coastal boats' (Figure 4d).

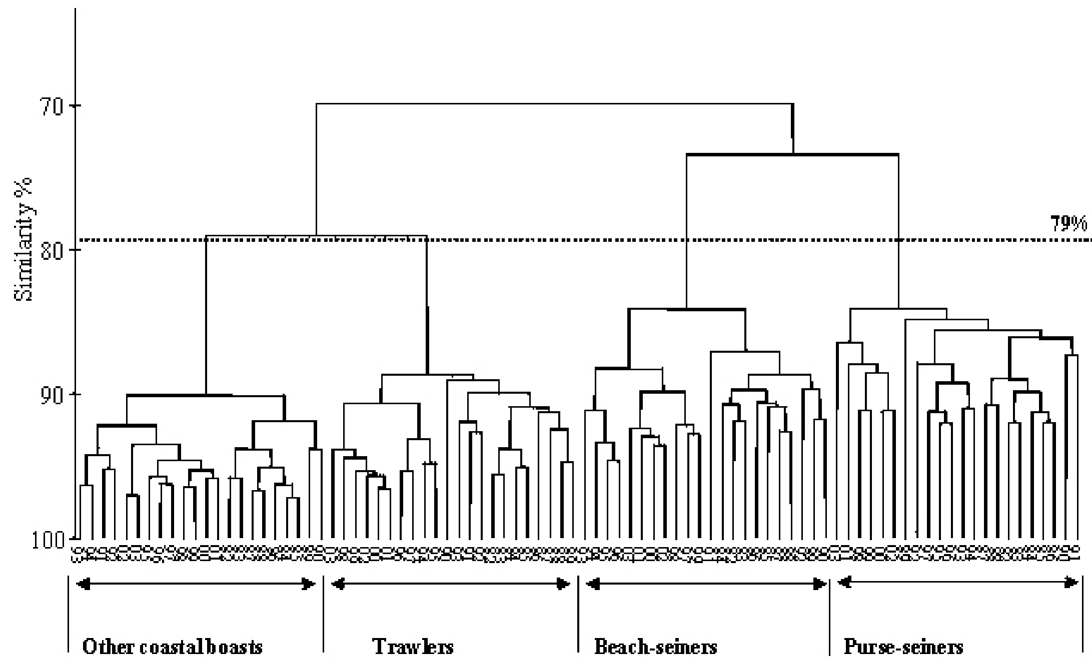
The monthly landings for the most abundant taxa participating in the landings revealed four general patterns (Figure 5): (a) six taxa exhibited a maximum in the summer months (Figures 5a, b, c, d, l, m), e.g. European anchovy and swordfish (*Xiphias gladius*); (b) eight taxa exhibited a minimum in the summer months (Figures 5e, f, g, h, i, k, n, p), e.g. red mullet (*Mullus barbatus*) and the European hake (*Merluccius merluccius*); (c) two taxa exhibited two maxima, tunas (*Thunnus* spp.) (Figure 5o) and Atlantic bonito (*Sarda sarda*) (Figure 5q); and finally (d) two taxa exhibited no clear seasonality, Atlantic mackerel (*Scomber scombrus*) (Figure 5j) and round sardinella (*Sardinella aurita*) (Figure 5r).

Such seasonality in fisheries landings is related to the operation of the main fishing gears involved in the fishery of the taxon defined by local fishery regulations, and the seasonal offshore and inshore stock migrations and spawning behaviour (STERGIOU *et al.,* 1997). In general, demersal stocks (e.g. *M. merluccius* and *M. barbatus*), which are exploited mainly by trawlers and beach-seiners, exhibit a

Figure 5: Seasonal sub-series plot of monthly commercial landings of the 18 most abundant taxa in Hellenic Seas, 1982-2003. Horizontial lines represent monthly averages in 1982-2003 period and vertical lines are actual monthly landing for each year during the same period.



minimum in the summer when trawling is prohibited. In contrast, the majority of small pelagic fishes that are largely exploited by the purse-seiners are landed in the spring/summer months. The landings



Other coastal boats		Trawlers		Beach-seiners		Purse-seiners	
Similarity:	91.8%	Similarity:	90.0%	Similarity:	86.6%	Similarity:	85.7%
Species	C%	Species	C%	Species	C%	Species	C%
Others	3.56	*Others*	3.53	*S. smaris*	5.53	*E. encrasicolus*	6.90
S. pilchardus	2.70	*M. merluccius*	3.35	*S. pilchardus*	4.26	*S. pilchardus*	6.53
Mugilidae	2.69	*M. barbatus*	3.00	*B. boops*	4.15	*B. boops*	4.79
B. boops	2.69	*T. trachurus*	2.85	Others	3.61	*T. mediterraneus*	4.76
Thunnus spp.	2.37	*S. smaris*	2.75	*T. mediterraneus*	3.15	*S. japonicus*	4.59
S. smaris	2.33	*M. poutassou*	2.68	Common squid	2.74	Others	3.53
X. gladius	2.32	Shrimp	2.54	*M. barbatus*	2.66	*S. sarda*	3.20
T. mediterraneus	2.31	*B. boops*	2.45	*E. encrasicolus*	2.51	*S. smaris*	2.97
Cum%	**20.97**	**Cum%**	**23.15**	**Cum%**	**28.61**	**Cum%**	**37.27**

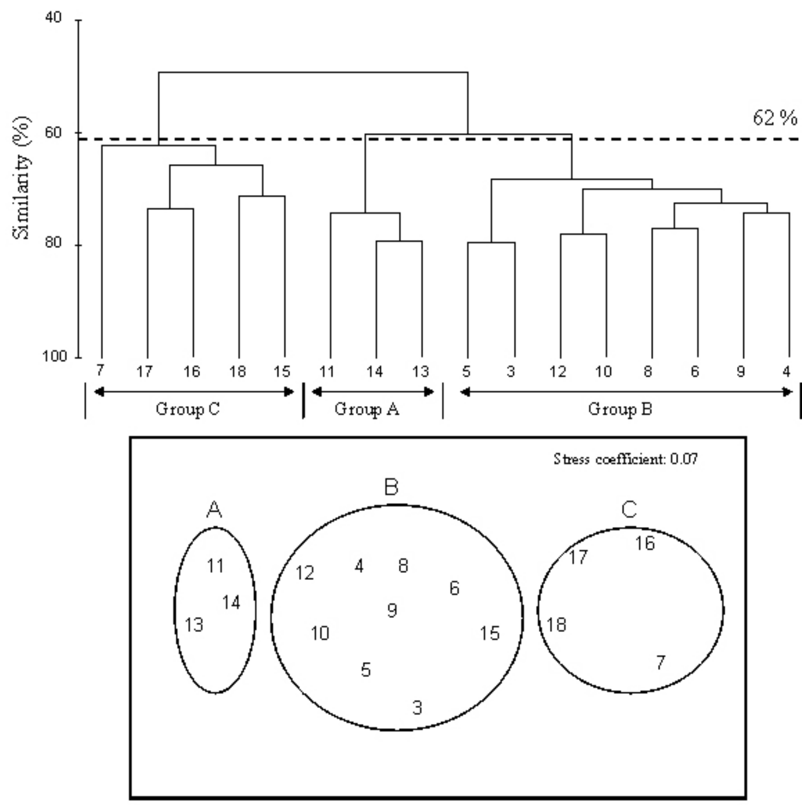
Figure 6: Dendrogram (group-average clustering) of the landings of all taxa per fishery (trawlers, purse-seiners, beach-seiners and 'other coastal boast'), Hellenic Seas, 1982-2003 and percentage contribution of each taxon to the average Bray-Curtis similarity (%) within each of the groups (C%). A matrix comprising the landings of each taxon caught by each gear per year was constructed. This matrix was transformed into a triangular matrix of similarities between all pairs of combinations using the Bray-Curtis coefficient with group-averaging linking. Consequently, this matrix was subjected to cluster and MDS techniques. Only groupings based on the agreement between the results of cluster and MDS analyses were accepted (FIELD *et al.*, 1982).

of the large pelagic species exhibit different patterns depending on the species. For instance, the seasonality in *X. gladius* landings is attributed to its exclusive exploitation by 'other coastal boats', whose fishing effort is largely dependent upon the weather conditions which are better in the summer months (KAPANTAGAKIS *et al.*, 2001).

SPECIES COMPOSITION PER MAIN FISHERY

The classification and ordination of the annual commercial landings of the 66 taxa, per fishing gear for the years 1982-2003 (88 fishery/year combinations) indicated four distinct and statistically significant (R-statistic>0.996; P<0.001) groups at 79% similarity level (Figure 6): (a) trawlers, (b) "other coastal boats", (c) purse seiners and (d) beach seiners. The results of the MDS (not shown here) were in full agreement with those of cluster analysis (stress coefficient=0.07).

Trawlers and 'other coastal boats' exploit primarily demersal/inshore stocks, purse-seiners primarily pelagic stocks, whereas beach seiners exploit a variety of both components (Figure 6). The number of the typifying taxa that cumulatively attributed more than 50% to the average Bray-Curtis simi-



Group A (N Aegean & Pagasitikos Gulf)	
Average similarity: 30.63 %	
Species	% contribution
E. engrasicolus	26.08
S. pilchardus	22.99
Various fishes	6.17
Trachurus spp.	5.25
M. merluccius	3.87
S. japonicus	3.38
Mugilidae	2.88
B. boops	2.39
S. solea	2.32
M. barbatus	2.22

Group B (Ionian & W/C Aegean)	
Average similarity: 41.98 %	
Species	% contribution
S. pilchardus	15.82
E. engrasicolus	12.45
S. smaris	10.46
B. boops	10.08
Trachurus spp.	6.67
M. merluccius	6.28
Various fishes	5.75
S. japonicus	3.27
M. barbatus	2.78
M. surmuletus	1.81

Group C (E/S Aegean)	
Average similarity: 46.85 %	
Species	% contribution
S. smaris	20.69
B. boops	16.75
Various fishes	13.59
M. surmuletus	5.23
Trachurus spp.	5.18
S. japonicus	4.52
M. barbatus	3.29
X. gladius	3.24
S. pilchardus	2.73
M. merluccius	2.58

Figure 7: Dendrogram (group-average clustering), and multidimensional scaling (MDS) ordination, based on Bray-Curtis similarities between landings of all taxa caught for each fishing subarea, Hellenic Seas, 1982-2003 and contribution of each taxon to the average Bray-Curtis similarity (C%) within each group (N: northern, E: eastern, S: southern, W: western; C: central). A matrix comprising the mean landings of each taxon caught in each fishing subarea for 1982-2003 was constructed. This matrix was transformed into a triangular matrix of similarities between all pairs of combinations using the Bray-Curtis coefficient with group-averaging linking. Consequently, this matrix was subjected to cluster and MDS techniques. Only groupings based on the agreement between the results of cluster and MDS analyses were accepted (FIELD *et al.*, 1982).

larity within the different groups identified, was lowest for purse-seines (14 species) and highest for 'other coastal boats' (24 species) indicating the high selectivity of the former and the multi-species nature of the latter. The typifying taxa per fishing gear were: 'other species', *M. merluccius* and *M. barbatus* for trawls; *E. encrasicolus* and *S. pilchardus* for purse-seiners; *Spicara smaris*, *S. pilchardus* and *Boops boops* for beach-seiners; and 'other species', *S. pilchardus*, Mugilidae and *B. boops* for 'other coastal boats' (Figure 6). Within the above main four fishery groups, sub-groups of year were formed which were consistent and significant (R-statistic>0.772; P<0.1): 1982-1990 and 1991-2003 for 'other coastal boats', 1982-1993 and 1994-2003 for trawlers, 1982-1991 and 1992-2003 for beach-seiners and 1982-1991 and 1993-2003 for purse-seiners (Figure 6).

GEOGRAPHIC VARIABILITY IN SPECIES COMPOSITION

Mutlivariate analyses revealed the existence of three groups of subareas (Figure 7): (A) the northern Aegean subareas 13 and 14, including the Pagasitikos Gulf, subarea 11; (B) the Ionian (subareas 3, 4, 5 and 6) and western/central Aegean (subareas 8, 9, 10 and 12); and (C) the eastern/southern Aegean subareas (7, 15, 16, 17 and 18). The taxa that cumulatively contributed more than 45% to the average Bray-Curtis similarity within the groups were (in order of decreasing importance): *E. encrasicolus* and *S. pilchardus* in group A (northern Aegean/Pagasitikos Gulf); *S. pilchardus*, *E. encrasicolus, S. smaris* and *B. boops* in group B (Ionian and western/central Aegean); *S. smaris*, *B. boops* and 'various fishes' in group C (eastern/southern Aegean).

The higher dominance of small-pelagic species in Group A is attributed to purse-seiners that operate mainly in the northern Aegean. The extended continental shelf compared to the rest of Hellenic waters, the higher productivity and lower temperature-less saline waters prevailing along the northern Aegean coast create favourable conditions for the dominance of *E. encrasicolus* and *S. pilchardus*. In contrast, the demersal *B. boops* and *S. smaris* are generally characterized by a more southerly distribution than the aforementioned small pelagic species and dominated the landings of the southern Aegean. In the southern Aegean, fisheries also target *X. gladius* using longlines with larger hook sizes than the ones used in typical small-scale fishery (KAPANTAGAKIS *et al.*, 2001).

GENERAL DISCUSSION-RECOMMENDATIONS

The long term increasing trends in Hellenic marine landings during 1964-1994 (Figures 1-3) are most probably attributed to the fleet modernization and geographic expansion of the fisheries over this period. However, the declining trends since the mid 1990s, suggest that such effects have ceased and fisheries are gradually becoming unsustainable.

The seasonality in the landings per major fishing gear is largely determined by the temporal national fisheries regulations (such as the prohibition of trawling from 1st June to 30th September each year) and the biology/ecology and fisheries aspects of the targeted-stocks (spawning, migration, etc.).

The geographic distribution of landings is determined by the seabed topography and the presence of water masses and river inputs that influence the primary production of the Hellenic seas (see e.g. STERGIOU *et al.*, 1997). This is particularly true for the small pelagic fish that make up the majority of the landings. The main taxa contributing the most to the landings differ from north to south.

Most gears operating in Hellenic waters are multispecies in nature. This is especially true for the trawlers and beach-seiners that exploit the demersal and benthopelagic stocks, while purse-seiners almost exclusively target small- and medium-sized pelagic fish.

Conventional fishery management schemes have failed to prevent the overexploitation of global fisheries' resources and are especially weak when multi-gear and multi-species fisheries are concerned. Thus, management strategies should be reoriented towards the ecosystem-based approach to fisheries' management (e.g. BROWMAN & STERGIOU, 2004). Whether within the ecosystem framework or not, fisheries management will benefit from the implementation of marine protected areas, i.e. areas permanently excluded from all fishing activities (see TSIKLIRAS & STERGIOU, this volume).

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III.7. MANAGEMENT AND LEGISLATION IN HELLENIC FISHERIES

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INTRODUCTION

Fishing activity in Hellas has a long and deep cultural and historical background. The landscape itself of the country serves to strengthen the age-old bonds with the sea. The huge number of islands linked to the difficulties of sea-passage encouraged the formation of small self-sustaining communities closely related to the sea. Fishing activities provided the means to survive in this environment and emerged as the dominant activity at the very centre of cultural and economic life. On the other hand, the lack of large stocks resulted in the creation of a small-scale artisanal fleet targeting mainly euryaline species. The low numbers of fish and the migratory character of many target species led to the development of a hunting mentality among fishers and a complete lack of any husbandry attitude.

The need for application of fishery management became apparent after the Second World War, when mechanization of a large part of the fleet changed the status of the fishing communities. Initially, fishery management rules focused on a more equitable sharing out of the non-growing stocks. Later the focus moved towards the protection of the stocks. After Hellas's join into the European Union, Hellenic fishery management followed the Common Fishery Policy rules. The European legal fishery framework, as expressed in the concatenated Regulations, is firmly embedded in the Hellenic legislative system.

The Hellenic national legislation system consists of a variety of laws, Presidential decrees (PD) and ministerial decisions that form a complex system of restrictions for the regulation of selective fisheries. This system contains approximately 90 legal texts applicable in 80 geographic areas, having 35 separate restrictions on gears or species as well as 25 different time duration restrictions. The legislation web of Hellas consists of:

- Royal decrees (RD) stemming from the period when Hellas was a kingdom.
- Legislative decrees (LD) stemming from the period of the military government in Hellas (1967-1973).
- Presidential decrees (PD) issued after1973.

The oldest law still in effect is the RD: 23/3/53 establishing the framework for the operation of purse seines.

THE LEGAL FRAMEWORK

The Hellenic fishery legislation system is built around three axes:

- Effort management
- Technical measures
- EU Common Fishery Policy application

The Hellenic fishery legislative system does not apply management quotas for any species. The pivotal law for the management of professional fishing activity in Hellas is RD: 666/66 which establishes the licensing system of the fishing fleet, specifying that a vessel is allowed to fish only if the vessel is licensed to practice fishing with the approved fishing gears. The same law also controls the issuance of new fishing licences which are further regulated by PD: 261/91. With this law the issue of new licences has been discontinued in favour of the Common Fishery Policy and the associated multi-annual guidance programmes for the restructuring of the Hellenic fisheries.

Common European fishery legislation has been embedded into the Hellenic legislation and is fully operational. Apart from the initial setting up of the European fishing Fleet Register, there are four EU Regulations which can be considered as milestones. These have had the greatest impact on Hellenic fisheries as they introduced significant changes in fishing capacity, fishing practice and fishery management:

- EU Regulation 3699/1993 introduced capacity management and the restructuring of the fleet. This Regulation provided the financial means that enabled the implementation of the Multi-annual Guidance Programmes. Three framework programmes have been implemented so far:
  - Framework programme 1994-1999: 2 655 projects
  - Framework programme 1994-1999 (PESCA): 411 projects
  - Framework programme 2000-2006: 5 000 projects

It is anticipated that one more framework programme will be launched for the period 2007-2013.

- EU Regulation 1626/94 defined, even more precisely than before, the geographic zones where fishing by each fleet segment should be

Table 1. Laws establishing the general operating environment of trawlers.

RD: 917/1966	RD: 666/66	RD: 50/67	Law: 420/70
PD: 94/19-2-75	PD: 938/29-2-75	PD: 2040/92 Article10)	PD: 2226/95 (Article9)
PD: 1063/80	PD: 346/82	PD: 143/86	

Table 2. Laws imposing geographic restrictions on the operation of trawlers.

PD: 89/78	PD: 555/79	PD: 739/79	PD: 988/80
PD: 698/81	PD: 1064/90	PD: 9/91	PD: 222/91

carried out. This Regulation has been replaced by Regulation 1967/2006.

- EU Regulations 2371/2002 and 2244/2003 introduced an independent satellite-driven vessel monitoring system (VMS). Vessels of all fleet segments exceeding 15 m in length are obliged to have a VMS device installed. With this system, the application of EU Regulation 1626/94 and its replacement EU Regulation1967/2006 can easily be tested.
- EU Regulations 1543/2000 and 1639/2001 introduced the concept of the scientific monitoring of all fishing activities throughout all EU countries. Those Regulations enable all EU countries to monitor regularly the fishing activities of all professional fishing fleets as well as the status of the stocks. The application of this Regulation began in 2002 and has so far provided a 5-year data series in the main fishing activity descriptors. As those data series are progressing they enable the scientific backing of any fishery management decision at the national level as well as at the European Union level.

Trawlers

The trawl is one of the most important bottom gears used by Hellenic fishermen. The trawl gear can be used only as a single trawl, equipped with otter boards of any kind. The trawl can be used only as bottom gear. Pelagic trawls have never been used in Hellenic fisheries. RD: 917/1966 is the principal law regulating the operation of trawlers. Although this law is still in effect it has been superseded by EU Regulation 1626/1994 and its replacement Regulation 1967/2006. The operation of the trawlers is subject to a web of general restrictions established by Hellenic and European Union legislation:

- Establishment of a total exclusion zone one mile from the coastline of the mainland and the islands.
- Establishment of a total fishing ban during the months of June, July, August and September.
- Establishment of a total exclusion zone which is: either a zone three miles from the coastal line or a zone shallower than 50 metres (EU Regulation 1626/1994 and 1967/2006).
- Minimum codend mesh size 20 mm. This minimum size has been increased by EU Regulation 1967/2006 which states that until 30/6/2008 the minimum mesh size is 40 mm and after this date it increases to the 50 mm (it remains 40 mm if square mesh is used).

In addition to those general restrictions (Table 1), there are eight restrictions referring to the local level (Table 2), prohibiting fishing in several geographic areas, mainly closed bays.

Purse seiners

Purse seines are the main gears for fishing of small pelagic fish. In this fishing activity the vessel vertically releases a large rectangular net equipped with metal rings across the bottom edge. A metal rope is set through the rings ending in a hydraulic winch which enables the gathering of the net making a bag-shaped grip that encloses the fish. Purse seines are operated either during the day (day seine) or at night (night seine). Day seiners use fish finders to detect fish schools, while night seiners use buoys equipped with artificial light sources to attract fish and auxiliary boats to move the buoys towards one location in order to form dense schools and increase catch per effort. Day seines and night seines are based on the same principle but there are technical differences in the two gears. Therefore, most of the vessels use either a night seine or a day seine. The fact that the day gear and the night gear are not the same makes it impossible for vessels to use both types of seines as this would incur extra costs. In the Hellenic legislation system there is only one type of purse seine license. The vessels may then choose either the day or the night seine. The majority of the Hellenic purse seiners use a night seine.

The main laws regulating the operation of the purse seine are: RD: 23/3/53 (which specifies the

technical characteristics of a purse seiner) and RD: 666/66 (which specifies the licenses). There are eight additional laws which introduce some modifications to the two main laws (Table 3).
In addition to the general restrictions there are seven restrictions (Table 4) referring to the local level, prohibiting fishing in several geographic areas, mainly closed bays.

The prohibitions in the operation of a purse seine are:
- Fishing at a distance less than 300 m from the shore line or in areas shallower than 30 m (EU Regulation 1626/1994).
- Fishing between 15 December and the end of February for the night seine and between 1 July and 31 August for the day seine.
- Fishing in areas closer than 1 000 m from aquaculture units or 500 m from pond trapping devices.
- Fishing with both night seine and day seine in a way that the seine is trawling.
- Fishing with the night seine two days before and after a full moon.
- Minimum mesh size for the night seine is 7 mm and for the day seine 20 mm. The minimum size has been increased to 14 mm by the new Regulation 1967/2006.
- The maximum length of the seine is 800 m while the maximum altitude is 120 m.

Boat seine
The boat seine is the most dynamic fishing gear used by small-scale fishery. In the past, the beach seine was operated very close to the shore line and it was raised by hand from the beach. Today the seine is operated by a single boat and the procedure is fully mechanized using winches. The net is deployed in the water and then it is slowly trawled and raised simultaneously while the boat is lying at anchor far from the gear opening. The gear is used in flat bottoms and in very shallow areas. The gear targets small fish such as picarel, red mullet and ink fish, as well as octopuses. Very often the catch using this gear contains many undersized fishes and it is, therefore, condemned in several research studies. For this reason the operation of this gear is heavily restricted in terms of usage time.
RD: 817/1966 is the main law regulating the operation of the beach seine. This law is subject to several modifications imposed by several other laws but also by the European Union legislation, in particular EU Regulation 1626/1994 and its replacement Regulation 1967/2006.
The following laws (Table 5) constitute the current operation status of the beach seine:
Six areas have been excluded from fishing for the beach seiners. The laws imposing those restrictions are shown on Table 6.
The following rules constitute the working environment of this gear:
- Fishing is allowed only during day time and spe-

Table 3. Laws establishing the general operating environment of purse seiners.

RD: 23/3/53	RD: 17/8/55	RD: 764/69
RD: 732/60	RD:445/63	RD: 666/66
LD: 420/70	PD: 921/75	PD: 1095/77
PD: 244/91		

Table 4. Laws imposing geographic restrictions on the operation of purse seiners.

RD: 31/8/57	RD: 732/60	RD: 357/70
PD: 189/78	PD: 554/79	PD: 550/81
PD: 25/93		

Table 5. Laws establishing the general operating environment of beach seiners.

RD: 817/66	PD:716/74	PD:15/76
PD: 553/79	PD: 669/80	PD: 1063/80
PD: 346/82	PD: 143/86	PD: 68/88

Table 6. Laws imposing geographic restrictions on the operation of beach seiners.

PD: 189/78	PD: 234/79	PD: 979/80
PD: 1064/80	PD: 698/81	PD: 988/80

Table 7: Laws ruling the operation of nets.

RD: 7/4/53	RD: 11/10/57	RD: 666/66
Law: 420/70	PD:1094/77	PD: 491/78
PD: 373/85	PD: 88/87	PD: 40/93

Table 8: Laws imposing geographic restrictions on the operation of gillnets.

PD: 497/88	Law: 435/70	PD: 189/78
PD: 338/80	PD: 986/80	PD: 144/86
PD: 497/88		

cifically one hour after sunrise and one hour before sunset.

- During fishing, the boat must remain motionless, operating only the winches. The distance of the boat from the shore line must be less than 70 m.
- Fishing is prohibited during the months of April, May, June, July and September.
- The minimum mesh size of the gear in the codend section is 8 mm.

Nets and longlines

Static nets and longlines are the main gears of small-scale fishery in Hellas. The majority of the vessels use trammel nets. The nets have been always used as static gears. There is no drift net fishing practice in Hellas.

The operation of the bottom-set gillnets is subject to the following restrictions:

- The maximum total length for the trammel net is 6 000 m
- The maximum depth for the trammel net is 4 m.
- The maximum depth for the trammel net is 4 m.
- The minimum mesh size is 16 mm.
- Monofilament or twine diameter of the bottom-set gillnet should not exceed the 0.5 mm.
- By way of derogation, if a bottom-set gillnet has a maximum length of 500 m, then the maximum drop may be up to 30 m.

If a vessel uses combined trammel net and bottom-set gillnets the following restrictions are applied:

- The maximum drop of a combined data set should not exceed 10 m.
- The maximum length of the combined gears should not exceed 2 500 m.
- Monofilament or twine diameter of the gillnet should not exceed 0.5 mm.
- By way of derogation, if a bottom-set gillnet has a maximum length of 500 m, then the maximum drop may be up to 30 m.

The Hellenic legislation system does not contain many restrictions on the operation of nets. The restrictions mentioned above are set by EU Regulation 1626/1994 and its replacement 1967/2006. The legal framework for the operation of nets is set by the laws presented in Table 7.

There are seven areas where the operation of gillnets is restricted (Table 8).

Longlines, very selective gears, are less popular with professional fishermen. Longlines are subdivided into two main categories, bottom longlines and drifting longlines. Bottom longlines are used as static gears operating on the bottom or above the bottom kept in the fishing position by means of floats and weights. They are much appreciated by amateur fishermen. Drifting long lines are large, highly professional, gears targeting large migratory species like swordfish and tuna.

The Hellenic legislation system does not set any restriction on the size of the bottom longlines. There are only two laws restricting the use of longlines in two geographic areas: PD: 435/70 and 189/78. The only restriction on this gear comes from Regulation 1626/1994 and its replacement 1967/2006, which states that the maximum number of hooks per fishermen is 1 000. The total maximum number per vessel is 5 000 hooks. Long-distance fishing vessels may use up to 7 000 hooks. If the vessel is fishing red sea-bream (*Pagellus bogaraveo*), the minimum length of the hook is 3.95 cm while the minimum width is 1.65 cm.

Drifting longlines are subject to the following restrictions:

- The maximum length of the main line is 70 Km.
- The maximum number of hooks for vessels fishing bluefin tuna (*Thunnus thynnus*) is 2 000.
- The maximum number of hooks for vessels fishing swordfish (*Xyphias gladius*) is 3 500.
- The maximum number of hooks for vessels fishing albacore (*Thunnus alalunga*) is 5 000.
- Long-distance fishing vessels are allowed to carry on board an equivalent number of spare hooks.

Other Gears

There is a large variety of artisanal fishing gears used by Hellenic small scale fishery. Most of them are gears adapted to the local fishing conditions. The most important of these are:

- The ring trammel net (kouloura). In some regions trammel nets are used to encircle a small area of the sea creating a trap of 150 m diameter. The fish are driven to the nets by means of acoustic shocks. PD: 88/1987 governs the use of this gear. The maximum length of the gear is 500 m, the maximum depth is 13 m and the minimum mesh size is 22 mm. The upper part of the gear (one metre) as well as the lower part (two metres) is gillnet while the middle part is trammel net. The net may be set at a distance from the shore line exceeding 300 m. The use of light sources as well as the use of pursing facilities is prohibited.
- The net trapping device (Volkos) is used during winter months in estuaries and lagoon bottlenecks to catch eels. In the other months they are used to catch fish. They are cylinder-like nets kept in shape by means of metal rings. In each ring there is a conic gate that leads the fish into the next department where the fish is trapped. The operation of these gears is regulated by RD: 805/68. The minimum mesh size 18 mm if the gears are targeting fish or 10 mm if the gears are targeting eels.
- Trap (kiourtos). These gears are used mainly for crustaceans and octopuses. To a lesser extent they are used for trapping fish occasionally (salpa fishing). The traps targeting crustaceans are lobster traps and Norway lobster traps. The octopus traps are pot-like tubes used mainly along the north Aegean coast. The law regulating the trap fishery is PD: 157/2004. The Regulation 1967/2006 restricts the total number of traps per vessel to 250 for deep water fishing.
- Dredges. Dredges are used either for sponge collection (Gagava) or mollusc fishing (Argalios, Tsougrana). The gagava is used in flat bottoms for sponge collection. The gear is trawled at low speed. For this reason the gear is subject to the laws regulating trawl fishery as well as RD: 110/64 and RD: 666/66. The gear is used mainly around the island of Kalymnos.
- Two types of dredges are used for mollusc fishing, argalios and tsougrana. The arglalios is a dredge with a triangular opening made of steel. The bottom metal frame is 1.2 m wide and has a rectangular indentation in the opening which leads to a net bag having a mesh size of 35 mm and length 1.5 m. The gear is trawled in muddy bottoms enabling the metal indentation to raise the molluscs to the net opening. The trawling washes out the molluscs that are, finally, collected in the net bag. The tsougrana is a 30 cm wide spike-tooth harrow with a small net bag at the end. The gear is operated by hand in shallow and muddy bottoms. Mollusc fishery is allowed from 1 October to 31 May of the following year and is governed by PD: 86/98.
- Mollusc fishing is also allowed by divers with either autonomous or semi- autonomous diving devices. Divers are not allowed to fish during the night or at depths below 10 m. They have to operate always in pairs.
- Coral fishery is allowed between 1 April and 31 December. The licence to fish coral lasts for one year. Three methods for coral collection are allowed:
    - By means of divers using either autonomous or semi-autonomous diving devices.
    - By means of trawling with a metal frame.
    - By means of an egg-shaped gear (Columbus egg).

Any other device is forbidden including the "Saint Andrea cross" gear. The laws regulating coral fishery are PD: 324/94 and the Ministerial decision 24790/98.

SPECIES PROTECTION

In order to protect some endangered species, fishing is restricted during the appropriate period of reproduction of each species (Table 9).

In terms of weight, it is forbidden to fish or to trade in:

- Lobster below 420 g
- Octopus below 500 g
- Bluefin tuna below 6.4 Kg

In terms of size, it is forbidden to fish for or trade any species with a total length below 8 cm. For some species, a minimum size (length) is specified. Additionally, there is a list of species whose minimum size is also specified by EU Regulation 1967/2006. Table 10 represents an amalgamation of the two lists of species. In many species there is some overlapping but there are also species which appear only in the Hellenic list. It is obvious that in the case of differences in the minimum size, the most rigorous is the dominant one.

Table 9. Time restrictions on the fishing of certain species.

Species	Restricted Period
Lobster	1 September – 31 December
Sword fish	1 October – 31 January
Warty venus (*Venus verrucosa*) GR: Kydoni	1 August – 31 October
Oyster	1 August – 31 March
Callista chione (Smooth callista) GR: Gyalisteri	1 April – 30 June
Other molluscs	1 April – 31 October

Table 10. Minimum size of some species.

Scientific name	Common name	Minimum size Hellenic Legislation	Minimum size 1967/2006
1. Fish			
Anguila anguila	Eel	30 cm	
Boops boops	Bogue	10 cm	
Dicentrarchus labrax	Sea bass	23 cm	25 cm
Diplodus annularis	Annular sea bream	15 cm	12 cm
Diplodus puntazzo	Sharpsnout sea bream		18 cm
Diplodus sargus	White sea bream	15 cm	23 cm
Diplodus vulgaris	Two-banded sea bream		18 cm
Engraulis engrasicolus	European anchovy	9 cm	9 cm (*)
Epinephelus spp.	Groupers		45 cm
Epinephelus guaza	Grouper	45 cm	
Lophius spp.	Anglerfish	30 cm	
Lithognathus mormyrus	Striped sea bream		20 cm
Lichia amia	Leer fish	14 cm	
Merluccius merluccius	Hake	20 cm	20 cm (**)
Mugil cephalus	Common grey mullet	16 cm	
Mullus barbatus	Striped mullet	11 cm	11 cm
Mullus surmuletus	Red mullet	11 cm	11 cm
Pagellus acarne	Spanish sea bream		17 cm
Pagellus bogaraveo	Red sea bream		33 cm
Pagellus erythrinus	Common pandora	12 cm	15 cm
Pagrus pagrus	Common sea bream	18 cm	18 cm
Polyprion americanus	Wrekfish	45 cm	45 cm
Sardina pilchardus	European sardine		11 cm (***)
Sardinella aurita	Gilt Sardine	10 cm	
Scomber japonicus	Chub mackerel	12 cm	18 cm
Scomber spp.	Mackerel	18 cm	18 cm
Solea vulgaris	Common sole	20 cm	20 cm
Sparus aurata	Gilt-head sea bream	20 cm	20 cm
Thunnus thynnus	Tune fish	70 cm - 6.4kg	
Trachurus spp.	Horse mackerel, scad	12 cm	15 cm
Xiphias gladius	Swordfish	120 cm	
2. Crustaceans			
Homarus gammarus	Lobster	240 mm	300 mm TL
		85 mm	105 mm CL
Nephrops norvegicus	Norway lobster	70 mm	70 mm TL
		20 mm	20 mm CL
Palinuridae	Crawfish	240 mm	90 mm CL
Parapenaeus longirostris	Deep sea rose shrimp		20 mm CL

(continued)

Table 10 (continued)

Scientific name	Common name	Minimum size Hellenic Legislation	Minimum size 1967/2006
3. Mollusc bivalves			
Aequipecten opercularis	Scallop GR: Hteni	5 cm	
Arca node	GR: Kalognomi	5 cm	
Barbaria barbata	GR: Psephtokalognomi	5 cm	
Callista chione	GR: Gyalisteri	4.5 cm	
Cerastoderma glaucum	GR: Pourlida	4 cm	
Chamellea gallina	GR: Psephtokydono	3.5 cm	
Dinax trunculus	GR: Tellina	3 cm	
Dosinia escoletta	GR: Strogili Ahivada	4 cm	
Flexopecten glaber	GR: Gyalistero Hteni	4.5 cm	
Gari depressa	GR: Esperos	4 cm	
Modiolus barbatus	GR: Havaro	5 cm	
Ostrea edulis	Oyster GR: Strydi	7 cm	
Pecten jacobeus	Scallop GR: Megalo Hteni	100 mm	10 cm
Spisula subtruncata	GR: Achivadaki	2.5 cm	
Ruditapes decussatus	Clam GR: Ahivada	4.5 cm	
Venerupis spp.	Clam GR: Ahivada	25 mm	
Venus spp.	Warty venus GR: Kydoni	4.5 cm	
4. Gastropods			
Haliotis tuberculata	GR: Afti	6 cm	
Bolinus brandartis	GR: Akanthotos strobos	6 cm	
Phyllonotus trunculus	GR: Strobos	5 cm	
Thais heamastoma	GR: Porphyra	5 cm	

TL = Total length
CL = Carapace length
(*) Anchovy: Member states may convert the minimum size to weight: 110 specimens per Kg
(**) Hake: Until 31/12/2008 a tolerance 15% of weight will be permitted for hake between 15 and 20 cm.
(***) Sardine: Member states may convert the minimum size to weight: 55 specimens per Kg

FORBIDDEN FISHING PRACTICES

There are several fishing practices and also some gears that are banned in Hellenic fisheries.

- Autonomous diving devices except for the collection of sponges, corals and molluscs. (PD: 324/94, PD: 86/98)
- Gripos. Gear consisting of two long side nets and a net bag like the trawl codend. It is operated from the beach by hand. (RD: 11/7/1949)
- Lentisia. This gear is a surrounding net without purse lines operated by a group of vessels. (RD: 11/10/1957)
- Grigraki. It is a small version of a purse seine operated by a small vessel very close to the beach. (PD: 542/1985)
- Monofilament nets. (PD: 1094/1977)
- Explosives
- Pelagic trawl (RD: 917/1966)
- Fishing around aquaculture units, and lagoon entry gates. (RD: 23/3/1953, RD: 16/8/1953, LD: 420/70, PD: 373/1985)
- Submersible lights. (PD: 1095/1977)
- Driftnets. (PD: 40/1993)
- Garfish net. Small surrounding net for the fishing of the species *Belone belone*. (PD: 320/1977)

SPORT FISHERY

For a large part of the population of Hellas, sport fishery enjoys cult status. It could not be otherwise in a country with more than 15 000 km coastline. There are three groups of sport fishing practices:

- Mechanized fishery. This kind of sport fishery uses a boat and a great variety of gears. The most popular gears are gillnets, longlines, trawl lines, bottom lines and traps. The target species are mainly sparides and octopuses.
- Snorkelling. Snorkelling is most appreciated by the younger sport fishers. They use spearguns

and their main targets are sparides, epinephelides and octopuses.

- Shoreline fishing. Shoreline fishing is the anti-stress occupation of the Hellenics. It is carried out by young and old alike throughout the year. They use a great variety of lines. Their main targets are sparides and octopuses.

Sport fishery is regulated by PD: 373/85. Sport fishery may be carried out by persons having a sport fishing license. If a boat is used, the boat has to be licensed as well. The following gears may be used:

- Gillnets having a minimum mesh size of 24 mm and maximum length of 100 m.
- Longlines having a maximum of 150 hooks per fisher or 300 hooks per boat.
- Two traps maximum per fisher with a minimum mesh size of 40 mm.
- Lines of any kind.
- Dip nets and harpoons.
- Spearguns.

Prohibitions:

- Trading in fish.
- Fishing in aquaculture ponds.
- Fishing of sponges and corals.
- Fishing with trammel nets.
- Fishing during the month of May each year.
- Fishing during the night when snorkelling.
- Fishing with the assistance of lights to attract fish.
- Fishing with submersible lights.
- Catching more than 5 Kg of fish round the clock with any gear except nets and longlines. If a single fish is caught this limitation does not apply.
- Catching more than10 Kg of fish round the clock with nets and longlines.

The application of EU Regulation 1967/2006 introduced the following new restrictions:

- The use of towed nets of any kind.
- The use of longlines for highly migratory species.

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III.8. EUROPEAN COMMISSION DATA COLLECTION REGULATION (EC 1543/2000)

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INTRODUCTION

The recently introduced EU fisheries policy (Anonymous, 2001) in European waters requires detailed and reliable information on stocks, fleets and catches, upon which technical advice for the management of the resources will be based. For the achievement of this objective, a standardized system for the collection and compilation of basic fisheries statistics needed to be developed all EU member states. It has been recognized that the existing Regulations, in particular Council Regulations (EEC) No 3759/92, (EEC) No 2847/93, and (EC) No 685/95, (EC) No 104/2000 and Commission Regulations (EC) No 2090/98, (EC) No 2091/98 and (EC) No 2092/98 do not cover all the activities for which data should be collected with a view to complete and reliable scientific analysis. The Regulations currently relate to data on an individual or global level but not data aggregated at the appropriate level for scientific evaluation. New provisions should therefore be introduced to produce multiannual sets of aggregated data that can be accessed by the appropriate authorized users.

The EC Data Collection Regulation (DCR, 1543/2000) has been implemented since 2001 with the aim of harmonising the collection of fisheries biological and economic data across the Member States. Regulation (EC) No 1543/2000 establishes a Community framework for the collection and management of data needed to evaluate the situation of the fishery resources and the fisheries sector (BOX 1). It stipulates that Member States set up national programmes for the collection and management of fisheries data in accordance with Community programmes. It is therefore necessary to establish a minimum Community programme covering the information strictly necessary for the scientific evaluations and to establish an extended Community programme which also includes information likely to improve in a decisive way the scientific evaluations. The information required for each programme is collected in the form of evaluation modules covering fishing capacities and fishing effort, catches and, finally, the economic situation of the sector (EC No 1639/2001).

The Member States' programmes for the collection of data for scientific evaluations is compatible with the collection of data for the management of other aspects of the common fisheries policy and with the collection of data pursuant to the Member States' obligations to the Community's statistical programme.

The Regulation established a Community framework for the collection and management of the data needed to evaluate the situation as regards fishery resources and the fishing industry. The Member States are responsible for collecting the data, carrying out a task, which is beneficial to the Community in that it contributes to the more efficient management of the common resources. While implementation of the programmes is the responsibility of the Member States, they should therefore qualify for a contribution from the Community towards certain costs incurred in collecting and managing the said data. The methods used to collect and process the basic data on fisheries

BOX 1. THE HELLENIC NATIONAL FISHERIES DATA COLLECTION PROGRAM

The Hellenic National Program has been prepared in accordance with the minimum requirements of the corresponding Community legislation (Article 5 of Regulation (EC) 1543/2000 and concerns the following modules:

- Collection of data concerning fishing capacities
- Collection of data related to fishing effort
- Collection of data related to catches and landings
- Collection of data concerning the catches per unit of effort
- Scientific evaluation surveys of stocks
- Assessment of the biological parameters of landings
- Collection of data concerning the processing industry and economic situation of the sector
- Facilitation access to computerized database containing the collected data

Table 1. Segmentation of the Hellenic Fishing Fleet per category of fishing technique and length (example given from 2006).

Type of fishing technique		Length category			
		<12 m	12-24 m	24-40 m	Total
Mobile gears	Demersal trawls		81	137	218
	Purse Seine	8	274	26	308
	Polyvalent		65	48	113
Passive gears	Longlines		73		
	Static Nets		343		
	Pots & traps	16782			
Polyvalent Gears*	Beach-seiner	349	52		401
Total vessels		17139	888	211	18238

* combining mobile and passive gears

should be compared and ways should be sought of improving them. The quality of the results obtained is examined and assessed regularly (i.e Commission Staff Working Papers). Commission regulation (EC) No 1639/2001 and 1581/2004 have established the minimum and extended programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of EC Regulation.

COLLECTION OF DATA BY MODULE

Fishing capacities

The data concerning fishing capacity of vessels are gathered on an annual basis for all vessels in the categories set out in Table 1 as defined in Council Regulation (EU) 1543/2000.

The fishing capacity parameters, which are recorded for each vessel per category, refer to the following characteristics and units:

1. Vessel tonnage (GT)
2. Maximum continuous engine power actually developed by the main engine, after derating if appropriate, expressed in kW as defined in the Council regulation (EU) 2930/86.
3. The age of the vessel calculated on the basis of the age of the hull.

Fishing Effort

According to the regulation this module includes data concerning (a) fuel consumption, (b) fishing effort by gear technique expressed as fishing days at sea and (c) specific fishing effort for stocks of special interest (Appendix VI of the regulation).

Fuel Consumption and Fishing Effort by Type of Technique

Logbooks are compulsory in the Mediterranean only for a minority of fleet (vessels of overall length exceeding 10 m) and only for vessels that catch and retain on board quantities exceeding 15 kg live weight of species included in a specific list (Regulation (EC) No 1967/2006). Moreover, data on landings recorded under the Regulations (EEC) 2847/93 and (EC) 104/2000 are collected in aggregated form and not in line with the requirements of the DCR, which must provide for quantities of landings by fleet segment of Appendix III. Therefore, effort data have been collected on the basis of a sampling procedure.

The basic elements, which make up the data collection and storage mechanism, are based on an information collection network from a large number of ports (30) whereas significant landings are made by the fishing fleet. All stations are equipped with computer systems and have connections to the Internet through which the information is transferred. The collection of information is done by subcontracting 30 local correspondents, most of who are Prefecture's Fisheries Inspectors. The data are collected on a monthly basis per fleet segment (Table 1) and sampling port (Figure 1).

Specific Fishing Effort

Data collection on specific fishing effort includes demersal, small and large pelagic species.

a) Specific Fishing Effort for stocks of demersal and small pelagic species

Data are collected from the sampling sites in the same way as in fuel consumption and fishing effort section. Fishing effort of the vessels will be correlated with the species mentioned in Annex VI of Regulation (EC) 1639/2001.

b) Specific fishing effort for stocks of large pelagic (migratory) species – Tuna, Swordfish

The fishing of large pelagic species (swordfish, blue-fin tuna, albacore tuna), by the Hellenic fishing

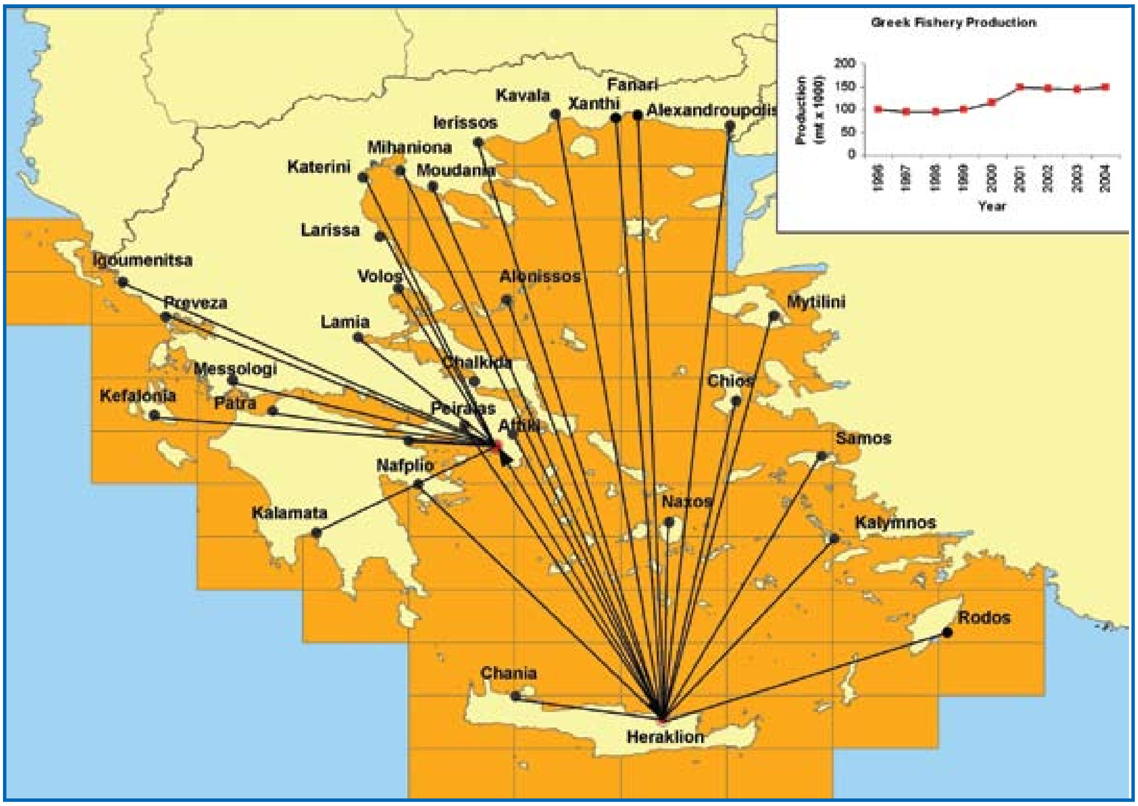

Figure 1: Sampling sites and data collection network.

fleet, is characterised by: a) the fact that the fleet, and particularly the vessels targeting swordfish, do not have fixed landing points, given that they cover great distances in the Aegean, Cretan, Libyan Seas and the Levantine following the migrations of those species, and b) the intense time-space fluctuations in fishing activity, resulting from the extensive migrations of those species. The aforementioned characteristics do not allow systematic collection of data from randomly selected vessels and require the adoption of a different sampling system from the fleet involved in the large pelagic fishery.

The main fleets involved in the fisheries of large pelagic species on the basis of their point of departure are:

- Swordfish: The Kalymnos, Chania and Western Hellenic Fleets (Western Peleponnisos – Ionian Islands)
- Blue fin tuna: The Kalymnos, Chania, Chalkidiki – Eastern Macedonia (Porto Koufo, Kavala) and Thrace fleets (Fanari Rhodopi)
- Albacore tuna: the Northern Sporades island (Alonnisos) and the Chalkidiki fleets (Porto Koufo).

Fisheries production of the above fleets represents 70-80% of the total Hellenic fisheries' production for large pelagic species. Given the movement of these fleets, constant monitoring by special technicians is required who will have to follow the fleet and move to the main landing points. In this manner calculation of the fishing effort in units related with the technique used will be feasible (e.g. number of hooks for the longlines) in accordance with the guidelines in the Field Manual of the ICCAT.

Collection of Data Related to Catches and Landings

In this module the following parameters are gathered:

- Commercial landings for all stocks
- Total catches landings and discards (for stocks mentioned in Appendix XII of the regulation)
- Catches for recreational and game fisheries in marine waters for stocks mentioned in Appendix XI of the regulation.

<u>Commercial landings for All Stocks</u>

<u>Landings of bentho-pelagic and small pelagic species</u>

Since logbook regulation is not applicable in the

Mediterranean, data are collected through the sampling procedure (sampling sites and methodology) described in the fishing effort section (Figure 1), in accordance to the levels for geographical grouping referred to in Annex I and fleet segmentation of Annex III.
The assessment of overall production will be based on random observations of production per unit effort (fishing days) at each site for each vessel category.

<u>Landings of large pelagic (migratory) species – Tuna, Swordfish</u>
For the reasons presented in the specific effort section, concerning large pelagic species fishery, the same sampling scheme has be applied for monitoring the landings. Random production per unit effort is recorded on a monthly basis for each category of vessel segment. The specific sampling methodology permits for the calculation of fishing production per unit effort in units relating to the technique used (e.g. number of hooks for long lines) in accordance with the guidelines of the ICCAT Field Manual.

<u>Total catches landings and discards (for stocks mentioned in Appendix XII)</u>
Data of catch, landings and discards for stocks mentioned in Appendix XII, are collected from observers onboard of commercial fishing vessels for the following fleet categories:

- Demersal trawls
- Purse seiner
- Coastal (nets – long line)
- Large pelagic species fishing vessels

Temporal and spatial stratification of the sampling has been followed in order to cover the period and the areas where each fleet segment operates their fishing activities.
The following data are recorded for each fishing operation: longitude and latitude of the site fished, the maximum and minimum depth, the duration of the haul, total weight of the retained catch, total weight of the discarded fraction of the catch and he weight, number of individuals and length for the retained catch and discarded fraction of species the species. Subsamples of 20 individuals per length interval are collected from the discarded fraction for length measurements. Details in chapter V.2.

Collection of Data Concerning the Catches per Unit of Effort and/or Effective Effort of Specific Commercial Fleets
Catch per unit effort (CPUE) indices are estimated for the large pelagic species exploited by the Hellenic fishing fleets, such as swordfish, bluefin tuna and albacore, according to STECF recommendations. CPUE indices are estimated from random catch-effort observations that are gathered from the main (pilot) Hellenic large pelagic fleets presented in the effort section.

Eligibility of the Scientific Evaluation Surveys of Stocks
<u>International Bottom Trawl Surveys in the Mediterranean (MEDITS)</u>
According to the Implementation Regulation this survey is classified as priority 1 survey. The survey is undertaken once a year (end of spring until the beginning of summer). The aim of this survey is to collect scientific data in Hellenic Seas using the MEDITS protocol and to study from the data series, which will arise, the trends existing in abundance indices and length frequency distributions of the commercial species being examined (Chapter III.2). The use of the data series from the aforementioned experimental cruises, in conjunction with the use of fishing activity data which is proposed in other actions in this program, as well as the cross checking of data arising from various methods, will provide more reliable results for assessing the stocks in Hellenic Seas.

<u>Large Pelagic Tagging</u>
Bluefin tuna and swordfish are highly migratory species heavily exploited in the world seas. ICCAT working groups have identified several uncertainties related with the assessment of bluefin tuna and swordfish stocks that could be clarified through tagging surveys. Those uncertainties include: spatio-temporal variability in growth, estimates of mortality parameters, distribution pattern of juveniles, rate of stocks mixing and calibration of CPUE series used in assessments.
Information from tagging will allow size variability by age to be taken into account in the assessments and will also provide information on mortality coefficients. In addition, tagging on juveniles will allow the hypotheses regarding the low mobility of juvenile fish to be examined. This would support regional and temporal fishery closures in the Mediterranean with direct scientific evidence. The aim of this survey is to realize tagging operations on about 150 juvenile swordfish in the eastern Mediterranean. Tagging operations are carried out during the autumn months when the juveniles are more abundant (September – November) and it is performed by hiring commercial boats (chapter VII).

Anchovy

This survey is part of the extended program of the regulation and aims:

(a) To assess the anchovy stocks in the Aegean using two independent methods- the daily egg production method and the acoustic method.

(b) To conduct integrated analysis of the fisheries' data which will be collected at the same time in the context of the 'minimum' Hellenic program, with fisheries independent estimates of biomass, for reliable assessment of natural mortality, abundance levels and pattern of exploitation.

The method is based on two concurrent surveys: (a) ichthyo-plankton survey to assess the daily egg production and (b) adult survey to assess the adult parameters (fecundity, spawning frequency, average weight of mature females and sex ratio). Sampling is taking place in June, which is the period of peak spawning for the anchovy. The study area includes the northern Aegean continental shelf (the Limnos and Samothrace plateau, the gulfs of Kavala, Strymon, Chalkidiki and Thermaikos as well as the Pagasitikos, Northern and Southern Evoikos and Saronikos Gulfs (chapter III).

Biological Sampling of Catches: Composition by Age and by Lenght

In order to meet all the needs of biological sampling of Hellenic landings as described in Articles 10 and 11 of Regulation 1543/2000 an extensive sampling plan is required which will cover all biological parameters for species mentioned in the regulation. This plan includes species which are collected using all fishing techniques, in different fishing ports and times of the year so that the length of catches and other biological parameters (length, age, maturity) described in the regulation are representative both in terms of time and geographical area and fishing technique.

Collection of economic data by group of vessels

The method that will provide acceptable results on the economic state of the fishing fleet is the sample-based collection of economic data from the sampling sites given in Figure 1.

The parameters that will be recorded for each individual vessel (in accordance to the Regulations (EC) 1543/2000 and 1639/2001) will be the following:

- Total income as well as distribution of income based on the species.
- Production costs detailed in categories (personnel, fuel, maintenance etc.).
- Fixed costs (average cost calculated from investment)
- Leverage ratio of own to foreign capitals.
- Assets.
- Prices of fisheries products per tonne for species sold in the market.
- Distribution of the personnel based on occupation and tasks.
- Technical description of the fishing vessel (tonnage, engine power, age and fishing gears used).
- Fishing effort.

Details are given in Chapter III.

Collection of data concerning the processing industry

According to the Regulation (EC) 1543/2000 annual data by type of processing industry must be collected, as specified in Annex IV, to estimate the following parameters:

- Production expressed in volume and value terms for product categories,
- The number of enterprises and the number of jobs
- Changes in production costs and their composition

Data to be studied will be provided by (1) interviews of all enterprises in the sector (completing of a specific questionnaire), (2) official bodies such as the Chamber of Commerce, the Ministry of Rural Development and Food, the Statistical Service, the fishing ports and (3) from official financial agencies (the press, institutes, etc.).

Database of Fisheries Data

The main features of the database that has been developed for the program are:

- The data storage and management system, which consists of a central relational database and regional databases. These regional databases constitute the servers for the raw data, which is then sent to the central database. There is two-way communication between the central database and the regional databases.
- A data diffusion system. This system consists of a webpage, which has a live connection to the central database and provides information to remote users via the Internet with the assistance of a wide number of available queries.

A complete version of the fisheries data management and statistical analysis software has been installed on both the local and central computer systems so that there is autonomy in entering, processing and tabulating results. Fisheries data base infrastructure is presented in Figure 2.

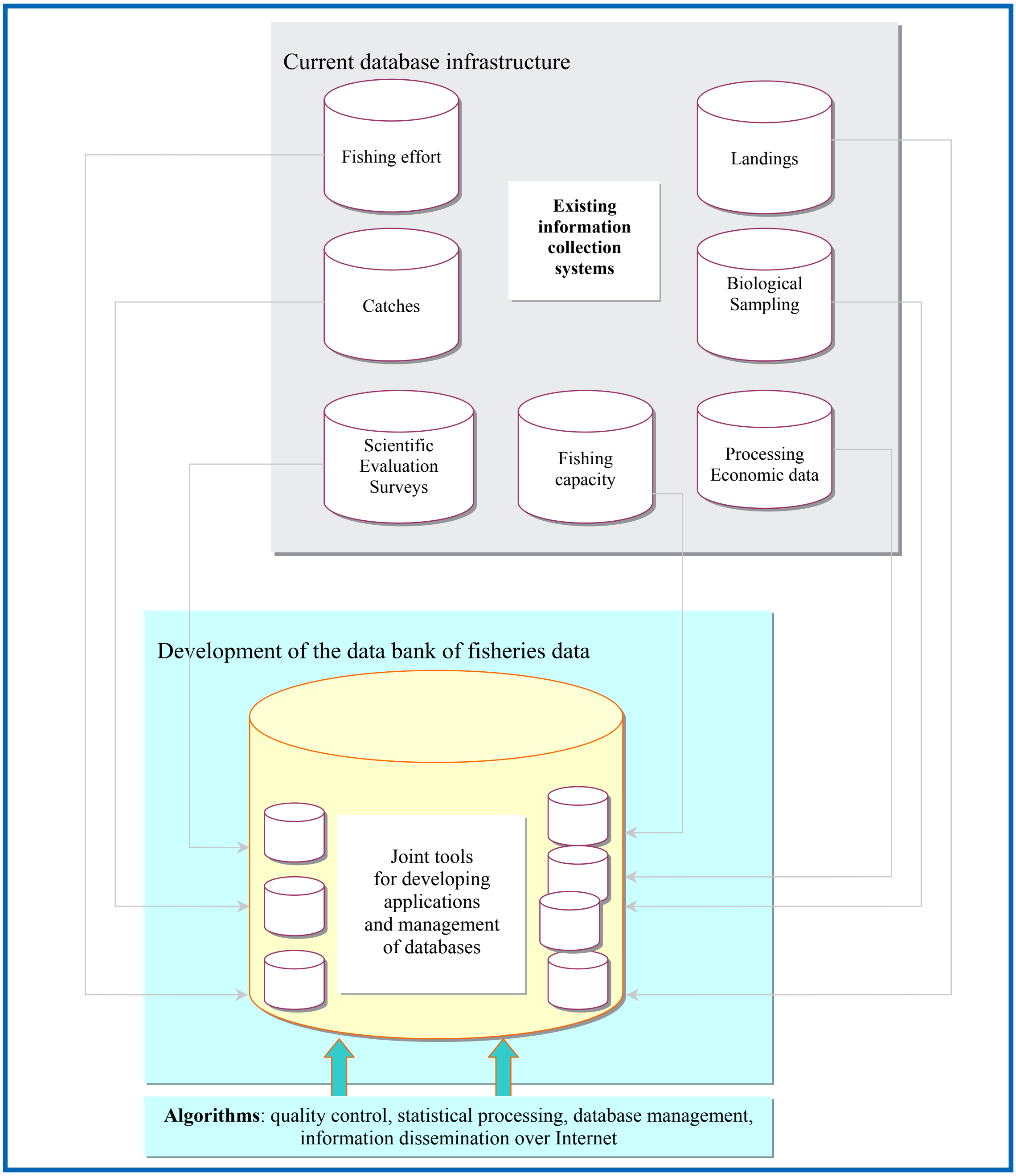

Figure 2: Flow chart of storage and management of fisheries data.

THE FUTURE FRAMEWORK

In 2006, there was an opportunity to review the Data Collection Framework. This opportunity will be used by the Commission to carry out wide consultation with Member States and end-users with the aim of establishing a firm basis for improving the Data Collection Framework.

The future goal of the new framework is to develop a long-term, integrated regional sampling programme. The Data Collection Framework will have to meet new demands, originating from the need to move towards fisheries management (fleet- and area-based management, rather than fish stock-based) and towards the ecosystem approach to fisheries management. One of the steps in this process will be the inclusion of collection of environmental data with the primary purpose to monitor fisheries impact on the marine ecosystem. Nevertheless, the possibility for conducting single stock-based assessments will have to be maintained.

Despite the recognized benefits brought about by the DCR, the scientific community and managers acknowledged that the current procedure of collecting biological data on a stock basis and economic data on a fleet based do not favor the provision of relevant inputs to fishery-based management advice. The setting up of the second stage of the DCR is the opportunity to integrate the fishery-based approach in the future collection of bio-economic data.

The new community framework that is expected to be implemented in 2009 aims at improving the data quality concerning the following issues:

- Support for new approaches to fisheries management (fleet- and area- based management, rather than fish stock-based)
- Support for moving towards the ecosystem approach to fisheries management
- Promote implementation of a more regional dimension to fisheries management
- Increase quality and validation of the data used in the fisheries management
- Improve access to and exchange of data
- Improve the use of the data
- Promote simplification of the data collection framework

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III.9. SEAFOOD PROCESSING

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INTRODUCTION

Processing of seafood is the main way by which spoiling can be slowed down or stopped. Processing methods usually change texture, taste and appearance of the seafood product so that the deterioration is slowed or halted, but the seafood characteristics also alter according to the process used. In general, two different species of seafood processed in the same way are more alike than the fresh and the processed product of the same species.

Processing methods

Removal of moisture: The moisture content of a fresh seafood product is about 80%. If this is reduced to about 25%, bacteria cannot survive and autolytic activity is greatly reduced. At moisture contents of 15% or less, moulds cease to grow. If stored under the right conditions, well dried seafood can be kept for several months. Drying can be carried out either on its own (Figure 1a), or in combination with smoking or salting. Whether seafood products are dried, smoke-dried, or salted and dried, the aim is to reduce moisture as quickly as possible, before deterioration can occur. Natural or mechanical drying, smoking and salting are the most common methods used for removal of moisture from seafood products.

Raising the temperature: This involves cooking the seafood by canning, boiling or smoking (Figure 1b). The seafood is subjected to high temperatures to kill bacteria and inactivate enzymes. The product must then be protected from further bacterial contamination by being hermetically sealed within a can. The inside of the can must be resistant to its

Figure 1a: Traditional drying process of the species Scomber scombrus.
Figure 1b: Salted sardine fillets in glas jars with metallic screwing cap.
Figure 1c: Decapitation and dry salting of anchovies; placing in 50 Kg metallic containers for the maturing process.
Figure 1d: Baked chub mackerel with tomato and garlic sause

contents and the outside, to ambient conditions. Canned fish will keep for long periods but canning is often an expensive process. Canning operations are generally successful only on a large commercial scale for species such as tuna, sardines, anchovies, etc. Furthermore, seafood can be boiled, with or without salt, to extend the shelf-life by several days.

Seafood marinades: These are made by storing seafood in acid, with or without salt (Figure 1c). The seafood or the final product may or may not be heat-treated. The shelf-life will depend on the processing conditions; low pH, higher salt content and heat will all tend to increase this.

Seafood sauces and pastes: They are produced mainly by mixing fish and salt together and allowing them to ferment. This results in the formation of either a paste or a liquid which is separated from the seafood solids and used for condiment purposes (Figure 1d). Different types of seafood produce pastes/sauces with their own characteristic flavour and odours.

Seafood processed products play an important role in the Hellenic National Economy including the activities of filleting, salting, drying, smoking, cooking and canning of the catch. This industry is made up of 50 small to medium-sized enterprises (SMEs) and a first assessment of their economic and social status was undertaken in December 2003. The economic status is represented by: (1) quantity and value of purchased raw material, (2) production costs, (3) value of total sales per processed species, and (4) productive capacity of the enterprises. The social status is attributed to total employment of human resources and problems of the enterprises. It is hoped that this study will contribute to the understanding of the progress of Hellenic enterprises, dealing with seafood processed products and will be beneficial to those who monitor, analyze and comment on the development of this industry and of the National Economy, in general.

METHODOLOGY

Socioeconomic data were acquired by distributing a properly structured questionnaire to SMEs of the industry, from September 2003 to February 2004. This questionnaire included five forms. The first form concerned information about the origin and value of raw material per species, and the cost of production and administration. The second form concerned the sales per species and the expenses involved. Productive capacity was dealt with in the third form. The fourth and fifth forms concerned the data of personnel employment and general information (problems) of the enterprises, respectively. The research results were gathered from processing and analyzing the data from 39 completed questionnaires (from a total of 50 distributed). The completed questionnaires produced a significantly high percentage of sampling (>80 %), based on purchases of raw materials for 2002 (2002 data were collected from the prefectural directorates of fishery and from personal communications with personnel in charge of the enterprises). As a result of this, credibility of estimations, conclusions and comparisons in time scales were enhanced. Furthermore, these data were cross-referenced to ensure their validity by visiting 14 (out of 50) SMEs. During the visits, besides the subjects covered in the questionnaires, further issues concerning production, development of new products, future trends in the sector, and the potential of collaborating with research institutes were discussed with the personnel in charge. During drawing, collecting and processing of the information of the questionnaire, problems such as the following came up: (a) mistrust and hesitation in providing data, especially for questions regarding receiving loans, sale prices of final products, price of raw material, and (b) difficulties in completing sections of the questionnaire concerning costs (production, sales, administration and financing), due to the lack of computerization in the small-capacity enterprises, and also due to the lack of time and availability of staff at the enterprises. Some basic points of the questionnaire, such as the identity of the enterprises, fundamental financial indices and the impact on the socioeconomic environment of the area, were also confirmed by the following sources: (a) prefectural chambers of commerce, industry and trade (i.e. brand name, location, V.A.T. number, phone and fax of the enterprise), and (b) prefectural directorates of fishery and veterinary that are supervised by the Hellenic ministry of rural development and food (i.e. purchase of raw material, production per species, total sales in quantity and value, employment, functioning regulations).

RESULTS

Classification of enterprises based on geographical location

The spatial distribution of enterprises that are dealing with the processed seafood products per region and prefecture, are given in Figure 2 and Table 1, respectively. It is interesting to note the decrease in the number of processing enterprises in the two most highly populated regions (Attiki, C. Macedonia). This decrease is explained by market

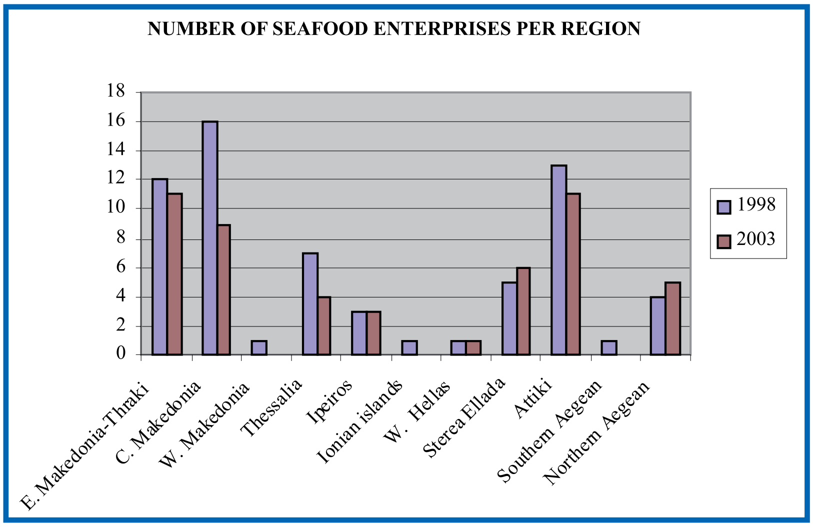

Figure 2: Spatial distribution of seafood exploitation enterprises per Region (1998 Data come from Ministry of rural development and food, Directorate of fishing applications).

Table 1. Spatial distribution of seafood exploitation per Prefecture.

PREFECTURE	Number of SMEs
Rodopi	3
Xanthi	1
Drama	1
Kavala	5
Serres	1
Kilkis	2
Thessaloniki	3
Chalkidiki	4
Magnisia	4
Ftihotida	2
Voiotia	2
Evvoia	2
Attiki	11
Achaia	1
Ioannina	2
Preveza	1
Lesvos	4
Chios	1
TOTAL	**50**

competition between the enterprises within the sector and merging of companies that resulted in shutting down of the smaller enterprises. In contrast to the decrease in numbers of enterprises, total sales of products increased. As can be seen from Table 1, there is high concentration of enterprises in Athens and in other cities like Kavala, Thessaloniki, Lesvos and Volos (Magnisia), where fish processing is a traditional form of occupation.

Hellenic seafood processing

The fish processing SMEs used 24 806 tons of raw material valued at 41 885.778 €, while the processed quantity was 21 476 tons and yielded 63 515 300 € (Table 2). The origin of this raw material was as follows: 69.7 % from local fish-piers, 24.7 % from other suppliers (imported from foreign markets), and, finally, 5.6 % from aquaculture units. Sardine and anchovy accounted for 52.4 % of the total processed quantity for 2003 (Figure 3). Sales of these two species brought in about 41.7 % of total sales of processed seafood products. The increased quantity of "other species" (1 364 tons) results because certain SMEs (1) did not provide detailed data for species and gave total data irrespective of processed species, and (2) included small quantities (299 tons) of species like gilthead sea bream, sea bass, hake and grey mullets' ovaries that are not included. In Table 3, there are comparative data of raw material for processing per species for three production years of the last decade. From Table 3, a slight increase (ca. 9 %) of processed quantity is seen, i.e. from 22 552 tons in 1995 to 24 806 tons in 2003. The Ministry of rural development and food, directorate of fishing applications is the source of data for the years 1995 and 1998. Despite the upward trend in processed quantity, the processing sector should be modernized and adjusted to current European and world specifications seeking solutions to (1) quality improvement and amelioration of hygiene, especially in the packaging stage, (2) reorganization and modernization, (3) promotion of technological innovations and "research & development" of new products, and (4) an increase in added value of processed products.

In the species smoothhands, mussel and "other" the differences between bought and processed quantities arise due to the non-processed quantities that came from the previous year. In the remaining species the differences arise due to quantities not processed during the same year and also to the sales of non-processed raw material.

Productive capacity

The quantity of processed raw material, defined as the productive capacity from 39 out of 50 companies of the seafood processing sector, reached 21 500 tons in 2003. According to current background (building and storage facilities and engineering equipment) these 39 companies can process more than 21 500 tons yearly. Consequently, there is a noticeable potential for an increase in

Table 2. Processed seafood products (yearly data 2003).

Species	Processed seafood products			
	Purchases		Processed quantity (tons)	Sales (€)
	Quantity (tons)	Value (€)		
Sardine	4 580	2 610 828	4 519	10 087 222
Anchovy	8 429	8 429 300	7 385	16 426 236
Hake	1 218	1 948 800	1 216	6 388 400
Smoothhands	19	24 700	21	27 571
Red porgy	2	5 600	2	-
Red mullet	10	18 180	10	20 429
Combers	16	62 700	11	134 750
Squid*	1 422	2 555 520	1 212	2 704 424
Cuttlefish	60	174 580	53	175 798
Octopus*	704	2 950 680	641	5 287 823
Shrimps	13	112 880	11	117 319
Trout	1 015	2 335 420	412	3 400 983
Mussels	15	46 500	17	6 502 434
Tunas	1 246	3 054 170	1 038	986 742
Chub mackerel	408	326 400	265	4 293 423
Atlantic mackerel	1 531	1 990 950	994	1 972 547
Herring	1 352	2 163 360	1 083	26 443
Surimi	7	22 770	6	201 000
Round sardinella	6	18 900	6	-
Grey mullets	5	7 500	2	29 500
Atlantic bonito	21	77 040	12	113 531
Salmon***	547	497 000	520	800 000
European eel***	811	63 000	790	84 550
Other**	1 364	1 477 000	1 735	3 651 000
Total	**24 806**	**41 885 778**	**21 476**	**63 515 300**

Note: *) The quantities of octopus and squid include musky octopus and broadtail squid, respectively.
**) Quantity «other» includes small quantities of the following species: gilthead seabream, seabass, hake and mullet ovaries.
***) In column «value» and «sales» the following were not calculated: (1) quantities of 447 t. of salmon and 804 t. of European eel because these products are final products for other enterprises, and (2) 1.065 t. from the 1.364 t. of «other» because the relevant information was not given by the enterprises.

production, provided that conditions such as: (1) increased demand for market supply (2) easy access to a plentiful supply of cheap and appropriate raw materials for processing (a particular problem of finding raw material was recorded in 2003 for sardines) (3) finding specialized production personnel, and (4) reduction of production costs by replacing the old equipment with new.

Production costs

Production costs are defined as the expenses incurred in the production of the final products and consist of: a) purchase of raw materials, b) salaries, c) energy, d) packing, and e) other expenses (such as transportation, maintenance, spare parts, rent). Administration costs and costs of distributing the

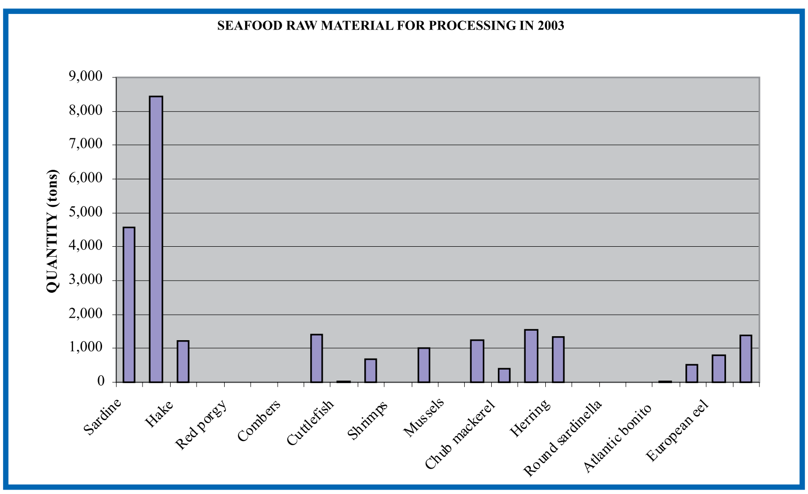

Figure 3: Quantity of seafood raw material for processing (yearly data 2003).

Table 3. Comparative data of quantities (in tons) per species concerning raw material in the seafood processing sector.

Species	1995	1998	2003
Sardine	8 679	7 269	4 580
Anchovy	7 495	7 006	8 429
Hake	-	22	1 218
Smoothhands			19
Common dentex			2
Red mullet			10
Combers			16
Squid*	351	697	1 422
Cuttlefish			60
Octopus*	735	306	704
Shrimps			13
Trout	1 669	2 118	1 015
Mussels			15
Tunas			1 246
Chub mackerel	345	1 413	408
Atlantic mackerel	2 229	1 345	1 531
Herring	54	184	1 352
Surimi			7
Round sardinella			6
Grey mullets			5
Atlantic bonito			21
Salmon			547
European eel	49	74	811
Other	946	1 585	1 364
Total	**22 552**	**22 019**	**24 806**

Note: *The quantities of octopus and squid include musky octopus and broadtail squid, respectively.

product (sales expenses) are not included in the above expenses. From a sample of 16 enterprises in the sector the following percentages were calculated for each expense in the total production cost: 51.9% for raw materials, 26.2% for production salaries, 14.6% for other expenses, 4.8% for packing and 2.8% for energy.

Employment data

In the processing sector (39 companies) 1 157 persons were fully or part-time employed (part-time employees were appropriately converted to full-time employees) during 2003. However, self-employment was not taken into account. The five bigger companies in the sector employed 68.7 % of the total personnel (795 out of 1 157 positions).

Problems encountered by the companies

Problems encountered by processing SMEs are classified according to their importance as follows: production costs (high labour costs, storage and maintenance costs for raw material and the final product), and ensuring sufficient raw material, which often results in speculation, and a high price for raw material. The transportation and the loading-unloading costs are of minor importance. In addition, other problems were mentioned such as: (a) increase in production costs and of general expenditures (electricity, telephone and fuel) mainly concerning small-capacity enterprises, (b) difficulty in distribution, sales of final products (mainly concerning small-capacity enterprises), (c) lack of support and cooperation problems with state or other authorities (social security, tax authority, Ministry of rural development and food, financing organizations), (d) intense competition between enterprises of the sector resulting in decreased profits, (e) lack of cooperation with fishermen and fish merchants, (f) low quality of raw material, (g) competition in prices with imported products (mainly canned and smoked products), (h) difficulties in finding specialized scientific and labour personnel and (i) lack of demand for traditional salted products, due to changes in the eating habits of consumers.

CONCLUSIONS

Within the frame of the above data, serious structural problems have been observed in the Hellenic seafood processing sector. For the modernization and increased competitiveness of the sector, both at the national and international production and trading levels, it is considered to be essential that the following problems must be effectively dealt with.

a) Raw materials: The seafood processing sector is facing a particular problem in finding raw material in abundance, quality and affordable prices. This is especially true for fish species coming from the local (national) market, i.e. sardines, anchovy and other small pelagics.

b) Sales: Consumers' interest in traditional processed products (salted fish) has dropped considerably and the import of similar and competitive canned products negatively affects the distribution and promotion of the above traditional products both in the Hellenic and the European markets. It is proposed that both the distribution and sales' networks for these products need to be ameliorated and that actions must be taken to establish international trading or exploitation rights for products that are of international renown and have been successfully marketed in the past. In addition, it is noted that compared to other food sectors, the seafood processing sector lags considerably behind in promoting its products. Therefore, the sector needs to invest in effective advertisement of its products, in order that the range of products available, their nutritional value, and their health-promoting qualities become known to the wider public.

c) Production costs: the increased production costs (labour costs, supply of raw material and other costs) during the last years caused sustainability problems to the whole sector and especially to small enterprises. It is suggested that the enterprises improve their organization and also improve, replace and automate their mechanical equipment.

d) Personnel - employment: the seafood processing sector is lacking in scientific and specialized personnel in production, administration and management. Furthermore, it is noted that 40% of employees in the seafood processing sector are seasonally employed. Finally, it is also noted that in small enterprises (family run) members of the family, other than the owners, are self employed.

Finally, a serious effort must be made towards a more advantageous crediting and financing policy to improve the liquidity of the SMEs in the sector. This will result in the redirection of available capital towards profit-making. Furthermore, it is considered to be very important that merging of smaller enterprises, which has been initiated in recent years, continues. The creation of larger enterprises is thought to promote the competitiveness at European as well as international levels.

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III.10. SOCIO-ECONOMIC STATUS OF THE HELLENIC CAPTURE FISHERIES SECTOR

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THE HELLENIC CAPTURE FISHERIES SECTOR

The Hellenic fishing fleet is characterized by its enormous share of small-scale coastal vessels: out of approximately 18000 units more than 17000 are smaller than 12 meters. Over 21% of the vessels of the Community fleet are registered in Hellas, but represent only 5% in tonnage and 8% in power. These characteristics also explain the main activities of this fleet, which are targeting coastal stocks around and between the numerous islands and some other stocks in the Mediterranean. Only a small group of Hellenic fishing vessels (about 35 accounting for ~12000 gt and 23000 kW) is active in international waters. The average age of the Hellenic fleet is 24.5 years. According to Eurostat (2006), in 2005 there were 18276 vessels from which 94% use passive gears (mostly coastal vessels) and 6% use towed gears (trawlers, purse seiners and shore-seiners). The average tonnage was 29 gt per vessel and the average engine power is 5 kW/vessel.

The distinction of the main types of fishing vessels is based on their main fishing gear registered for the particular vessel. These gears are the following:

1. Bottom otter trawls
2. Purse seines
3. Coastal gears: gillnets, trammel nets, longlines, hand-lines with hooks, traps and pots
4. Boat seines operated from the shore

To make things more complicated, each vessel usually has registered more than one gear license so that the fishermen can exercise fishing activities throughout the year despite the prohibitions enforced by Hellenic law. The trawls can be used for 243 days, the purse seines for 230 days and the boat seines for 182 days per year. The coastal gears are not regulated regarding their use during the year.

The importance of the capture fisheries' sector for the Hellenic socio-economy is not its annual production and value which is 0.6-0.7% of the gross domestic product of Hellas. In 2005, the total fisheries production reached 196 thousand tonnes (Figure1) from which 126 thousand tonnes was the total production of capture fisheries wich represendt a value of 645 million € (Data Collection Regulation, 2005). Its importance is that it creates jobs and income security especially in the rural areas of Hellas and the remote islands. Another important issue is the continuous negative trade balance of all European Union member states of the fisheries' sector which today is around -11 billion € for the European Union-25 and -75 million € for Hellas (Eurostat, 2006) (Figure 2).

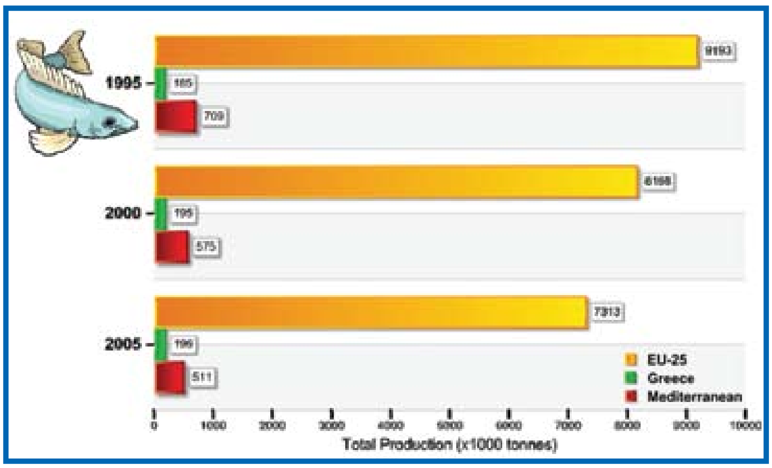

Figure 1: Total fisheries production (capture fisheries, inland water fisheries and aquaculture) trends in European Union-25 and Hellas. Source data: Eurostat, 2006.

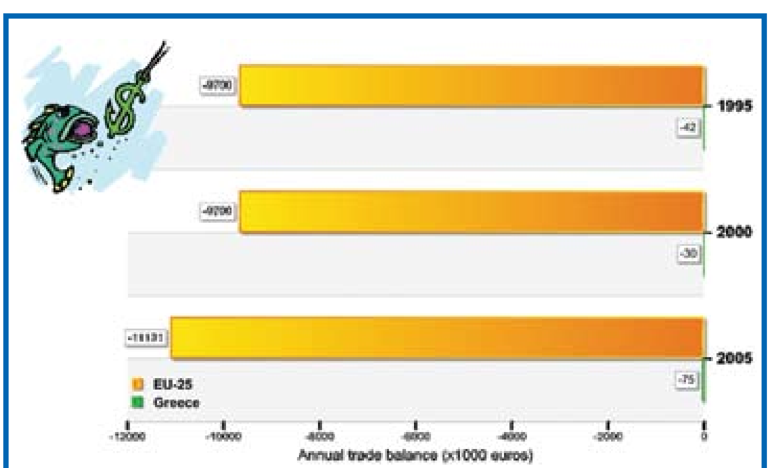

Figure 2: Annual trade balance in European Union-25 and Hellas. Source Data: Eurostat, 2006.

THE STRUCTURE OF THE HELLENIC FLEET

In 2005 census data (Data Collection Regulation, 2005), the fleet was composed of 18964 vessels. The most important segment of the fleet in terms of number of vessels is the coastal and artisanal one. This is composed of approximately 17900 vessels or 94.3% of the total fleet (Figure 3). The main characteristics of the fleet are summarized in Table I.

It is obvious that the structure of the Hellenic fleet also explains the deficiencies in the fishing sector since the majority of the vessels is coastal (small and rather old vessels equipped with small engines and incapable of making long fishing trips away from their home ports in order to exploit richer fishing grounds) and therefore, the capacity of the fleet for large production is low. In addition to this, pollution of coastal areas from the various human activities along the coastal zone (urban development, agriculture, tourism, etc.) affects the coastal stocks negatively and in turn, the coastal production is very low and significantly fluctuating during the year or from year to year, creating financial pressure on the majority of the professional fishermen and their households.

In accordance to the Hellenic law, every vessel is required to have a professional fishing license which specifies also the type of fishing gears that can be used from each particular fishing vessel. It is typical in the case of the Hellenic fleet that the vessels carry licenses for more than one fishing gear even though in many cases the vessel owners use only one (Table 2).

EMPLOYMENT

The majority of the coastal vessels is operated by 1 or 2 professional fishermen. In the case of boat seines (a part of the coastal fleet segment), the crew is composed of 2-3 fishermen. One of these persons is the vessel's owner who either operates his vessel alone or with the aid of another hired professional fish worker or fellow fisherman. In most cases the nationality of the hired staff is Hellenic. The workers are rarely nationals of another country. In all cases the workers have a friendly relationship with the owner or are related to him. The percentage of Hellenic workers in the personnel is 70-80%. Rural Hellas is characterized by closed societies and therefore, the fishing workers and the owners are often acquainted. In the case of coastal vessels, 79.4% of the workers onboard are family related to the owner (ACEA/University of Patras, 2003; H.C.M.R., 2003).

In the case of medium fisheries (trawlers and purse seiners), the fishing activity is more intense and difficult away from the coast and the home ports and therefore, experienced personnel is preferred. However, because the conditions of working are tough, Hellenic nationals do not choose to work onboard these vessels or they work for small periods of time creating problems to the owners or captains of the vessel who constantly need to hire crew. For this reason, the crews of these vessels are composed mostly of foreign nationals, about 60-70% (the vast majority is Egyptians) who remain with the same vessel for many years. In addi-

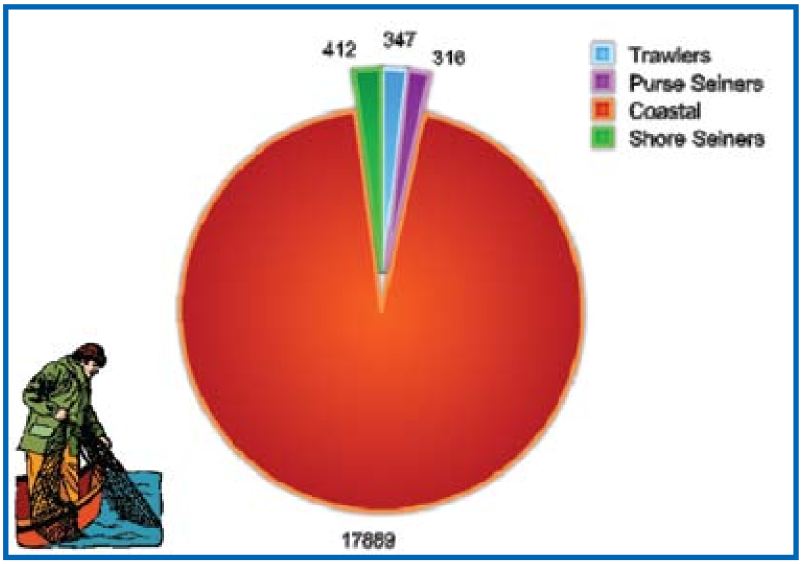

Figure 3: Composition of Hellenic fishing fleet in number of vessels (2005). Source Data: Collection Regulation, 2005.

Table I. Summary of major characteristics of Hellenic fishing vessels.

	Average tonnage (gt)	Average power (kW)	Average length (m)	Average age (years)
Trawlers	82.30	274.90	23.72	22.63
Purse Seiners	45.68	153.90	18.18	41.30
Coastal vessels	9.47	63.10	10.93	20.86
Boat Seiners	9.80	79.80	11.25	38.47

(Source Data: Collection Regulation, 2005)

Table 2. Summary of major characteristics of Hellenic fishing vessels.

	Percentage of vessels (%)
Trawlers (mixed with purse seines)	0.55
Trawlers (mixed with other gear)	1.96
Purse Seiners	0.53
Purse Seiners (mixed)	1.65
Coastal vessels (mixed gears; longlines, gillnets, traps and pots, hooks, handlines)	94.16
Boat Seiners (mixed)	1.98

Source data: European Union fleet register

Table 3. Level of education of Hellenic fishermen (%).

	No education	Elementary school	Pre high-school	High-school	Technical School	Other education
Coastal fishermen		38.5	30.8	19.2	11.5	
Trawl and purse seine fishermen		64.9	10.8	21.6	2.7	
Boat seine fishermen	7.7	61.5	19.2	7.7		3.9

Source data: ACEA/University of Patras, 2003; H.C.M.R., 2003.

tion, foreign nationals usually come from countries where medium fisheries are an important fishing activity and they are experienced, not only on the operation of the vessel and its equipment, but also in other areas of work, such as gear, net and minor vessel maintenance. The average crew is 6 for the trawlers and 7 for the purse seiners. In the case of medium fishery vessels, 38.9% of the workers onboard are family related to the owner (ACEA/ University of Patras, 2003; H.C.M.R., 2003).

TRAINING AND EDUCATION

The Hellenic professional fishermen in most cases are educated. The majority of the fishermen have graduated from elementary school and pre-high school (>60%), some are graduates from high-school (~10%) and a few have graduated from a technical school (<10%; Table 3).

HOUSEHOLDS

An important socio-economic indicator is the size of the fishermen households. This indicator provides important information on the number of people directly or indirectly involved in the fisheries' sector and which are directly supported by the operation of the vessel and the income emanated by this activity. A typical characteristic of Hellenic fishermen's families is that they are large. The families of boat seine fishermen can be composed of up to 9 persons with an average of 4. The families of the coastal fishermen are often composed of more than 5 persons with an average of 2 (ACEA/ University of Patras, 2003; H.C.M.R., 2003).

GENDER ISSUES

Women are not directly involved in fishing activities. However, their role in supporting the fishermen (especially in the case of coastal and artisanal fisheries) as well as their role as workers in the processing industry is extremely important. The average percentage of women participating in fishing activities of the coastal and artisanal segment is 6-7% and nil for the medium fisheries' segment.

FISHING OPERATIONS AND COSTS

The cost of fishing is a highly variable socio-economic indicator for the fishermen. It is affected not only by national problems but also international with the prices of fuel and fuel derivatives (oil) being the most important. Among the national reasons for cost fluctuation, the most important are the regional VAT levels set by the Ministry of Economics and Finance and product transportation costs. In addition, there are several cost items characteristic for particular fleet segments which affect further the instability of the costs. In the case of coastal fisheries this is the cost of maintaining the gear (mainly gill nets) which are damaged on a regular basis either during normal fishing operations or because of damages from endangered species or species under protection such as dolphins,

seals and rarely turtles. The cost of medium fishery operations is mainly affected by the fuel prices since this fishing activity is characterized by very long fishing trips far away from home and landing ports. Until today, the cost of fishing did not seem to affect net income from medium fisheries while it affects significantly the net income from the coastal fishing operations which in many cases is negative and the debts of the coastal fishermen are usually very high (either as bank loans or debts to the local fishing gear retailers).
According to recent studies (H.C.M.R., 2003), the total cost of trawlers, purse seiners (medium fisheries) and boat seiners (coastal fisheries) is approximately 307 000 € and 66 000 €, respectively (Table 4).
The total cost of fishing operations for the various Hellenic fleet segments in accordance to the Data Collection Regulation data is summarized in Table 5.

PRODUCTION AND INCOME

The average annual fishing production of trawlers and purse seiners is 80.90±22.7 tn while that of the boat seiners is 17±8 tn per vessel. The annual average production of the coastal vessels is 850-1000 kg per vessel. With an average price of 7.7 €/kg for the most important fisheries products in 2005 (Data Collection Regulation, 2005), the average annual product of fisheries per vessel is 600-630.000 € for the trawlers and purse seiners, 130-140.000 € for the boat seiners and 7-10.000 € for the coastal vessels. From Table 5 it is obvious that the coastal fishermen cannot cover their operational costs from their fishing activities. For this reason more than 90% of these fishermen are elsewhere occupied as well (services, agriculture activities, etc.) on a seasonal or part-time basis and this is also the reason for high debts as mentioned before. More than 80% of the fishermen have another source of income, such as:

- Ownership of retail fishery product stores (common)
- Ownership and exploitation of agriculture plots and/or livestock herds as permitted by Law 1361 (very common)
- Occupation as seasonal workers in regional authorities (fire department, etc. - common)
- Members of the families (wives) also work

Table 4. Summary of fishing costs of the major Hellenic fleet segments and gears.

COST ITEM	TRAWLERS PURSE-SEINERS	BOAT SEINERS
Captain's salary	44 247.00 €	14 926.62 €
Crew salary	71 386.25 €	11 725.82 €
Vessel maintenance (damages)	10 785.13 €	3 803.25 €
Fishing gear maintenance (damages)	7 705.32 €	1 745.24 €
Vessel maintenance (regular)	15 140.53 €	1 666.36 €
Fishing gear maintenance (regular)	11 177.60 €	3 549.80 €
Fuel	53 796.00 €	5 413.91 €
Crew supplies	14 184.49 €	9 436.69 €
Fishing supplies	550.00 €	- €
Packaging etc.	5 558.57 €	1 327.93 €
Insurance costs	32 317.66 €	3 644.44 €
Unforeseen	40 027.28 €	8 586.01 €
TOTALS	**306 875.82 €**	**65 826.07 €**

Source data: H.C.M.R., 2003.

Table 5. Summary of fishing cost of the major Hellenic fleet segments and gears.

COST ITEM	ANNUAL COST	
	2004	**2005**
Trawlers	263 841.02	199 614.75
Purse Seiners	170 858.98	185 912.00
Coastal and artisanal segment	17 845.41	21 401.80
Boat Seiners	31 318.77	22 498.00

Source data: Data collection Regulation, 2004, 2005.

(common)
- Ownership of taverns (rare)
- Tourism, such as rental of rooms (extremely rare)

Mathematical analysis of socio-economic data on cost and income of fisheries has shown that these indicators are affected by various variables (Table 6 and 7).

MAIN SOCIO-ECONOMIC CHARACTERISTICS OF THE HELLENIC FISHING SECTOR

Alienation: the concept of alienation is that extreme specialization can cause the separation of a sector or a group of people from the surrounding society in two ways: society cannot approach or aid this group of professionals and support them in their work due to a differences in aims and other general issues and at the same time, the group cannot follow society's trends since they are mostly unable to change the ways they carry out their profession.

Specialization: the various sectors of the fishing industry require a high degree of specialization in order to achieve the expected results. High degree is required due to the scarcity of the resources.

Interdependence/Individuality: the economic concept of interdependence is based on the fact that specialization and labour division may lead eventually to the interdependence between social groups in order to achieve the same goal of prosperity. The 'individuality' of the fishing profession may not help the fisherman to gain monetary value from distributing his overheads over a greater chain of production unless he has a second occupation (seasonal and part-time in most cases) and/or own a fish retail shop.

Traditionality/Modernization: fishing in most cases is carried out using traditional methods, which were taught by the older fishermen. This is especially true for coastal and artisanal fisheries. Medium fisheries show a high level of modernization with the use of modern electronic equipment for locating fish schools. However, also in this case modernization refers to equipping the vessels with navigational aids mainly since they operate in the open sea.

Public Goods: even though the fishermen are not liable to taxes, they benefit from public goods. In this case, these public goods (apart from the usual ones such as schools, roads, hospitals, etc.) are mainly ports and fishing refuges for the protection of their vessels and gears. However, the intention of the Ministry for the Environment, Planning and Public Works which is responsible for

Table 6. Summary of sources of variation of income from fisheries.

VARIABLE	COASTAL VESSELS	TRAWLERS AND PURSE SEINERS	BOAT SEINERS
Average length of fishing trip (days, hours)	X	X	
Distance of fishing trip (km)		X	
Length of vessel	X		
Days of fishing during year	X		
Number of crew	X		
Vessel tonnage (gt)			X

Source data: ACEA/University of Patras, 2003; H.C.M.R., 2003.

Table 7. Summary of sources of variation of fishing cost.

VARIABLE	TRAWLERS AND PURSE SEINERS	BOAT SEINERS
Captain's salary	X	X
Damages to fishing gear		X
Damages to fishing vessel	X	
Regular annual vessel maintenance		X
Daily crew supplies	X	

Source data: H.C.M.R., 2003.

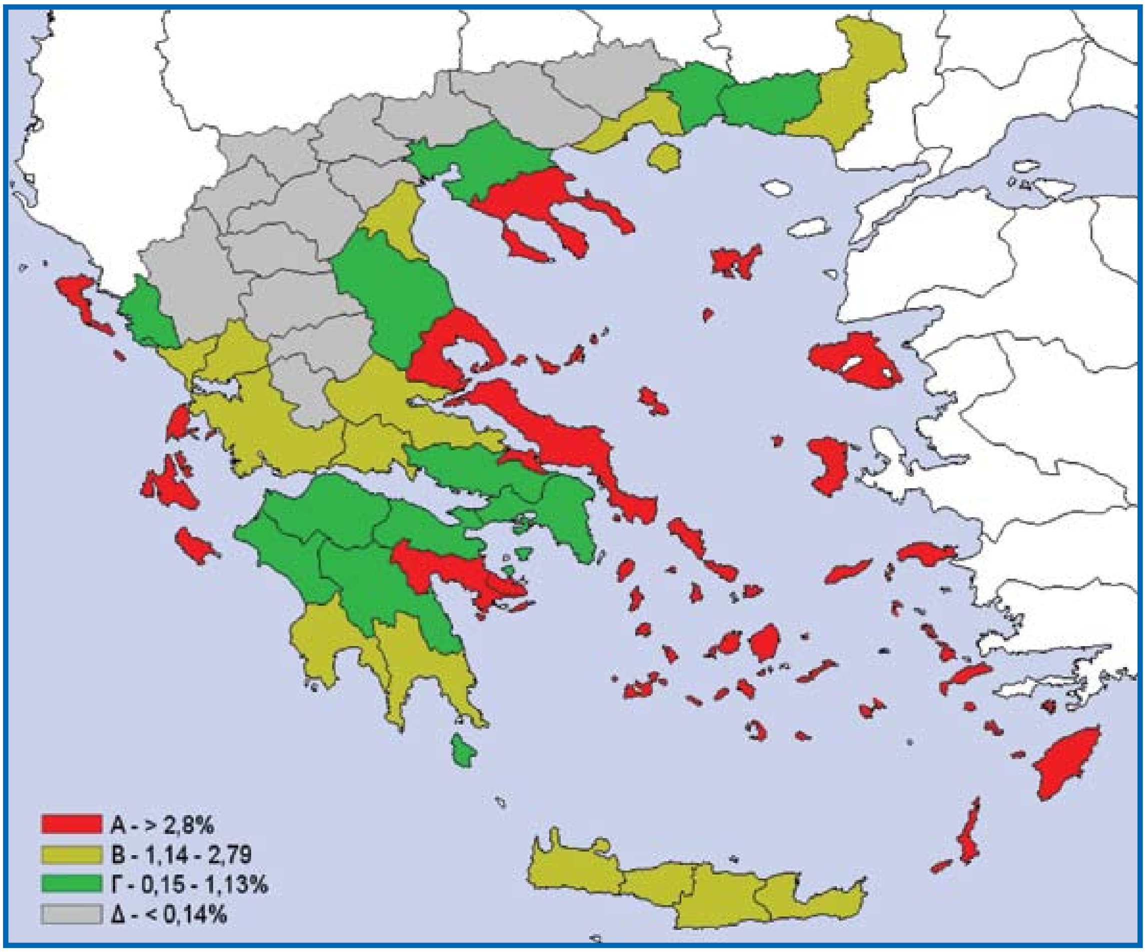

Figure 4: Dependency to fisheries zones in Hellas.
Source: Regional socio-economic studies on employment and the level of dependency on fishing, Hellas (lot 11), Final Report, November 1999, Macalister Elliott And Partners Ltd, DG XIV-Fisheries).

these works, is not to support only the fishermen since these structures also aid tourism activities (yachting, sport fishing, etc.) and in general, these works contribute to the welfare of the community. The main issue is that there are no actions from the central government directed to the fishermen alone unless there is a specific programme from the European Commission to co-fund these works in conjunction with benefiting others.

FISHING PROFESSION AND ALTERNATIVE SOURCES OF INCOME

According to the National Statistical Survey of Greece, the latest annual unemployment rate is 8.5-9.5%. The total annual unemployment rate is more or less stable and around 0.1% for the fisheries' sector. For the age class 15-24, the unemployment rate of the fisheries' sector is 5.8% and for ages above 24, the rate is 0%. This is in contrast to the other economy sectors of agriculture, livestock, retail and wholesale commerce, tourism, services and health which present rates up to the 65+ age class. This indicates that the need for working force in the sector of fishing is still high and which is in accordance with the general knowledge that Hellenic nationals do not want to work in the fishing sector. There are two main recognized reasons for explaining the stability of unemployment rates: (a) there is still a demand for workers and (b) the professional fishermen almost never change their occupation. The same result is obtained when the rates of total employment are considered: Hellenic annual rate of total employment is 55-57% (European Union-25 is 58-60%). This indicates that the available working positions in Hellas are fewer but better and more stable than in the European Union.
An important socio-economic aspect of the Hellenic labour force is that they do not like to be

part-time or seasonally employed. They prefer permanent job positions. This percentage in Hellas is merely 4.04% when in other European Union member states it may reach 40%. It is, therefore, expected that the fishermen who will be unemployed following the decommissioning of the vessels will remain active in fisheries. Actually a percentage of 4-5% of the workers in medium fisheries and 27-28% of the workers in coastal fisheries are retired professional fishermen.

Another important issue is the yield of the domestic capital. The ratio of total capital per unit of product increased from 2.43 €/unit to 4.46 €/unit (2000) with 32.73% participation of private capital and 67.26% of public funds. This means that the actual production cost of one unit of product has doubled during the last 30 years. Such an economic environment is negative for the fisheries' sector which already suffers from the reduction of annual landings and the significantly fluctuating fishing costs (especially fuel and fuel derivatives). To better understand the current economic state of the fishermen's households, the high average percentage of capital blocked to cover the household debts (loans for housing and consumer goods) which is around 23.6% and the inability of the fishermen to spread their overheads to other economic activities as well, should be considered.

Hellas, as illustrated in Figure 4 can be divided in four zones regarding the dependency on fishing (ratio between the fishermen and the total working force) at NUTS II level:

Zone A: > 2.8%
Zone B: 1.14-2.79%
Zone C: 0.15-1.13%
Zone D: < 0.14%

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CHAPTER IV

CURRENT STATE OF THE FISHERIES RESOURCES

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INTRODUCTION

An alarming decline in global fish stocks has been going on over recent decades. Despite different responses to exploitation the decline in landings was staggered in time, beginning in developed, and spreading later to developing countries waters, through the export of capacity from the former to the latter. The United Nations Food and Agriculture Organization (FAO) has produced recently a scientific consensus report, Review of the State of World Marine Fishery Resources, according to which 25% of the world's fisheries are overexploited or depleted, while an additional 50% are fully exploited, leaving little room for further increases in catches.

In the Mediterranean, catches per unit of fishing effort are also dropping, especially in demersal fisheries, and overfishing is considered among the leading problems. Although routine analytical stock assessments are not carried out in the region, and many of the commercial stocks remain non-assessed, according to the European Environmental Agency some 10 to 20% of the assessed ones are considered to be outside safe biological limits (or overfished stocks) suggesting that the fishing pressure (mortality) exerted on them, exceeds sustainability. The sustainable exploitation of fish stocks among EU member countries is regulated through the Common Fishery Policy. In the NE Atlantic and the Baltic Sea Total Allowable Catches (TACs) and quotas are set annually for the stocks by the Fisheries Council. In the Mediterranean Sea, where no TACs have been set, except for the highly migratory tunas and swordfish, fisheries management is achieved by means of closed areas and seasons and particular technical measures aiming to keep fishing effort under control and make exploitation patterns more rational.

Fisheries in Hellenic waters are characterized as multispecies and target mainly demersal and pelagic fish stocks. The demersal species such as hake, red mullet, cephalopods and shrimps are mainly caught by trawlers, while small pelagics such as sardine, anchovy, bogue, mediterranean horse mackerel and scobridae are caught by purse seiners. Among highly migratory species (tuna and tuna-like species), the main commercially valuable species are bluefin tuna, swordfish and albacore. About 50 – 60% of total domestic fisheries production consists of small pelagics. Existing assessments from research surveys indicate that most of these stocks are overfished conveying growing concerns with regard to the sustainability of both commercial catches and the aquatic ecosystem from which they are extracted, as well as to safeguarding the livelihoods of fishermen.

In the current chapter information on the state of Hellenic fishery resources is made available to readers in a clear and explicit form. Contributors have prepared comprehensive essays in which they discuss biomass trends of the demersal, small and large pelagic, deep-sea, and lagoon stocks in Hellenic waters, they underline the necessity to expand existing data collection and analysis programs to assure an adequate knowledge base that can efficiently support sound scientific advice to decision makers, and they even provide suggestions that may contribute to the improved management of fishery resources, highlighting the importance of developing such management mechanisms that will promote the sustainable exploitation of our marine resources to optimally accommodate the increasing demands from diverse stakeholders.

Vassiliki F. Vassilopoulou

IV.1. CURRENT STATE OF DEMERSAL FISHERIES RESOURCES

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INTRODUCTION

One of the main tasks of the institutions related with fisheries research is the collection of data on the distribution, biology and population dynamics of the fisheries resources in order to contribute to their stock assessment. These data are necessary at a national level for the production of advice for the sustainable management of these resources and also at an international level in the framework of the Common Fisheries Policy for the Mediterranean.

The demersal species represent about 40% of the total Hellenic fisheries production, which corresponds to about 48 000 t/year and they include a large number of high value species (Table 1). The most important of these species have been studied in many Hellenic areas using different methods, mainly experimental surveys but also fisheries data (catches/landings, onboard observation) (see chapters 8d & 6: Fisheries Data Collection Programme). An overview of the results of these investigations will be presented in order to estimate the current state of the demersal resources in Hellenic Seas. The most important species for trawl fisheries (hake and red mullet) will be analysed in more detail.

Table 1. Mean total yearly production and percentage of production per gear for the most important demersal species, as well as percentage of mean yearly production of each species to the mean total yearly fisheries production (data of Hellenic National Statistical Service, 1995-2005).

Species common name (Hellenic name)	Gear				Total (tons)	% total fisheries production
	Trawler (%)	Purse seine (%)	Beach seine (%)	Other (%)		
Bogue (gopa)	8.74	44.41	9.79	37.06	7786	6.15
Picarel (marida)	17.53	9.99	48.77	23.70	5847	4.62
Hake (bakaliaros)	56.24	1.89	4.45	37.43	4191	3.31
Red mullet (koutsomoura)	62.51	2.32	9.58	25.59	2497	1.97
Common octopus (htapodi)	24.97	0.69	5.18	69.16	2476	1.96
Cuttlefish (soupia)	19.88	0.57	3.74	75.82	2130	1.68
Stripped red mullet (barbouni)	36.68	2.05	5.85	55.43	2043	1.61
Soles (glosses)	15.49	3.47	1.13	79.91	1430	1.13
Blue whiting (prosfigaki)	88.06	1.29	3.52	7.14	1331	1.05
Pink shrimp (garides)	67.01	0.79	3.44	28.76	1328	1.05
Gurnards (vrastopsara)	45.00	2.23	6.69	46.08	1328	1.05
Prawn (gambari)	84.35	1.37	4.24	10.05	1149	0.91
Anglerfish (peskandritses)	79.94	1.36	3.74	14.96	851	0.67
European squid (kalamari)	34.52	13.15	22.33	29.99	832	0.66
Other octopus (moskii)	88.02	1.06	4.64	6.28	816	0.64
Blotched picarel (tseroula)	43.70	11.21	8.95	36.14	807	0.64
Common pandora (lithrini)	35.86	2.79	5.04	56.31	805	0.64
Scorpionfish (skorpii)	23.07	2.60	2.91	71.42	790	0.62
Saddled seabream (melanouri)	4.73	23.71	3.47	68.09	787	0.62
Norway lobster (karavida)	86.11	0.88	2.34	10.67	731	0.58
Broadtail squid (thrapsalo)	77.12	5.05	3.86	13.98	656	0.52
Salema (salpa)	7.64	42.15	4.33	45.88	571	0.45
Annular seabream (sparos)	12.37	9.58	2.25	75.81	536	0.42
White seabream (sargos)	5.78	10.36	2.68	81.18	517	0.41

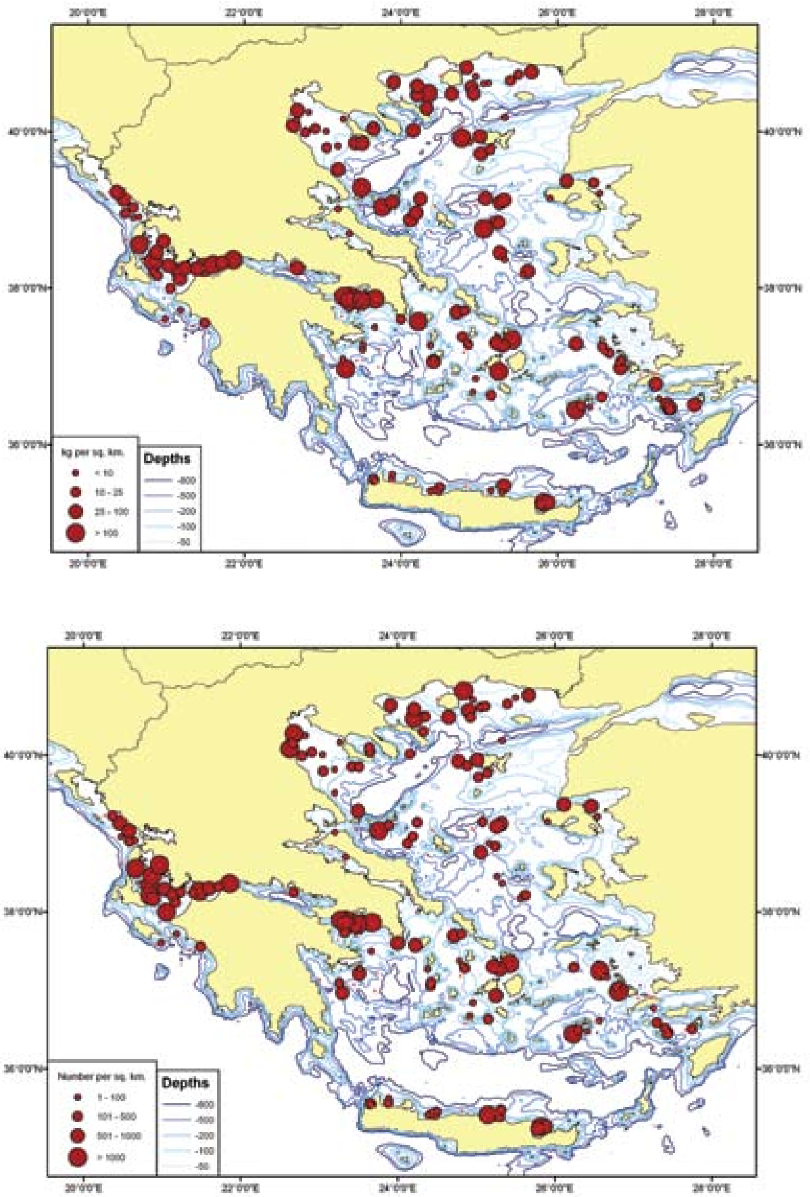

Figure 1: Distribution and abundance of hake in numbers and weight in Hellenic waters according to MEDITS-GR.

STATE OF STOCKS

Hake

Hake is fished mainly by bottom trawlers, while long lines and gill nets play also an important role in its fisheries (Table 1).

According to the trawl survey data, hake is distributed in all Hellenic Seas at depths mainly down to 600 m, although it also reaches higher depths. (Figure 1). Its length ranges from 5 to about 70 cm, however, specimens larger than 40 cm are scarce and are found mainly in depths >500 m (Figure 2). Juveniles are present all year round in all areas studied; mostly in depths < 500 m. However, the most important nursery ground of the species was observed in the Saronikos Gulf, while other important nursery grounds were also found in the Thermaikos Gulf, Thracian Sea, east of Kefallonia, south of Corfu and the Patraikos Gulf (POLITOU *et al.,* 2001; POLITOU *et al.,* 2006).

According to fisheries data, hake is fished at all depths in the Kyklades and the Ionian Sea and down to 300 m depth in the Thracian Sea (POLITOU *et al.,* 2001). The lengths of the specimens fished by trawlers range from 5 to 60 cm with those larger than 40 cm being scarce. It is worth mentioning that specimens smaller than the MLS (20 cm) are fished by trawlers in most areas during the whole fishing period. Some of them are forwarded to the market, whereas most of them are discarded. The lengths caught by fixed nets are from 20 to 45 cm, while long lines catch larger specimens (23-75 cm) (ANON., 2006). The percentage of discards of the total hake catch is estimated from 1.5 to 20 % depending on the area and the gear (ANON., 2006).

The population parameters estimated for hake in Hellenic waters from different sources are summarised in Table 2. Hake was found to be overexploited in the Ionian Sea with the highest exploitation rate in the Patraikos and Korinthiakos Gulfs. This was attributed to the fact that the first area particularly is a nursery ground of the species (PAPACONSTANTINOU *et al.,* 1988).

In most areas of the Aegean Sea, the assessments indicated that hake was overfished. The only exceptions were the Evvoikos and Pagasitikos Gulfs, where the stock was found to be under an optimal exploitation state.

Furthermore, according to the recently published data of the MEDITS Working Group on population and community indicators using the data time-series of the MEDITS programme the following results were obtained for the period from 1994 to 2004 (MEDITS, 2007): For the Aegean Sea, no significant changes during time were observed in the abundance, mean length and mortality of hake indicating a steady state. A slightly better situation for this species was observed in the Ionian Sea, with no significant changes in its mean length and mortality, but with a significant increase of its abundance with time (Table 3).

Merluccius merluccius

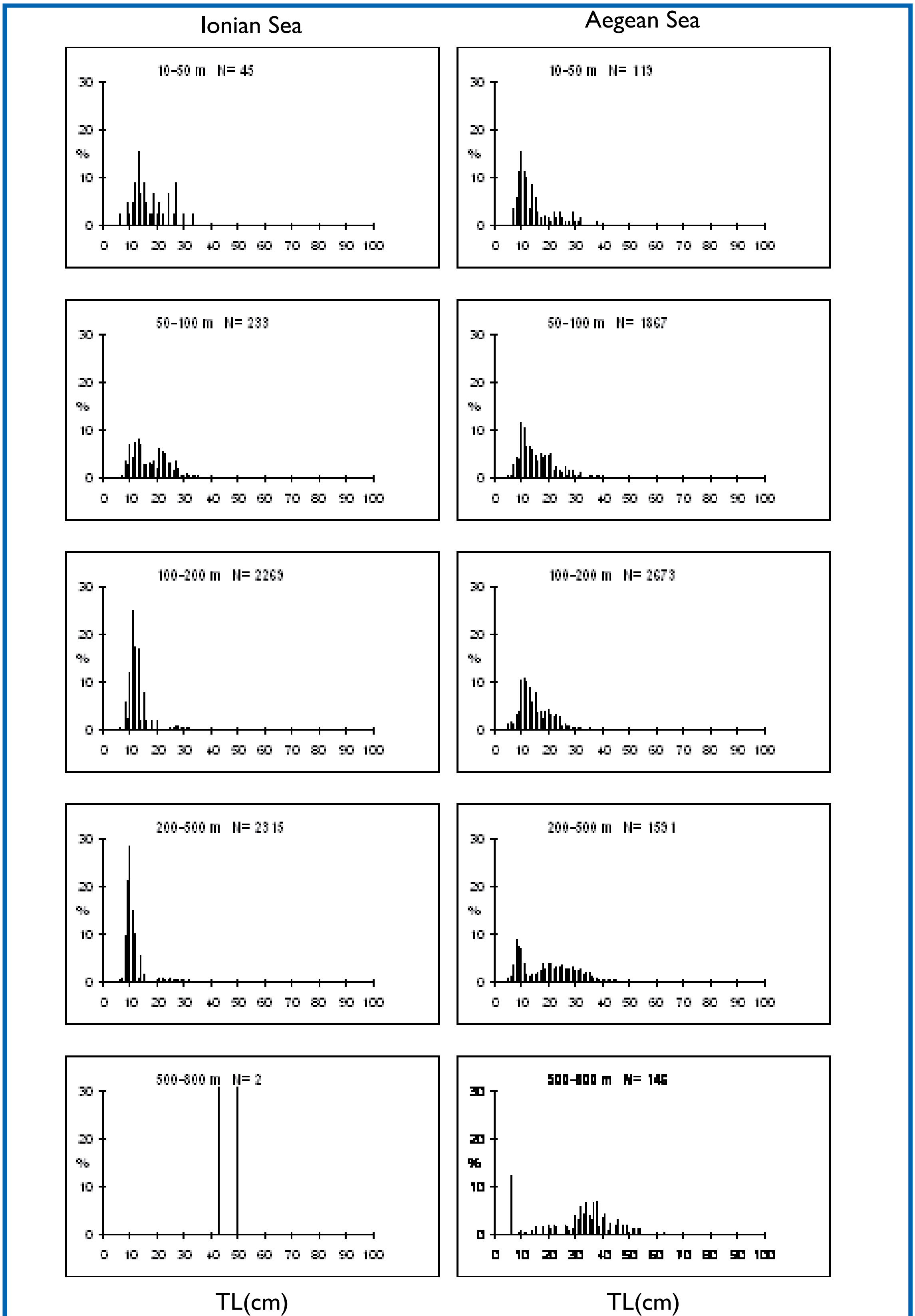

Figure 2: Length distribution of hake in Hellenic waters for different depth strata according to MEDITS-GR data.

Table 2. Summary of population parameters of hake estimated during different studies in Hellenic waters.

Area	Year	L_∞ (cm)	k	t_0	M	Z	F	E	Source
Ionian Sea									
Patraikos Gulf	1983-1984				0.18	1.17	0.99	0.85	1
	1984-1985				0.18	1.23	1.05	0.79	1
Korinthiakos Gulf	1983-1984				0.18	0.94	0.76	0.81	1
	1984-1985				0.18	1.07	0.89	0.83	1
Ionian Sea	1983-1984				0.18	0.85	0.67	0.79	1
	1984-1985				0.18	0.78	0.60	0.77	1
Total		62.0	0.174	-0.20					1
Total	1994	52.4	0.131						2
	1995	83.8	0.086		0.22	0.74	0.52	0.70	2
	1996	88.6	0.092		0.22	0.85	0.63	0.74	2
	1997	68.7	0.129		0.22	0.94	0.72	0.77	2
	1998	70.2	0.079		0.22	0.66	0.44	0.67	2
	1999	68.6	0.119		0.22	0.82	0.60	0.73	2
Aegean Sea									
Cretan coasts	1988-1991				0.32	0.75	0.43	0.57	3
Evvoikos-Pagasitikos	1986-1988	59.8	0.145	-1.60	0.32	0.56	0.24	0.43	4
North Aegean Sea	1990-1991	103.8	0.075	-1.82	0.16	0.98	0.81	0.83	5
	1990-1992				0.16	1.00	0.84	0.84	5
Thermaikos-Thracian	1991-1993	65.2	1.030	-0.17	0.32	0.76	0.47	0.62	6
Kyklades	1995-1996	64.8	0.120	-2.10	0.24	0.78	0.54	0.69	7
Dodekanisos	1995-1996	61.8	0.130	-2.19	0.29	0.79	0.50	0.63	7
Saronikos Gulf	1988-1992	73.1	0.270		0.41	2.40	1.99	0.83	8
	1998-1999	73.1	0.270		0.41	3.50	3.09	0.88	8
								E_{max}/E_{cur}: 0.51	9
Kyklades	1999-2000					2.50		E_{max}/E_{cur}: 0.54	9
Aegean Sea	1994	72.5	0.098		0.21	0.59	0.38	0.65	2
	1995	69.1	0.121		0.21	0.69	0.48	0.69	2
	1996	97.1	0.086		0.21	0.87	0.66	0.76	2
	1997	95.4	0.118		0.21	0.63	0.42	0.66	2
	1998	87.0	0.076		0.21	0.86	0.65	0.75	2
	1999	78.5	0.091		0.21	0.73	0.52	0.71	2
Sea of Kriti	1994	59.5	0.145		0.21	0.73	0.51	0.71	2
	1995	41.0	0.133		0.21	0.70	0.48	0.69	2
	1996	59.3	0.103		0.21	0.83	0.61	0.74	2
	1997	60.3	0.157						2
	1998	53.7	0.092						2
	1999	51.3	0.152						2

1: PAPACONSTANTINOU et al., 1988; 2: LABROPOULOU *et al.*, 2001; 3: TSERPES, 1996; 4: PAPACONSTANTINOU *et al.* , 1989; 5: PAPACONSTANTINOU *et al.*, 1993; 6: PAPACONSTANTINOU *et al.*, 1994; 7: PAPACONSTANTINOU *et al.*, 1998; 8: VRANTZAS *et al.*, 2000; 9: KARLOU-RIGA & VRANTZAS, 2001.

Table 3. Trends in population parameters observed for hake in Hellenic waters according to the MEDITS 1994-2004 data (MEDITS, 2007). The significant ($P<0.05$) trends are in bold.

Area	Slope Abundance	P value Abundance	Slope Mean Length	P value Mean Length	Slope Z	P value Z
Ionian Sea	**0.19**	**0.011**	-0.742	0.07	-0.12	0.43
Aegean Sea	0.07	0.079	-0.048	0.845	-0.04	0.39

Red mullet

The highest percentage of red mullet is fished by bottom trawlers. Fixed nets and beach seines are also important in its fisheries (Table 1).

According to the existing trawl survey data, red mullet is distributed mainly on the shelf of all Hellenic Seas (Figure 3) in lengths from 4 to 27 cm (Figure 4). The recruitment takes place mainly in autumn in the shallows (<50 m depth) of all areas, however, undersized specimens (<11 cm) are present in the samples of all seasons (POLITOU *et al.,* 2001).

According to fisheries data, the length of red mullet fished by trawlers ranges from 8 to 26 cm in the Aegean Sea and from 6 to 27 cm in the Ionian Sea. However, the main bulk of the catches measures from 11 to 20 cm. Fixed nets catch specimens of lengths between 12 and 21 cm in the Aegean Sea and 15 to 25 cm in the Ionian Sea. The discarded part is very low (<1%) for all gears. Concerning the beach seines, their landings are composed of lengths ranging from 8 to 19 cm, however, the undersized specimens are very few (ANON., 2006).

The stock of red mullet in the Ionian Sea was generally found under an exploitation rate not highly exceeding the optimum (Table 4). The best situation was observed in the Patraikos Gulf, whereas in the other areas the exploitation rate was higher and varied among years. Concerning the Aegean Sea, in the Evvoikos and Pagasitikos Gulfs, the exploitation rate (E) and the yield per recruit (Y/R) values showed that the species was quite optimally exploited. Similar results were obtained for the species in the Saronikos Gulf. In the Thermaikos-Thracian Sea area, although the exploitation rate was found slightly high, the Y/R method indicated a situation near the optimum. In the other areas of the Aegean Sea, the species seems to be more or less overfished with the highest exploitation rate estimated for the area of Dodekanisos.

Finally, according to the recently published data of the MEDITS Working Group using the data time-series of the MEDITS programme, the following results were obtained for the period 1994-2004 (MEDITS, 2007): In the Aegean Sea, no significant changes during time were observed in the abundance, mean length and mortality of red mullet indicating a steady state. A slightly better situation for this species was observed in the Ionian Sea, with no significant changes in its mean length and mortality, but with a significant increase of its abundance with time (Table 5).

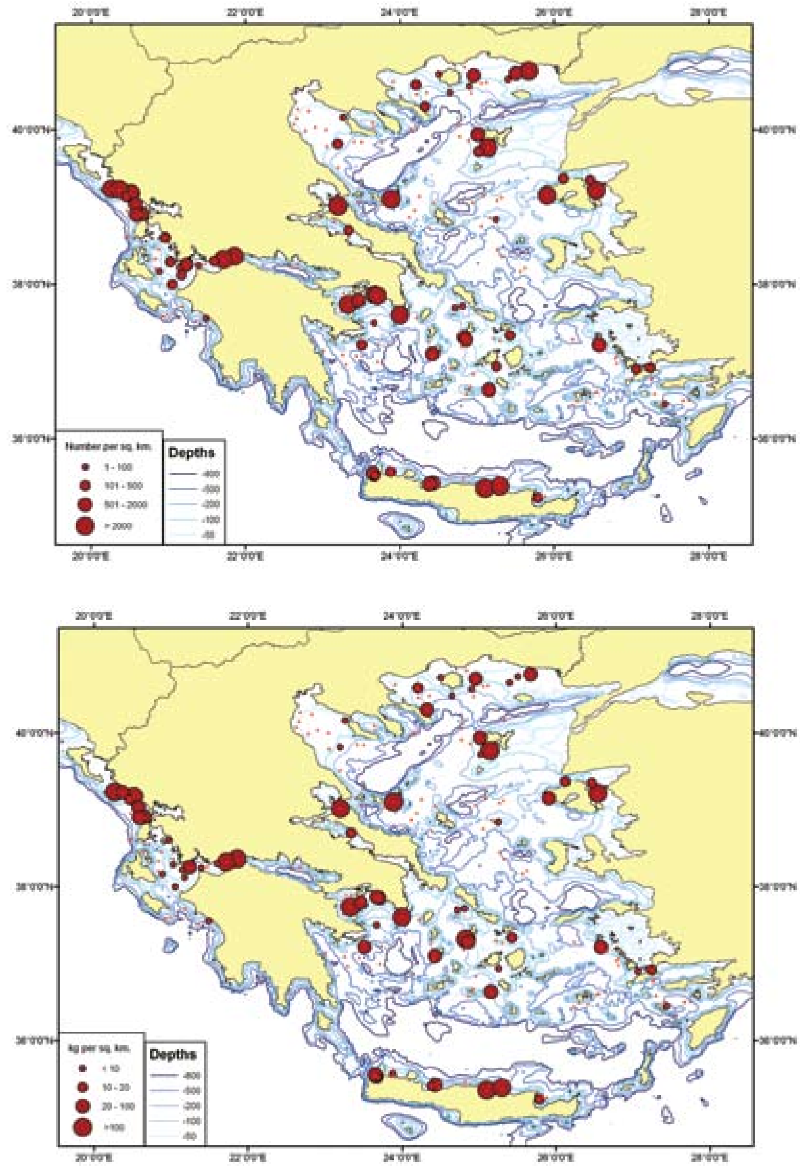

Figure 3: Distribution and abundance of red mullet in numbers and weight in Hellenic waters according to MEDITS-GR.

STATE OF THE DEMERSAL COMMUNITY

In general, the fishing impact on the demersal resources of Hellenic waters could be considered strong for depths shallower than 500 m. There was a considerable increase in the fishing effort from 1964 to 1989 and STERGIOU *et al.* (1997) applying the Fox model between catches and fishing effort found that F>Fopt at the end of that period.

Furthermore, according to the existing data the stocks of hake and common pandora in the Ionian Sea were found under a strong fishing impact, while that of red mullet was found in a slightly bet-

Mullus barbatus

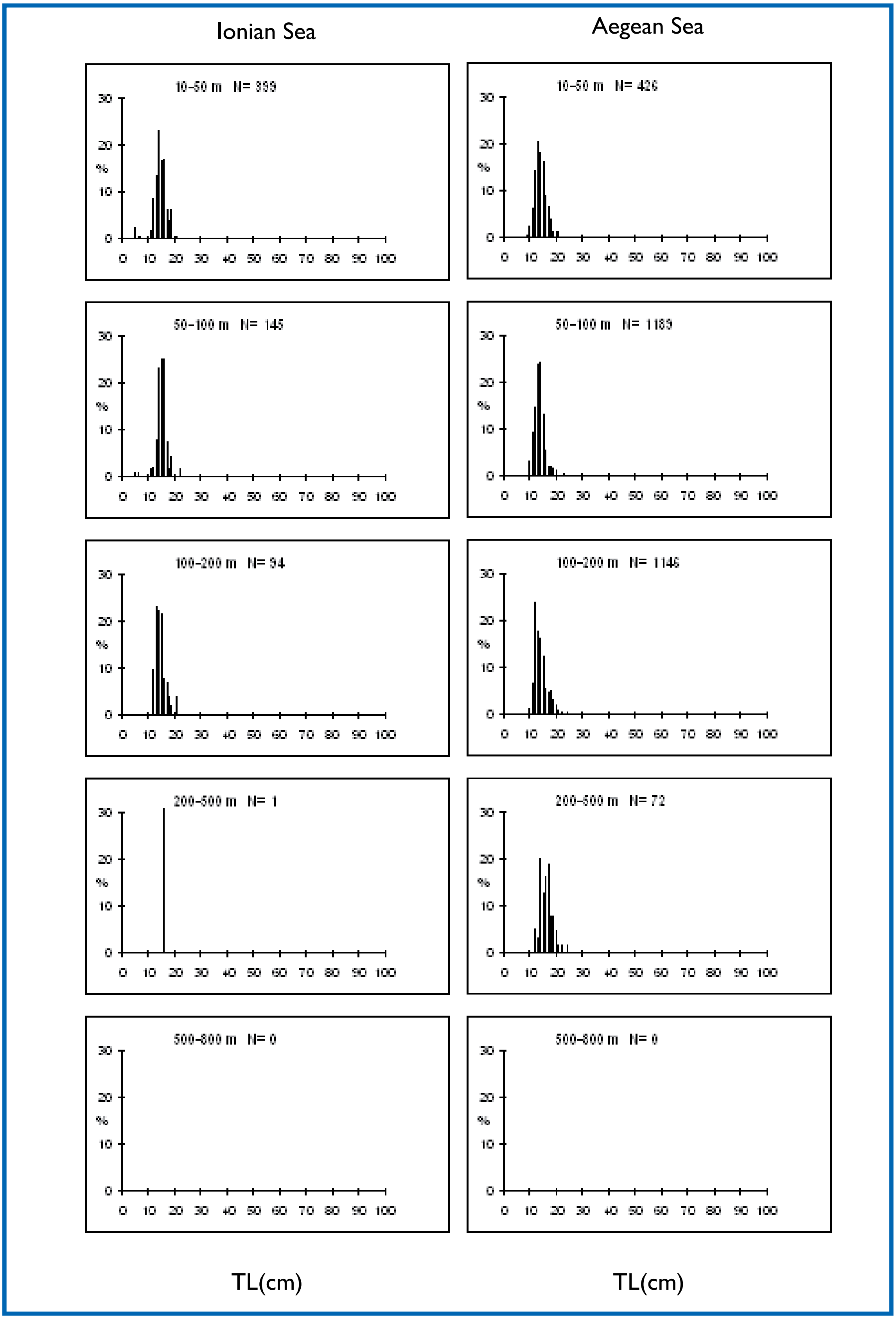

Figure 4: Length distribution of red mullet in Hellenic waters for different depth strata according to MEDITS-GR data.

Table 4. Summary of population parameters of red mullet estimated during different studies in Hellenic waters.

Area	Year	L_∞ (cm)	k	t_0	M	Z	F	E	Source
Ionian Sea									
Patraikos Gulf	1983-1984				0.19	0.43	0.24	0.56	1
	1984-1985				0.20	0.40	0.20	0.52	1
Korinthiakos Gulf	1983-1984				0.19	0.48	0.29	0.60	1
	1984-1985				0.20	0.52	0.32	0.64	1
Ionian Sea	1983-1984				0.19	0.51	0.32	0.63	1
	1984-1985				0.20	0.44	0.24	0.52	1
Total		24.5	0.135	-0.10	0.18				1
Aegean Sea									
Cretan coasts	1988-1991				0.3	1.03	0.73	0.71	2
Evvoikos-Pagasitikos	1986-1988	M:24.7 F: 32.9	M:0.15 F:0.11	M:-3.21 F:-2.52	0.34	0.72	0.38	0.47	3
North Aegean Sea	1990-1991	25.4	0.21	-2.13	0.49	1.30	0.80	0.62	4
	1990-1992	22.8	0.30	-1.68	0.49	1.80	1.35	0.74	4
Thermaikos-Thracian	1991-1993	25.4	0.21		0.47	1.28	0.81	0.62	5
Kyklades	1995-1996				0.26	1.30	1.02	0.79	6
Dodekanisos	1995-1996				0.26	1.60	1.36	0.84	6
Saronikos Gulf	1988-1992	23.6	0.51		0.95	2.00	1.05	0.53	7
	1998-1999	23.6	0.51		0.95	2.61	1.66	0.64	7
								E_{max}/E_{cur}: 1.25	8
Aegean Sea	1998				0.3	0.93	0.63	0.68	9
	1999				0.3	0.95	0.65	0.68	9
Cretan Sea	1998				0.3	0.93	0.63	0.68	9
	1999				0.3	0.99	0.65	0.70	9

1: PAPACONSTANTINOU *et al.*, 1988; 2: TSERPES, 1996; 3: PAPACONSTANTINOU *et al.*, 1989; 4: PAPACONSTANTINOU *et al.*, 1993; 5: PAPACONSTANTINOU *et al.*, 1994; 6: PAPACONSTANTINOU *et al.*, 1998; 7: VRANTZAS *et al.*, 2000; 8: KARLOU-RIGA & VRANTZAS, 2001; 9: LABROPOULOU *et al.*, 2001.

Table 5. Trends in population parameters observed for red mullet in Hellenic waters according to the MEDITS 1994-2004 data (MEDITS, 2007). The significant ($P<0.05$) trends are in bold.

Area	Slope Abundance	P value Abundance	Slope Mean Length	P value Mean Length	Slope Z	P value Z
Ionian Sea	**0.15**	**0.0127**	-0.055	0.717	0.04	0.66
Aegean Sea	0.13	0.1117	0.050	0.871	0.01	0.87

ter state (PAPACONSTANTINOU *et al.,* 1988). Similarly the demersal stocks of most studied areas of the Aegean Sea were found overfished to a higher or lower degree depending on the area and the species (PAPACONSTANTINOU *et al.,* 1993; PAPACONSTANTINOU *et al.,* 1994; TSERPES; 1996; PAPACONSTANTINOU *et al.,* 1998; VRANTZAS *et al.,* 2000; KARLOU-RIGA & VRANTZAS, 2001; LAMBROPOULOU *et al.,* 2001). The only exceptions were the Evvoikos and Pagasitikos Gulfs, the demersal stocks of which seemed to be under an optimal exploitation state (PAPACONSTANTINOU *et al.,* 1989). It must be noted that large parts of this area are totally closed to trawl fishing and the rest of the area is closed to trawl fishing for 6 months instead of 4 months applied generally to Hellenic waters.

However, changes in the fishing intensity have occurred from 1993 to 2004, when there was a gradual decrease in the number of boats operating in Hellenic waters, because fishers were subsidised for laying up their boats. Furthermore, the EC regulation 1626/94 imposed an increase of the cod-end mesh opening from 28 mm to 40 mm and a more distant operation of the trawlers from the coast, in areas where the depth was less than 50 m. The consequences of these measures on the resources can be studied by analysing time-series of abundance and of biological data. The longer

Table 6. Summary of trends in population and community indicators in MEDITS-GR areas for the periods 1994-2004 and 2000-2004. Uncoloured: no change (number of increasing populations equal to number of decreasing populations, or less than 5% populations with significant trends). Hatched: changes consistent with increasing impact of fishing (more than 5% populations with significant trends, and more populations with significant trends towards the fishing impact direction than in the opposite direction).
Light grey: changes consistent with decreasing impact of fishing (more than 5% populations with significant trends, and less populations with significant trends towards the fishing impact direction than in the opposite direction).

	1994-2004		2000-2004	
Population indicators	**Ionian Sea**	**Aegean Sea**	**Ionian Sea**	**Aegean Sea**
LnAbundance ↘	1	3	0	0
LnAbundance ↗	13	13	1	2
LnAbundance →	32	34	45	48
MeanLength ↘	4	6	0	0
MeanLength ↗	1	3	2	1
MeanLength →	34	41	31	49
Z ↘	0	0	0	0
Z ↗	0	1	0	0
Z →	4	15	0	0
Community indicators				
Total Abundance	↗	↗	→	→
Total Biomasse	→	↗	→	→
Mean Weight	↘	↘	→	→

standardized time-series of such data concerning the demersal resources of Hellenic waters is that of the MEDITS project (1994-2006). These data are being analysed by the MEDITS Working Group on population and community indicators in order to assess the state of the demersal resources in different Mediterranean areas. The published results for the years 1994-2004 are summarized in Table 6 (MEDITS, 2007). Although some of the indicators used (mean length and mean weight for both the Ionian and the Aegean Sea and mortality for the Aegean Sea) showed an increasing fishing impact on the demersal community for the whole period, there is indication of a decrease in the impact of fishing after 2000 both for the Ionian and the Aegean Sea. However, a longer time-series and more investigations are needed in order to arrive to safer conclusions.

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IV.2. SMALL PELAGICS FISH

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INTRODUCTION

Small pelagic species (anchovies, sardines, herrings, gilt-sardines, etc.) comprise a very important part of the total world fisheries' catch. Their world production ranges from one third to nearly half of the global annual totals (FREON & MISUND, 1999). In Mediterranean landings of small pelagics fluctuated greatly from year to year, presenting an increasing trend up to the mid 1980s followed by a decreasing trend by the end of the 1990s, with a noticeable fall during/due to the Yugoslavian civil war (Figure 1a). Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are the two most important small-sized pelagic species in the Mediterranean (Figure 1b). The two species making up 18-25% of the total Hellenic landings and 60% to 70% of the total purse seine landings.

In recent years, the total Hellenic fisheries' production has levelled off at about 150 000t, in contrast to the gradual rise of the fishing effort and is inadequate to meet market needs. From the two main components: pelagic and demersal fish, pelagic fish contribution to the total yearly national catch, ranges between 25-30 %. Anchovy landings were increasing reaching a maximum in 1987 and subsequently showed a descending trend, while sardine catches remained at relatively stable levels, with a drop observed by the end of the 1990s (Figure 1c).

From a management point of view, the distribution of the pelagic stocks is usually much extended covering large areas and the same stock is exploited by different countries. In the Mediterranean Sea three genetically different stocks of anchovy have been identified: a) The Aegean Sea stock, which receives influences from the Black Sea stock mainly through the inflow of eggs and larvae, b) the "Adriatic Sea" stock, and c) the western Mediterranean Sea stock covering the area from the Ionian to the Alboran Sea (MAGOULAS *et al.,* 2006). These discrete stocks demand a separate and coordinated management, which is also the appropriate approach for the two existing stocks in Hellenic waters that of the Aegean Sea and that of the Ionian Sea (belonging to the western Mediterranean –type stock) (Figure 2). This is not the case for sardine stock which consists of a panmictic population (SPANAKIS *et al*., 1989).

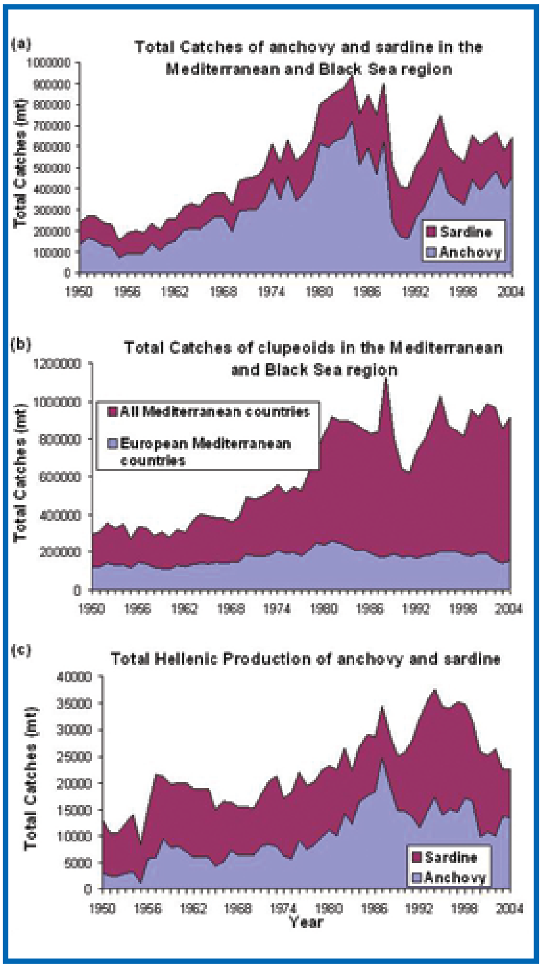

Figure 1: Landings of small pelagics in Hellenic Seas and the Mediterranean Sea.

SPECIFIC FEATURES OF SMALL PELAGICS

Small pelagics, such as anchovy and sardine, present a series of specific characteristics that are very important for their assessment and management (live in the water column, exhibit vertical and horizontal movements and they are found in high abundances because of their low trophic level). The most important characteristic of anchovy and sardine is their short life span; the bulk of the individuals found in the sea are up to three years old. This feature results in a high dependence of abundance and composition of the stocks on the in year successful recruitment. As a result, small pelagic fish stocks exhibit large fluctuations in population size which varies on interannual, decadal and centennial time-scales, implying a higher relation between small pelagic and environmental conditions in respect to other species. Many hypotheses have been proposed to explain these fluctuations, one of which being that changes in ocean climate may affect the extent or spatial and temporal location of suitable spawning habitats (van der LINGEN & CASTRO, 2004). In addition, small pelagic fish usually cover larger distances than the demersal fish and consequently their spatial distribution could significantly vary among years.

All the above-mentioned features raise several questions and demand transformations regarding application of techniques such as VPA, because the landings are not representative of the age structure of the population at sea. Especially in Hellas, where the small pelagics are explored legally only by the purse-seine fleet and pelagic trawl fishery is banned, there is a bias towards large specimens in landings (Figure 3), implying the need for in year monitoring of the stocks through fisheries' independent techniques (e.g. acoustics; Daily Egg Production Method).

Vertical migration

The diel vertical migration towards the surface at dusk, when the schools disperse and towards the sea bed at dawn, when the schools reform, is another well known specific feature of clupeids (WOODHEAD, 1966; BLAXTER & HUNTER, 1982). Earlier investigations led to the conclusion that light played a major role in initiating these vertical migrations (WOODHEAD, 1966). The importance of vertical migrations is high because it affects fisheries, as purse seining takes advantage of the schooling behaviour of fish and their attraction to light. Acoustic data derived from research surveys in the Aegean Sea, have given a more detailed description of the vertical migration of sardine (GIANNOULAKI *et al.*, 1999). Sardines were found to regulate their position in the water column according to the ambient light intensity when it was not restricted by the sea bed. In this case the fish responded to the changes in the surface light intensity, with a lag of one hour. Sardines presented a different response to light at dawn and dusk, as the existing schools dispersed more rapidly at dusk, whereas the dispersed fish seem to need more time to congregate into a school. Cosine analysis (Figure 4) revealed that sardines reached a maximum depth of 60 – 70 m at 37-45

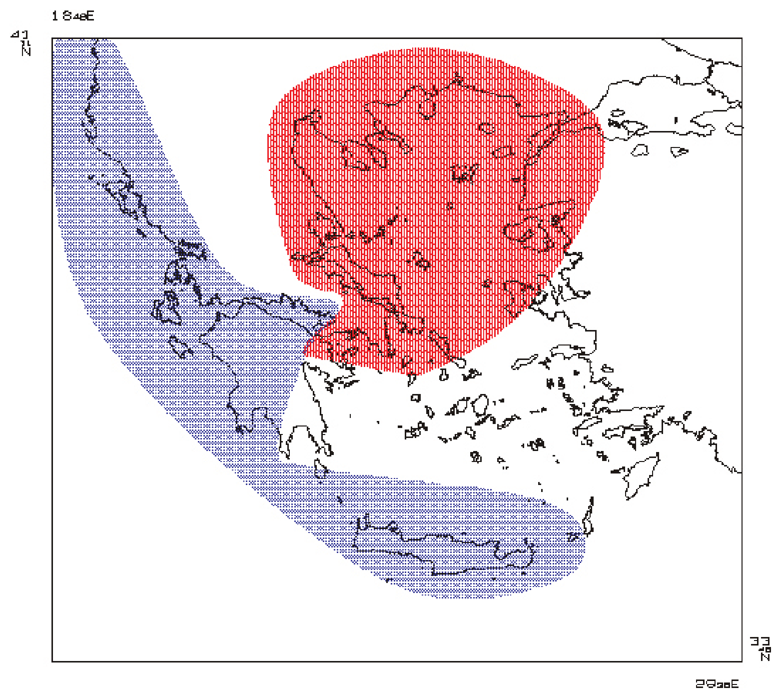

Figure 2: Distribution areas in Hellenic Seas of the Aegean anchovy stock (red) and the western Mediterranean stock (blue).

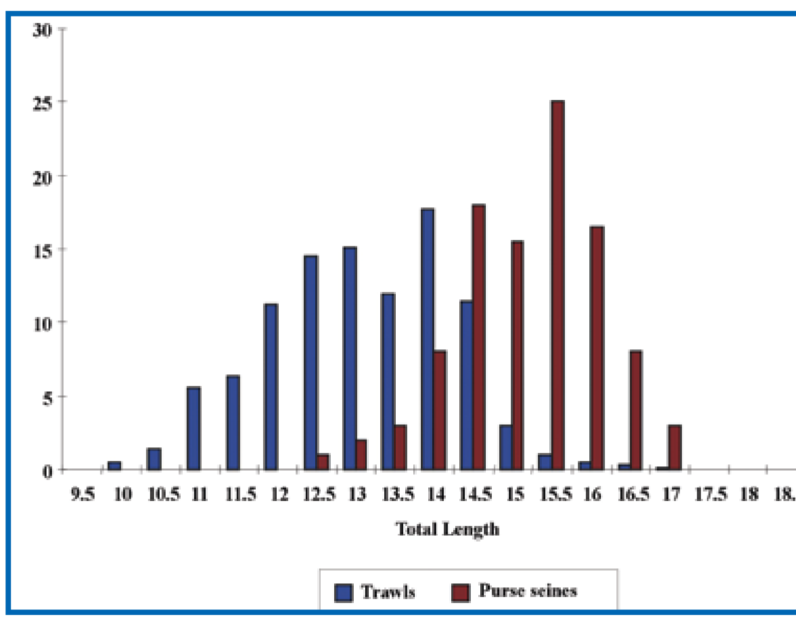

Figure 3: Length frequency distribution of anchovy collected from experimental pelagic trawling and from commercial purse seines in June 1995.

minutes after midday (maximum light intensity), whereas anchovies were observed much deeper, at depths greater than 100 m.

Three phases of sardine movements have been distinguished during the day-time: (a) descending

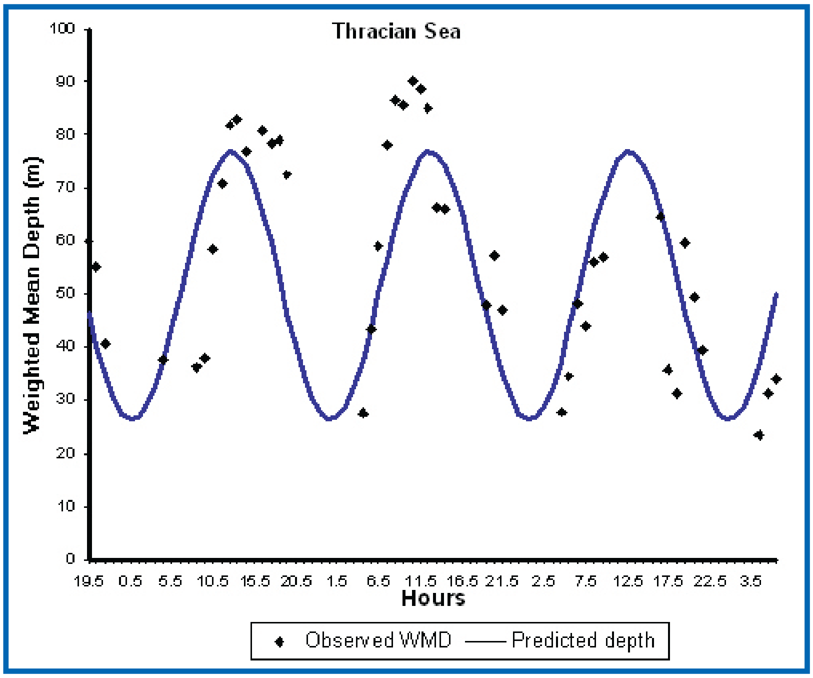

Figure 4: Observed mean depth of sardine, weighed by its abundance (WMD) and its predicted depth according to a cosine model, along with the time of day (GIANNOULAKI *et al.,* 1999).

at dawn, (b) holding depth, and (c) ascending at dusk. In between dawn and dusk, the sardine remained at about the same depth, with only a small adjustment of their position to the ambient light intensity. It seems that the background luminance and consequently the sun's position is the most important factor for the vertical migration of the sardines than the luminance *per se* (GIANNOULAKI *et al.,* 1999). During the early hours of the day the sudden increase in the light over the dark background of the sea, activates a negative phototactic behaviour resulting in the fish descending. Subsequently, when the light becomes diffuse and the background light intensity high, sardines do not change their depth significantly. An equal change in the ambient light intensity results in much smaller changes in the sardines' position compared to the early hours of the day. The minimising of the contrast between the fish and their background light intensity seems to be a criterion for adjusting the school depth. At dusk the decrease in light activates the reverse effect, a positive phototactic behaviour. Specifically, the light intensity decreases, the background becomes darker and the light less diffuse. When the background becomes dark enough a positive phototaxis is activated and the fish emerge. Fishing with light at night takes advantage of this behaviour (GIANNOULAKI *et al.,* 1999). During the night, the sardines tend to concentrate in the vicinity of isolated light sources (purse seines lamps) within a distance that remain invisible in relation to the dark background.

Other biological features

The spawning period of anchovy in the Hellenic Seas extends from May to September (SOMARAKIS, 1993; MACHIAS *et al.*, 2000a; TSIANIS *et al.,* 2003), but some spawning activity can be observed up to December in the central Aegean Sea (unpublished data). Spawning peaks around June in all areas studied so far (Figure 5) (SOMARAKIS, 1993; MACHIAS *et al.*, 2000a; TSIANIS, 2003). The major spawning grounds of anchovy in the Aegean Sea are located in areas characterized by a wide continental shelf and enrichment processes associated either with the outflow from large rivers or the Black Sea Water (BSW) in the northern Aegean Sea (SOMARAKIS, 1993; SOMARAKIS *et al.*, 2000a). Consequently, the highest egg densities have been typically observed over the northern Aegean Sea continental shelf (Figure 6a).

Data on the spawning period of sardine exist for the coastal areas of the central Aegean and Ionian Seas as well as for the northern Aegean Sea (Figure 5) (MACHIAS *et al.*, 2001; GANIAS, 2003; VOULGARIDOU & STERGIOU, 2003; TSIANIS, 2003; SOMARAKIS *et al.,* 2006). In the coastal waters of central Hellas, spawning takes place from October to May but it peaks earlier in the Aegean (November-January) than in the Ionian Sea (January-February) (Figure 5b). Gonadosomatic index data for sardine in the northern Aegean Sea (Figure 5a) suggest the existence of two spawning peaks: one in November-December and a second in March. The second peak increased its importance during the period 1996-2000 (TSIANIS, 2003). The latter was attributed to the decrease in the mean TL with time (TSIANIS, 2003), given that, in general, smaller sardines spawn later than larger ones (GANIAS, 2003).

Available studies suggest that the reproductive tactics of anchovies and sardines in Hellenic waters differ substantially (SOMARAKIS, 1999; GANIAS, 2003). Sardines seem to rely mainly on fat reserves stored in the muscles and viscera during summer to reproduce during the winter. It is characterized by low seasonal and interannual variability in batch fecundity and spawning frequency (SOMARAKIS *et al.*, 2002, GANIAS, 2003, GANIAS *et al.*, 2003; 2004). On the other hand, the reproductive effort of the summer spawning European anchovy seems to be closely associated with adult prey fields (meso-zooplankton), i.e. energy allocated to reproduction is derived primarily from food intake. In comparing batch fecundity and spawning frequency estimates between June 1993 and June 1995 over the north eastern Aegean Sea continental shelf, SOMARAKIS (1999) showed that adult food availability was higher in 1993, when waters were significantly cooler and fresher. Concurrently, female anchovies were in better condition, producing numerous large-sized eggs at a higher spawning frequency (short interspawning interval). These observations were consistent with a ration-related reproductive tactic in the European anchovy (SOMARAKIS *et al.*, 2000b; MARAVEYA *et al.*, 2001; SOMARAKIS *et al.*, 2005).

Lengths at first maturity of anchovies and sardines have been estimated for the central Aegean and Ionian Seas from samples collected during DEPM surveys. Anchovies reach maturity at approximately 105 mm total length and sardines at around 115 mm, i.e. at the completion of the first year of life (Figure 7).

There are very few age and growth studies for anchovies and sardines in Hellenic waters and otolith readings have not been generally validated. Published growth curve comparisons among stocks, areas and years have not shown any significant differences for either anchovies or sardines (TSERPES & TSIMENIDES, 1991; NIKOLOUDAKIS *et al.*, 2000). Von Bertalanffy growth parameters (Table 1) estimated from samples collected from landings, experimental trawling and onboard the commercial fishing fleet, clearly indicate (as already mentioned) that commercial catches might be biased with respect to lengths-at-age, at least for the one and two years' old fish (Figure 3). In addition, there is a clear indication that the mean length of sardines (VOULGARIDOU & STERGIOU, 2003; TSIANIS, 2003) and anchovies (LOUKMIDOU & STERGIOU, 2000) in the north western Aegean Sea has declined in recent years.

DISTRIBUTION AND SPATIAL CHARACTERISTIC OF SMALL PELAGIC IN HELLENIC SEAS

The published knowledge of the distribution of anchovies and sardines and the linkage to hydrological regimes and the topography is generally restricted in the oligotrophic eastern Mediterranean Sea. This knowledge is very important for the assessment and management of the small pelagic in the Hellenic Seas. Hellas lies in a critical transitional zone between the Aegean, Adriatic and western Mediterranean stocks and it consists of a series of separate basins connected to each other with more or less narrow passages, while it receives the influence from the Black Sea. This peculiar topography forms an ideal area to study the linkage

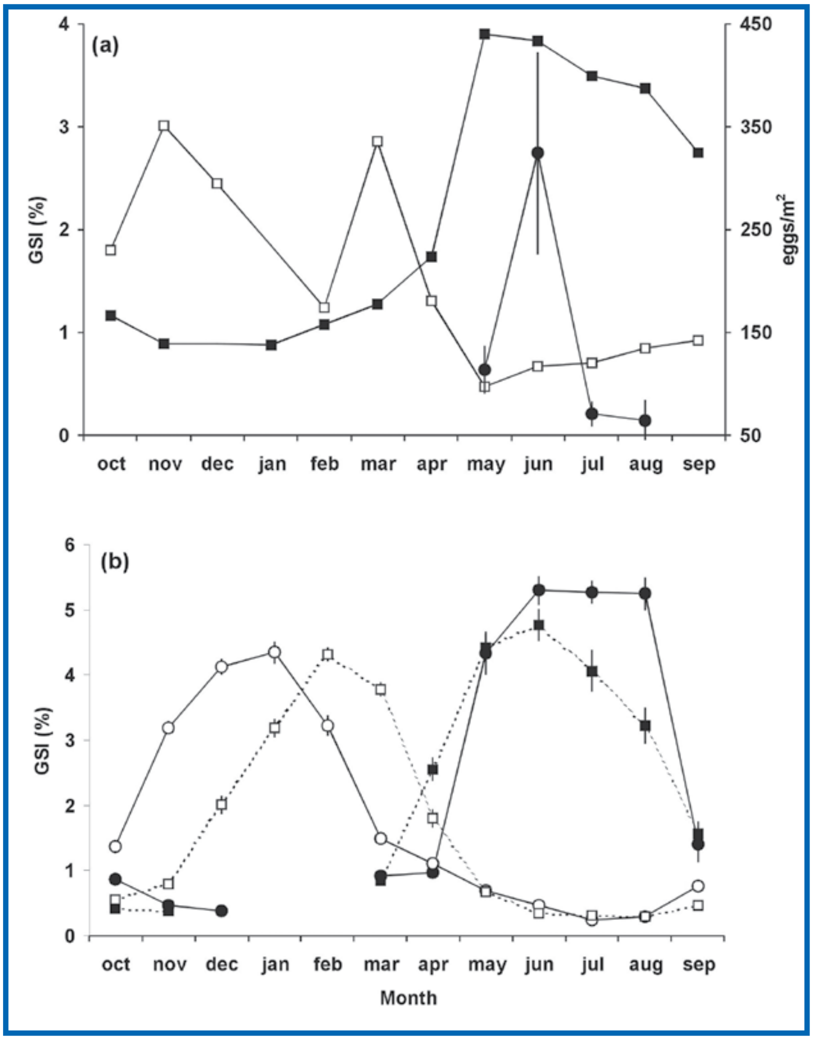

Figure 5: Data relevant to anchovy and sardine spawning periods in the Hellenic Seas. (a) northern Aegean Sea. Monthly evolution of the gonosomatic index (GSI=100*ovary weight/ovary-free weight) for sardine (□) and anchovy (■) and mean abundance of anchovy eggs in the plankton (●). Data from SOMARAKIS (1993), VOULGARIDOU & STERGIOU (2003) and TSIANIS (2003). (b) Central Aegean and Ionian Seas. Monthly evolution of the gonosomatic index (GSI=100*ovary weight/eviscerated weight) for sardine in the Aegean (○) and the Ionian (□) as well for the anchovy in the Aegean (●) and the Ionian Sea (■). Source data from MACHIAS *et al.*, (2000a, 2001b). Bars: ±SE.

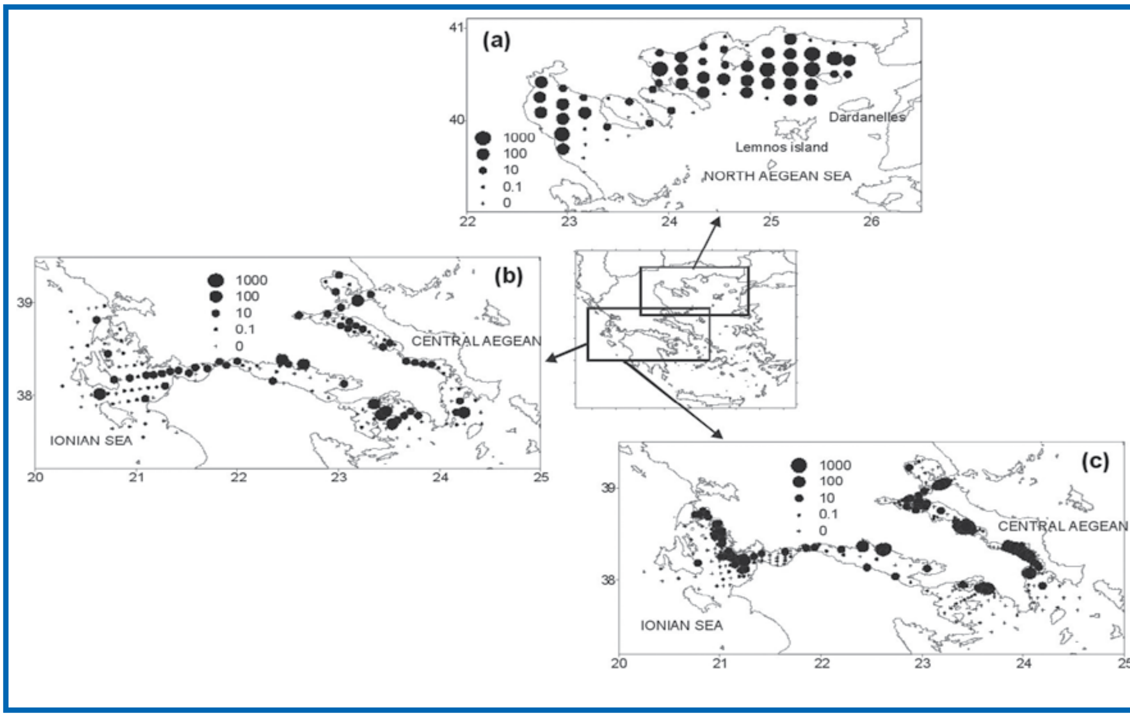

Figure 6: Distribution and abundance of anchovy and sardine eggs from ichthyoplankton surveys. (a) Anchovy, northern Aegean Sea, June 1996. (b) Anchovy, central Aegean and Ionian Seas, June 1999. (c) Sardine, central Aegean and Ionian Seas, winter 2000-2001. Data from TSIMENIDES *et al.*, (1998), SOMARAKIS *et al.*, (2002), SOMARAKIS *et al.*, (2001).

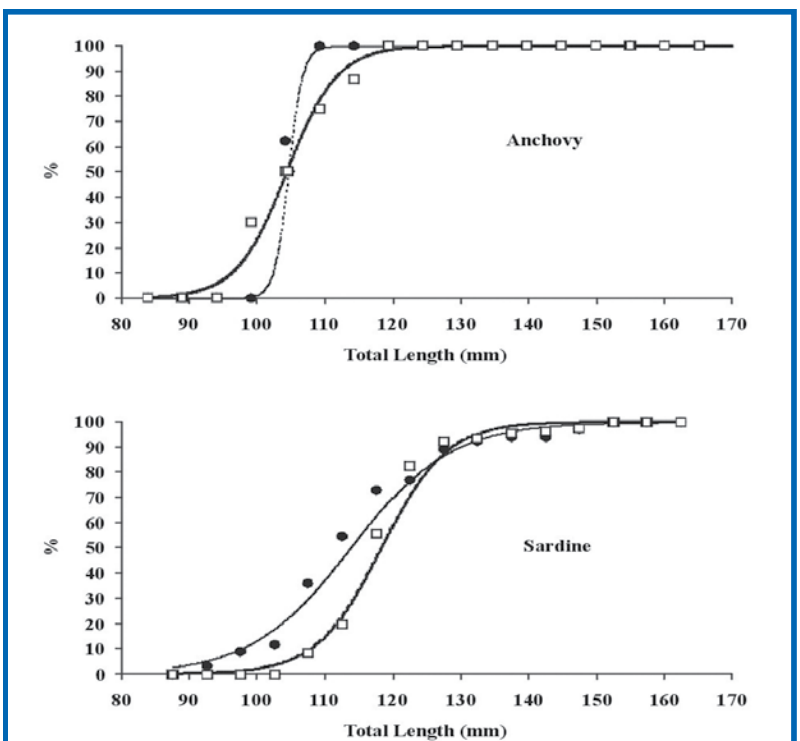

Figure 7: Length at first maturity of anchovy and sardine. Percent of mature females per length class in the central Aegean (□) and Ionian (●) Seas. Fitted logistic curves are also shown.

of environmental conditions with the distribution and abundance of small pelagic. To improve the understanding of the mechanisms that are responsible for the availability of these resources, there is a need to integrate environmental information with biological and fishery knowledge. Habitat selection affects the spatial distribution of the species and is often the outcome of the trade-offs among different agents such as heredity, predation and availability of food (FREON & MISUND, 1999).

The monitoring of landings as well as data from concurrent hydroacoustic and hydrographic surveys revealed that the main anchovy and sardine concentrations are found in the northern Aegean Sea (Figure 8). The higher concentrations of the species have been observed between the islands of Thasos and Samothraki, as well as between the island of Thasos and the Athos peninsula; areas that are characterized by the presence of two anticyclonic systems one in the Samothraki plateau (the Samothraki gyre) and another one in the Strymonikos Gulf (SOMARAKIS *et al.*, 2002; GIANNOULAKI *et al.*, 2005a). These gyres are an almost permanent feature in the area during early summer and coupled with a cyclonic system located south of the island of Thasos, the overall circulation being mainly determined by the pres-

Table 1. Estimates of the von Bertalanffy growth parameters for anchovy and sardine in Hellenic waters.

Species	Area	Year	K	L_∞ (mm)	t_0	Sampling	Method	Reference
Anchovy	Northern Aegean Sea	1993	0.280	191	-2.480	Purse seine landings	Otolith analysis	TSIMENIDES *et al.*, (1995a)
	NW Aegean Sea	1997-1998	0.75	200		Purse seine landings	Length-frequency analysis	LOUKMIDOU (1998)
	NW Aegean Sea	2000-2003	0.77	175		Purse seine landings	Length-frequency analysis	TSIANIS *et al.*, (2003)
	Thracian Sea	2000-2001	0.49	176	-1.276	Purse seine landings	Otolith analysis	KALLIANIOTIS *et al.*, (2003)
	Central Aegean & Ionian Seas	1998-1999	0.509	175	-0.888	Experimental pelagic trawl samples & onboard sampling	Otolith analysis	MACHIAS *et al.*, (2000a)
Sardine	NW Aegean Sea	1996-2003	0.80	219		Purse seine landings	Length-frequency analysis	TSIANIS (2003)
	NW Aegean Sea	1996-1999	0.86	208		Purse seine landings	Length-frequency analysis	VOULGARIDOU & STERGIOU (2003)
	Aegean & Ionian Seas	1983-1984	0.300	181	-3.210	Purse seine landings	Scale analysis	TSERPES & TSIMENIDES (1991)
	Central Aegean & Ionian Seas	1999-2001	0.314	191	-1.839	Experimental pelagic trawl samples & onboard sampling	Otolith analysis	MACHIAS *et al.*, (2001)

ence of the Limnos-Imvros stream, which carries waters of Black Sea origin on to the Samothraki plateau (SOMARAKIS *et al.*, 2002). Furthermore, both species are found in close relation to the most productive areas, such as river inflow basins and semi-closed gulfs, e.g. North Evvoikos Gulf, western part of the Saronikos and Patraikos Gulfs (Figure 8).

Anchovies and sardines are associated with anti-cyclones, which are plankton retention areas and characterized by high concentrations of mesozooplankton (SOMARAKIS, 1999), i.e. high food availability for small pelagic fish. Such structures are also known to entrain fish eggs and larvae and restrict their dispersal (HEATH, 1992). Furthermore, sardines have been found selective for warm waters, which was not the case for anchovies (GIANNOULAKI *et al.,* 2005a). Hence the sardines' selection for warm waters is probably related to growth optimisation. Another significant relationship for sardines is their affinity to shallow waters (GIANNOULAKI *et al.,* 2005a). Inshore waters are the preferred habitat for age-0 fish, which dominate the sardine population during early summer (MACHIAS *et al.,* 2001).

As mentioned earlier, anchovies and sardines form

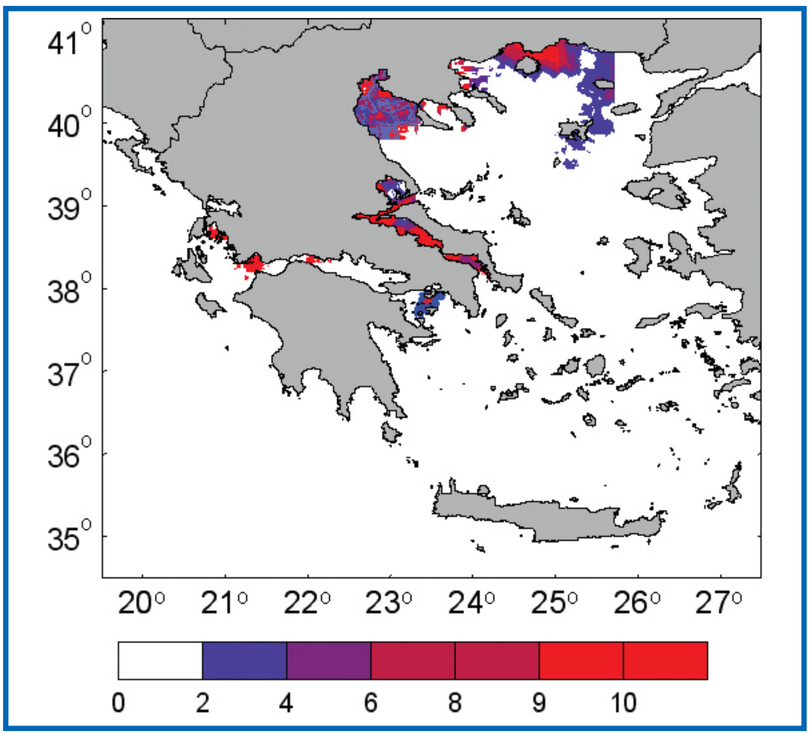

Figure 8: Distribution map of anchovies in the Hellenic Seas according to the echo integration data.

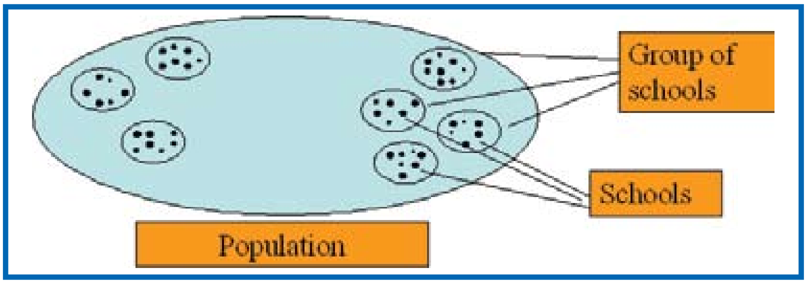

Figure 9: Diagrammatic presentation of the organization of pelagic fish spatial structure.

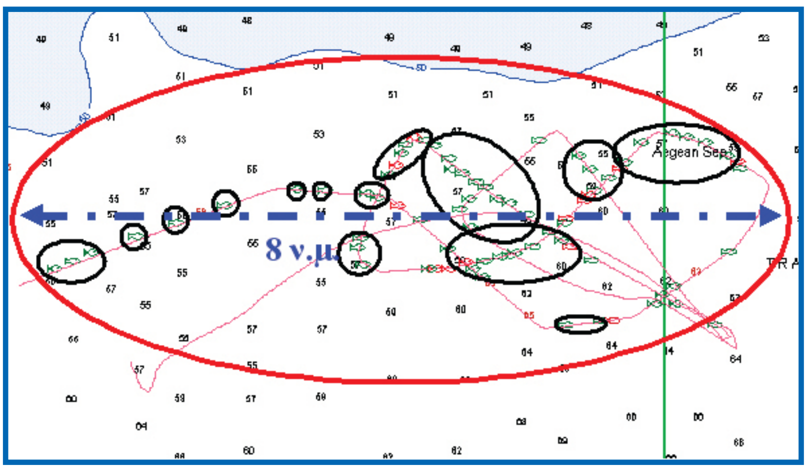

Figure 10: Schools (fish symbol) and group of schools (Black circles) noted by a fisher on the map along the seaway of the vessel (red line) during a search for anchovy in the Thracian Sea. Blue line indicates the maximum size of fish aggregation.

schools which are further organized into clusters of schools (Figure 9) as has been described in many stocks (FREON & MISUND, 1999, PETITGAS *et al.,* 2001 and references therein). This organization of fish schools into aggregations (Figure 10) is probably related to the patchiness of the environment (SCHNEIDER, 1989; SWARTZMAN, 1991). It is known that within a cluster of schools the spatial distribution can be very heterogeneous (FREON & MISUND, 1999). The structure and location of fish patches are strongly affected by two major agents: the specific way in which the fish occupy available space and secondly, the geometry of the habitat (PETITGAS, 1993).

The knowledge of the spatial organization of pelagic fish stocks is essential to fisheries' scientists because it affects both stock catchability and the results of assessment surveys, as well as contributing to the understanding of fundamental ecological processes affecting the population (FREON & MISUND, 1999). In many cases landings remain more or less stable although the stock declines, because fishing activity regarding small pelagics tends to concentrate on specific "hot spots". The investigation of the spatial structure of the fishing effort along with the spatial structure of the stock is a recently provisory research (BERTRAND *et al.*, 2004; 2005). In addition, recent studies have shown that the spatial characteristics of pelagic fish aggregations are related to the status of the stock (WARREN, 1987) and may serve as an indicator for managerial decisions.

Such studies in the Hellenic Seas have shown that further to the hydrological conditions, the peculiar topography of the Hellenic Seas affects the distribution and the spatial structure of small pelagics. This is not the case in open sea areas to which the majority of such studies are referring (MARAVELIAS & HARALABOUS, 1995; MARAVELIAS *et al.,* 1996; BARANGE & HAMPTON, 1997). The peculiarity of Hellenic Seas (islands, numerous gulfs of varying degree of enclosure, etc.) implies the need to investigate how topography affects the spatial structure of small pelagics, in order to improve survey design, better understand the seasonal movement and the interaction among species. It has been found that the geometry of the area affected the organization of the spatial structure (the way clusters of schools are organized) but not its maximum size. However, an overall effect of the area enclosure on the spatial structure of small pelagic fish populations (Figure 11) has been found independently of season (GIANNOULAKI *et al.*, 2003; 2006). Specifically, a common pattern was observed for closed areas during both summer and winter (i.e. more heterogeneous spatial structures for closed than for open areas), regarding the overall pelagic fish assemblage, as well as anchovies and sardines solely (Figure 12). The patchiness in fish distribution seems to be related to the aggregating response of fish to ambient variability, which is amplified by the coastline effect in closed areas. The extended coastline increases localities of exogenous nutrient enrichment and enhances spatial variation in the wind mixing effect and water column stratification.

Furthermore, examining the effect of area size on anchovies and sardines separately, it has been found that each species tends to distribute into patches within a small area in the winter (heterogeneous fish aggregations in small areas). This behaviour composes the picture of homogeneous fish aggregations in an overall small pelagic fish assemblage, because fish patches are complemented

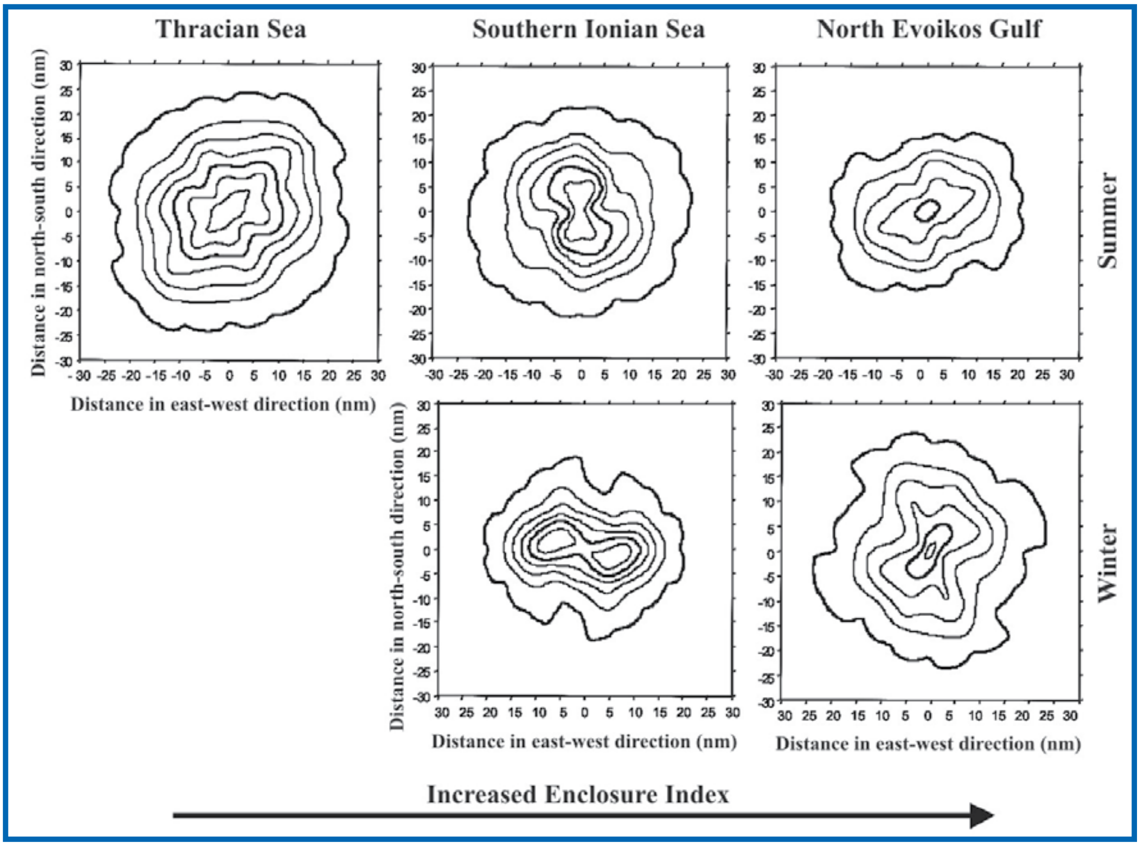

Figure 11: Changes of the small pelagic spatial structure along with the degree of enclosure.

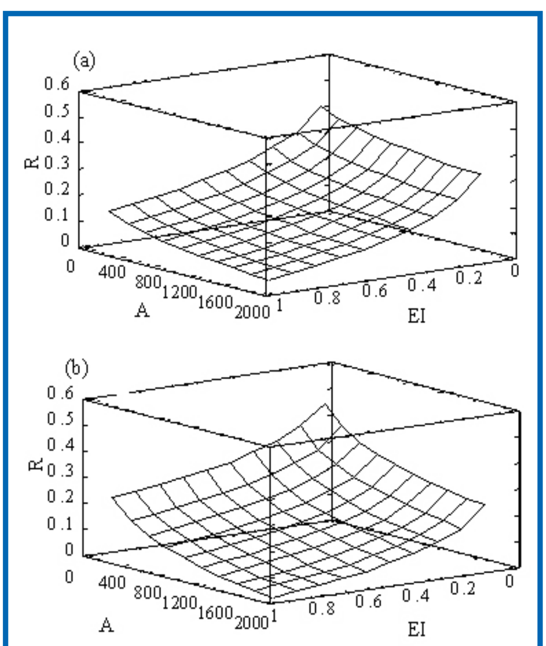

Figure 12: Changes of heterogeneity (R) with the degree of enclosure (EI) and the size (A) of the area of small pelagic fish assemblage.

between the two species, resulting in the occupation of most of the available space (GIANNOULAKI *et al*., 2003; 2006).

During winter, both anchovies and sardines tend to concentrate into more protected areas, such as small gulfs or coastal shallow waters, in order to avoid the adverse weather (with its enhanced turbulence) in open waters (FREON & MISUND, 1999). The limited available space, the heterogeneity in food availability in small gulfs along with the increase in fish concentration, results in heterogeneous spatial structure of anchovy and sardine aggregations (GIANNOULAKI *et al*., 2003; 2006). This heterogeneity in fish spatial structure is not observed during summer, when weather conditions (i.e. low turbulence) allow fish to disperse, seeking food and suitable habitats over a wide range of area. The latter could also be enforced by the high exploitation of small pelagic fish during the summer.

These characteristics of anchovy and sardine, along with the aforementioned peculiarity of the Hellenic topography should be taken into consideration in an effective management scheme of small pelagics. This need is enforced if we take into account that the management strategy due to the

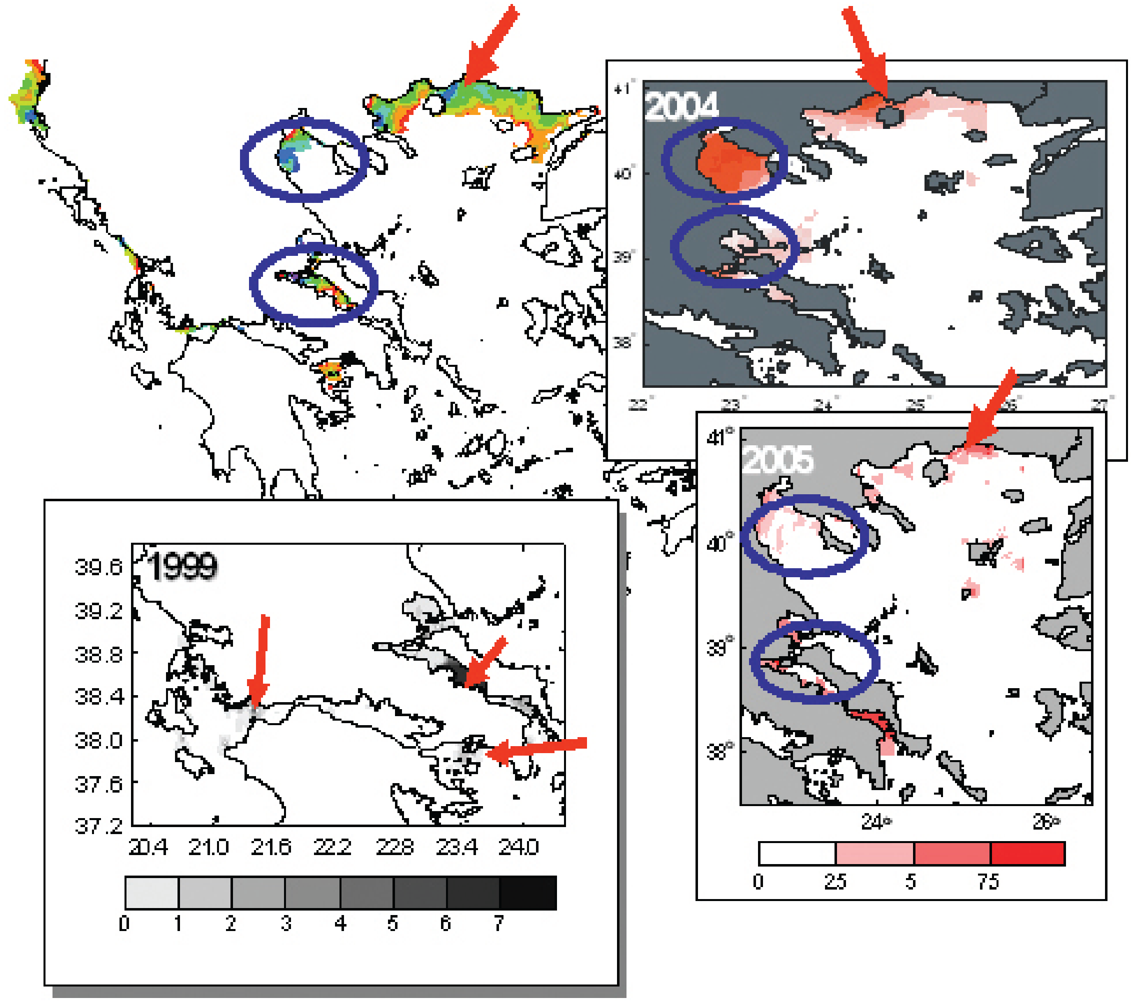

Figure 13: Predicted potential anchovy habitat in Hellenic Seas in June 2005 (top left map) based on Thracian Sea acoustic data along with maps of anchovy abundance distribution according acoustic surveys (2005, 2004, 1999).

small life span of the species should be directed to those areas and the timing in order to protect the juveniles effectively.

A weak point in the management of small pelagics in the Mediterranean Sea is that this should be ideally addressed to the total stock that usually is shared among several states. Besides the absence of a common policy between countries regarding the management, another difficulty occurs as the status of the populations of the stock in several countries is largely unknown. For example, even if we know the status of the stock in the Hellenic part of the Aegean Sea, the status in Turkish waters is largely unknown. This is also the case for the population in the Ionian Sea regarding the status of the populations in Albanian waters.

POTENTIAL HABITAT OF SMALL PELAGIC FISH

In order to partly overcome the aforementioned embedment of management, a method that gives information for the entire area that a stock occupies. This could be achieved by taking advantage of the high dependence of small pelagics on environmental conditions.

Specifically, the presence of anchovies and sardines as derived from acoustic data together with environmental satellite data (e.g. sea surface temperature, sea surface salinity, chlorophyll-a concentration, irradiance and sea level anomaly, etc.) are used through a model (e.g. GLM, GAMs, etc.) to identify the environmental characteristics that describe those areas that serve as a potential habitat of the species. In a subsequent step, GIS techniques are applied to identify and map the geographical areas where the specific set of environmental param-

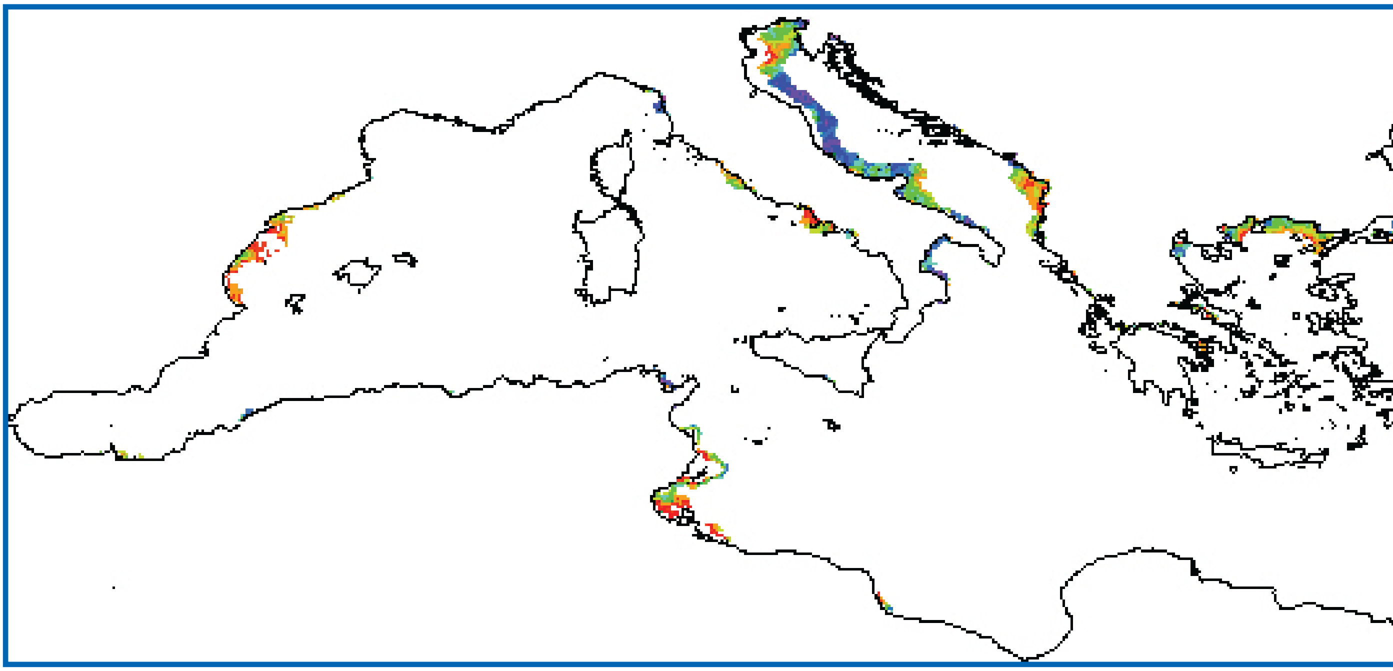

Figure 14: Predicted potential anchovy habitat in the Mediterranean Sea in June 2005 based on Thracian Sea acoustic data.

eters is met, implying the existence of potential small pelagic habitat (VALAVANIS *et al.,* 2004).

Results based on acoustic data from successive surveys (June 2004 and June 2005) in the Thracian Sea along with satellite data were used to identify and map the potential habitat of anchovies with GIS techniques (GIANNOULAKI *et al.,* 2005b). Other areas with known distribution of anchovy concentrations in the Aegean and Ionian Seas were used for the cross validation of the results. GIS mapping seems to describe sufficiently the locations where the main anchovy concentrations were found, as cross validation with existing data in Hellenic Seas shows (Figure 13).

In addition, GIS mapping also indicated areas where the specific set of environmental conditions in the eastern Mediterranean basin are met (e.g. the northern part of the Ionian Sea, Marmara Sea, etc.), as well as the Albanian waters of the western Ionian Sea; areas where the distribution of anchovy is unknown. GIS mapping for the entire Mediterranean region (Figure 14) describes quite well the areas of anchovy presence, failing however, to predict the presence of anchovy in the Gulf of Lions and the Sicily Channel. The use of data from additional areas and pooled data from several years could better define the set of the environmental parameters that characterize the areas of the main anchovy concentrations and improve results.

TRENDS IN LANDINGS AND ABUNDANCE OF SMALL PELAGICS

The spatial patterns in catch/day of anchovy and sardine identified by the IMBR data agree to a large extent with the results of the analysis of the NSSH (National Statistical Service Hellas) catch data by fishing subarea (STERGIOU *et al*., 1997). These patterns also indicate that catches are much higher in the north Aegean Sea when compared to other fishing subareas and decline from north to south. The main factors contributing to such a geographical differentiation in mean catch/day as well as total catches of small pelagics could be: (a) the gradient in eutrophy and river runoff of the Aegean Sea waters along a NNW to SSE axis, and (b) the differences in the extent of the continental shelf within the Aegean Sea (STERGIOU *et al*., 1997). The eastern Mediterranean Sea is known to be one of the most oligotrophic marine regions of the world. However, within this generally oligotrophic environment relatively eutrophic areas, such as N. Aegean Sea, do exist (STERGIOU & GEORGOPOULOS, 1993). Black Sea waters enter the Aegean Sea from the Dardanelles Strait and are colder, less saline and much richer in nutrients than the waters of Levantine origin that enter the Aegean Sea mainly from the eastern straits of the Cretan Arc.

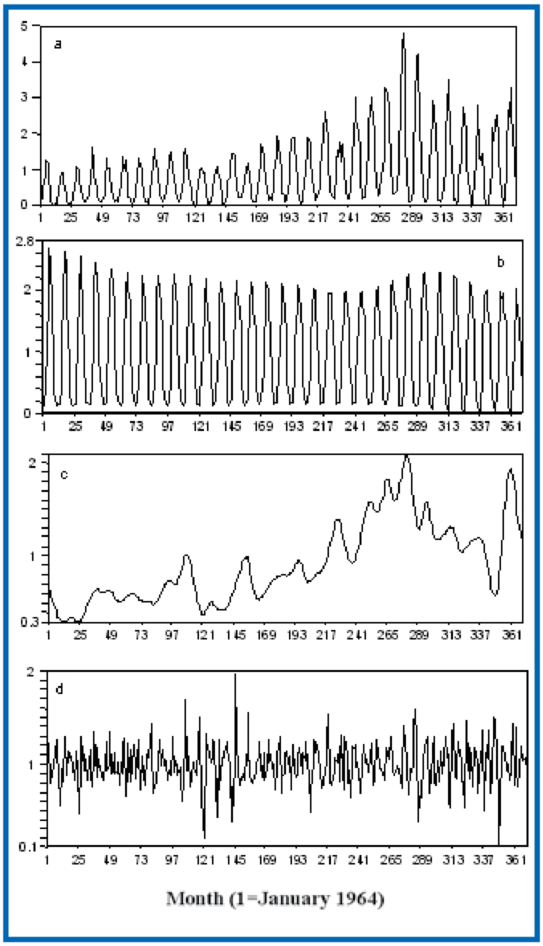

Figure 15: (a) Landings of anchovy in Hellenic waters (1964-1997) and separation of landings into the different components identified using the XII census technique; (b) seasonal (c) trend-cycle and (d) irregular (STERGIOU, 2000).

Some of the empirical models built (Figure 15), as well as the application of spectral and cross-spectral analysis on the anchovy and sardine landings (STERGIOU, 1989; 1990; 2000; STERGIOU & LASCARATOS, 1997), indicated the following interactions: (a) persistence of landings; (b) landing periodicity of 2-3 and 4-5 years; (c) that climate might affect long-term trends and short-term variation in the landings of both anchovy and sardine; and (d) variability and replacement of anchovy by sardine landings.

For the period 1996-2005, the data collected from the 30 stations of the Institute of Biological Resources of the Hellenic Centre for Marine Research showed that the total landings of purse seine fluctuated from a minimum of 9 000 – 10 000 mt to a maximum close to 17 000 – 18 000 mt per species. In the same period the landings of anchovies and sardines were highly complemented (Figure 16). The mean monthly catch/day of the purse seiners fluctuated around to 500 kg/day. The minimum values were observed in December, i.e. at the beginning of the closed period for the purse seine fishery (10/12 to 28/2). No increasing or decreasing trend has been estimated in landings of both species. In general, the monthly anchovy catch/day for purse seiners exhibited a maximum in the summertime (Figure 17). The mean monthly sardine catch/day for purse seiners exhibited maxima in spring and autumn (Figure 17). (ANONYMOUS, 2001).

The purse seiners operate between 18 and 21 days per month depending on the weather conditions, the full moon and several local practices (e.g. not fishing on Saturday). A significant increasing trend of the fishing effort, expressed as days at sea, was observed in the period 1996-2005 (Figure 18).

Taking into account the fact that the fishers maintain high catch rates by fishing "hot spots", an increase in the effort as well as an increase in landings do not necessarily reflect the status of the stock, especially in species with a short life span, such as small pelagics.

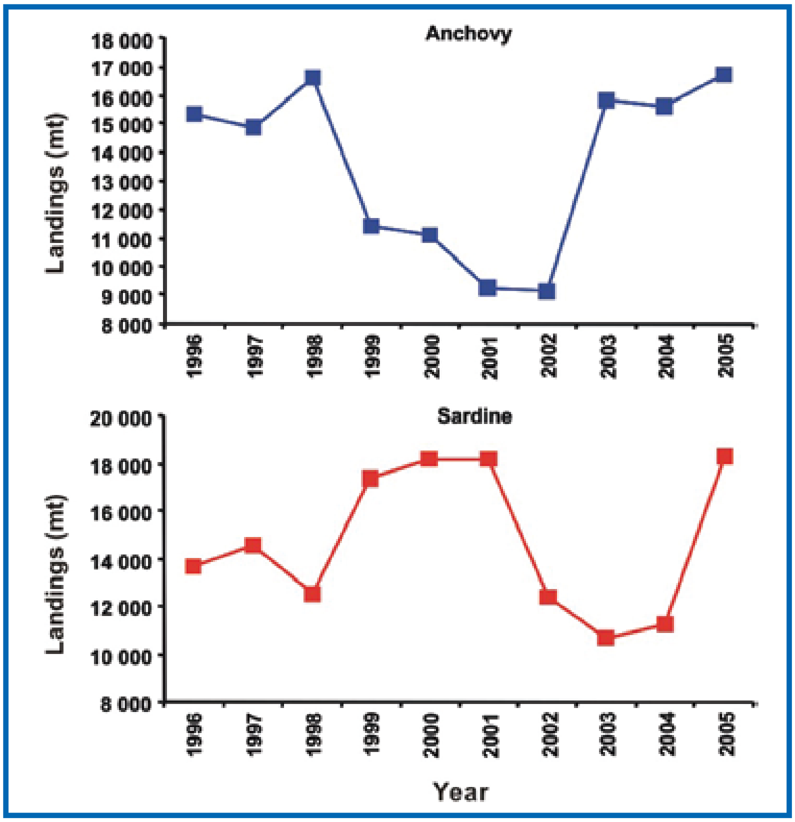

Figure 16: Purse seine landings of anchovies and sardines in Hellenic waters from 1996 to 2005.

On the contrary, if this increase in landings is associated with a decrease in the stock biomass at sea as estimated from direct assessment methods, an overfishing of the species is likely to occur. Direct biomass estimates for anchovies and sardines through acoustic and/or egg surveys have been obtained in recent years (Figure 19) in the framework of various European and National projects (TSIMENIDES *et al*., 1995a; 1998; MACHIAS *et al*., 2000a; 2001). The first acoustic surveys in the Hellenic Seas have been conducted in the northern Aegean Sea in 1987-1988, in the central Aegean Sea in 1989-1990 and in the south Aegean Sea in 1991, all aiming towards the study of the echo-distribution of small pelagic fish assemblages (TSIMENIDES, 1989; TSIMENIDES *et al*., 1995b).
A series of surveys in 1995-2001 focused on the study of the vertical and the horizontal distribution along with the estimation of anchovy and sardine biomass in the northern Aegean Sea and the coastal areas of central Aegean and Ionian Seas (MACHIAS *et al*., 2000a; 2001; GIANNOULAKI *et al*., 1999; TSIMENIDES *et al*., 1998). In these surveys the acoustic method has been applied concurrently with the Daily Egg Production Method (DEPM) for anchovy stock assessment in the northern Aegean Sea (June 1995-1996), and in the central Aegean and Ionian Seas (June 1998-1999), as well as for sardine stock assessment in the latter area (winter 1999-2000). From 2003 up to date, anchovies are regularly assessed in the Aegean Sea by acoustic and DEPM, while sardines are also assessed by means of acoustics. The abundance estimates of anchovies (Figure 20) during the reproduction period approximate the yearly landings by a factor of two. During the last years the estimated stock biomass declines whereas the landings and the fishing effort increase, implying an overfishing of the stock.

MANAGEMENT CONSIDERATIONS

The inadequacy of the regulations currently enforced for small pelagic fisheries (i.e. closed seasons, limited issue of licenses, minimum legal landing sizes, mesh size regulations, banning of pelagic trawl, prohibition of fishing small pelagics with bottom trawl or with electric light) is justified by the fact that anchovy stocks are declining. A detailed study for displacement of the existing closed season from December-March, protecting sardine spawning stocks with limited effect on anchovies, towards Autumn or Spring, will be beneficial for both species, by protecting the young of the year, as well as the stocks of at least one of the two species at the onset of the spawning period (MACHIAS *et al*., 2000b).

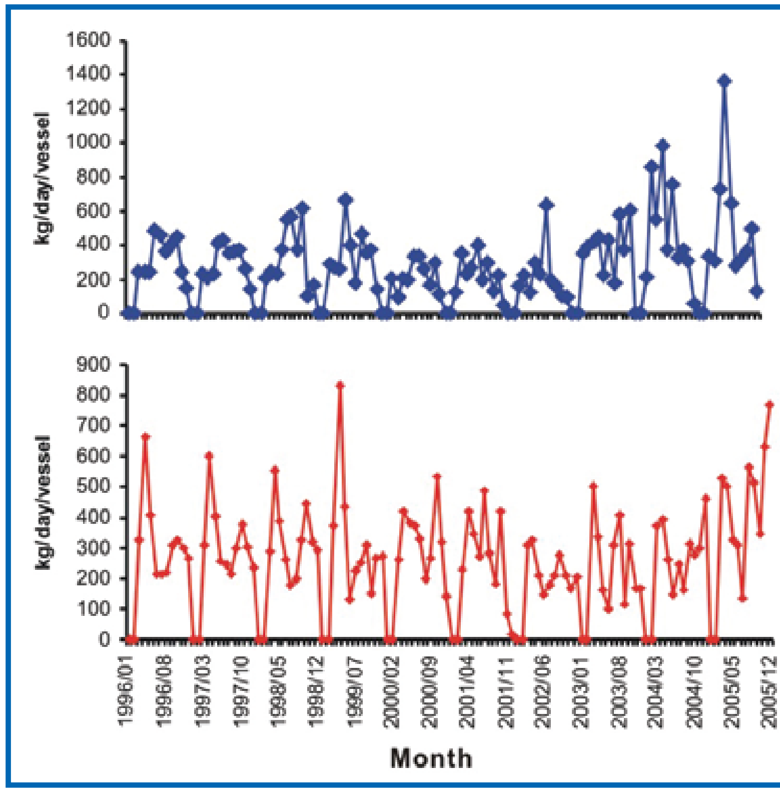

Figure 17: Catch per day per vessel and per month of anchovies and sardines 1996 – 2005.

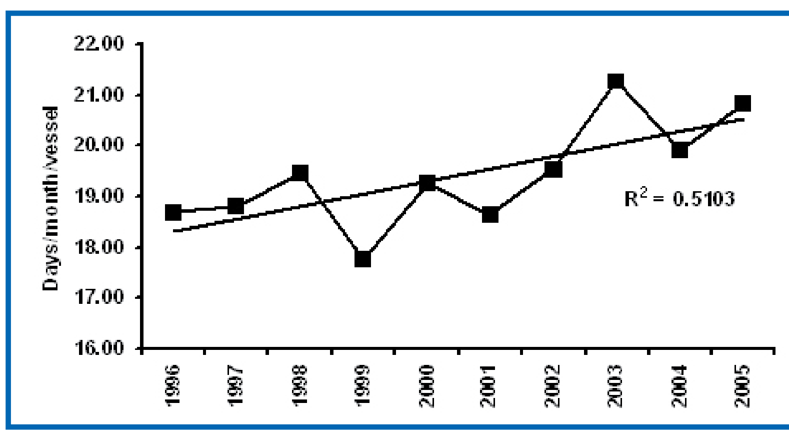

Figure 18: Mean effort expressed in days per month and per vessel along with the estimated positive trend, from 1996-2005.

Placing fisheries' management into an ecosystem perspective seems to be the only alternative (e.g. PAULY, 1998; GISLASON *et al*., 2000; STERGIOU, 2002), and the adoption of a variety of "ecosystem" indicators and reference points that trigger management actions becomes a necessity. These can be defined directly, through the use of mod-

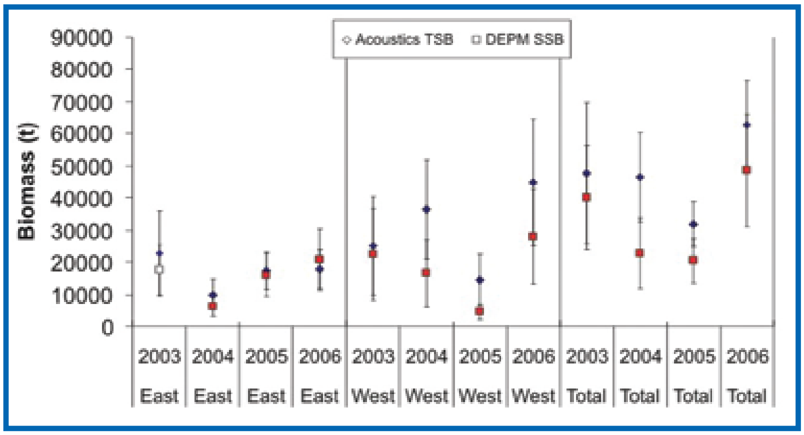

Figure 19: In year anchovy estimation in the Aegean Sea (eastern part, western part and total), by two methods: a) Acoustic estimation of total biomass (TSB) and b) Daily eggs production method estimation of spawning biomass (DEPM SSB).

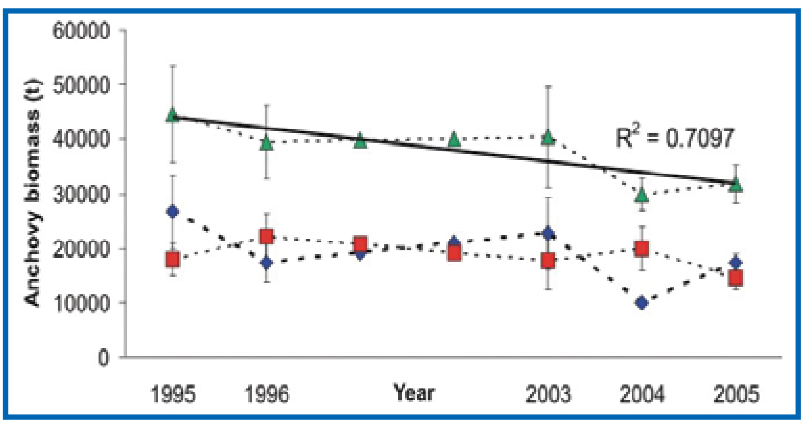

Figure 20: The trends of the Aegean anchovy stock biomass, based on acoustic estimations of the total biomass. No trend has been observed in the eastern or western part of Aegean Sea, but a significant decline trend has been estimated in the Total stock.

elling tools such as the ECOPATH/ ECOSIM/ ECOSPACE (CHRISTENSEN & PAULY, 1993; PAULY *et al*., 2000), which are invaluable for studying the effects of fisheries and have been successfully applied in various areas (e.g. CHRISTENSEN & PAULY, 1993; SHANNON *et al*., 2000).

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IV.3. HIGHLY MIGRATORY SPECIES

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INTRODUCTION

In the Mediterranean, commercial fisheries target three highly migratory (large pelagic) species: swordfish *(Xiphias gladius)*, bluefin tuna *(Thunnus thynnus)* and, albacore *(Thunnus alalunga)* (Figure 1). Hellas has one of the most important large pelagic fisheries in the Mediterranean and the Hellenic fishing vessels mainly exploit fisheries grounds of the Aegean, Ionian and Cretan seas. Seasonally, they also extend their activities to the eastern Levantine basin.

Swordfish comprises the main bulk of the Hellenic large pelagic catches and its annual production lately is around 1 200-1 600 MT (Figure 2). Swordfish fishing is carried out using drifting long lines. Since the middle 1990s, the traditional long lines have been gradually replaced by the so-called American-type and currently, only a few vessels of those targeting swordfish on a systematic basis use the traditional gear (TSERPES & PERISTERAKI, 2004). The fishing season lasts from February to the end of September, as a closed season is in effect from October to January, aiming for the protection of newly-born individuals. The fishing activity pattern for swordfish is higher in the southern Aegean and eastern Levantine, coinciding with the distribution pattern of the species (Figure 3). According to the records of the International Commission for the Conservation of Atlantic Tunas (ICCAT), Hellas is among the three most important swordfish producers in the Mediterranean (ANONYMOUS, 2006). The bluefin tuna is fished by means of hand lines and surface long lines. Most of the boats targeting exclusively bluefin tuna are scattered in the north Aegean Sea, and use mainly hand lines. The main fishing period lasts from September to April, following the market's demand. In the southern Aegean the large pelagic fleets primarily target swordfish by means of surface drifting long lines, and bluefin tuna is a secondary target or by-catch species, at least during the swordfish season. The annual Hellenic bluefin tuna production increased from about 100 MT in 1990 to 1 200 MT in 1997. Recently, after the establishment of production quotas by the European Community (EC), the Hellenic production is around 400 MT.

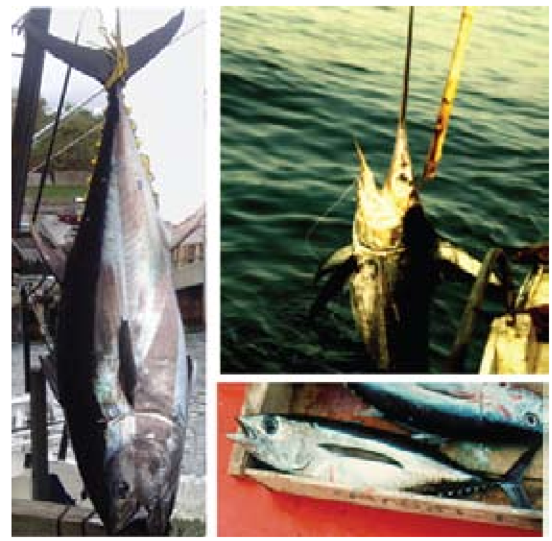

Figure 1: Bluefin tuna (left), swordfish (above right) and albacore (bottom right).

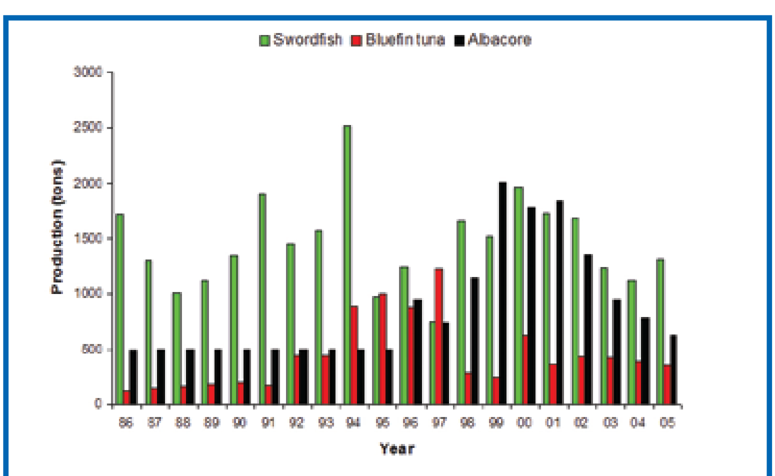

Figure 2: Hellenic large pelagic fisheries production by species and year. Source data: ICCAT (www.iccat.es)

Albacore fishery is limited to certain areas mostly during the autumn months and is carried out by means of hand lines, troll lines and long lines. The latest annual production fluctuates from 600-1300 MT. Hellas is the second, after Italy, albacore producer in the Mediterranean.

As large pelagic fish are a highly migratory species, their stocks are considered to be international and their assessment and management in the Atlantic and the Mediterranean Sea are under the responsibility of ICCAT. Regarding swordfish and albacore, ICCAT considers the existence of unique Mediterranean stocks, while for bluefin tuna they are considered as a common east-Atlantic – Mediterranean stock. Swordfish and bluefin tuna stocks are subject to regular assessments, based on data from the ICCAT member countries (EU is an ICCAT member), while the Mediterranean albacore stock has not been assessed so far due to lack of sufficient data.

Hellenic fisheries data have been collected using standardized protocols since the late 1980s within the framework of different European research projects, and since 2002 within the framework of the National Fisheries' Data Collection Programme. Analysis of those data has resulted in the estimation of various biological, population and fisheries' parameters such as growth rates, food consumption rates, catchability differences among gears, length – weight relationships, etc., (TSIMENIDES & TSERPES, 1989; MEGALOFONOU *et al*., 1995; TSERPES & TSIMENIDES, 1995; MEGALOFONOU & DE METRIO, 2000; MEGALOFONOU, 2000; STERGIOU *et al*., 2003; TSERPES *et al*., 2001a; 2001b; 2003a; 2003b; 2003c; 2004a; 2006; PERISTERAKI *et al*., 2003; 2005).

Results of the latest swordfish and bluefin tuna assessments, together with specific estimates from the Hellenic fisheries are provided in the subsequent chapters. The state of the albacore stock is unknown as no assessment has been conducted so far due to lack of sufficient data.

SWORDFISH

The latest assessment of the Mediterranean stock was accomplished in 2003 using production models and Virtual Population Analysis (VPA) (see ANONYMOUS, 2004 for details). Both types of models indicated the presence of a stable situation in terms of recruitment, spawning and total stock biomass (Figure 4). These findings suggested that the current exploitation pattern and level of exploitation are sustainable, in the short-term. However, the lack of sufficient historical data did not allow the determination of stock status relative to Maximum Sustainable Yield (MSY) benchmarks. It has been also noted as a matter of concern the high presence of small-sized swordfish (ages 1-3, many of which have never spawned) in the catches (Figure 5).

Estimates of annual abundance indices for a 16-year period, derived from a combined analy-

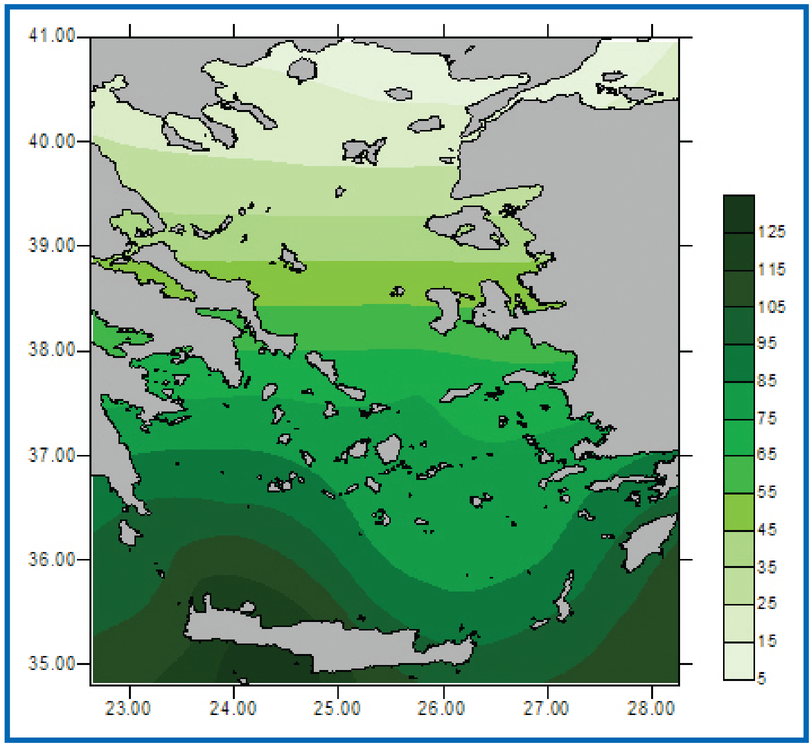

Figure 3: Distribution pattern of swordfish in the Aegean Sea based on the extrapolation of standardized abundance indices (kg/fishing day) from the long line fisheries operating during 2000-2003. Source: HCMR, unpublished data.

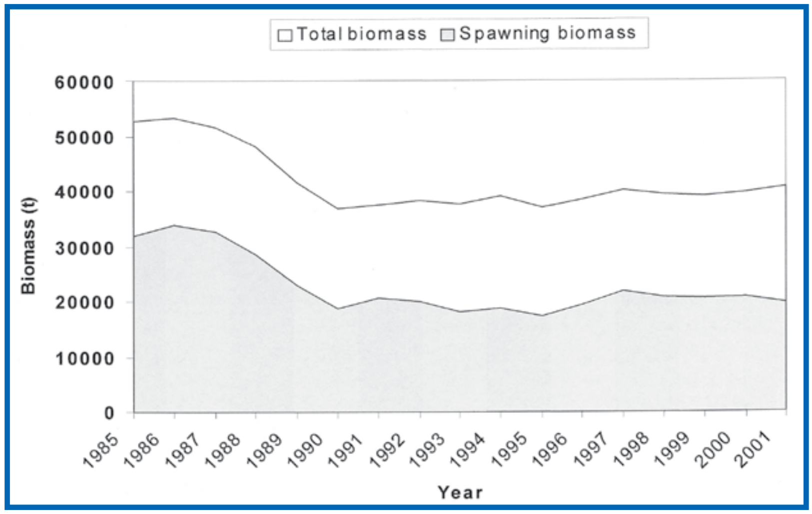

Figure 4: Total and spawning swordfish biomass estimates by year. Source data: ANONYMOUS, 2004.

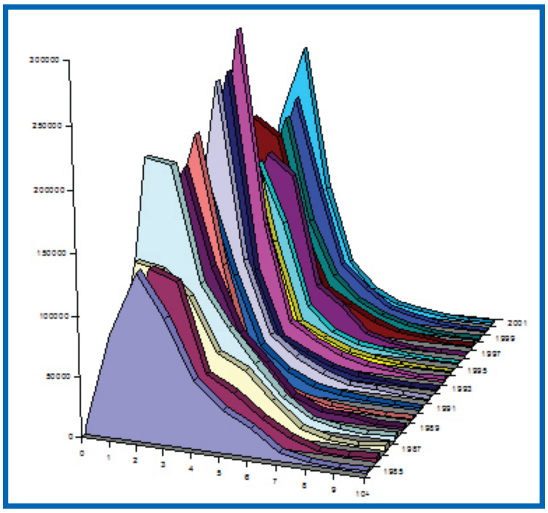

Figure 5: Age distribution of swordfish catches in the Mediterranean by year (1985-2001).
Source data: ANONYMOUS, 2004.

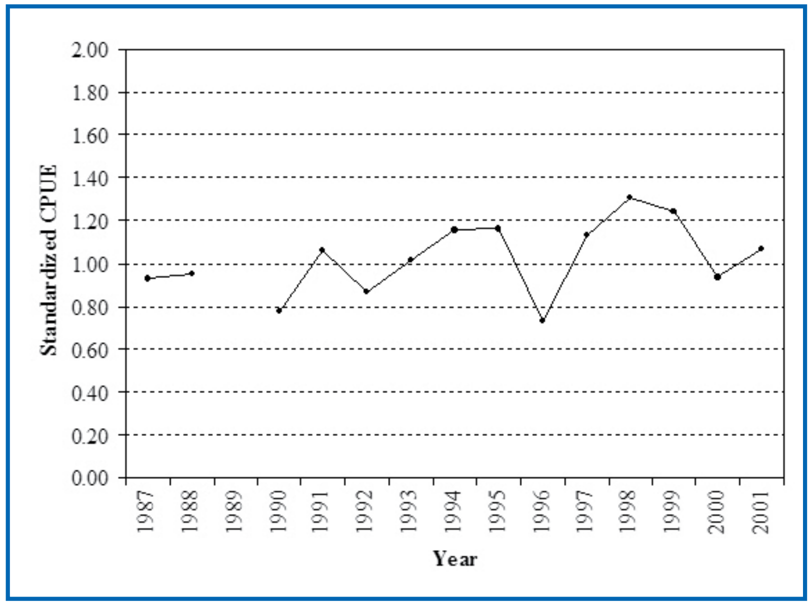

Figure 6: Standardized swordfish Catch Per Unit Effort (CPUE) estimates scaled to the mean value, based on Hellenic and Italian fisheries'.
Source data: TSERPES *et al*., 2004b).

sis of Hellenic and Italian fisheries data (TSERPES *et al*., 2004b) revealed generally low annual variations (Figure 6). This finding is in line with the assessment results. Based on the above, ICCAT recommended that the current levels of exploitation should not be exceeded under the current exploitation patterns.

BLUEFIN TUNA

The latest assessment of the stock, carried out in 2002 (see ANONYMOUS, 2003 for details), demonstrated that the current spawning stock biomass (SSB) levels are much lower than those observed in the early 1970s. An increase in fishing mortality rates has been also demonstrated, especially for older fish after 1993 and a general

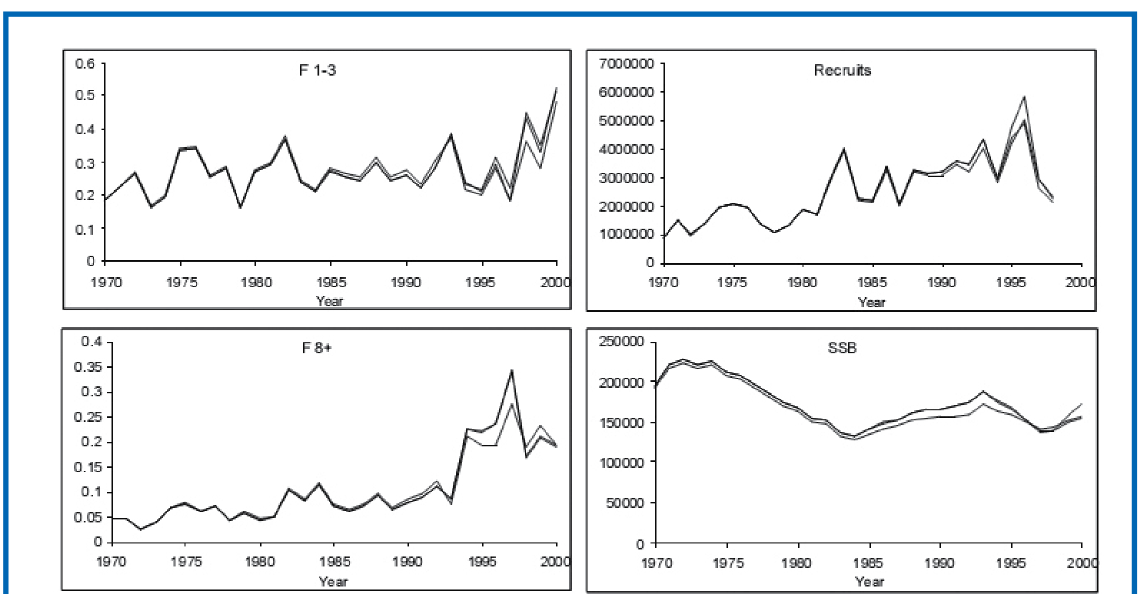

Figure 7: East Atlantic and Mediterranean bluefin tuna: Estimates of fishing mortality rates (average for ages 1-3 and 8+), recruitment and spawning stock biomass (SSB) obtained by three models.
Source: ANONYMOUS, 2003.

trend of increasing recruitment in the early 1980s followed by a period without trend (Figure 7). It was estimated that the 2000 level of fishing mortality was almost 2.5 times higher than that which maximizes yield per recruit. Projection scenarios suggested that the current catch levels cannot be sustained in the long-term under the current selectivity pattern and current fishing mortality rate for the stock. In addition, the high fishing pressure on small fish contributes substantially to growth over-fishing, and it seriously reduces the long-term potential yield from the resource. Furthermore, the abrupt increase of catches of large fish since 1994 is of grave concern because these levels are considered unsustainable.

However, it has been pointed out that uncertainties and lack of basic catch statistics from several important Mediterranean fisheries affect the robustness of the assessment and make the formation of definitive management recommendations difficult. The high expansion of bluefin tuna farming operations in the Mediterranean Sea has increased the amount of under-reported catches and has significantly affected exploitation patterns and data collection schemes.

Analysis of data from the Hellenic long line fisheries operating from February to September in the eastern Mediterranean during the period 1999-2001, indicated a significant variation in catch rates between months and areas. Relatively higher standardised catch rates have been estimated for the Cretan Sea and the Levantine basin while yearly variations did not show any trend (Figure 8).

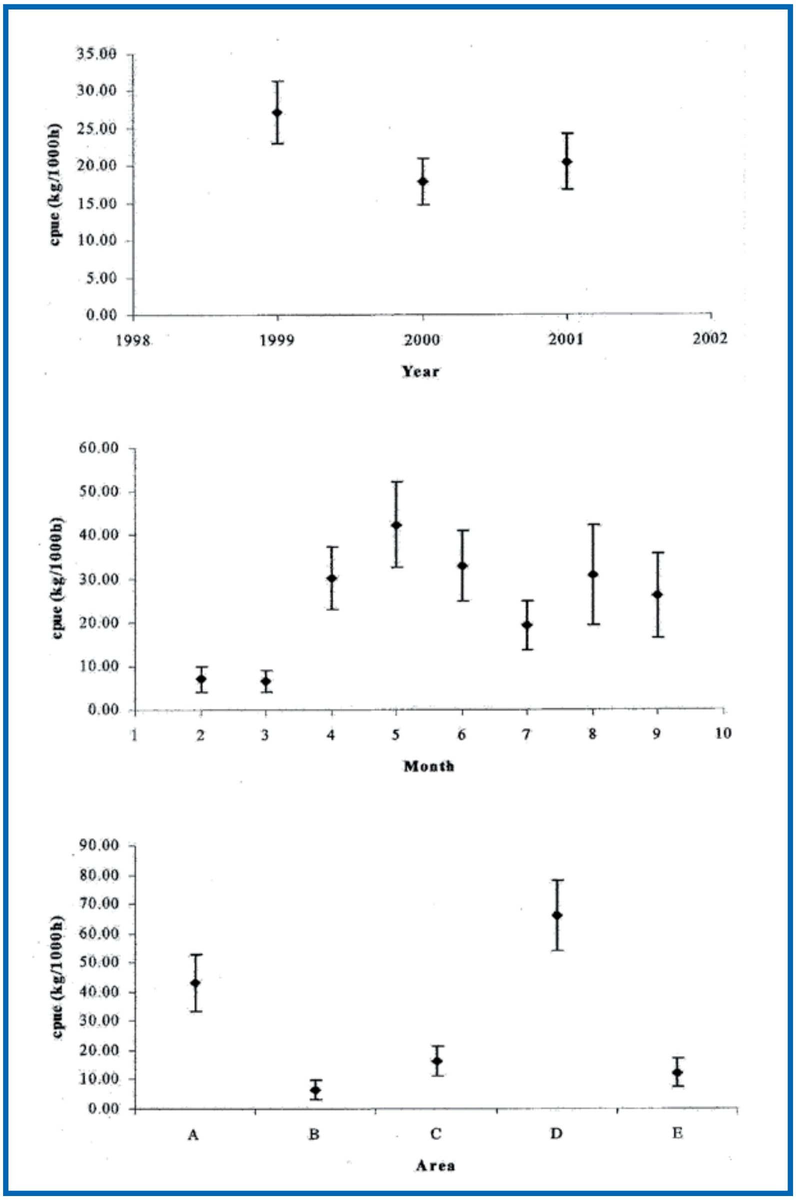

Figure 8: Standardized bluefin tuna CPUE estimates for the American type long line by year, month and area. Vertical bars represent the corresponding standard errors. (A = Cretan sea, B = South-western Aegean, C = South-eastern Aegean, D = Levantine and E = North Aegean) Source data: TSERPES *et al.*, 2001c.

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IV.4. DEEP-WATER FISHERIES RESOURCES IN THE HELLENIC SEAS

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INTRODUCTION

Deep-sea small-scale fisheries have been conducted in certain locations around the world for more than a century, but large-scale commercial deep-water fisheries are a more recent phenomenon, caused by the depletion and increased regulation of shallow-water fishery resources (MOORE, 1999). In the ICES Area, the fishery by trawlers and modern long liner fleets started in the late 1960s and 1970s. In the 1980s and 1990s, a decline of the traditional shallow stocks stimulated fleets to turn to deep-sea species. As deep-sea fisheries increased, scientists started to study the deep-sea environment, the size of its stocks and the exploitation they can support (BERGSTAD *et al*., 2005). Deep-sea species currently comprise approximately 3% of the global marine catch and it is estimated that 40% of the world's trawling grounds are now in waters deeper than the continental shelves (HOWELL *et al*., 2006).

The commercial fishery in Hellas is generally a multi-species fishery. It is conditioned by the great length of the coastline, the large number of small islands, the narrow continental shelf with rocky bottoms, which restrict the grounds for trawling, the large areas of deep waters, the low productivity of the Hellenic Seas, the high number of exploited species resulting in a multi-species fishery, and the long reproductive period, early onset of sexual maturity, short life-span and small size of adults for most species (STERGIOU *et al*., 1997). Such factors have favoured the development of small-scale, multi-gear fisheries, operating mainly close to the coast; from the 18 443 vessels that form the Hellenic fishing fleet operating in Hellenic waters, 94% are small coastal fishing boats (ANON., 2006). As a consequence, the fishing activities in the Hellenic waters are mainly carried out down to 400 m depth, and therefore, large marine areas of deeper waters (Figure 1) and their resources remain almost or completely unexploited.

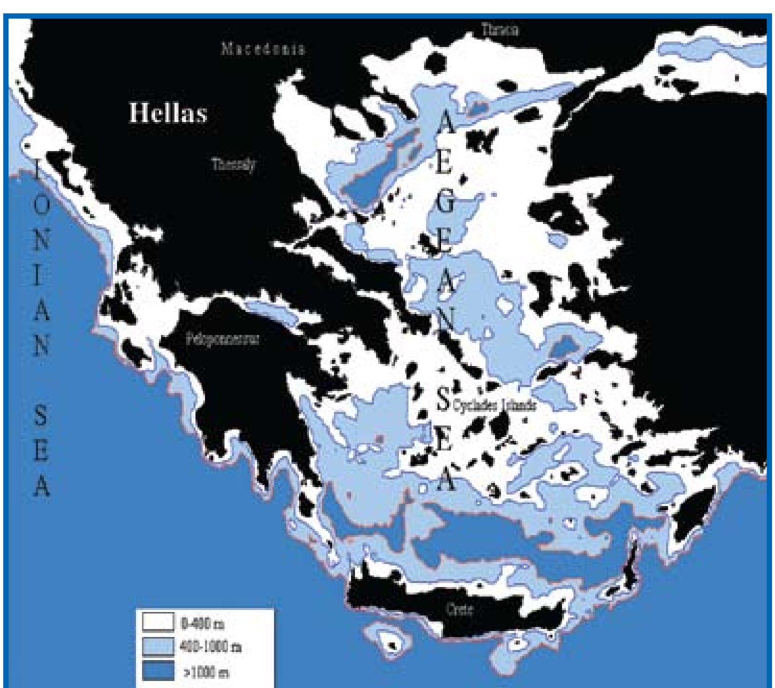

Figure1: Map of the Hellenic waters showing the isobaths of 400 and 1 000 m depth.

Deep-water fishery is not developed in the Hellenic waters as a special sector of the Hellenic fishery. Up to now, limited fishing activities are carried out by the Hellenic fishermen in deep waters. Long lines and nets are used targeting mainly hake (*Merluccius merluccius*), red-blackspot seabream (*Pagellus bogaraveo*) and wreckfish (*Polyprion americanus*) and bottom trawl is used targeting mainly hake, Norway lobster (*Nephrops norvegicus*) and red shrimps (*Aristaeomorpha foliacea* & *Aristeus antennatus*). Limited information exists on these activities, since no particular data for deep-water fishing (catches, landings, fishing effort, areas and depths) are gathered either by the National Statistical Services (NSS) or the National Fisheries Data Collection Programme. The investigation for the Hellenic deep-water fishery and resources constitutes a relatively recent research field. The Institute for the Marine Biological Resources (IMBR) initiated this activity in 1996 by means of various research projects (Chapter VII, MYTILINEOU *et al*.).

In the present work, the description of the state of the Hellenic deep-water fisheries resources will be attempted based on the results of the research projects carried out by IMBR and the National Statistical Services data. Although this information is not very recent and/or precise in all cases, it could be considered as a first approach to investigate the status of the deep-water fisheries and resources in Hellas since no other data exist.

STATE OF THE DEEP-WATER FISHERIES RESOURCES IN HELLENIC WATERS

Red-Blackspot seabream (*P. bogaraveo*) deep-water resources

This species (Figure 2) is fished mainly in the Ionian, southern Aegean Sea and Cretan Sea with long lines, gill nets and trammel nets on rocky banks at depths from 200 to 600 m. The fishery of red seabream started in the early 1980s with long lines. Recently, gill nets and trammel nets are also used. In the early years of this fishery the catches of red seabream were quite high, but they declined considerably very quickly, the main reasons appearing to be over-fishing, the introduction of gill nets, recreational fishing and ghost fishing (PETRAKIS *et al*., 2001).

In the Ionian Sea in the mid 90s, a total catch of about 80-100 Kg/day was common with long lines. The average days at sea per year used to be 106.4

Figure 2: Red-blackspot sea bream (*Pagellus bogaraveo*). Source: Fishbase

(PETRAKIS *et al*., 1999a). A few years later, the reported average catch was 61.7 Kg/day and the average days at sea 15.5 (PETRAKIS *et al*., 2001). The length of the fished specimens ranged mainly between 30 and 50 cm. From interviews conducted in the south-eastern Aegean Sea at the end of the 90s, the reported catch reached a maximum of 100 Kg/day (PETRAKIS *et al*., 1999a). In the Cretan Sea, during the same period, the maximum reported daily catch was 200 Kg/day. It is common knowledge nowadays that the catches have declined in both areas, although similar data studies do not exist for the last decade.

The gill net *P. bogaraveo* fishery, starting in 1996-97, is exercised only in the Ionian Sea. It is carried out from 200 to 600 m depth, near rocky banks, all year round, but it is more intensive during the summer time, because the weather is better and the prices are higher. At the end of the 90s, the catch consisted almost exclusively of *P. bogaraveo*, but a few years later, it decreased to 76% by number and 47% by weight (Chapter IIV, MYTILINEOU *et al*.). In the past, for a professional vessel the catch of *P. bogaraveo* ranged from 0-50 Kg per net (300 m) or between 50-150 Kg per day (PETRAKIS *et al*., 1999a). Recently, the estimated average catch was estimated 65 Kg/day and the average total yearly catch was calculated at 7 800 Kg. The estimated average days at sea were 57.3, whereas in the past they were 156.4 (PETRAKIS *et al*., 2001). As a response to this situation, some fishermen quitted the metier, whereas others decreased the mesh size with negative consequences such as increased quantities of discards, lower price in the market, higher pressure on the stock and reduction of the spawning biomass (CHILARI *et al*., 2006). The length and age composition of the red seabream in the catches changed also along the years including smaller individuals (Figure 3); the length of the red sea breams ranged from 16 to 40 cm (mainly 20-30 cm), consisting mainly of fish three to six years old (PETRAKIS *et al*., 2001), whereas in the past the main bulk of the catch ranged between 25-30 cm and 5-7 years old (PETRAKIS *et al*., 1999b).

Trammel net *P. bogaraveo* fishery is exercised in the central, south-eastern and south-western Aegean and the Cretan Sea with different characteristics depending on the area (PETRAKIS *et al*., 1999a). No particular data are available for this fishery.

According to the NSS data, the annual landings of *P. bogaraveo* from passive gears (long lines, nets) for the years 1994-2004 (Table 1), showed generally a slightly declining trend ($r = -0.56$, $b= -1.8$, $P= 0.07$). Passive gears catch the species almost uniquely in deep waters, therefore, the reported by NSS landings could be considered as landings from the deep-water fishery of this species. However, other species such as *Pagellus acarne* and *Dentex maroccanus* may also be included in the landings.

Assessment studies of demersal species in the framework of MEDITS programme in Hellenic waters (Chapter VII, POLITOU *et al*.), did not show a clear trend in the abundance of red-blackspot seabream in deep waters (200-500 & 500-800 m depth zones) during the period 1998-2005 (POLITOU, unpublished data).

Hake (*M. merluccius*) deep-water resources

The hake (Figure 4) deep-water fishery is exercised with long lines in Hellenic deep-waters down to 700 m. However, in the Aegean and Cretan Sea, gill nets and trammel nets are also used to catch hake in similar depths.

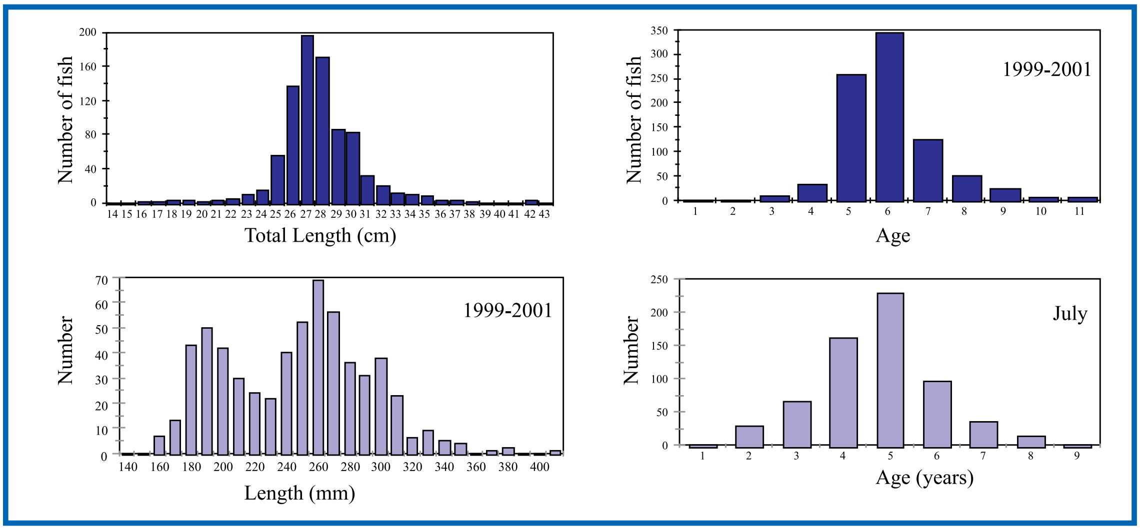

Figure 3: Length and age composition of red-blackspot sea bream from gill net fishery in the Ionian Sea in 1996-1999 (PETRAKIS *et al.,* 1999c) and 2000-2001 (PETRAKIS *et al.,* 2001), respectively.

Table1. Annual landings (tn) of red seabream, hake and wreckfish from passive gears (longlines & nets), and anglerfish, Norway lobster and pink shrimp from trawl in the Hellenic waters for the period 1994-2004 (National Statistical Services data).

Year	Red seabream	Hake	Wreckfish	Anglerfish	Norway lobster	Pink shrimp
1994	437.6	2,313.3	100	1078.8	907.1	927,9
1995	568.1	2,196.6	100.7	1215.9	962.1	693,2
1996	317.6	1,842.3	69.4	622.6	379.6	909,2
1997	375.4	1,846.3	77.6	691.8	238.5	1157,9
1998	510.8	1,388.1	149.2	586.3	340.8	759,3
1999	444	1,106.6	123	546.9	173.5	639,8
2000	314.5	987.1	86.2	778.3	202.5	655,7
2001	261.9	989.6	62.3	512.8	139.5	522,0
2002	242.9	1,171.5	58.7	557.4	105.3	647,3
2003	294.1	1,180.6	65.1	703.3	208.3	601,8
2004	400.6	1,204.4	29.7	907.1	307.7	844,2

PETRAKIS *et al.* (1999a) mention that hake long line fishery is carried out all year round. However, some of the vessels target swordfish during summer, and therefore, the effort for hake is higher during winter when swordfish fishery is closed. In the Ionian Sea, during the late 90s, the catch of hake reported by the fishermen was about 100-200 Kg/day, consisting generally of large specimens (>35 cm). In the north Aegean Sea, the reported catch during the same period, reached up to 200 Kg per trip. In the central Aegean Sea, it was about 50-100 Kg/day. In the south-western Aegean Sea (east coast of the Peloponnisos), the catch of hake ranged between 40-60 Kg/day and in the south-eastern Aegean it was 100-150 Kg/day. Finally, in the Cretan Sea, the catch varied between 40-120 Kg/day.

Figure 4: Hake (*Merluccius merluccius*).
Source: Fishbase

Information concerning the size composition of hake long line landings, derived in the framework of the National Fisheries Data Collection Pro-

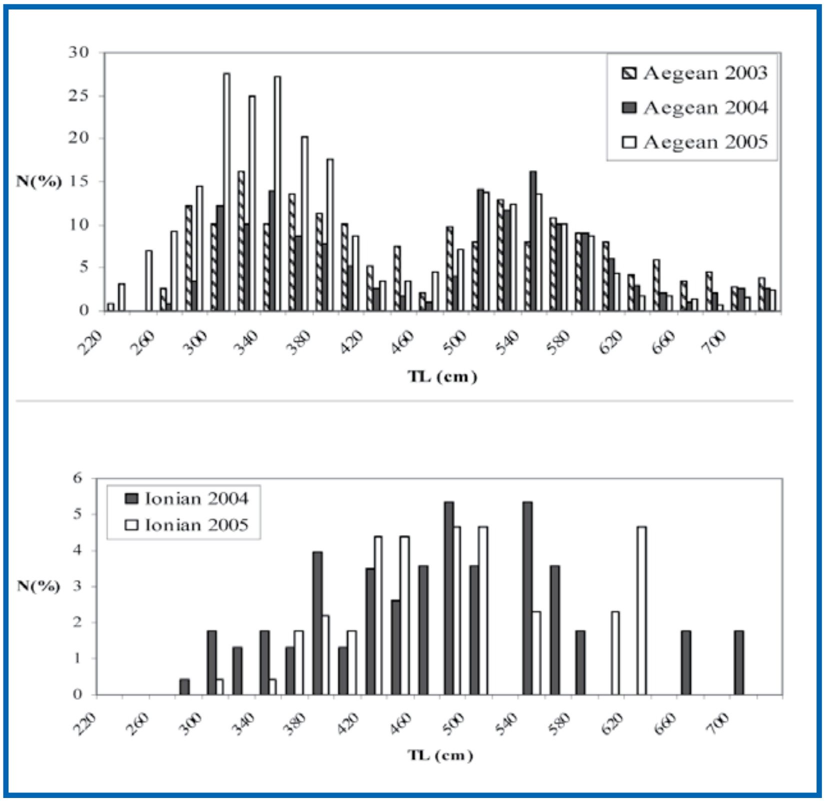

Figure 5: Length frequency composition of hake landings from the long line fishery in the Aegean and Ionian Sea for the years 2003-2005 (National Programme for the collection of Fisheries data; ANON., 2004, 2005, 2006).

Figure 6: Wreckfish (*Polyprion americanus*). Source: Fishbase

gramme during 2003-2005, is shown in Figure 5; a decrease in the percentage of large individuals appears in both the Aegean and the Ionian Sea, although this indication is very rough because of the limited time-series.

Gill nets are also used to catch hake in the deep waters of the Cretan Sea. Fishing is carried out on muddy bottoms at depths down to 600 m. The daily catch, reported during the late 1990s, was about 100-120 Kg/day. During the same period, the trammel net catch of hake in the deep waters of the central Aegean was about 10-15 Kg/day (PETRAKIS *et al.*, 1999a).

The annual landings of hake from the passive gears (long lines and nets) appear in Table 1 (NSS data), showing generally a declining trend during the last decade (r= -0.64, b= -121.2, P= 0.034). No precise information could be extracted for the deep-water landings of hake from these data since the hake trammel net landings from shallow waters (possibly of minor importance) are also included.

Assessment studies in the framework of the MEDITS programme carried out in Hellenic waters showed a decreasing trend in the abundance of hake in deep waters (500-800 m depth zone) after 2001 (POLITOU, unpublished data).

Wreckfish (*P. americanus*) deep-water resources

Wreckfish deep-water fishery is exercised mainly with long lines in the Ionian, southern Aegean and Cretan Sea. In the early 90s, a trammel net fishery also started up in the Cretan Sea targeting wreckfish at depths from 150 to 550 m during daylight (PETRAKIS *et al.*, 1999a). However, the fishermen target less and less wreckfish, because their catches are now very low. The species (Figure 6) is localised at specific fishing sites, characterised by seamounts, steep continental slopes and hard bottoms. The fishing depth ranges between 300-1 000 m, but mainly between 500-850 m. Wreckfish may also be found over flat hard bottoms, but fishermen seem to prefer fishing at areas of steep slope, because these are easy to locate and catches are higher (MACHIAS *et al.*, 2001).

In the Cretan Sea, two distinct wreckfish fisheries were found: the fishery mainly targeting both big hake and wreckfish and that mainly targeting wreckfish. The difference between these two fisheries was only the contribution of wreckfish in the total catch (MACHIAS *et al.*, 2001). In 1999-2000, the mean CPUE for *P. americanus* was estimated 49.74 Kg/1 000 hooks with a minimum of 10 Kg and a maximum of 116 Kg. The total landings were 60 tons during 1999 and 47 tons in 2000. Landings during the winter months are low due to bad weather conditions. For the length composition of the catches from the long line wreckfish fishery in the Cretan sea and other biological information (Chapter VII, MYTILINEOU *et al.*). According to

MACHIAS *et al.* (2001), total and fishing mortality values were high in Cretan waters; however, yield per recruit analysis was not applied due to the lack of data needed to estimate the status of exploitation of the stock.

According to NSS data, the annual landings of wreckfish from passive gears (hooks, nets) showed a slightly declining trend (r= -0.56, b= -5.6, P=0.07) for the period 1994-2004 (Table 1). The species is caught by hooks or nets almost uniquely in deep waters, therefore, the presented landings could be considered as landings from the deep-water fishery of this species.

Bottom trawl deep-water fisheries resources

In Hellas, bottom trawl deep-water fishery does not exist as a specific type of fishery. Trawlers operating in coastal waters may shift their activity to deeper waters. The deep-water bottom trawl fishing activity is exercised mainly between 400 and 500 m depth, targeting Norway lobster (*Nephrops norvegicus*-Figure 7), hake, megrim (*Lepidorhombus boscii*-Figure 8), anglerfish (*Lophius budegassa*-Figure 9) and pink shrimp (*Parapenaeus longirostris*-Figure 10). In the late 90s, fishermen stated that the catch of hake in these waters reached up to 300 Kg/day and the catch of a *Plesionika* spp. 250 Kg/day (PETRAKIS *et al*., 1999a).

Recently, mainly after 2000, bottom trawling began to expand occasionally in waters down to 800 m. This activity occurs mainly at the end of the trawl fishing period (end of spring) when coastal catches decline and it takes place mainly in the Ionian Sea and south-eastern Aegean. Target species in these waters are largely the giant red shrimp (*A. foliacea*-Figure 11) and the blue and red shrimp (*A. antennatus*) and to a lesser extent the blackbelly redfish (*Helicolenus dactylopterus*-Figure 12), the megrim, the blackmouth catshark (*Galeus melastomus*-Figure 13), the golden shrimp (*Plesionika martia*) and the longnose spurdog (*Squalus blainvillei*) (MYTILINEOU *et al*., 2003). Today, fishermen point out that when they operate in deep waters, the catch of red shrimps is 80 Kg/day. In general, red shrimp stocks in Hellenic waters are considered to be unexploited (Chapter VII, MYTILINEOU *et al.*). In the last years, Italian fishermen operate in the deep international waters, close to Hellenic waters, targeting red shrimps during the closed period for trawling in their country.

From experimental deep-water fishery carried out at 300-1 000 m depths between 1999-2001 (ANON., 2001a; MYTILINEOU *et al*., 2003), the length composition of hake and red blackspot sea

Figure 7: Norway lobster (*Nephrops norvegicus*).
Source: Biopix J.C Schou.

Figure 8: Megrim (*Lepidorhombus boscii*).
Source: Fishbase.

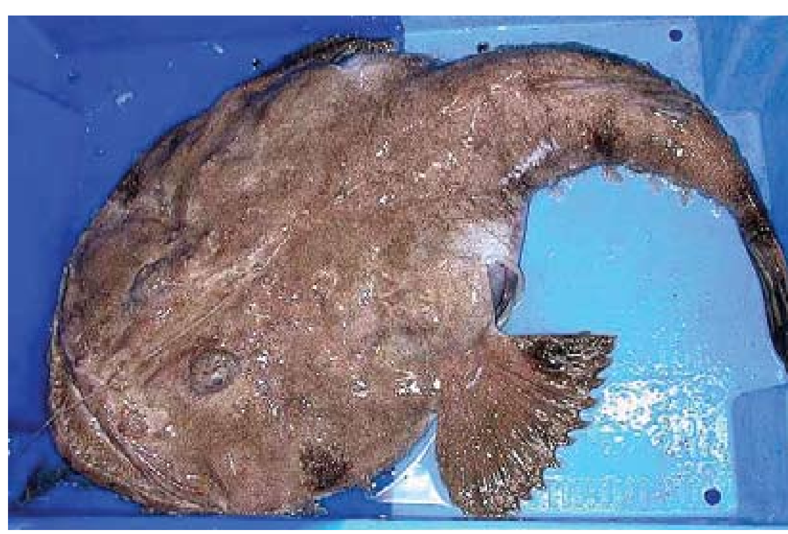

Figure 9: Angler fish (*Lophius budegassa*).
Source: www.schule-bw.de

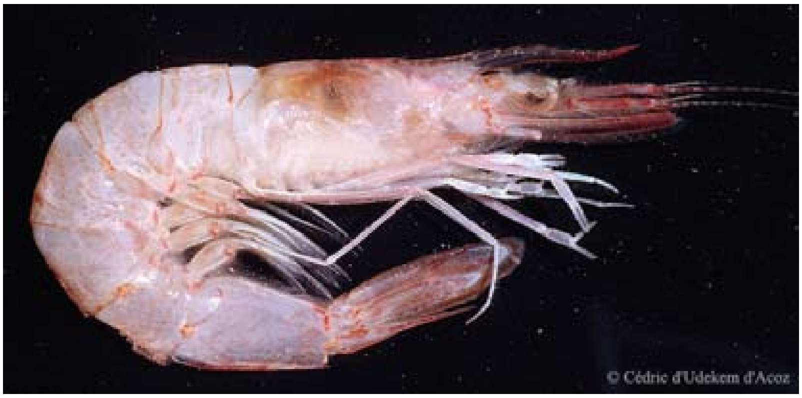

Figure 10: Pink shrimp (*Parapenaeus longirostris*). Source: Cedric d' Udeken d'Acoz.

Figure 11: Giant red shrimp (*Aristaeomorpha foliacea*).

Figure 12: Blackbelly redfish (*Helicolenus dactylopterus*). Source: Fishbase.

bream catches indicated that the main bulk of individuals caught by trawl ranged between 12-40 cm and 14-23 cm, respectively (MYTILINEOU, unpublished data); these sizes are quite lower than those of the specimens caught by gill nets (Figure 3) and long lines (Figure 5). In certain species, the majority of the collected fish had sizes close or larger to the length at first maturity (i.e. megrim: >13 cm and pink shrimp: >20 mm); in others, however, most specimens had smaller sizes than their respective length at first maturity, and this was the case for angler fish (>25 cm), blackbelly redfish (>10 cm), blackmouth catshark (>15 cm), longnose spurdog (>20 cm), Norway lobster (>20 mm), red shrimp (>20 mm) and golden shrimp (>15mm) (MYTILINEOU, unpublished data).

No specific NSS data exist for deep-water bottom trawl catches. Only the pooled catches from shallow and deep waters are available (Table 1), which show a decreasing trend for Norway lobster (r= -0.73, b= -65.2, p=0.01) although for anglerfish and pink shrimp the trend in landings in the last decade was not statistically significant.

Assessment studies on demersal species in the framework of the MEDITS programme carried out in Hellenic waters, showed no clear trend in the abundance of angler fish, blackbelly redfish, blackmouth catshark in deep waters during the period 1998-2005, except in the case of pink shrimp which indicated an increasing trend in the 200-500 m depth zone (POLITOU, unpublished data).

Shark fisheries resources

PETRAKIS *et al.* (1999a) mentioned that in the Cretan Sea, at depths from 600 to 1.500 m, a fishery with long lines targeting *Hexanchus griseus* was occasionally carried out. Although, the species had a low commercial value, the catch was quite high and the fishery was profitable. Fishermen pointed out that catches, consisting of large specimens (100-200 Kg each one), were about 1 000 Kg/day. A similar type of fishery but less intense, appeared also to take place in the central Aegean during the same period. (PETRAKIS *et al.,* 1999a) Since then, however, no further information has been gathered to shed more light on existing trends.

MANAGEMENT OF THE DEEP-WATER FISHERIES RESOURCES

No particular measurements exist for the deep-water resources in Hellenic waters, except those adopted in the framework of the Common Fishery Policy (minimum landing size for some species and a ban for fishing activities in more than 1 000 m depth).

Among the deep-water commercial species, minimum landing size (MLS) exists for *P. bogaraveo*, *M. merluccius*, *P. americanus, Lophius budegassa*, *Lophius piscatorius, L. boscii, N. norvegicus, P. longirostris, A. foliacea* and *A. antennatus*.

The MLS for *P. bogaraveo* changed recently with a new regulation (1967/2006) from 12 to 33 cm. As a result, almost all the catch from deep-water bottom trawl and a large amount of the catch from deep-water gill net fishery is illegal, since in general, this consists of fish between 15 and 30 cm (Figures 3, 14). Individuals of lower sizes segregate in shallow waters (MYTILINEOU & PAPACONSTANTINOU, 1995) exploited by coastal fishery. No detailed studies concerning the reproductive biology of red seabream exist in Hellenic waters; however, female specimens smaller than 24 cm (age 5) were found to be immature (CHILARI *et al*., 2006; MYTILINEOU, unpublished data). The new established MLS will contribute to the sustainability of the red seabream stocks, but it is expected to decrease profits considerably from this deep-water fishery.

The catch of *M. merluccius* from long line fisheries in deep waters consists of larger than 20 cm TL specimens, which coincides with the established MLS; however, those from deep-water bottom-trawl consist of quite smaller specimens, beginning from 10 cm TL (Figure 14). Length at first maturity of hake has been estimated between 30-36 cm (TSIMENIDIS *et al*., 1978; MYTILINEOU & VASSILOPOULOU, 1988), which shows that part of the stock fished in deep waters consists of juveniles, and hence established measures should be reassessed and a larger MLS should be enforced for this species.

The MLS of *P. americanus* is 45 cm. The length at first maturity of this species has been estimated at 70-80 cm (MACHIAS *et al.,* 2001). The size of fish caught in deep-water long line fishery is larger than 70 cm (MACHIAS *et al*., 2003). Problems could arise from other fisheries (purse seine, FADS, drift nets) catching accidentally small specimens (<50 mm) during the pelagic phase of their life cycle. For this reason, the increase of MLS at least to 65 cm (the estimated upper end of the settlement range) has been proposed aiming to avoid catches of juvenile fish (MACHIAS *et al*., 2003).

Regarding all other species, caught by deep-water bottom trawling, their MLS is in most cases (except for the pink shrimp) lower than the length at first maturity. Minimum landing sizes should be reconsidered in order to protect juveniles and the spawning stock, particularly for species that are also intensively fished in shallower waters (e.g. megrim, anglerfish) or that seem to be more vulnerable to fishery (e.g. giant red shrimp, blackbelly redfish).

Figure 13: Blackmouth catdig (*Galeus melastomus*). Source: Fishbase

Urgent measures should also be taken for red-blackspotseabream, hake and wreckfish deep-water long line, gill net and trammel net fisheries. Their catches, as presented above, show a declining trend during the last years. Therefore, established measures should be reassessed and specific measures should be adopted for particular gears used. A mesh size of 90mm and closing of the fishing season during the reproductive period have been proposed for gill net red seabream fishery (PETRAKIS *et al*., 2001).

Bottom trawl deep-water fishery is not very developed in Hellas. Red shrimp stocks, caught in deep waters by trawl, have been considered unexploited in the Hellenic waters. However, the giant red shrimp, *Aristaeomorpha foliacea*, is considered quite vulnerable to fishing pressure, a fact that should be taken into consideration (Chapter VII, MYTILINEOU *et al*.). No particular information exists for other deep-water stocks living in Hellenic waters. In the western and central Mediterranean, where bottom trawl deep-water fishery is carried out intensively for many years, some of the deep-water stocks are already over exploited (the case of *A. foliacea* in the Italian Ionian: D'ONGHIA *et al.,* 1998; MYTILINEOU *et al*., 2001) and others have almost disappeared (the case of *A. foliacea* in the Ligurian Sea and the Gulf of Lions: ORSI-RELINI & RELINI, 1985 & CAMPILLO *et al*., 1999, respectively). Selectivity studies for deep-water bottom trawling carried out in Italian waters showed that trawl cod-end mesh size should be more than 50-60 mm (CARLUCCI *et al*., 2006). A closed period between spring-early summer and a limit of 900 m depth for red shrimp fishery have also been proposed (ANON., 2001a, b; MYTILINEOU *et al*., 2003). Under the perspective of a possible future development of a deep-water fishery in the Hellenic Seas, studies focusing on the deep-water

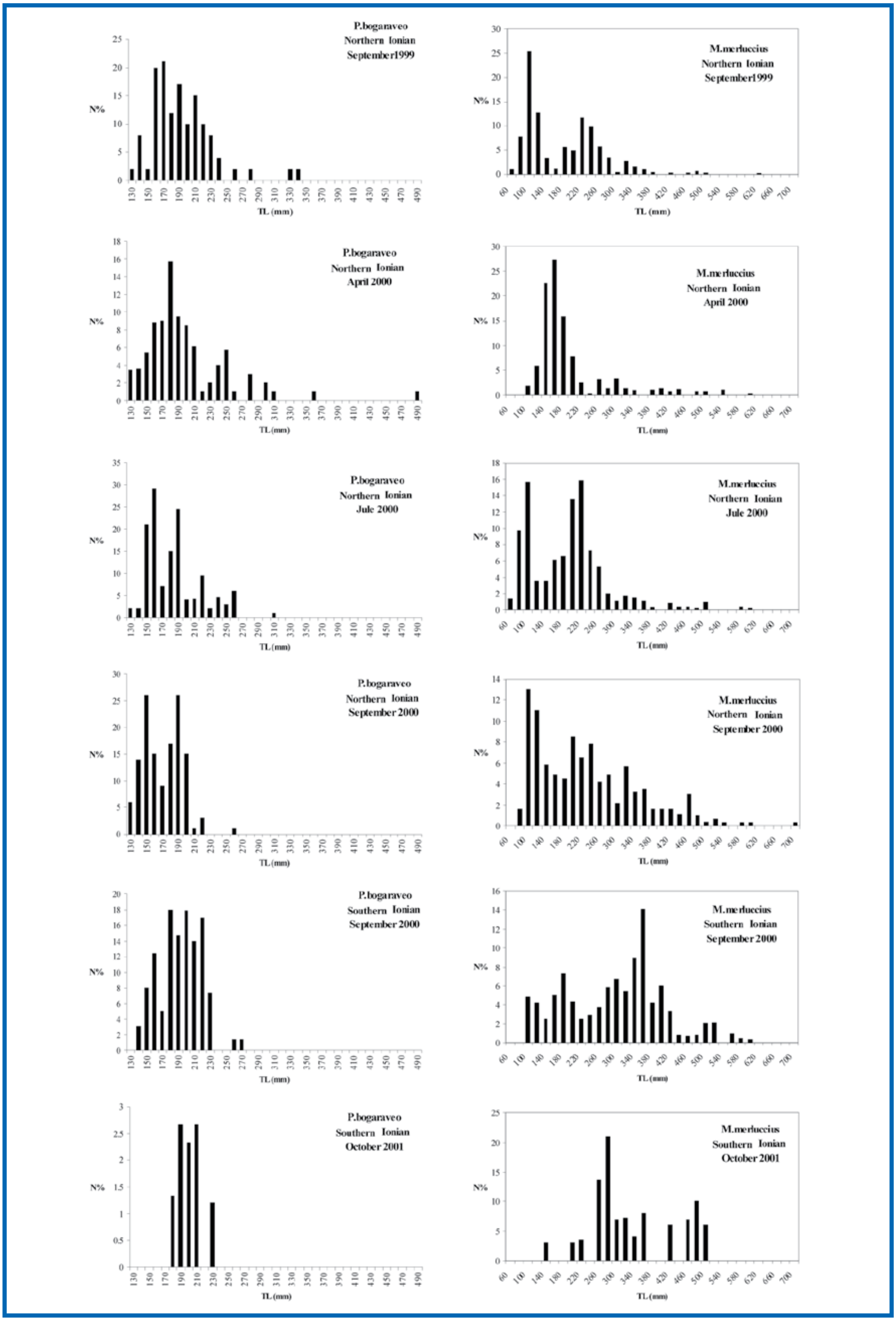

Figure 14: Length compositions of hake and red sea bream from depths between 300-900 m in the northern and southern Ionian Sea (MYTILINEOU, unpublished data).

stocks and environment should be promoted. An examination of past and current deep water fisheries shows what we can expect from the development of new fisheries targeting unexploited deep-sea resources. Previous deep-water fisheries exhibit a pattern of rapid development, depletion of the resource, and very slow recovery. If future deep-water fisheries are to avoid this fate, development of new fisheries will require a better understanding of the resource, its relationship to the environment, and a precautionary approach to resource management.

In general, deep-sea systems have low productivity in comparison with shallow water communities, and bathyal species generally have low P/B or turnover rates (HAEDRICH, 1996). Deep-water species exhibit clear "k-selected" life-history characteristics: extreme longevity, late age of maturity, slow growth and low fecundity, and as a consequence they are notably unproductive, highly vulnerable to over-fishing and sensitive to any change that occurs over a few generations (KOLSOW *et al*., 2000). The increase of commercial fishing activities in deep waters without firm knowledge of local abundance and fragility of the species could lead to the depletion of the resource. As a consequence, significant decreases have occurred in the catches of exploited deep-sea fish only a few decades after exploitation began, such as in the case of roundnose grenadier, *Coryphaenoides rupestris*, in the North Atlantic. Even the application of TACs (Total Allowable Catches) per area, as in orange roughy, *Hoplostethus atlanticus*, off New Zealand, did not prevent the symptoms of over exploitation. Only deep-sea fisheries that are managed sustainably by using relatively selective gears (e.g. the long line fishery for *Aphanopus carbo* off the Azores), or that are unable to access the recruitment areas of the stocks (e.g. the red shrimp *Aristeus antennatus* fishery in the deep Mediterranean), do not show strong evidence of over exploitation. From the perspective of long-term management, detailed studies of life-history dynamics are required (UIBLEIN *et al*., 1996). The biological characteristics (low growth rate, low fecundity and retarded reproduction) of the deep-water resources should be taken into consideration and management of the deep-water fishery should be precautionarily designed. Essential fish habitats, including nursery, feeding and spawning grounds should be defined. Closed areas and seasons should be established to protect the young of the year and the reproductive biomass. Minimum landing sizes should be adjusted according to the length at first maturity. Measures for the mesh sizes should be proposed according to selectivity studies. Finally, regulations for international deep waters should also be defined under the hypothesis of the exploitation of shared stocks since deep-water stocks are extended outside the geographical boundaries of the countries.

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IV.5. LAGOON FISHERIES RESOURCES IN HELLAS

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INTRODUCTION

Lagoons are particularly important for fisheries in many areas of the world, since marine fish species migrate towards the lagoons which provide favourable conditions for feeding and shelter (Colombo, 1977). The physical characteristics of the Hellenic lagoons allow us to distinguish two main types of lagoons in Hellas, i.e. open and closed type lagoons, depending on the surface of the lagoon - sea exchange area.

Hydrology, including water quantity, quality, distribution and flow patterns, is possibly the most important factor affecting the successful operation, management and/or restoration design of lagoons. Accurate hydrologic, hydraulic and water quality computations significantly reduce restoration design risks. The improvement of aquatic lagoon environments is also one of the purposes of EU Directive 2000/60/EC (Water Framework Directive, WFD), which defines qualitative, quantitative and ecological objectives to protect the highly valuable lagoon ecosystems (EUROPEAN UNION, 2000; ELLIOT & MCLUSKY, 2002).

Mediterranean lagoons are important for fisheries and extensive or intensive aquaculture, and contribute significantly to the fishery economies in many countries. In Hellas, fisheries' exploitation of coastal lagoons was the first type of applied aqua-

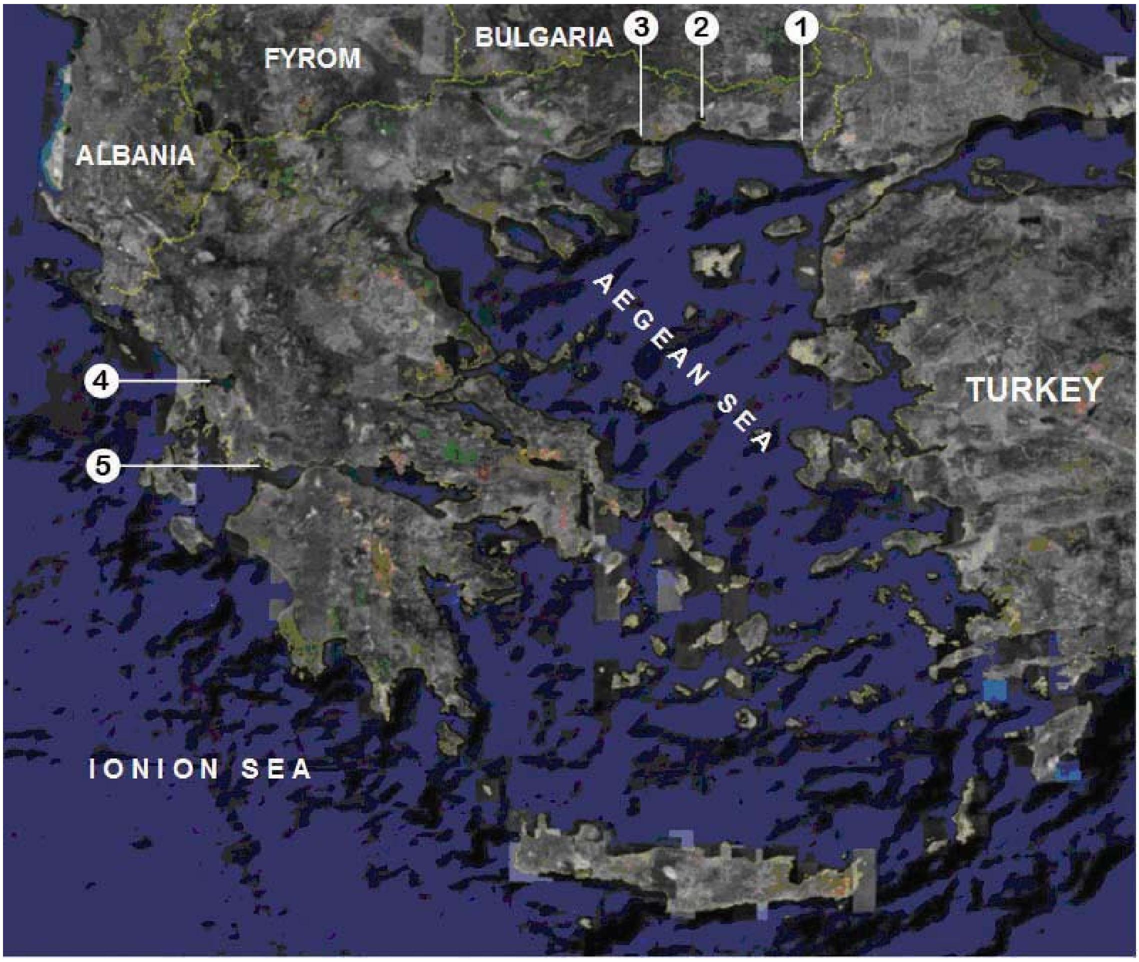

Figure 1: Map of Hellas showing the main lagoon complexes: (1) Evros River Delta Lagoon complex; (2) Porto Lagos Lagoon and Vistonis Lake complex; (3) Nestos River Delta Lagoon complex; (4) Amvrakikos Gulf Lagoon complex; (5) Messolonghi-Aitoliko Lagoon complex. Source: Google Earth 4.0.

Figure 2: Permanent fish entrapment devices, which catch live fish as they move seawards (Vassova and Erateino Lagoons, Nestos Delta). The arrow shows the direction of fish movement. Source: E.T. Koutrakis.

culture and it has been practiced since ancient times. According to a study carried out in 2001, 700-1600 t of fish are landed annually from fishing and extensive aquaculture activities in 56 lagoons (21 in the Aegean and 35 in the Ionian Sea) with a total area of about 354 km^2 (ECONOMIDIS *et al.*, 2001). The majority of the commercially important lagoons are located in Northern Hellas in the Region of East Macedonia & Thrace from Evros to Kavala (Evros River Delta Lagoon complex, Porto Lagos Lagoon and Vistonis Lake complex, Nestos River Delta Lagoon complex) and in Western Hellas from Patra to Igoumenitsa (Amvrakikos Gulf Lagoon complex, Messolonghi-Aitoliko Lagoon complex) (Figure 1 & Table 1 in Annex).

FISHERIES' EXPLOITATION AND COMMERCIAL SPECIES

Fishery exploitation is based mostly on traditional barrier fish traps consisting of permanent entrapment devices (Figure 2), i.e. stationary installations that catch live fish as they move seawards. These devices used to be wooden installations, consisting of wooden sticks hammered into the lakebed sustaining a net of reeds (Figure 3). Most of these installations were replaced after the 1980s with cement installations that copied the Italian "vallicoltura" capture systems. In the Northern Hellas lagoons, and to a certain extent also in the Amvrakikos Gulf, fish entrapment devices are usually combined with fish wintering channels, i.e. deep, dredged channels in which the juvenile fish spend the cold season without being fed artificially (KALLIANIOTIS 2004; KOUTRAKIS, 2005).

Figure 3: Traditional fishing traps located at the south of the Messolonghi Lagoon separating the lagoon from the open sea. Source: Yahoo images archive; www.yahoo.com

Catches correspond to species-specific inshore-offshore migrations influenced by seasonal or ontogenetic factors. Fish are allowed to enter the lagoons for feeding and shelter during spring and early summer, after which the entrapment devices are closed. During the summer, most fish remain in the lagoons and the most commercial species are caught in the fish traps during their reproductive migration to the sea during autumn and early winter. So far, management activities for fish production inside the Hellenic coastal lagoons have been totally empirical and based on traditional principles (MYLONA *et al.,* 2007). In many cases these activities are similar to the well-known "vallicoltura" practiced in Italy. Nets (trammel nets mainly) are also used in some lagoons that do not have permanent trapping installations, or during periods of the year outside the fish migrating season.

The fish fauna of the Mediterranean lagoons consist of the following categories:

- resident species that complete their life cycle in the lagoons (e.g. *Pomatoschistus marmoratus*, *Aphanius fasciatus*, *Gambusia affinis*),
- migrant species that visit the lagoons at some stage during their life cycle for food, repro-

duction or shelter (e.g. Mugilidae, *Dicentrarchus labrax*, *Sparus aurata*), and
- species that occasionally enter lagoons for food or shelter (e.g. *Sardina pilchardus, Boops boops*).

The main commercial species fished in the Hellenic lagoons are shown in Figure 4. The highest catches belong to the family of Grey mullets (Mugilidae: *Mugil cephalus, Liza saliens*, *Liza aurata*, *Chelon labrosus, Liza ramada*), which constitute approximately 56% of the total lagoon production in Hellas. Grey mullets migrate to the sea, where maturity is reached, 1-2 months before their reproduction period, which is different for each species. The highest abundance in catches is observed during September - October, with production rates reaching almost 90% of the total. Annual catches depend on the abundance of juveniles that have entered the lagoons, which in turn depends on the successes of reproduction and ascendant immigration.

An appreciable by-product of Grey mullets is fish-roe, a traditional product that constitutes an important source of income for the fishermen of the lagoons (Figure 5). It is made from the mature female ovaries of the Flathead grey mullet (*M. cephalus*), has a great commercial value (about 140 €/kg in 2005) and the highest production comes from the Messolonghi-Aitoliko Lagoon. It is very famous and is one of the nine products in the EU that, under the trademark "*Avgotaracho Messolonghiou*", belongs to the products with *Protected Designation of Origin (PDO),* in the category of "*Fresh fish, molluscs, crustaceans and products derived therefrom*" as defined by the laws of the Hellenic Government and the European Union. The annual production of fish-roe is estimated at about 7% of the landings of flathead mullet caught during their spawning migration period (KATSELIS *et al*., 2005).

In addition to Grey mullets, other important species for the lagoon fisheries include the Gilthead seabream, (*Sparus aurata*), the European sea bass (*Dicentrarchus labrax*), the Sand smelt (*Atherina boyeri*), the eel (*Anguilla anguilla*) and the common sole (*Solea* spp.). Moreover, the Karamote prawn (*Melicertus kerathurus*) and the Mediterranean mussel (*Mytilus galloprovincialis*) give an additional income to many lagoon fishermen.

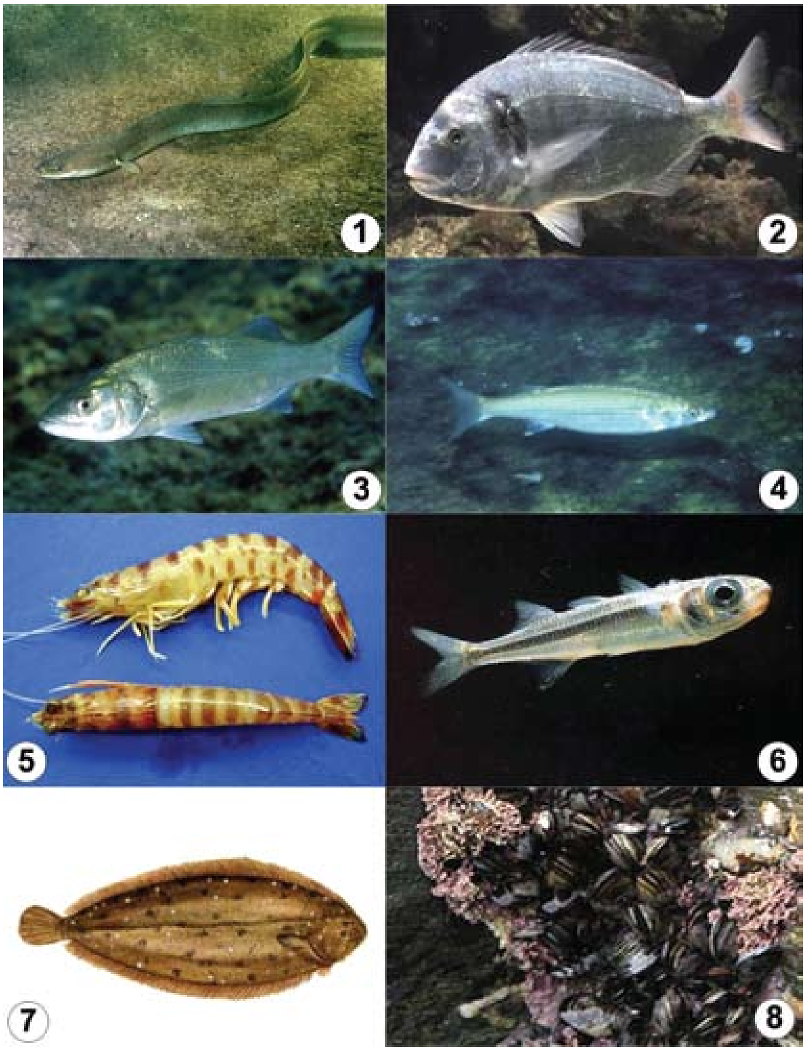

Figure 4: Commercially important species caught in Hellenic lagoons; (1) Eel (*Anguilla anguilla*); (2) Gilthead seabream (*Sparus aurata*); (3) European sea bass (*Dicentrarchus labrax*); (4) Flathead grey mullet (*Mugil cephalus*); (5) Karamote prawn (*Melicertus kerathurus*); (6) Sand smelt (*Atherina boyeri*); (7) Common sole (*Solea* spp.), (8) Mediterranean mussel (*Mytilus galloprovincialis*).
Source: Yahoo images archive; www.yahoo.com

NORTH HELLAS LAGOONS

The lagoons of North Hellas cover more than 115 km^2 and are mainly found between the estuarine systems of the Evros and Nestos Rivers; however, lagoons where fishing exploitation exists cover less than 86 km^2 (see also Table 1 in the Annex). Three big lagoon complexes are located in this area, the Evros River Delta Lagoon complex (Evros Prefecture), the Porto-Lagos Lagoon and Vistonis Lake complex (Xanthi Prefecture) and the Nestos River Delta Lagoon complex (Kavala Prefecture). Moreover, in the same area in the Rodopi Prefecture, six small coastal lagoons are found, while the rest of the North Hellas lagoons are small and most of them are not commercially exploited.

Their catches range from 400-900 t/y (i.e. 4.5-11 t/ km^2/y), which is the highest rate of all Hellenic

Figure 5: The preparation of the grey mullet's fish-roe, a traditional product that constitutes an important source of income for the lagoon fishermen. Source: E.T. KOUTRAKIS.

regions. The main species produced in the North Hellenic lagoons belong to the family of Grey mullets (Mugilidae). Other important species are the Gilthead sea bream, the European sea bass, the Sand smelt and the common sole (*Solea* spp.). Most of the lagoons are managed by Fishing Cooperatives through the use of permanent fish entrapment devices combined with fish wintering channels. The wintering channels are deep (5-6 m) and used during the winter months for protecting the fish from freezing weather, which is a very intense problem in North Hellas. Small-sized fish, which are not marketable or sold only very cheaply, are also kept in these channels. They remain there until they reach marketable size or until they are released into the lagoon.

The Evros River Delta Lagoon Complex

The lagoons in the Evros River Delta form a complex located at N40°45΄-E26°26΄ (Figure 1). The main lagoons of this complex are the Monolimni (4.2 t/km^2/y) and Drana Lagoon. The Drana Lagoon was a fishery-exploited lagoon (fish production of 8 to 20 t during 1974–1986) and was drained illegally in 1987 by local farmers, believing that the lagoon's saltwater affected their adjacent cultivations. The lagoon's re-flooding (by opening a new 5 m long entrance), together with other restoration works, were carried out during June 2004, but until the end of 2005 the lagoon was not yet in a state to be exploited, since it had very low abundance of commercial species (which migrate from the sea), probably because inlet dynamics characterized by strong flood currents and limited ebb duration affected the entry of juveniles into the lagoon (KOUTRAKIS *et al.*, 2007).

The Porto-Lagos Lagoon and Vistonis Lake Complex

The next estuarine ecosystem is the Porto-Lagos Lagoon and Vistonis Lake complex, covering an area of 65 km² and located at N41°00΄-E25°07΄, which is part of the East Macedonia and Thrace National Park and is not only important from an ecological point of view but also from a commercial perspective, given the fact that in this area alone 400 t of fish are landed per year (i.e. 4,8 t/km^2/y in 2005). Sand smelt is a species particularly fished in the Vistonis estuarine system. It is a small, euryhaline species with a high degree of osmoregulatory plasticity, which enables it to inhabit coastal and estuarine waters over a wide range of salinity. Most fish remain in the vicinity of spawning areas, resulting in semi-isolated populations, each with a characteristic morphology and life history. The high degree of plasticity of the sand smelt allows adaptation of life history responses to variable environmental parameters characteristic of coastal and lagoonal habitats; the sand smelt is thus pre-adapted for the exploitation of novel and vacant niches (HENDERSON & BAMBER, 1987). This is probably the case for the adaptation of sand smelt in the Vistonis estuarine system. During the 1980s, salinity in the southern part of the Vistonis lake area increased due to a combined intrusion of seawater and limited freshwater inflow (BABAJIMOPOULOS & ANTONOPOULOS, 1992). As a result, many freshwater species feeding on zooplankton and benthic organisms (e.g. *Alosa vistonica*, *Cyprinus carpio*) moved towards the northern part of the lake, thus leaving vacant niches in the southern part of the lake, which were soon occupied by sand smelt. Since then, an abundant population has been formed which began to be commercially exploited in 1990, and today sand smelt is the most important commercial species in the lake, representing more than 50% of the total fish lake production (200-400 t/y, KOUTRAKIS *et al*., 2004, 2005).

The Nestos River Delta Lagoon Complex

The lagoons in the Nestos River Delta form a complex with an area of 9.5 km² located at N40°54΄-E24°36΄, which is also part of the East Macedonia and Thrace National Park. Seven of them are found in the Kavala Prefecture (Monastiraki, Keramoti, Agiasma, Chaidefto, Erateino, Vassova) and one in the Xanthi Prefecture (Erasmiou). Four of the lagoons found in the Prefecture of Kavala are exploited by a local fishermen cooperative with a fish production of 180 t/y and were the first to install stationary fishing devices during the 1980s and the first to apply different management alternatives (TSIHRINTZIS *et al.,* 2007). They also have the highest annual fish production per km² (e.g. Keramoti 23.3 t/km²/y and Vassova 14.8 t/km²/y) (ECONOMIDIS *et al.,* 2001).

WEST HELLAS LAGOONS

The lagoons in the West of Hellas cover more than 270 km² and are found mainly in the area between the Acheloos and Evinos Rivers (Patraikos Gulf: Messolonghi-Aitoliko Lagoons complex), in the area of the Louros and Arachthos Rivers (Amvrakikos Gulf Lagoon complex) and close to the Kalamas River (Figure 1). Also, a few lagoons, which cover about 55 km², are located, isolated in the coastal zone of the prefectures of Aitoloakarnania, Achaia, Elia, Messinia and on the island of Kerkyra.
Most of the lagoons are "closed" type lagoons and because of their ecological importance are protected by the Ramsar convention and they are included in the Natura 2000 network. These ecosystems are also important fishing grounds. The catches vary from 0.1–11 t/km²/y. The lower rates are observed in lagoons where the fishermen focus on high value species (e.g. eels), while the higher rates are observed in lagoons exploiting a wide range of fish species. On the other hand, there appears to be a negative relationship between this rate and the lagoon surface (Figure 6) due to fact that the larger lagoons provide limitations on their management (guard, infrastructure works, etc.).

The Messolonghi-Aitoliko Lagoon Complex

The Messolonghi-Aitoliko Lagoon is located at N38°22΄-E21°21΄. The complex consists of a central part, called Kentriki limnothalasa, of 80 km², which includes the fishing sites of Tourlida, Vasiladi, Komma, Schoinias and Prokopanistos, and a series of peripheral lagoons including Klisova, Diavlos, Aitoliko, Tholi, Paleopotamos. The total area of the lagoon complex is 150 km². In the central part, the lagoon is no deeper than 1.5 m, whereas the centre of the Aitoliko Lagoon is as deep as 28 m.
The surrounding coastal region is an extensive irrigation-drainage system for intensive agriculture from which all runoffs are directed into the lagoon. Landscape alterations and the creation of canals diverting the flow of freshwater away from the lagoon have caused an increase in water salinity and the isolation of several parts of the lagoon from the open sea. This has lead to the occurrence of severe hypoxic conditions, causing large scale mortalities of fish and other organisms, especially in the northern parts of the lagoon, i.e. the Aitoliko Lagoon in which water layers deeper than 10 m are permanently anoxic (LEONARDOS & SINIS, 1997).
Fisheries' production is mainly carried out using permanent traps along the southern part of the lagoon towards the open sea, but independent professional fishermen also fish in the lagoon using traditional fishing vessels (Figure 7). Fishermen also use traditional houses located in the Messologhi lagoon (Figure 8). During the period 1988-1998, the recorded production from permanent fish entrapment devices in the Messolonghi-Aitoliko Lagoon complex ranged from 1.03-2.21 t/km²/y, which represented an estimated 30% of the total fish production in the lagoon (the rest being fished by individual fishermen). The main species fished in the lagoon belong to the families of Grey mullets (Mugilidae) and Sea breams (Sparidae, mainly *S. aurata*), each of them comprising approximately

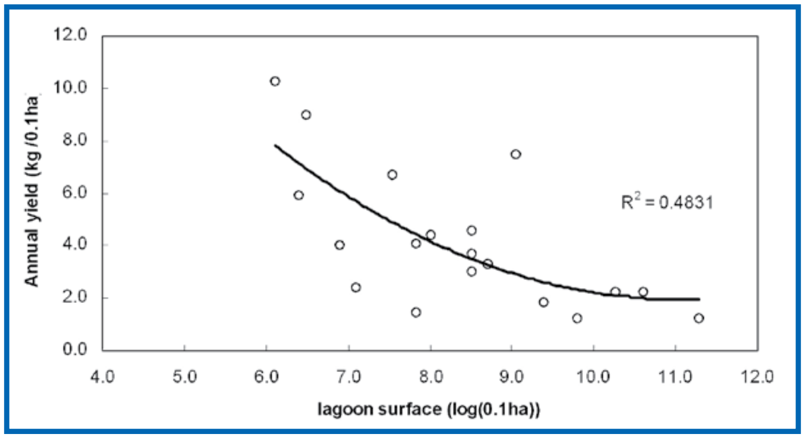

Figure 6: Annual yield according to the lagoon's surface of Western Hellas lagoons.
Source of data: ECONOMIDIS *et al.,* 2001.

Figure 7: Traditional fishing vessels for operation in lagoons. These vessels are very small with a flat keel due to the very shallow depths in the lagoons (less than 0.5 m in many places).
Source: Yahoo images archive; www.yahoo.com

Figure 8: Traditional fishermen's houses located in the Messolonghi Lagoon.
Source: Yahoo images archive; www.yahoo.com

40% of the total lagoon production. Other important species are eels (*A. anguilla*, 10-15% of the total production) and Sea bass (*D. labrax*, 5-10% of the total production (ECONOMIDIS *et al.*, 2001). A significant part of the landings is composed of small-sized individuals which are not marketable or they are sold cheaply (DIMITRIOU *et al.*, 1994). Despite the initial investment, in several cases the wintering channels remain under-exploited and they are not integrated into the management of the lagoon fisheries.
The fisheries' landings follow two seasonal patterns linked to the fish spawning behaviour and/or their reaction to environmental forcing. The higher landings are linked to the spawning migration of each species and they occur at different seasons depending on the species' life cycle. The peak of landings is observed in two periods: (a) summer-autumn (August to October) mainly *L. saliens, M. cephalus* and *D. annularis,* and (b) autumn to winter transition (November - December) for *L. aurata, A. anguilla*, *S. aurata*, *Mullus barbatus* and *L. ramada.* Lower landings of all species are recorded during the rest of the fishing period (KATSELIS *et al.*, 2003). In a smaller temporal scale (week to month), the migrations are controlled by the meteorological conditions and the lunar cycles (KATSELIS *et al.*, 2007).

The Amvrakikos Gulf Lagoon complex

The Amvrakikos Gulf Lagoon complex is located at N39°03´-E20°52´ an area of 61.3 km². It consists of two main parts: the Preveza Prefecture in the North, which comprises of the lagoons of Mazoma, Vathi, Tsopeli and Pogonitsa, and the Arta Prefecture in the East with the lagoons of Tsoukalio-Rodia, Logarou, Agrilos, Koftra-Paliobouka, Agios Georgios, Tsoukalos, Konstandina and Sakoletsi. In addition, there is a series of small coastal lagoons in the southern part of the Amvrakikos Gulf, i.e. the lagoons of Rouga, Kokkala, Myrtari, Katafourko and Saltini, which belong to the Prefecture of Aitoloakarnania.
From 1988 to 1999 the recorded production in the two main parts of the Amvrakikos lagoon ranged from 2.5-9.8 t/km²/y in Preveza and from 1.6-2.9 t/km²/y in Arta, with the bulk amount of fish production coming from the lagoons of Tsoukalio-Rodia and Logarou. The main fish species caught are Grey mullets and Sea breams, which are fished throughout the lagoon, whereas in the lagoons of Logarou, Agrilos, and Mazoma significant quantities of eels and gobies, (*Gobius* spp.) are also caught, which in some cases reach 20-30% of the total production. The Logarou Lagoon also produces sole (*Solea* spp.). Sea bass are fished mainly in Tsoukalio-Rodia and Pogonitsa. In the Aitoloakarnanian part of the gulf, recorded production numbers ranged from 0.7-2.3 t/km²/y in 1988-1999. The main species fished upon here are Grey mullets and sea breams, with additional production of goby, eel and sole in the Kokkala Lagoon, and sea bass in the Myrtari Lagoon. Finally, it is noteworthy to mention the production of the Karamote prawn (*M. kerathurus*), a large peneid prawn species the Amvrakikos Gulf and considered a culinary delicacy. Recorded production numbers do exist for the lagoons of Tsoukalio-Rodia, Logarou, Kokkala and Myrtari, but they are far from complete since much of the freshly fished product is sold directly to local restaurants and tavernas.
In the Amvrakikos Gulf and more precisely in the

Prefecture of Preveza, each lagoon has its own species' specific composition despite the short distance separating them (some km) (KENTROU *et al.,* 2005) and this is due to their individual topographic and hydrological characteristics. During the last decade, some changes in the landings species' composition are observed. They are characterized by the considerable increase of sea bream and the decrease of eels and gobies. The eel's decrease was synchronous in coastal ecosystems of both the Ionian and the Aegean Sea and coincided with the decrease of the entire European eel fishery production (ZOMPOLA *et al.*, 2001).

On the other hand, the increase of sea bream landings can be linked to the rapid development of the fish farms producing this species (DIMITRIOU *et al.,* 2007) and in several enhancement trials carried out in the lagoons of the Amvrakikos (KENTROU, 2005). In fact, more than 25% of Hellenic fish farms and 20% of Hellenic hatcheries of gilthead sea bream (*S. aurata*) and sea bass (*D. labrax*) are located along the Western Hellenic coast. During the last decade, a spectacular increase in both the number of farms and their production, accompanied by a substantial price decrease and modification of their structure and functioning, has been recorded. These changes resulted in the maintenance in cages of large individuals (more than 500 g) of Gilthead sea bream, which are potential spawners. DIMITRIOU *et al.,* (2007) confirmed reproduction in cages based on both the maturity stage and the decrease in individual mean weights during the reproductive period of the species. In parallel, during the last five years a remarkable increase (about 80%) in sea bream landings from the fish trap fisheries of the Messolonghi-Aitoliko Lagoon, which is a typical nursery for the species, was recorded. The increase was accompanied by a decrease both in price and mean size of the 0-group individuals. These observations point out the possible influence of the rearing activities in the area, the density dependent mechanisms and the negative impacts of this unintentional enhancement of the traditional lagoon fisheries.

ADMINISTRATION, MANAGEMENT AND EXPLOITATION OF HELLENIC LAGOONS

The Hellenic lagoons are generally owned by the Hellenic State. However, their economic exploitation is extremely diverse. In some cases exploitation occurs directly by the Ministry of Environment, Rural Development and Public Works, but most of the lagoons are managed by the local regional authorities. A few of them are owned and exploited by the Ministries of Development and Economics, and some others by local municipalities. In any case, economic exploitation usually happens by leasing of the lagoon or parts of it for a certain period of time (in most cases 10 years). The owner can lease it either directly or by auction. Organisations that are interested in renting lagoons are usually local professional fishermen's cooperatives, but sometimes private companies are also interested. Priority is given to local fishermen in order for them to have a more secure income and to create new job opportunities. Moreover, it was found that lagoons exploited by fishermen's cooperatives are in a better state than those leased to private companies and that fisheries' exploitation can also help ecosystem' conservation (KOUTRAKIS, 2005).

The lagoons of North Hellas and the Amvrakikos Gulf are all managed locally and all are wholly leased to local fishermen's cooperations, which therefore, have the sole right to exploit the lagoon's fish. The North Hellas lagoons (Evros, Porto Lagos-Vistonis, Rodopi and Nestos complexes) support approximately 300 fishermen, whereas the Amvrakikos Gulf Lagoon complex supports approximately 450 fishermen.

In the Messolonghi-Aitolikon Lagoon complex the situation is somewhat different. The peripheral lagoons are all leased as a whole to local fishermen's cooperations, as is the case in the abovementioned lagoon complexes, but in the central part it is actually the entrapment installations that are leased and not the lagoons itself. As a result, the central lagoons are also open to exploitation by individual fishermen not belonging to any professional cooperation. Furthermore, the entrapment installations are usually leased directly for a period of one year only. For these reasons, management of the Messolonghi-Aitolikon Lagoon complex is mainly concentrated on maintaining the existing entrapment installations and external fences, and management practices such as creation of winter channels and release of hatchery-born fingerlings are not systematically performed. On the whole, the Messolonghi-Aitolikon Lagoon complex supports approximately 60 fishermen belonging to professional cooperations, as well as an additional 600 individual fishermen.

FISHERIES' MANAGEMENT PROBLEMS

The main problem that the lagoon fishermen face is the decrease in catches. KOUTSIKOPOULOS *et al.*, (2004) elaborated the data collected from a study based on the characteristics of 76 lagoons, which represent the majority of the Hellenic lagoons where fisheries' exploitation occurs (ECONOMIDIS *et al.,* 2001) and revealed interesting facts concerning their dynamics, structure, functioning, and importance. For several lagoons, landings of 20 to 30 year time-series were analyzed. The results show a clear trend of steadily decreasing landings in all lagoons, albeit with different patterns, with drastic changes occurring during short time periods without obvious restoration (accidents) and increased inter-annual fluctuations (Figure 9).

Other important problems faced by the Hellenic lagoons are pollution by agricultural activities, domestic sewage in some coastal areas, the shortage of freshwater input into the lagoons, the draining (partial or total) of certain lagoons, such as the Drana Lagoon in the Evros Delta, and the poor infrastructure of most Hellenic lagoons. Erosion is also a potential problem in some coastal areas, since the strips of sand that separate many coastal lagoons are diminishing.

In Northern Hellas, low temperatures and the formation of ice on the lagoon's surface during winter negatively affect fisheries' production. According to data from the meteorological station of the Fisheries Research Institute in Kavala (Macedonia), ice formed on the surface of the lagoons during January or February in five of the last seven years (i.e. in 2000-2006), causing almost total fish mortality in almost all North Hellenic lagoons (Figure 10). In addition, there is an ongoing problem of protecting fish maintained in the wintering channels from attacks by cormorants. Finally, the efforts

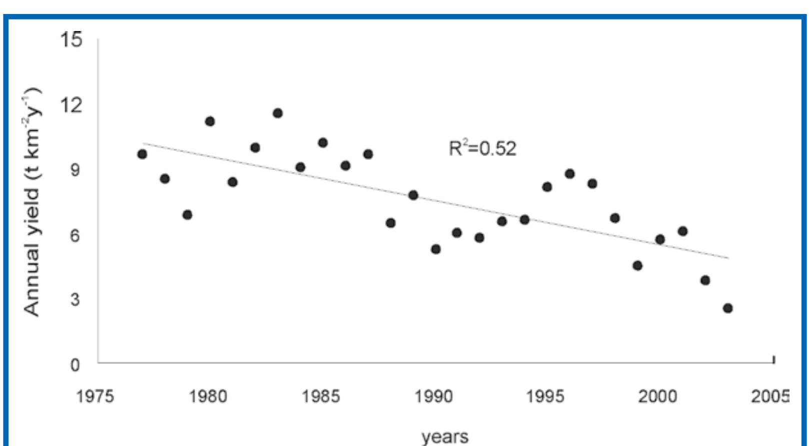

Figure 9: Long term trend of the annual yield of four lagoons in the Amvrakikos Gulf (Prefecture of Preveza).
Source data: ECONOMIDIS *et al.*, 2001.

Figure 10: Mass mortalities of fish caused from ice on the Agiasma Lagoon (Nestos Delta).
Source: A. KALLIANIOTIS.

made by some fishing cooperatives to increase the fish production in the lagoons of Northern Hellas and the Amvrakikos Gulf complex, has lead to dangerous practices, such as the introduction of juveniles (notably sea bream) derived from commercial hatcheries. The negative aspects of these practices have not yet been evaluated.

Nevertheless, human pressure on lagoon ecosystems is more limited in those with well-established and productive fishing cooperatives, whereas lagoons with no fishing activities suffer from a rapid decrease in total surface area and environmental quality. Thus, fishermen not only protect lagoon ecosystems because of the dependency of their income, but they also participate in all efforts regarding lagoon conservation. This means that the fisheries' exploitation of a lagoon could be an interesting tool for its conservation, since local communities exploiting the fisheries protect the lagoons against the development of antagonistic activities (KOUTRAKIS, 2005).

The particular character of the lagoon ecosystems and the pronounced traditional character of the human societies linked to the lagoons limit the flow of information on the functioning and dynamics of these ecosystems and the needs of such communities. Despite the important investments made by subsequent Hellenic governments, there is still a considerable lack of information (KOUTSIKOPOULOS *et al.*, 2004).

Despite the ecological, social and economic importance of the lagoons, their management neglects fundamental aspects of their nature, in particular, their important role as nurseries for coastal resources. Moreover, these particular sites suffer from increasing competition and pressure from other human activities such as rural development, tourism and agriculture. With regard to the inland fisheries' management, several trials such as enhancements are carried out without a well-defined approach. The reconsideration of their position and the role of these lagoons is a major challenge for the future of both the ecosystems and the human communities linked to them.

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ANNEX I

Table 1

List of the commercially most important lagoons in Hellas per region. Lagoons noted with asterisk used to have fishing activities but nowdays they are not exploited for different reasons.
Source: ACEA SA, 1997; DAFIS *et al.*, 1996; ECONOMIDIS *et al.*, 2001; ELIAS, 2001.

Name	Prefecture	Area (km^2)
EAST MACEDONIA & THRACE		
Monolimni - Paloukia	Evros	2.8
Drana*	Evros	4.8
Lakki*	Evros	2.0
Akrotiriou Samothrakis*	Evros	0.1
Mavrolimni-Arogi-Karatza	Rodopi	1.8
Mesi-Aliki-Touzla	Rodopi	3.0
Xirolimni-Fanariou	Rodopi	2.5
Ptelea	Rodopi	2.0
Limni	Rodopi	0.5
Elos-Karagatselia	Rodopi	2.0
Vistonida	Xanthi	45.0
Porto-Lagos	Xanthi	3.2
Lafri	Xanthi	1.5
Lafrouda	Xanthi	1.1
Erasmiou-Magganon-Palia koiti Nestou	Xanthi	0.3
Monastiraki-Gefyrakia	Kavala	0.4
Keramotis	Kavala	1.5
Agiasma	Kavala	4.3
Chaidefto	Kavala	0.5
Erateino	Kavala	3.5
Vassova	Kavala	2.7
Palia koiti Strymona*	Kavala	0.6
CENTRAL MACEDONIA		
Aylakas Papapouliou	Pieria	0.3
THESSALIA		
Avalakas Palaiopotamou	Larisa	0.37
IPEIROS		
Kalaga	Thesprotia	0.9
Vounta	Thesprotia	5
Loutsa-Papadia	Thesprotia	3.6
Riho	Thesprotia	0.8
Vatatsa	Thesprotia	0.9
Vathi	Preveza	0.5
Mazoma	Preveza	1.9
Pogonitsa	Preveza	0.5

Name	Prefecture	Area (km^2)
IPEIROS		
Tsopeli	Preveza	1.2
Agios Georgios*	Arta	0.2
Tsoukalos	Arta	2.0
Konstantia	Arta	4.7
Rodia- Tsoukalio	Arta	28.5
Logarou	Arta	40.0
Sakoletsi	Arta	0.4
Agrilos	Arta	2.5
Koftra-Paliompouka	Arta	0.8
IONIAN ISLANDS		
Antiniotiki-Acharavis	Kerkyra	0.6
Chalkiopoulou*	Kerkyra	2.7
Korission*	Kerkyra	6.3
Aylaimona-Stenou Lefkadas	Lefkada	5.0
Palio	Lefkada	3.0
Alikis Alexandrou	Lefkada	0.7
WESTERN HELLAS		
Aegiou*	Achaia	0.3
Araxou-Pappa-Kalogrias	Achaia	3.0
Aitolikou	Aitoloakarnania	28.0
Vonitsas-Myrtari	Aitoloakarnania	0.5
Katafourko-Anoixiatiko	Aitoloakarnania	3.0
Klisova	Aitoloakarnania	18.0
Kentriki Limnothalassa Messolonghiou	Aitoloakarnania	80.0
Tholi	Aitoloakarnania	14.0
Paleopotamos	Aitoloakarnania	4.5
Diavlou	Aitoloakarnania	2.5
Petalas	Aitoloakarnania	2.5
Bouka-Sykia	Aitoloakarnania	0.6
Saltini	Aitoloakarnania	1.9
Kokkala	Aitoloakarnania	0.3
Kotychio-Nevythos	Ilia	7.0
MAINLAND HELLAS		
Megalo Livari	Evvoia	1.0
PELOPONNISOS		
Gialova	Messinia	4.5

CHAPTER V

FISHERIES-ENVIRONMENT

CHAPTER V
FISHERIES-ENVIRONMENT

INTRODUCTION

The effects of the environment on fish distribution and abundance in Hellas have been systematically analyzed and quantitatively identified only recently. A number of studies emerged during the last decade that examined fish-environment relationships and established quantitative relationships between them.

These studies were mainly the outcome of various EU and HCMR research programmes (see Table 1 for most recent ones) and can be broadly categorized into those dealing with: a) pelagic fish species, b) demersal fish species c) deep-water decapod crustaceans and d) cephalopods. Major findings of these studies are addressed in the following papers.

The effects of fishing on the environment and the ecosystem encompass the complexity of the environment (the multitude of dependencies of different relationships) in which exploited and non exploited faunas and multi-species communities are embedded as well as the wide diversity of different types of capture methods and their different intensities.

Fishing techniques and gears are classified as active and passive.

- Active methods include towed gears such as bottom otter trawls or beam trawls and dredges as well as fishing with explosives or chemicals. Passive gears include gillnets, baited hooks, traps and pots. Active gears and in particular beam trawls and dredges are the most detrimental in terms of impacts on the non target species and habitats

Passive or static gears can also have negative impacts either through fishing or "ghost-fishing". Accidental capture in gill nets is thought to be a cause of population decline of some endangered species such as the monk seal *Monachus monachus* and the loggerhead turtle *Caretta caretta*. Small dolphin species are infrequently caught by gill nets and on rare occasions, turtles and sharks are caught by long lines.

TYPES OF EFFECTS

Impacts of fishing can be either direct or indirect although their ecological footprint and severity will depend among others on the gear used and the habitat fished. Direct effects include:

1. Removal or damage: fishing mortality on species' populations (target commercial and non target species) during the fishing process, either by removal (to land or to discard) or by killing them without actually retaining them in the gear (non-catch mortality), and/or by making them vulnerable to scavengers and predators (through exposure and damage)
2. Changes in food availability: energy subsidies and increasing food available to other species in the system by discarding unwanted fish, fish offal and benthos in parallel with loss of prey and predators due to fishing mortality
3. Changes in habitat terrain: physical disturbance

Table 1. Studies related to Environment-Fisheries' Interaction with Hellenic coordination and/or participation.

Study Period	Project Title	Contractor	Study Areas
2002- to now	**NATIONAL** "National Fisheries Data Collection Programme"	EU ERANET	Aegean & Ionian Seas
2005-2007	**Small Pelagic**: Improvement of in-year management of small pelagic fish in the Aegean Sea	EU DGXII	Aegean Sea
2002-2005	**ANREC**: Association of Physical and Biological processes acting on Recruitment and post-Recruitment of Anchovy	EU- FP5	North Aegean
2007- 2009	**SARDONE:** Impact assessment and management of small pelagic species in the Mediterranean Sea	EU FP6	Aegean Sea

and/or loss of marine habitats, e.g. by altering the seabed surface topography or by destroying coral reefs and maerl habitats.

Indirect effects are the knock-on effects that follow from a direct effect, including:

1. Effects on diversity, abundance and body size, alterations of benthic community function and structure.
2. Species interactions and predator and prey responses to the removal of target species.
3. Nutrient regeneration and effects on biochemical processes due to changes or removal of key functional groups (e.g. bioturbators, filter feeders) and changes in habitat terrain (e.g. mechanical disturbance of sediments and sediment resuspension).

STUDIES ON THE IMPACTS OF FISHING

A substantial number of projects, supported by the European Union and the Hellenic General Secretariat for Research and Technology, have been carried out recently in Hellenic waters aimed at the study of the effects of fishing and particularly the study of trawling effects. The studies that have been completed to date fall into several categories although multiple aspects may have been completed in a particular study. A certain amount of work has been published in scientific journals, although the majority of it is in the grey literature or still to be published. Major findings of this work are reported here along with gaps in the knowledge and work still to be done.

A number of research projects have been undertaken investigating trawling impacts in Hellenic waters (Table 2). Theses projects have been undertaken in the Thermaikos Gulf (Table 2, Study 2), the Southern Evvoikos Gulf (Study 5), the Pagasitikos

Table 2. Funded research projects on fisheries' ecosystem interactions undertaken in Hellas (IMBC: Institute of Marine Biology of Crete, NCMR: National Centre for Marine Research, IMBC and NCMR were merged into HCMR in 2003), AMP engineering: Armenis, Moraitis and Partners engineering Company, NAGREF: National Agricultural Research Foundation).

Study	Study Period	Project Title	Contractor	Hellenic Participants	Study Areas
1	2002-2004	**COST-IMPACT**: Costing the impact of demersal fishing on marine ecosystem processes and biodiversity.	EU DGXII	IMBC	Irakleio Bay
2	2001-2003	**INTERPOL**: Impact of natural and trawling events on resuspension, dispersion and fate of pollutants.	EU DGXII	NCMR, IMBC	Thermaikos Gulf
3	1999-2000	**FGE2/OTIP**: Comparison of rapid methodologies for quantifying environmental impacts of otter trawling.	EU DGXIV	IMBC	Irakleio Bay
4	1999-2001	A new method for the quantitative measurement of the effects of otter trawling on benthic nutrient fluxes and sediment biogeochemistry.	EU DGXIV	IMBC	Irakleio Bay
5	1996-1997	**TRIBE**: Trawling impact on benthic ecosystems.	EU DGXIV	NCMR	S. Evvoikos Gulf
6	1993-1996	**FGE:** The environmental impact of demersal fishing gears on the marine environment.	EU DGXIV	IMBC	Irakleio Bay Pagasitikos Gulf
7	1990-1993	**FAR**: New methods of using fixed fishing gears in the Mediterranean sea : adaptability and profitability	EU 2nd FP	NCMR	Ionian Sea

(continued)

Table 2: (continued)

Study	Study Period	Project Title	Contractor	Hellenic Participants	Study Areas
8	1991-1994	Small-scale fisheries in the South Evvoikos Gulf (Greece): species composition and gear competition	EU DGXIV	NCMR	S. Evvoikos Gulf
9	1993-1995	L´ impact de l´ activité de la pêche a la senne de plage	EU DG-XIV	AMP engineering	Saronikos Gulf. Kyklades Ionian Sea
10	1994-1996	Selectivity of square mesh windows in Fish and *Nephrops* Trawls	EU DG XIV	IMBC	Irakleio Bay
11	1997-1999	*Pagellus bogaraveo* gill net metier in Ionian Sea: Gill net selectivity, assessment and biology	EU DG XIV	NCMR	Ionian Sea
12	1999-2001	*Nephrops* Trawl Discard Reduction using Activating Selection Grids	EU DG XIV	NAGREF	N. Aegean Sea
13	1999-2000	**TURTLE:** Assessing marine turtle by-catch in European drifting longline and trawl fisheries for identifying fishing regulation	EU DGXIV	IMBC	Aegean & Ionian Seas
14	2004-2007	**NECESSITY:** Nephrops and Cetacean Species Selection Information and Technology www.rivo.dlo.nl/sites/necessity	EU 6th FP	HCMR	Pagasitikos Gulf
15	1995-1996	**DISCARDS**: Analysis of trawls' discard operation in the central and eastern Mediterranean Sea	EU DGXIV	IMBC, NCMR	Aegean & Ionian Seas
16	1997-1998	**DISCARDS**: Analysis of trawls' discard operation in the central and eastern Mediterranean Sea	EU DGXIV	IMBC, NCMR	Aegean & Ionian Seas
17	1999-2000	**DISCARDS**: Analysis of trawls' discard operation in the central and eastern Mediterranean Sea	EU DGXIV	IMBC, NCMR	Aegean & Ionian Seas
18	2002-to now	**NATIONAL** "National Fisheries Data Collection Programme"	EU ERANET	HCMR	Aegean & Ionian Seas
19	2005-2009	Monk seal and Fisheries: Mitigating the conflict in Greek seas	LIFE 05NAT/GR/000083	Mom WWF Hellas NAGREF	Aegean & Ionian Seas

Gulf (Study 6) and Irakleio Bay Kriti (Studies 1, 3 4, 6). The Thermaikos Gulf project studied a commercial trawling ground in the closed and open season (silty clay, 30-90 m depth). The study in the Evvoikos Gulf compared commercially trawled and untrawled areas with seasonal sampling (muddy-sand, 70 m). The Pagasitikos' investigation (silty sediment 80 m) was a before and after experimental impact study. The work undertaken in Kriti has been the most extensive and includes a before and after trawling study (70 m depth, coarse sediment), a simulated trawling study (70-150 m muddy sand) and comparisons between commercially trawled and untrawled areas (200 m, silty sediment). Much work has been undertaken at the latter site (Studies 1, 3, 6) where there is a closely defined commercial fishing lane with similar depth untrawled study areas in very close proximity (< 1 km).

A smaller number of research projects have been undertaken investigating the impacts of passive gears including gillnets, longlines and traps (Table 2). These projects have been undertaken in various parts of the Aegean and Ionian Seas and although most of these have other primary objectives (e.g. selectivity studies) they have also looked into aspects of fishing impacts (removal of non target species and production of discards).

A large amount of work has been put into moni-

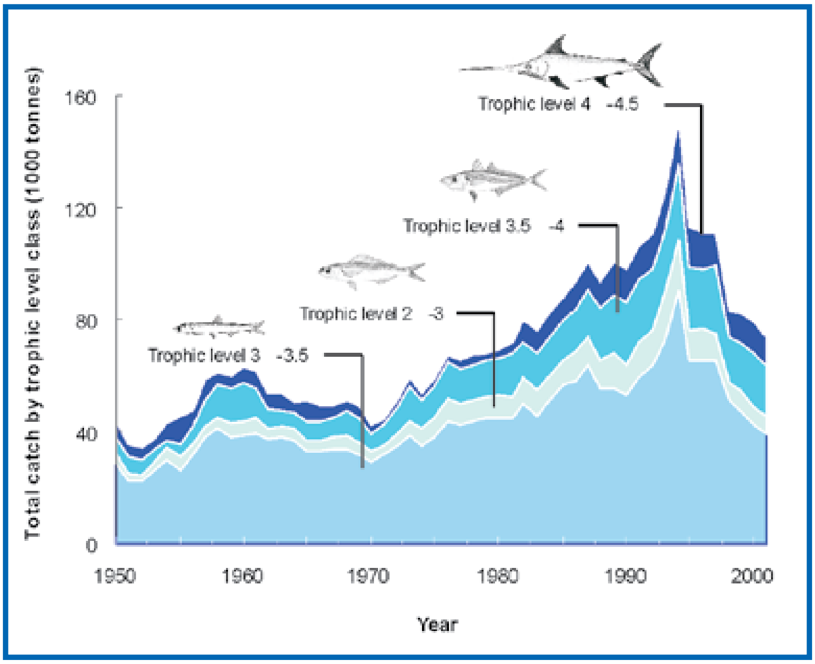

Figure 1: Long-term changes in fish catches in Hellenic waters aggregated by four trophic level classes.
Source: STERGIOU, 2005.

toring and quantifying the discards, with surveys covering both the Aegean and Ionian Seas. The first surveys started in 1994 through a series of DG XIV/DG Fish EU funded Research Projects. More recently (from 2002) the NATIONAL ERANET project "National Fisheries Data Collection Programme" conducts annual surveys following on from the MEDITS and DISCARDS projects, building up an important time series of data.

Among the various effects of overfishing, those related to foodweb and trophic structure changes have received particular attention in recent years. Since trophic levels in marine organisms generally increase with size, again both between- and within-species, intense fishing lowers the relative catch contribution of large-sized organisms, positioned high in the food web. As a result fisheries' catches are progressively dominated by small-sized fishes (i.e. the mean trophic level of the catches declines with time). For the Hellenic Seas, a preliminary analysis by STERGIOU & KOULOURIS (2000) showed that in many areas of the Aegean Sea (i.e. the Saronikos Gulf, the Thermaikos Gulf and the Thracian Sea, Southern Aegean) the mean trophic level of the catches decreased during the last years. In contrast, "fishing down" was less pronounced in the Hellenic part of the Ionian Sea. A later review (STERGIOU, 2005) has confirmed that the mean trophic level of catches in Hellenic waters has decreased during the last five years (Figure 1). Trends of mean trophic levels has been tested as a potential indicator to evaluate the impact of trawling on demersal fish assemblages in the Aegean sea (see Chapter VI.6.: Indicators for ecosystem structure and functioning of Hellenic Fisheries)

The study of the feeding habits of the commercially exploited fish species and of other important components of the marine ecosystems such as large crustaceans, cephalopods, marine mammals, turtles and seabirds together with estimates of their trophic levels is also of primary importance for quantifying trophic interactions and energy flow as well as for the identification of the effects of fishing on the Hellenic marine ecosystems. However, this issue has been addressed in detail by STERGIOU & KARPOUZI (2002) and updated by STERGIOU (2005).

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V.1. EFFECTS OF ENVIRONMENT ON HELLENIC FISHERIES

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INTRODUCTION

The effects of environment on fish behaviour, abundance and distribution are the main subjects of fisheries oceanography (LAEVASTU & HAYES, 1981). Fisheries oceanography deals with those aspects of oceanography that can be applied to fisheries ecology, fisheries management, and practical fishing, i.e. research relating the production and dynamics of fished populations to the marine environment (LAEVASTU & HELA, 1970). The degree of fish aggregation, its timing and its location have major impacts on the fisheries management, conduct of research, interpretation of results and, needless to say, practice of commercial fisheries. Studying the factors influencing changes in the spatio-temporal distribution of fish not only elucidates the ecological basis of adaptive behaviour; it is critical to successful fisheries management, since failure to recognise spatial complexity has resulted in stock collapses (HILBORN & WALTERS, 1992). A physical-biological interaction that usually happens in the sea is the alternation between vertical mixing and stratification that leads to enhanced production, mainly by diatoms (MANN, 1993). Diatoms are in general eaten by mesozooplankton such as copepods (CUSHING, 1989) or they sink to the bottom and are eaten by benthic invertebrates (COLEBROOK, 1986). In either event, they are the basis of the "traditional food chain" by which energy and materials are passed through mesozooplankton to fish. Evidence is now mounting that natural environmental factors played some part in the collapse of important fish stocks worldwide (e.g. Peruvian anchovy in early 1970s and North Sea herring stocks in late 1970s). As BAILEY & STEELE (1992) stated, if recruitment is poor over an extended period because of an environmental change, then the spawning stock will decrease regardless of whether there is a causal relationship between recruitment and stock. The environmental effect is exacerbated by heavy fishing pressure because the adult stock then decreases much more rapidly. However, ocean conditions may change significantly from year to year and it is therefore unlikely that fish distribution will always have the same simple quantitative relationship to abiotic and biotic factors. Relationships would be expected to be nonlinear and non-parametric, although general features of the relationship might hold true from year to year (MARAVELIAS & REID, 1997).

In other seas the pioneer work was done in late '30s, e.g. within the North Sea, HARDY (1936) who showed a negative relation between herring catches and dense phytoplankton blooms and a positive relation between herring catches and their food organisms, particularly *Calanus*. Using the plankton indicator (i.e. a torpedo-shaped towed instrument to sample plankton samples) he showed that waters rich in *Calanus* were associated with good catches of herring. The relation was so convincing that the indicator was used by the commercial drifters to ensure good catches.

The eastern Mediterranean is dominated by important basin and sub-basin features, such as gyres, jets eddies and meandering currents, which reflect its complex geometry, bathymetry and highly variable atmospheric forcing (PAPACONSTANTINOU & STERGIOU, 1995). The Aegean Sea is characterised by complex bathymetry, narrow continental shelf (with the exception of its northeastern part), many small islands (approximately 2000) and until recently was considered as an area of low biological productivity. The Greek part of the Ionian Sea (i.e. the eastern Ionian Sea) is characterized by the existence of the deep Hellenic Trench, lying along the western and southwestern Hellenic coast and the islands of the Cretan Arc.

FISHERIES OCEANOGRAPHY STUDIES IN THE HELLENIC SEAS

Within the Hellenic Seas, several studies have occasionally hypothesized that the spatial distribution of fish species and corresponding catches may be linked to the marine environment (references in STERGIOU *et al.*, 1997). However, the effects of environment on fish distribution and abundance have been systematically analyzed and quantitatively identified only recently. A number of works emerged during the last decade that examined fish-environment relationships and establish quantitative relationships between them. These studies were mainly outcome of various HCMR research programmes and can be broadly categorized into those dealing with: a) PELAGIC FISH SPECIES, b) DEMERSAL FISH SPECIES c) DEEP-WATER

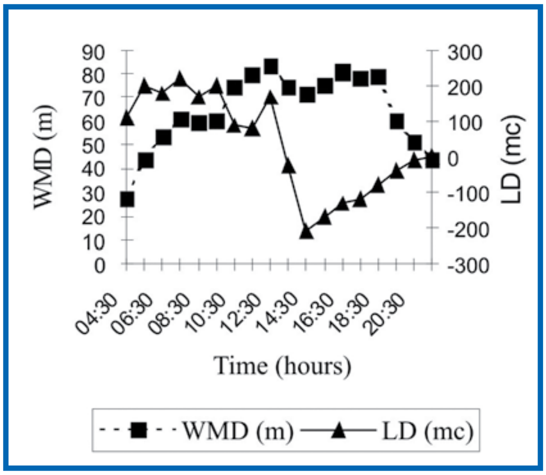

Figure 1: The average depth of sardine (WMD) in the Thracian Sea with the corresponding hourly changes in ambient light intensity (LD). Positive values of LD indicate increase in light intensity during the first part of the day, while negative values indicate decrease in light intensity during the second part of the day.
Source data: GIANNOULAKI *et al.* (2005).

DECAPOD CRUSTACEANS and d) CEPHALOPODS.

A) Effects of environment on pelagic fish species

The acoustically derived distribution of anchovy and sardine schools were related for the first time to hydrographic regimes in the North Aegean (MARAVELIAS *et al.*, 1997). Since then both species spatial patterns have been repeatedly associated with ocean environmental conditions (GIANNOULAKI *et al.*, 1999; 2005). In the northern Aegean Sea and within the range of available temperatures, sardine was further selective for warm waters, which was not the case for anchovy (GIANNOULAKI *et al.*, 2005). Light intensity and bottom depth were found to affect the movements of the sardine (Figure 1).The centre of sardine density tended to level out as the light intensity increased and a wide range of "preferred" light intensity was observed (GIANNOULAKI *et al.*, 1999).

B) Effects of environment on demersal fish species

a) Hake (*Merluccius merluccius*)

In certain regions of the Hellenic Seas a number of studies have examined the distribution patterns of European hake (a thorough literature review is given in PAPACONSTANTINOU & STERGIOU, 1995 and references therein). As environmental data were scarce in the past, it was not feasible to examine, in depth, the effect of environment on hake distribution/abundance. Lately, routine research surveys collected oceanographic data thus enabling the population dynamics of hake to be linked to the ocean environment.

In the northern Aegean Sea hake abundance distribution has been related to the bathymetry, spatial location and the temperature-based variability of the ecosystem (MARAVELIAS *et al.*, 2006) using generalized additive models (GAM). It was found that geographic position and sea bottom characteristics influence the temporal distribution patterns of hake. Data revealed area-specific aggregation patterns and an important habitat utilization of the area. Results indicated that areas with the highest hake abundances were located in waters of ~160 m having bottom temperature of ~16°C and avoided the shallower waters (<70 m) regardless of their bottom temperature (Figure 2). Colder bottom waters in all depths were associated with lower than average hake abundance.

b) Red mullet (*Mullus barbatus*)

The distribution patterns of red mullet in the Hellenic Seas have been studied repeatedly in the past (VASSILOPOULOU & PAPACONSTANTINOU, 1993; STERGIOU & POLLARD, 1994; TSERPES *et al.*, 1999 & 2002; MARAVELIAS *et al.*, 2003; MARAVELIAS & PAPACONSTANTINOU, 2006). Smaller red mullet preferentially distribute in shallower waters in the south part of the northern Aegean throughout the year and avoid waters deeper than 200 m (Figure 3; MARAVELIAS *et al.*, 2003). Larger red mullet are observed in the period between March and June (VASSILOPOULOU & PAPACONSTANTINOU, 1993; TSERPES *et al.*, 1999). The higher CPUE and biomass values observed in the northern Aegean Sea have been attributed to the bathymetry and topography of the area and the existence of relatively shallow and smooth bottoms which red mullets are known to prefer as opposed to the narrow continental shelves and great steep depths in Cyclades and Ionian Sea regions (MARAVELIAS & PAPACONSTANTINOU, 2006).

The temperature-based variability of the northern Aegean ecosystem has also been found to modulate the temporal distribution patterns of red mullet (MARAVELIAS *et al.*, 2006). Red mullet abundance is consistently highest in areas having shallower depths (35-60 m) and warmer bottom waters (around 19°C). Using GAMs the

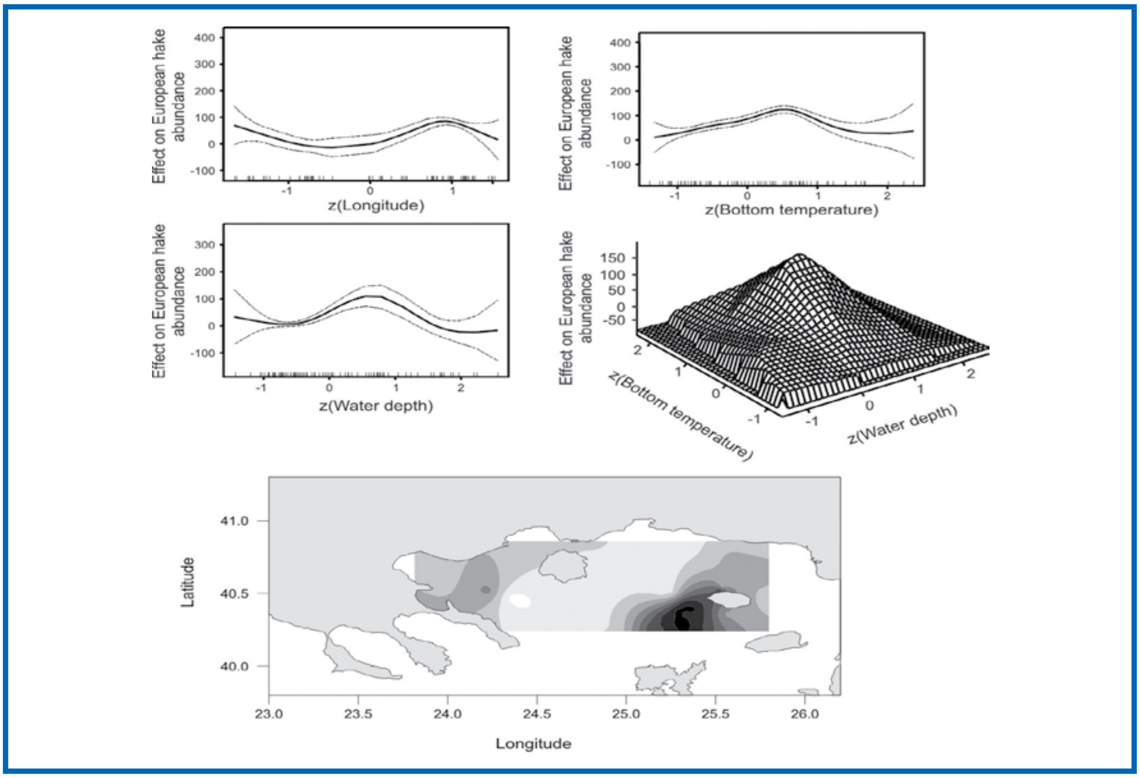

Figure 2: Generalized additive model-derived additive effects of longitude, water depth, bottom temperature and interaction of water depth with bottom temperature for European hake in 1997. Dashed lines represent two standard error ranges around the covariate main effects. Spatial distribution of GAM-estimated abundance of European hake and auxiliary variables (longitude, water depth, bottom temperature and the interaction of water depth with bottom temperature) in 1997 in the northern Aegean Sea.

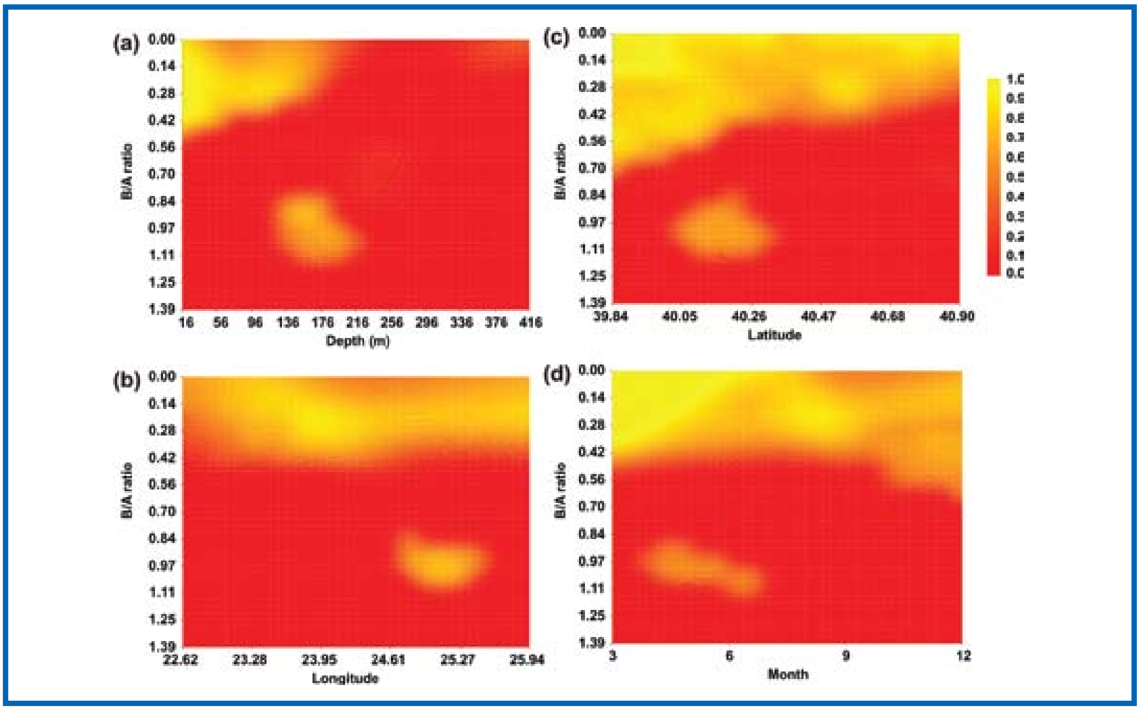

Figure 3: Artificial Neural Networks (ANNs) estimated probability of *M. barbatus* presence as a function of predictor variables in the northern Aegean Sea. B/A ratio: Biomass / Abundance ration of the species (kg/number).

red mullet were evidenced to avoid the cold bottom waters (<16°C) of the deeper regions (Figure 4) in the northern Aegean Sea. Red mullet abundance increased with increasing bottom temperature values (>16°C) and remained higher than average up to bottom temperature values of ~21°C. In shallower waters there was also an increase on average red mullet abundance with increasing bottom temperature up to a bottom temperature value of ~19°C beyond which mullet abundance decreased.

c) Anglerfish (*Lophius budegassa*)

In the Mediterranean, including Greece, information on the effects of environment on *Lophius* species dynamics is lacking. Apart from the poor availability of environmental data until recently, this is also due to the species being regarded as a by-catch and of low economic importance in the past. Since then there has been a remarkable increase in the commercial value of anglerfish, with recent market prices being five times greater than in the mid 1990s. As a result, black anglerfish became an important target species and *Lophius budegassa* landings increased remarkably.

Recently the spatial distribution patterns of black anglerfish, *Lophius budegassa* in relation to size category, bathymetry, locational covariates, and season were analysed in the northeastern Aegean Sea (MARAVELIAS & PAPACONSTANTINOU, 2003). In this work the hypotheses that there was size-related variation in species' habitat associations and that the study area might serve as a nursery ground for black anglerfish was examined under the framework of generalized additive models (GAMs). Data were presented that reveal size-dependent aggregation patterns of black anglerfish and an important habitat utilization of the north-eastern Aegean area as a nursery ground. The different size-classes exhibited significant seasonal effects and preferences for specific regions and distinct water depths (Figure 5). The results of this study also suggested that 1-y-old fish and potential spawners appeared to concentrate in the vicinity of the same areas. Two main areas of juvenile aggregations were detected in the deeper water regions of the study area on a seabed of around 300m depth; both emerged in the proximity of the locations of larger fish. The bathymetric distribution of intermediate size anglerfish followed an inverse trend, with fish captured mainly in shallower waters. Results indicated a preferential aggregation of 1-y-old *L. budegassa* in the study area that is hypothesized to influence the supply of recruits to distant regions of the Aegean Sea.

d) John dory (*Zeus faber*)

In the eastern Mediterranean the species is fairly abundant and is exploited mainly by trawl and artisanal fisheries (STERGIOU *et al.*, 1997). John Dory is usually considered a valuable by-catch although some seasonal targeting has also been observed (DUNN, 2001). Despite its commercial importance, information on John Dory's habitat use and ecological preferences is sparse, as until now, no study has examined the species/environment relationships.

The quantitative relationships between John Dory seasonal abundance data, their spatial distribution and abiotic factors have been analyzed for the central Aegean Sea (Cyclades and Dodecanese areas, MARAVELIAS *et al.*, 2007a). To the best of our knowledge, this was the first study attempting to quantitatively identify the relationship of John Dory with geographical position and ocean environmental variables with the main aim being to draw inferences for the mechanisms that give rise to the seasonal distribution of the species. The

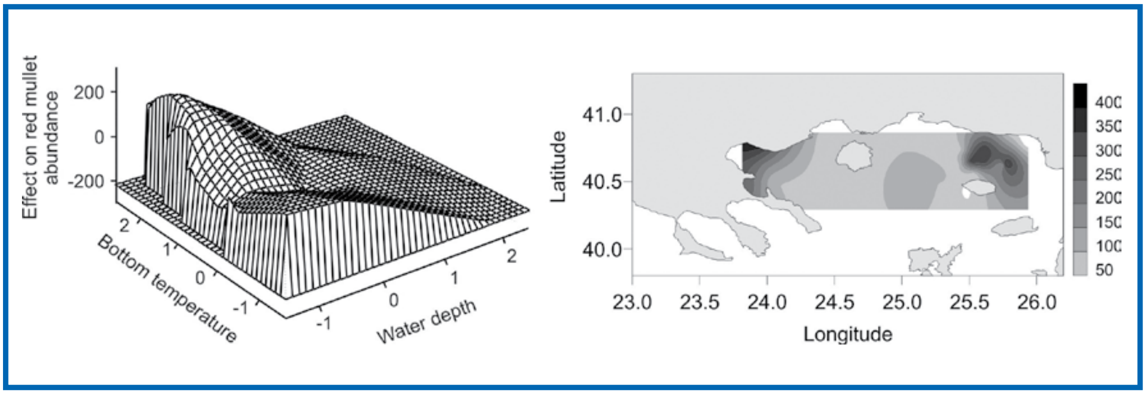

Figure 4: Generalized additive model-derived additive effects of interaction of water depth with bottom temperature in 1996 for red mullet (left). Spatial distribution of GAM-estimated abundance (n h^{-1}) of red mullet and auxiliary modelled variables (longitude, bottom temperature and the interaction of water depth with bottom temperature) in 1996 (right) in the northern Aegean Sea.

sea bottom temperature had a significant effect on seasonal John Dory abundance both directly, as a main effect, and indirectly, through its interactive effect with the water depth (Figure 6). John Dory seasonal abundance was consistently greater in the shallower (< 80 m) regions of the area having warmer bottom waters (> 16.5°C) and characterised by weak hydrographic activity, throughout the year. Results indicated a distinct southward shift as progressing through the year, with peak abundances being observed in gradually lower latitudes of shallow areas as seasons evolved (Figure 7). John Dory appeared to avoid the deeper waters regardless of their bottom temperature and geographic position. During winter John Dory were most likely benefiting by the proximity of their preferred feeding grounds to an area of intense hydrodynamic regime while the spatial aggregation of the species in hydrologically quieter sheltered grounds in summer was related to habitat preferences during the spawning period.

e) Morocco dentex (*Dentex maroccanus*)
In the northeastern Mediterranean the species has been recorded occasionally during scientific trawl surveys conducted for stock assessment purposes. It is considered a valuable by-catch species and is exploited mainly by trawl and artisanal fisheries. There is little detailed information on biology and species ecological preferences. The first data on the seasonal aggregation patterns and spatial distribution of Morocco dentex in relation to ocean environmental conditions have been presented for the Cyclades and Dodecanese regions (MARAVELIAS *et al.*, 2007b). Morocco dentex exhibited a preferential seasonal aggregation in specific geographic and bathymetric regions of the study area (Figure 8). In all four seasons, these favourable regions were found to be relatively stable and distinct (not shown here, for more details see MARAVELIAS *et al.*, 2007b), had the highest CPUE and were located over shallower grounds (50-70 m) having bottom salinity around 39.1 (Figure 9). Throughout the year, the species was confined below the thermocline and avoided the deeper waters (>80 m).

C) Effects of environment on decapod crustaceans

The *Aristeus antennatus, Aristaeomorpha foliacea* and *Penaeus kerathurus* constitute an important fishery resource in the Hellenic waters. Altough the biology, distribution and population structure have been examined repeatedly (KAPIRIS *et al.*, 2001; PAPACONSTANTINOU & KAPIRIS, 2001 & 2003; POLITOU *et al.*, 2004; SARDA *et al.*, 2004 and references therein), there is little detailed information on the effects of environment on these economically important shrimps. CONIDES *et al.* (2001) concluded that temperature and dissolved oxygen are extremely important and may affect positively CPUE of *P. kerathurus* in the Ionian Sea. MYTILINEOU *et al.* (2006) related linearly both *A. antennatus* and *A. foliacea* to environmental factors in the Ionian Sea and found their abundance to be statistically significant related with temperature, latitude and depth (in that order of importance). POLITOU *et al.* (2004) also suggested that *A. foliacea* is linked to warmer and more saline water masses than *A. antennatus* in order to explain the different distribu-

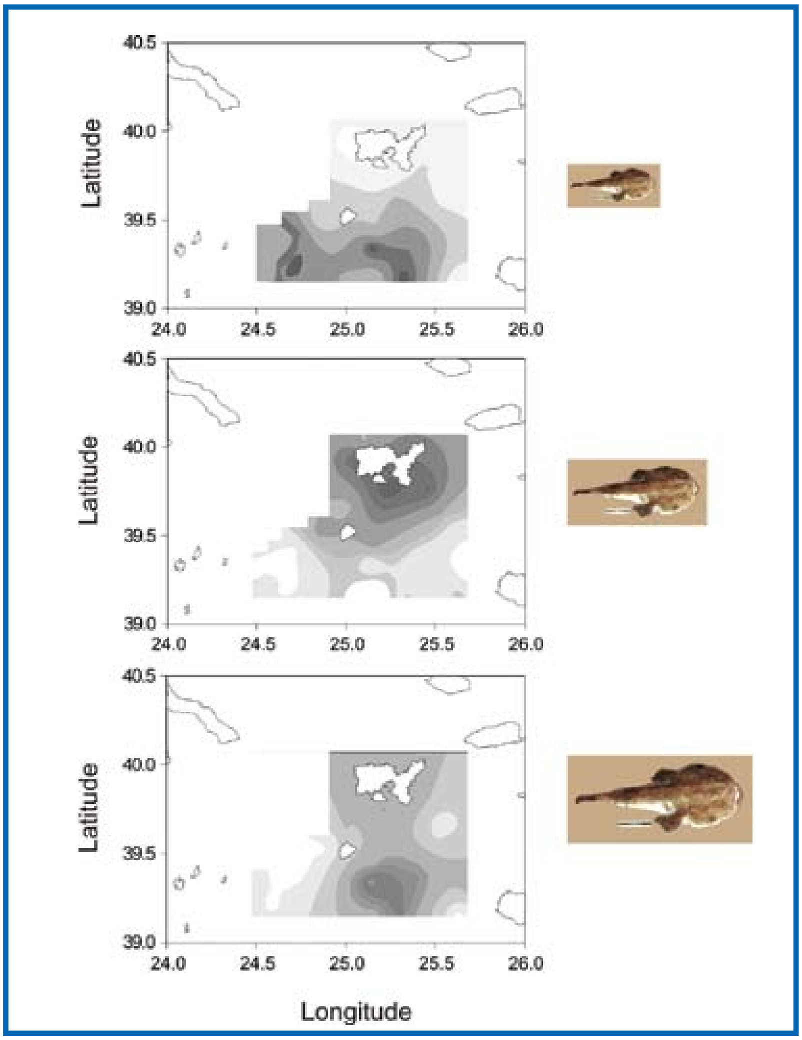

Figure 5: Spatial distribution of GAM-estimated abundance (n h^{-1}) of *L. budegassa* for each size class and auxiliary modelled variables (longitude, water depth, sampling season) during the study period.

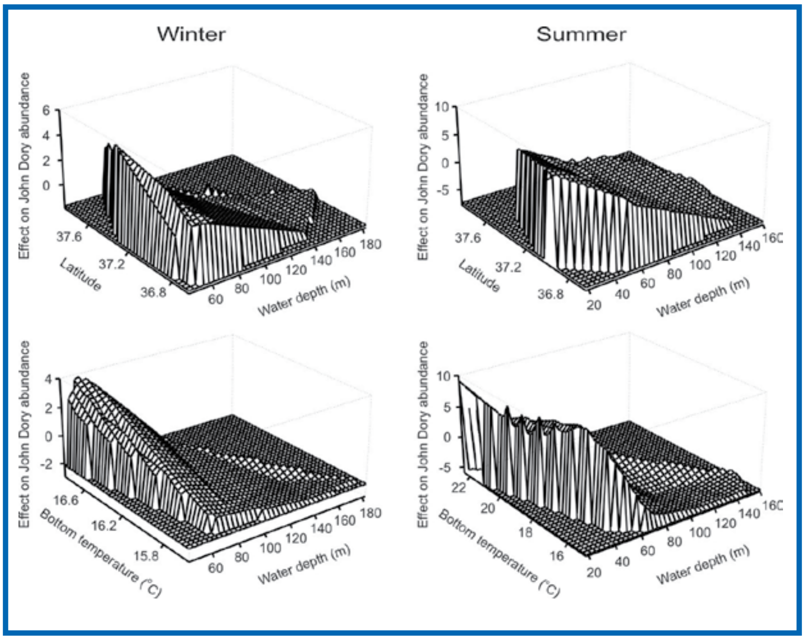

Figure 6: Generalized additive model-derived additive effects of water depth, latitude, sea bottom temperature and significant interactions for John Dory in winter and summer.

tion patterns of the two species in the Ionian Sea.

D) Effects of environment on cephalopods

Landings and effort data for *Loligo vulgaris* have been correlated to average daily air temperature (°C), daily rainfall (mm), hourly wind speed (knots) in coastal areas in northern Greece (LEFKADITOU *et al.*, 1998a). Results showed that temperature was the most significant explanatory variable for CPUE variation, wind was important only during winter whereas rainfall was significant only in one area of less saline waters. LEFKADITOU *et al.* (1998b) examined the seasonal and spatial changes in the abundance and distribution of *Eledone moschata* (Cephalopoda: Octopoda), in the South Aegean Sea (Eastern Mediterranean). The CPUE and mantle length frequency distribution from experimental trawl surveys was descriptively related to mean monthly SST. It was suggested that there is a likely effect of temporary upwelling and shelf structure on seasonal abundance, as well as, on recruitment timing and duration.

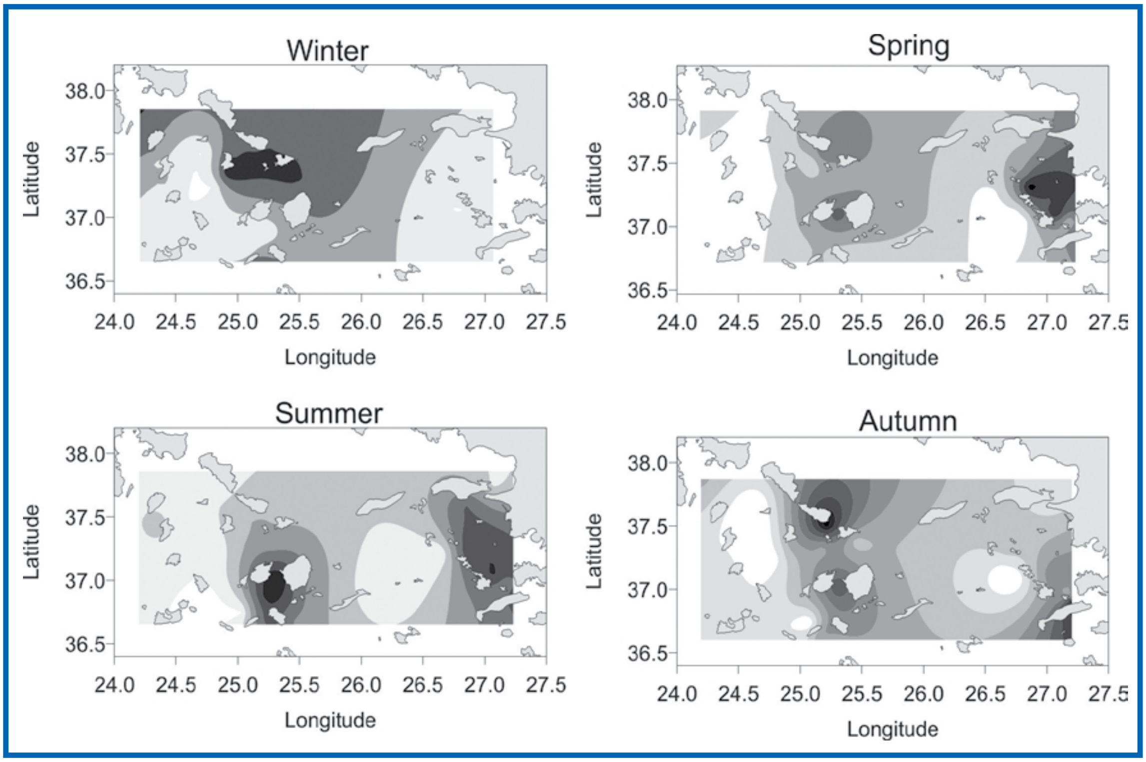

Figure 7: Seasonal spatial distribution of GAM-estimated abundance (number of individuals caught per hour trawling, n h^{-1}) of John Dory with auxiliary modelled variables (Latitude, Water depth, Bottom temperature and interactions of Water depth with Latitude and Bottom temperature).

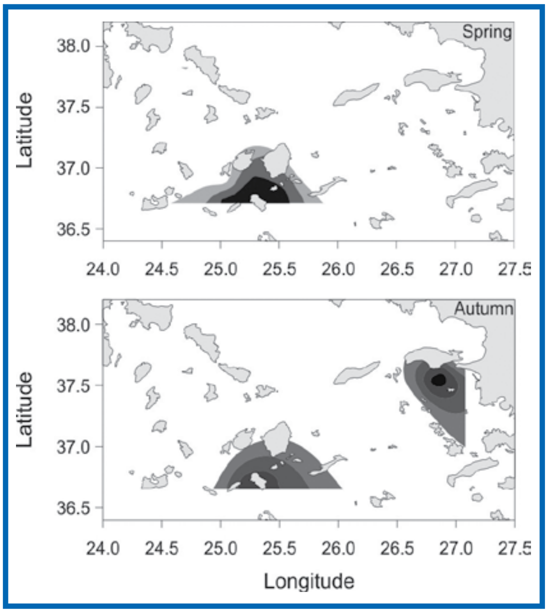

Figure 8: Spatial distribution of GAM-estimated CPUE (kg/h) of Morocco dentex with auxiliary variables (bottom salinity, water depth and longitude).

CONCLUSIONS

The revealed relationships of species and ocean environmental conditions suggest that, with the inclusion of additional years' data, preferred areas for location of the species can potentially be reasonably predicted. It is not possible to determine from the present evidence how general the phenomena may be. There is a clear need to conduct further research both on a finer scale and on the wider scale. It is more than likely that a further improvement in models' performance may be achieved through incorporation of additional factors not currently included in the analysis (e.g. prey availability, substrate type, currents, water velocity, turbulence). Predicting the occurrence of economically important demersal fish in a multi-species marine environment, such as the Mediterranean Sea, can be of considerable value to the long-term sustainable development of the fishing industry and to the protection of biodiversity. Reliable habitat models can delineate areas of likely occurrence of target species and that might potentially reduce the by-catch of non-target species. Evidently, such habitat models could be useful tools for decision making and conservation planning.

Environmentally induced responses of fish have long been quantified on the bases of deterministic cause and effect. Some randomness (probabilistic results) in the reactions and responses of fish however, do exist. The reasons for the varied responses are several, the main reason being that several factors (stimuli) affect the fish simultaneously and therefore we might expect deviations from an expected response to a single factor. In addition it is more likely that the effect of an environmental factor is indirect through interacting effects with other parameters. The problem is further complicated by the fact that the environmental requirements change during the various stages of growth. Furthermore, the temperature requirements of a certain species also change seasonally at least in connection with spawning. Moreover the concentration of food is temperature dependent which makes the determination of the "optimum" temperature for a fish complicated (CUSHING, 1975 & 1982). There are also time-delayed responses as well as indirect effects through interactions with other environmental factors. Thus several concurrently occurring conditions and factors should be evaluated and always considered that the expect-

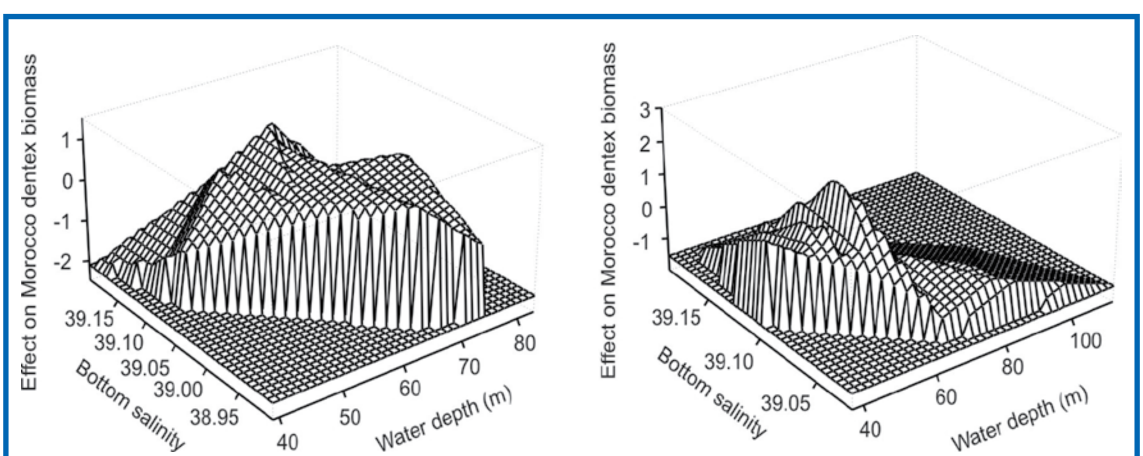

Figure 9: GAM-derived additive effects of bottom salinity, water depth and longitude for Morocco dentex in winter (left) and summer (right).

ed phenomenon has a given degree of probability of occurrence.

Secondly, something that is usually ignored: any findings of a study, does not necessarily apply to the fish population. Any descriptive statistical model (such as regression) is used for the particular realization of the phenomenon under study. A model is never unique and can be judged only on its adequacy to solve the particular problem at hand (JOURNEL, 1986). In other words, if a particular model fits the present data set, this does not necessarily implies that the model also describes adequately the underlying structure of the population. This is what MATHERON (1989) calls a "radical error".

Currently there is a need for improved methods of fish stock assessment. A substantial amount of money and effort is directed annually to fishery research surveys. Results from the present study could have a direct impact on fish stock assessment and management decisions. Convincing, stable relationships between fish species and environmental variables, which have also been quantitatively identified, can be used for more appropriate stratification in future research surveys. This could result in more accurate stock biomass estimates. The results of the above studies clearly showed that environmental variables can be used to characterize specific range of fish values. These could be either the highest concentrations of fish or the lowest (i.e. zero) concentrations. Thus, areas where highest densities may occur can reasonably be predicted. Apart from enabling us to conceive further the factors that influence the explicit spatial distribution of fish abundance this could also be of great assistance in future surveys and stock assessment issues. More precisely, it can be used as a means to reduce the variance in abundance estimates by providing additional information for the part of the survey area that requires more sampling effort due to high variability, through covariates that are easy to measure. In other words, it could be used as an indicator of areas where it is worth increasing the sample density for estimation of the global stock biomass because they are sufficiently rich and they have a high variance; a phenomenon common in schooling species. Conversely, it can be used as an indicator of areas where is worth decreasing the sampling intensity because of a consistent low abundance.

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V.2. BY-CATCH AND DISCARDS IN MULTI-SPECIES FISHERIES AND THEIR IMPACT IN THE HELLENIC WATERS

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INTRODUCTION

All animals caught during a fishing operation do not have the same value. Hence, fishers aim at increasing their revenue by discarding (i.e. throw overboard) the least valuable part of their catch. Moreover, fisheries' management policies, comprising output controls that limit landings (quotas) or some other characteristics such as minimal landing size, increase the incentives to discard. CLUCAS (1997) summarized the available data on the extent of the discarding practice in commercial fisheries around the world and observed generally lower levels of discarding in single or few species fisheries compared with those of multi-species fisheries. Therefore, discarding is expected to occur mainly in multi-target demersal fisheries, such as those applied in the Mediterranean, where it is perceived mainly as throwing away unmarketable by-catch species, and/or undersized individuals of target species. In fact, for commercial fisheries, although defining target, by-catch, incidentally caught and discarded species is an important issue, particularly for management purposes, there is still confusion in the terms used. Here we follow the terminology proposed by ALVERSON *et al*., (1994) and HALL (1999), illustrated in Figure 1 (i.e. incidental catch is the commercially valuable portion of the catch that was not the target, and by-catch is the incidental catch plus the discards: STERGIOU *et al*., 2003).

Discards are returned to the sea either dead or alive. Although the bulk of discarded fish are returned to the sea dead, the survival rate varies between different species; some fish such as dragonets *Callionymus lyra* are extremely vulnerable and nearly 100% die after capture, whilst others such as the starfish *Asterias rubens* are less susceptible to physical damage and less than 6% die (LINDEBOOM & DE GROOT, 1998). Discarding provides an additional source of potential food that can be utilized by scavengers either at the sea-surface, in mid water or on the sea bed. In particular, it has been found that sea birds following trawlers may consume around 40% of the discards in particular the roundfish and smaller flatfish (CAMPHUYSEN *et al*., 1995). Those discards not eaten by sea birds sink through the water column, where some may be eaten by cetaceans and fishes (WASSENBURG & HILL, 1990) and the remainder sink to the sea bed where they become available for bottom feeding scavengers. Recent studies have shown that benthic scavengers feed on both fisheries' discards and on animals damaged *in situ* by fishing gears (RAMSAY *et al*., 1998). Damaged benthos is mainly consumed by fish while discarded fish are mainly consumed by invertebrate scavengers such as crabs, starfish, sea urchins and whelks (GROENEWOLD & FONDS, 2000).

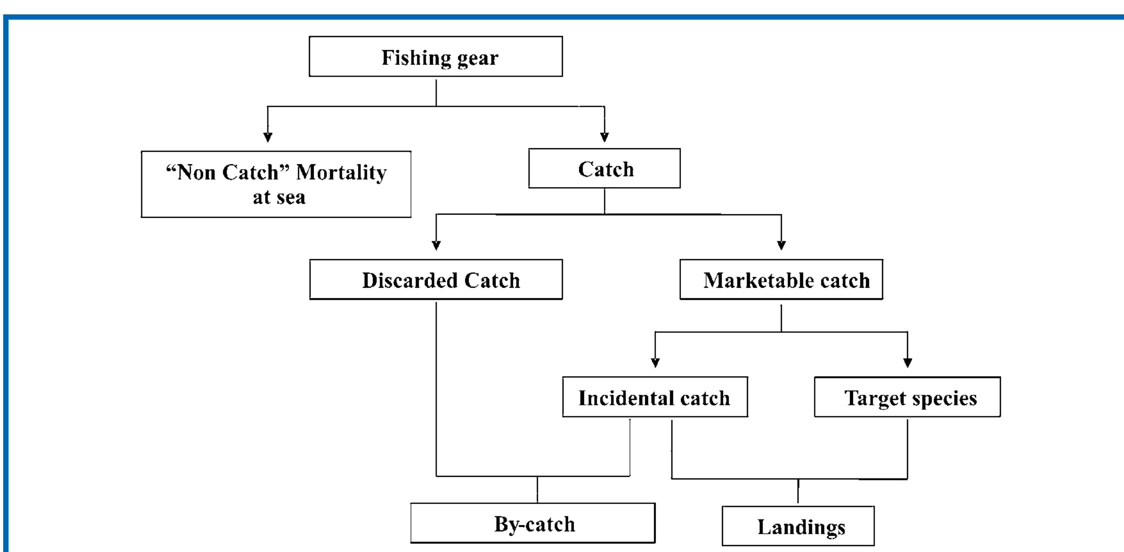

Figure 1: The possible fate of organisms caught by a fishing gear.

THE MAGNITUDE OF DISCARDS PRODUCED BY COMMERCIAL VESSELS

Results discussed herein are derived from a number of studies aiming to monitor discarding practices by commercial vessels in the Hellenic Seas. For trawlers, catches have been recorded on board commercial vessels since 1995, while for purse-seines and small-scale fishing vessels shorter time-series exist since monitoring activities have been initiated in 2003, in the framework of gathering data for the National Fishery Programme. Those results underline the impact of environmental conditions on discard quantity and structure and are in accordance with the findings of other similar studies (STRATOUDAKIS *et al.*, 1998, 2001; D'ONGHIA *et al.*, 2001; SANCHEZ *et al.*, 2004). In particular, it was established that certain spatio-temporal factors (i.e. season, area, depth) influence amounts of discards, discarded species' composition and length composition (MACHIAS *et al.* (2001) for more information). Another outcome of these studies was that all types of fishing activities in Hellenic waters produce discards. However, small-scale fisheries produce lower amounts of discards due to their passive and more selective nature (TZANATOS *et al. 2007*; VASSILOPOULOU *et al.*, 2007), while higher amounts result from trawlers, which is in accordance with the findings of STERGIOU *et al.*, (1998). In fact, the mean discarded quantity for bottom trawling was estimated in about 45% of the total annual catch, according to which total quantities of discards yielded by bottom trawls annually range from 13 500 t to 22 000 t (MACHIAS *et al.*, 2001). The latter reveal the considerable impact that fishing activities and particularly trawling may have on the ecosystem.

ALVERSON *et al.*, (1994) estimated a negative trend in the ratio between discards and trawl codend mesh size, based on Northwest Atlantic data. The ratio estimated in the present study was much lower than that predicted from this trend line. Specifically, the codend mesh size of trawls is 28 mm for Hellas (40 mm for other European Mediterranean countries) and the expected discard ratio >70% of the total catch. This difference could mainly be related to the differences between Mediterranean and Northern Atlantic fisheries. Specifically, in the Mediterranean, codends used are small because the commercial species are different and have much smaller sizes than those of northern areas. Furthermore, the number of marketable species is greater. The ratio of the discard/ marketable fraction fluctuated greatly (Figure 2), as has also been reported in similar multi-species fisheries (D'ONGHIA *et al.*, 2001, SANCHEZ *et al.*, 2004). The absence of any particular trend in this ratio could be the result of a slow response to fishing pressure because of the complexity in the community interactions.

Sizes of discards

In the Mediterranean Sea, due to the phenomenon

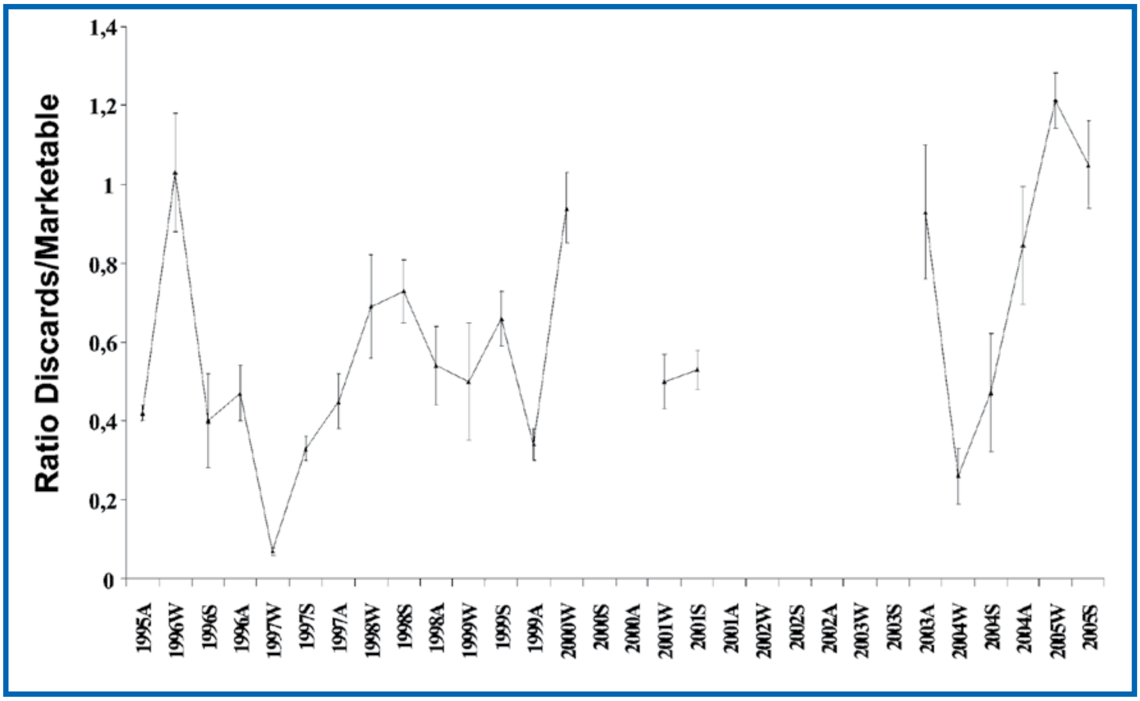

Figure 2: Ratio of discarded to marketable catch. A: Autumn, W: Winter, S: Spring.

known as the Mediterranean nanism (i.e. marine communities have many different species with generally smaller individuals; ZENETOS *et al*., 2002), the sizes of commercial species are small, resulting in even smaller sizes for discarded individuals.
The length frequencies of the overall marketable and discarded fractions were used to estimate the length at which 50% of individuals were discarded (L_{50}) by trawl fishery.
An overall estimation was derived for Ionian Sea trawl fishery, by pooling individual species' length frequencies, after weighing by species' abundance (TSAGARAKIS, 2005). The L_{50} was determined from the logistic relationship between percentages P of fish discarded at length class L (MACHIAS *et al*., 2001). As shown in Figure 3, the estimated length at which the 50% of the specimens were discarded was rather small (13.6 cm), which is characteristic for Mediterranean fisheries.

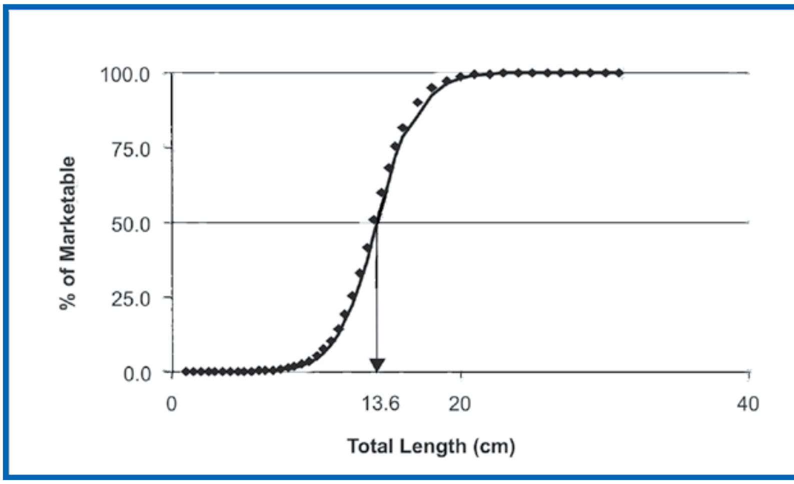

Figure 3: The L_{50} estimation for all species caught by trawlers 1996-2005.

The L_{50} varied among seasons, being highest in winter (mainly because the adverse weather conditions decrease the duration of sorting) and lowest in the autumn because of the recruitment (MACHIAS *et al*., (2004) for more information). The overall estimation of L_{50} is only indicative of the sizes of discarded fish. The L_{50} varied among species, greatly depending on the sorting procedure. A common feature of the discarding procedure in the eastern Mediterranean seems to be that the skippers tended to collect all marketable species and sizes (legal or not). The crews give more attention to collecting all specimens of some species (e.g. *Mullus surmuletus* and *Pagellus erythrinus*) that have high commercial prices, although these species are caught in small quantities, which resulted in less specimens discarded for these species and no estimation of their discard sizes in some areas. In addition, the market demands in each area were also reflected in the discarded sizes of the different species (Figure 4). Lower market price resulted in higher discard sizes, such as for *T. trachurus* in the Kyklades islands (see MACHIAS *et al*., (2004) for more information). Among the target species, the bulk of undersized specimens were those of *M. merluccius*. The estimated L_{50}s were quite close

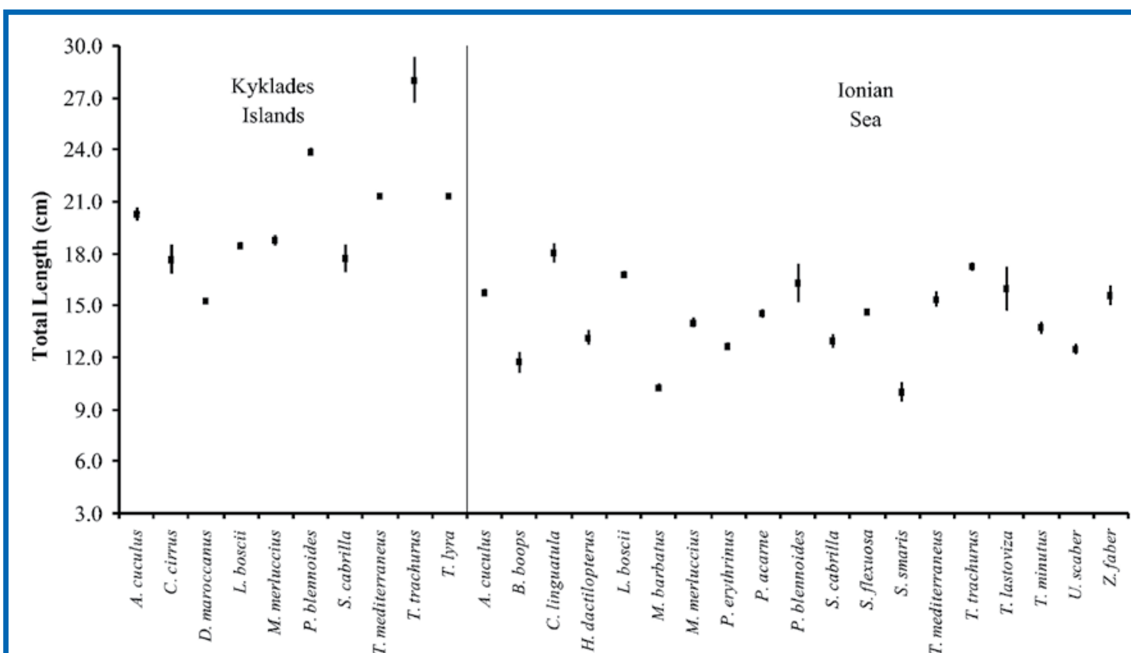

Figure 4: The estimated L_{50} of the main species caught by trawlers in three areas of central Aegean and Ionian Seas.

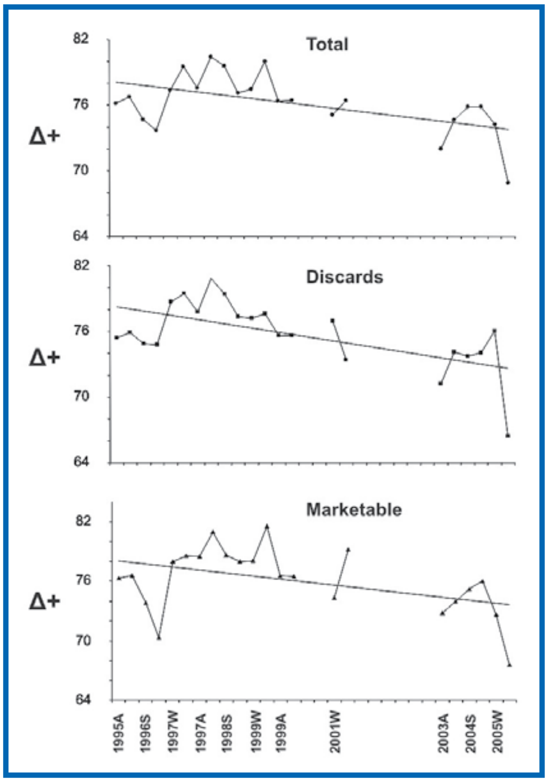

Figure 5: Trends in phylogenetic indices Δ+ 1995 -2005 in trawlers catches. A: Autumn, W: Winter, S: Spring.

to the legal sizes in most cases, with one exception, that of *Merluccius merluccius* in the Ionian Sea, where the estimated L_{50} was 4-5 cm lower. In fact the L_{50} of *M. merluccius* was close to the legal size only in the Kyklades islands (Figure 4). The fishing fleet operating in that area landed the catches in the port of Peiraias, where the monitoring of the landings by the authorities is rather strict. In addition, on the Kyklades plateau catches comprise mainly big specimens (VASSILOPOULOU & PAPACONSTANTINOU, 1998).

USING DISCARD ESTIMATES FOR ASSESSING THE IMPACT OF FISHING ON BIODIVERSITY

Fisheries in the eastern Mediterranean have four distinct features compared to those of other areas: 1) highly oligotrophic conditions; 2) a diversity higher than in other northern temperate environments, but lower than in tropical systems; 3) a number of marketable species much greater than in other temperate environments, but lower than in tropical systems, and 4) the small size of species, coupled with the very small mesh size of trawl net, increase the diversity and the amount of discard (STERGIOU *et al.*, 1998). As a result, a far wider range of taxa is directly affected by fishing, with ≈45% of the catches discarded.

The species collected during several surveys aiming at monitoring discarding practices by trawl fishery could be classified into three categories: (1) commercial species: those that consistently exhibited marketable and discarded fractions (46 fish, 3 crustaceans, 10 cephalopods); (2) local commercial species: those that were not present in all areas, or those that in other areas had a marketable fraction and in others only a discarded fraction (67 fish, 7 crustaceans, 6 cephalopods); and (3) discarded species: those that in all cases were discarded (82 fish, 52 crustaceans, 8 cephalopods) (Tables 1,2,3; MACHIAS *et al.*, 2001).

In order to trace the diversity of the artificial assemblages which are derived from the discarding process, we examined several diversity / evenness indices and mean trophic level for the whole trawl catch as well as for the two artificial assemblages (Marketable, Discards). The trends in time of their mean values for each sampling period (season of a particular year) were estimated. Changes in diversity are usually estimated in sets of data covering long periods (HALL & GREENSTREET, 1996; BIANCHI *et al.*, 2000). Although the time scale of the surveys analysed here was about 10 years, a declining trend was apparent especially for phylogenetic indices such as Δ+ (Figure 5) which have been proposed as more sensitive measures of the ecosystem response to disturbance (CLARKE & WARWICK, 2001). These significant trends detected in all different assemblages suggest deterioration with time. On the other hand, a decline of species richness (S) appeared in the case of Discards' assemblage but not in the case of the Marketable one. The absence of such a trend could be attributed to the transfer of specimens and species from the Discard fraction to the Marketable one (e.g. *Spicara flexuosa*, *S. smaris*). This transfer of specimens and species supplemented the main commercial species and varied depending on the quantity and prices of landings. The poor response of other indices (such as H' etc.) could be attributed to the long-term exploitation of the area, since in the Mediterranean Sea the main changes in a community take place during the first five years after the establishment of fishing (PINNEGAR & POLUNIN, 2004).

The values of the diversity metrics significantly differ between the assemblages (Figure 6). The inter-assemblage differences in terms of diversity metrics reflect human decisions on separation of fractions (i.e. Marketable and Discards) rather

Table 1: List of commercial fish species.

*Argentina sphyraena***	*Lepidotrigla cavillone***	*Scomber japonicus***
*Arnoglossus laterna**	*Lithognathus mormyrus***	*Scomber scombrus**
Aspitrigla cuculus *	*Lophius budegassa**	*Scophthalmus rhombus***
*Aspitrigla obscura***	*Lophius piscatorius**	*Scorpaena elongata**
*Aulopus filamentosus***	*Merlangius merlangus euxinus***	*Scorpaena notata**
*Blennius ocellaris***	*Merluccius merluccius**	*Scorpaena porcus**
Boops boops *	*Microchirus variegatus***	*Scorpaena scrofa**
*Boops salpa***	*Micromesistius poutassou**	*Scyliorhinus canicula**
*Callionymus lyra***	*Molva elongata***	*Scyliorhinus stelaris***
*Callionymus maculatus***	*Monochirus hispidus***	*Serranus cabrilla**
*Callionymus phaeton***	*Mugil cephalus***	*Solea kleini***
*Centracanthus cirrus***	*Muliobatis aquilla***	*Solea solea***
*Centrolophus niger**	*Mullus barbatus**	*Sparus aurata***
*Centrophorus granulosus***	*Mullus surmuletus**	*Sphyraena sphyraena***
*Citharus linguatula**	*Mustelus asterias***	*Spicara flexuosa**
*Conger conger**	*Mustelus mustelus***	*Spicara maena**
*Dasyatis centroura***	*Ophidion barbatum***	*Spicara smaris**
*Dasyatis pastinaca**	*Pagellus acarne**	*Spondyliosoma cantharus***
*Dentex dentex***	*Pagellus bogaraveo**	*Squalus acanthias***
*Dentex macrophthalmus***	*Pagellus erythrinus**	*Squalus blainvillei***
*Dentex maroccanus**	*Pagrus pagrus**	*Symphurus nigrescens***
*Dicologoglossa cuneata***	*Peristedion cataphractum***	*Synodus saurus***
*Diplodus annularis***	*Phrynorhombus regius***	*Torpedo marmorata***
*Diplodus puntazzo***	*Phycis blennoides**	*Trachinus araneus***
*Diplodus sargus***	*Phycis phycis**	*Trachinus draco**
*Diplodus vulgaris***	*Pomatomus saltatrix***	*Trachinus radiatus***
*Engraulis encrasicholus***	*Pteromylaeus bovinus***	*Trachurus mediterraneus**
*Epinephelus guaza***	*Raja alba***	*Trachurus picturatus**
*Esox lucius***	*Raja asterias***	*Trachurus trachurus**
*Eutrigla gurnardus**	*Raja circularis***	*Trigla lucerna**
*Galeorhinus galeus***	*Raja clavata**	*Trigla lyra**
*Galeus melastomus***	*Raja miraletus**	*Trigloporus lastoviza**
*Gobius niger***	*Raja montagui***	*Trisopterus minutus capelanus**
*Helicolenus dactylopterus**	*Raja naevus***	*Uranoscopus scaber**
*Heptranchias perlo***	*Raja oxyrinchus***	*Zeus faber**
*Hexanchus griseus***	*Raja polystigma***	
*Lepidopus caudatus***	*Raja radula***	
*Lepidorhombus boscii**	*Sardina pilchardus***	
*Lepidorhombus whiffiagonis**	*Sarpa salpa***	

(*) the species that consistently exhibited marketable and discarded fractions; (**) local commercial species: the species that were not present in all areas, or in other areas had a marketable fraction and in others only a discarded fraction.

than ecological processes. The assemblage of Marketable species showed a higher dominance than that of the Discards, which is reasonable since our analysis revealed that trawl landings were mainly comprised of particular fish species, reflecting market demands. On the other hand, the Discards showed a high diversity because they comprised the non-marketable species as well as the discard fraction of the commercial species.

Further to diversity indices the examined assemblages exhibited differences regarding their trophic level. The Discards' cluster presented a significantly lower trophic level than that of the Marketable one, although no significant trends were observed in any of the examined clusters, in the time span examined.

LAMPRAKIS *et al.*, (2006) found also that the mean trophic level of the discarded fishes in the

Table 2. List of totally discarded fish species.

Acantholabrus palloni	*Deltentosteus quadrimaculatus*	*Ophidion rochei*
Alosa fallax	*Diaphus metopoclampus*	*Oxynotus centrina*
Anthias anthias	*Diplodus cervinus*	*Parablennius gattorugine*
Antonogadus megalokynodon	*Echelus myrus*	*Parablennius tentacularis*
Aphia minuta	*Echiodon dentatus*	*Parophidion vassali*
Argyropelecus hemigymnus	*Epigonus telescopus*	*Raja brachyura*
Arnoglossus imperialis	*Etmopterus spinax*	*Raja melitensis*
Arnoglossus rueppelli	*Gadella maraldi*	*Rhynorhombus regius*
Arnoglossus thori	*Gadiculus argenteus*	*Sardinella aurita*
Atherina boyeri	*Gaidropsarus mediterraneus*	*Serranus hepatus*
Atherina hepsetus	*Gnathophis mystax*	*Solea ocelata*
Blennius tentacularis	*Gobius colonianus*	*Solea variegata*
Bothus podas	*Gobius cruentatus*	*Squatina aculeata*
Buglossidium luteum	*Gobius geniporus*	*Squatina oculata*
Callanthias ruber	*Hippocampus hippocampus*	*Stomias boa*
Callionymus fasciatus	*Hippocampus ramulosus*	*Symphodus cinereus*
Callionymus reticulatus	*Hoplostethus mediterraneus*	*Symphodus mediterraneus*
Callionymus risso	*Hymenocephalus italicus*	*Symphodus roissali*
Capros aper	*Lappanella fasciata*	*Symphodus rostratus*
Carapus acus	*Lepidotrigla dieuzeidei*	*Symphurus ligulatus*
Cepola rubescens	*Lesueurigobius friesii*	*Synchiropus phaeton*
Chimaera monstrosa	*Lesueurigobius suerii*	*Syngnathus acus*
Chlorophthalmus agassizi	*Macroramphosus scolopax*	*Syngnathus typhle*
Chromis chromis	*Maurolicus muelleri*	*Torpedo marmorata*
Coelorhynchus coelorhynchus	*Microchirus ocellatus*	*Torpedo nobiliana*
Coris julis	*Molva dipterygia macrophthalma*	*Trachyrhynchus trachyrhynchus*
Crenilabrus cinereus	*Nezumia sclerorhynchus*	
Deltentosteus colonianus	*Ophichthus rufus*	

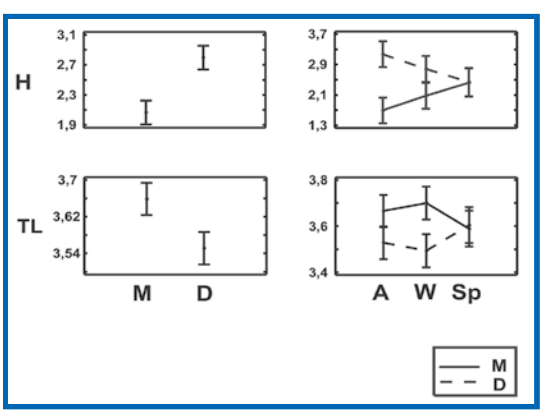

Figure 6: Estimated GLM means and 95% confidence intervals for the comparisons between the 'Marketable' (M) and 'Discards' (D) assemblage. Left panel: overall estimates for M and D. Right panel: estimates by season (interaction plots). Only significant differences are shown. A: Autumn, W: Winter, Sp: Spring, H: Shannon-Wiener diversity index, TL: mean trophic level.

Thracian Sea was significantly lower than that of the marketable ones by approximately 0.5 trophic level. The low trophic level of the Discards' assemblages was to be expected as they mainly consisted of small-sized species and individuals. Although the detailed knowledge of the trophic web is quite complicated, the artificial split of the community reveals two main assemblages; the Discard cluster consisted of species and individuals that serve as a potential food resource for the Marketable cluster, given the higher trophic level of the latter as well as the known prey of the main Marketable species (TSAGARAKIS *et al*., submitted). In other words, the Marketable cluster of the community partly "feeds" on the Discard cluster. Thus, marketable species belonged to a significantly higher mean trophic level and were removed from the ecosystem at a higher relative abundance than discards. The latter appears also in fisheries around the world and might contribute to the observed decline of trophic levels of global fisheries' landings (i.e. fishing down the marine food web) in recent decades at a rate of about 0.1 per decade (PAULY

Table 3. List of commercial crustacean and cephalopods species, as well as the discarded crustacean and cephalopods species.

COMMERCIAL CRUSTACEANS	COMMERCIAL CEPHALOPODS	
*Calappa granulata***	*Eledone cirrhosa**	*Scaeurgus unicirrhus***
*Homarus gammarus**	*Eledone moschata**	*Sepia elegans***
*Macropipus tuberculatus***	*Illex coindetii**	*Sepia officinalis**
*Maja squinado***	*Loligo forbesi**	*Sepia orbignyana**
*Nephrops norvegicus**	*Loligo vulgaris**	*Todarodes sagittatus**
*Palinurus elephas***	*Neorossia caroli***	*Todaropsis eblanae***
*Parapenaeus longirostris**	*Octopus salutii***	
*Penaeus kerathurus***	*Octopus vulgaris**	
*Plesionika edwardsii***	*Pteroctopus tetracirrhus***	
*Squilla mantis***	*Rossia macrosoma**	
DISCARDS-CRUSTACEANS	DISCARDS-CEPHALOPODS	
Alpheus glaber	*Pagurus excavatus*	*Abralia veranyi*
Atelecyclus rotundatus	*Parthenope macrocheles*	*Alloteuthis media*
Calappa granulata	*Pasiphaea sivado*	*Alloteuthis subulata*
Chlorotocus crassicornis	*Pilumnus hirtellus*	*Bathypolypus sponsalis*
Dorippe lanata	*Pilumnus spinifer*	*Pteroctopus tetracirrhus*
Eriphia verrucosa	*Pisa carinimana*	*Rondeletiola minor*
Ethusa mascarone	*Pisa muscosa*	*Sepietta oweniana*
Galathea strigosa	*Pisa nodipes*	*Sepiola intermedia*
Goneplax rhomboides	*Plesionika antigai*	
Homola barbata	*Plesionika gigliollii*	
Ilia nucleus	*Plesionika heterocarpus*	
Inachus comunissimus	*Plesionika martia*	
Inachus leptochirus	*Polycheles typhlops*	
Inachus parvirostris	*Pontocaris cataphracta*	
Inachus thoracicus	*Pontocaris lacazei*	
Latreillia elegans	*Pontophilus spinosus*	
Liocarcinus corrugatus	*Processa acutirostris*	
Liocarcinus depurator	*Processa canaliculata*	
Macropodia longipes	*Processa macrodactyla*	
Macropodia longirostris	*Processa macrophthalma*	
Macropodia rostrata	*Rissoides desmaresti*	
Medoripe lanata	*Rissoides pallidus*	
Microcassiope minor	*Scyllarus pygmaeus*	
Munida irs var. rutlanti	*Solenocera membrancea*	
Munida tenuimana	*Typton spongicola*	
Ophioderma longicauda	*Xantho incisus*	

(*) the species that consistently exhibited marketable and discarded fractions; (**) local commercial species: the species that were not present in all areas, or in other areas had a marketable fraction and in others only a discarded fraction.

et al., 1998). Indeed, according to DAYTON *et al.,* (1995) heavy fishing is "causing a rebirth of the Mesozoic-like system dominated by echinoderms and crustaceans because over-fishing removes the evolutionarily-new teleost predators".
Furthermore, our results suggested that the Marketable cluster indicated an increase of the diversity towards the end of the fishing period, while the reverse trend was estimated for the Discards' cluster. These trends seem to be a result of the exploitation process of the community. The beginning of the fishing period coincides with the recruitment period for most species, so more juveniles are present contributing mainly to the Discard assemblage. Towards the end of the fishing period species' abundance decreases because of the exploitation and more species are transferred to the Marketable cluster, based on the sorting strategy

as described above. In other words, the observed converging of the indices is related to a convergence in sizes, number of individuals and species, as well as to the trophic level of the species forming the clusters, expressing thus the effect of the exploitation process on the community. The ratio of the diversity and/or trophic level indices of the different exploitation clusters of the community (e.g. Marketable/Discard) could be a useful tool to study the exploitation status. The main disadvantage of such indices is the absence of reference points. A reference point could be defined through meta-analysis of existing data from several areas, clustering together the areas under different levels (low or high) of exploitation (TUDELA *et al*., 2005).

FOOD SUBSIDIES PRODUCED BY DISCARDS

Discarded catch produces a shortcut in trophic relationships, increasing the recycling rate of organic matter, and enhancing secondary production (GROENEWOLD & FONDS, 2000). As mentioned earlier, it has been found that about 40% of the discarded catch is consumed by seabirds (CAMPHUYSEN *et al*., 1995). According to the results of a study conducted in the north-western Mediterranean, it was suggested that for some seabirds, especially large gulls, discard availability may improve their breeding productivity, but overexploitation of fishing grounds in the last few decades, decreased the availability of natural prey for seabirds and seemed to cause a decrease in seabird productivity, which may in turn affect the long-term stability of their colonies (ORO, 1999).

The discarded part of the catch not eaten by sea birds sinks to the bottom becoming available to mid-water and benthic predators and scavengers (CAMPHUYSEN *et al.,* 1995). The results of a study conducted in the Aegean Sea provided indications that, although in areas open to trawl fisheries tolerant scavengers belonging to megabenthic epifaunal communities (i.e. asteroids and pagurids) increase in numbers, the opposite phenomenon appears in commercial crustaceans (i.e. *Parapenaeus longirostris, Squilla mantis*). In areas closed to trawl fishing, experimental trawling led initially to an increase of species' diversity which was later reduced as most of the colonisers were incidental (i.e. scavengers) and left the area as soon as discarded food scraps were eliminated (ANONYMOUS, 1997).

The above give an inkling of the impact of discarding on bird and marine community structure through complex alterations in existing trophic relationships. However, the quantification of the impacts of fishing activity at the population and ecosystem levels remains a challenge. Discards represent an input of more or less localized but important quantities of energy and may constitute a perturbation of the trophic system, resulting in significant non-selective predation and scavenging. This energy is often directly available to the higher trophic levels, which in the present study are mainly represented by the Marketable cluster of the community. The contribution of recycled discards to the energy budget may be significant in some marine ecosystems (PAULY & CHRISTENSEN, 1995) and in particular in highly oligotrophic ones, such as that of the eastern Mediterranean, where the complex and dynamic discard behaviour (STRATOUDAKIS *et al*., 1998) makes the situation even more complicated.

CONCLUSIONS

Mediterranean nanism is reflected on fishery catches comprising a relatively great number of marketable species with rather small-sized individuals, and discards with even smaller sizes. Trawling, being the least selective of all fishing activities, yielded the greater portion of by-catch, and discarding reached some 45% of the total annual catch. The discarded fraction of trawl catches showed a higher diversity than the marketable one, and marketable species belonged to a significantly higher mean trophic level than discards. The latter group, providing food subsidies to avian and marine scavengers, impacts ecosystem structure and function, and this impact might be quite pronounced in oligotrophic areas such as the eastern Mediterranean. Our findings suggest that further research is needed to elucidate matters associated with the assessment of discards and to the quantification of their impact on different ecosystems. At the same time, however, actions should be taken to address the by-catch/discard issue, bearing in mind that it constitutes a wasteful use of living marine resources and as such it decreases the sustainability of fisheries.

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V.3. EFFECTS ON BIOLOGICAL DIVERSITY AND COMMUNITY STRUCTURE AND FUNCTION

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TYPES OF EFFECTS

Faunal impacts, although they should not be viewed or dealt with in isolation, can be broadly classified into two categories: (1) effects at community level and (2) effects at the level of individual species.

Effects at community level are defined as effects on:

a) diversity including extinctions, extirpation (local losses of stocks or sub-populations) and various aspects of diversity (from total number of species to statistics that indicate species richness, evenness, dominance as well as taxonomic based diversity indices) and

b) community structure including changes in relative abundance of species, in mean growth rate, maximum length, age at maturity and length at maturity across all species.

Effects at the individual or species level include: changes in abundance, size structure, sex ratio and reproductive potential.

The effects at these two levels, which can be direct or indirect, are intricately interlaced and difficult to quantify.

METHODS AND TOOLS TO STUDY AND QUANTIFY EFFECTS

A number of approaches and methods can be and has been used in order to study the effects of fishing on fauna. These may be tailored towards the study of the impacts on target species or non-target species or both, and include both experimental and monitoring studies, i.e.:

1. BACI (Before After Control Impact) studies where experimental trawling of known predefined intensity (e.g. one-off passage of a trawl or numerous passages equivalent to existing real world fishing intensity and fishing effort) is carried out in small defined areas and in similar adjacent undisturbed control areas, to look at initial impacts such as immediate removal and immediate or short-term recovery (usually up to a few days or some months after the disturbance).
2. Comparative studies of commercially trawled areas with similar (e.g. in terms of habitat, sediment composition and depth) un-trawled areas. Comparative studies of commercially trawled areas over time (e.g. repeated trawling within the open season for trawling, during the open and closed season for trawling or before and after closures) with the aim to study short-term community structure changes or recovery, in response to changes in effort.
3. Comparative studies of commercially trawled areas with similar or not (e.g. in terms of habitat, sediment composition and depth) trawled areas of different fishing intensity or severity depending on the fishing gear used with the aim to study and contrast the impacts at specific combinations of fishing gear-habitat-fishing effort parameters.
4. Comparative studies of commercially trawled areas with historical data sets from the same areas to ascertain long-term impacts and changes on single species and multispecies' community structure.

A substantial number of projects, supported by the European Union and the Hellenic General Secretariat for Research and Technology, have been carried out recently in Hellenic waters aimed at the study of the effects of fishing and particularly so at the study of trawling effects. The studies that have been completed to date fall into several categories although multiple aspects may have been completed in a particular study. A certain amount of work has been published in scientific journals, although the majority of it is in the grey literature or still to be published. Major findings of this work are reported here along with gaps in the knowledge and work still to be done.

RESULTS FROM RESEARCH IN HELLENIC WATERS

Effects at the species' level: examples from megabenthos

Depending on a number of parameters including morphology, motility and functional ecology each species' response to trawling will vary, ranging from no response to a significant increase or decrease in its abundance. Studies from outside the Mediterranean, looking at the taxa level, report both decrease (e.g. erect epifaunal groups such as sponges and gorgonians) and increase (e.g. hermit crabs) in megafaunal abundance or biomass for certain taxa (KAISER *et al.,* 1998, COLLIE *et al.,*

Table 1. Comparisons of means of abundance between the experimental trawling lane (TR) and control (C) site for each sampling period for the dominant megafaunal species from Gouves area, S. Aegean Sea. NS denotes no significance. Source data: COGGAN *et al.,* 2001.

Species	Before	24hrs	2 months	4 months
Hyalinoecia tubicola	NS	TR<C	TR<C	TR<C
Hermione hystrix	NS	NS	TR<C	TR<C
Epimeria cornigera	NS	NS	NS	NS
Ophiacantha setosa	NS	NS	NS	NS
Ophiura ophiura	NS	NS	NS	NS
Inachus parvirostris	NS	NS	TR<C	NS
Pagurus pridaux	NS	TR<C	NS	NS
Pleurobranchus mecheli	NS	TR>C	TR>C	TR>C
Gobius gasteveni	NS	NS	NS	TR>C
Eurynome aspera	NS	TR<C	TR<C	TR<C
Antedon mediterranea	NS	NS	TR<C	NS
Cidaris cidaris	NS	TR<C	TR<C	TR<C

2000, WASSENBERG *et al.,* 2002). Hellenic studies (COGGAN *et al.,* 2001) comparing the abundance of dominant megafaunal species (benthic animals larger than 1-2 cm, sampled with an Agassiz trawl) between control and experimentally trawled sites at a shallow maerly site, have shown different responses for some of these species. These included immediate (24hrs after trawling) responses as well as responses 2 and 4 months after trawling (Table 1). The dominant tubicolous surface dwelling polychaete worm *Hyalinoecia tubicola* decreased in abundance in the experimental trawling lane 24hrs after the trawling event and was significantly lower in abundance than in the control site even 4 months later. The polychaete *Hermione hystrix* indicated an initial increase in abundance 24hrs after the trawling event with decreasing abundances thereafter. The opisthobranch mollusc *Pleurobranchus mecheli* was the only species with consistently higher abundance in the trawling lane, whilst the crab *Eurynome aspera* and the echinoid *Cidaris cidaris* had consistently higher abundances in the control area. For both the ophiuroids *Ophiura ophiura* and *Ophiacantha setosa* as well as the gammaridean amphipod *Epimeria cornigera* there were no differences in abundance between the trawling lane and the control sites.

Other studies (SMITH *et al.,* 2000, COGGAN *et al.,* 2001 and SMITH & PAPADOPOULOU, 2005) have compared the abundance of dominant megafaunal species between control and commercially trawled sites at a deep muddy area, during both the closed (June to end September) and open for trawling season (October to end May). Changes in community structure were quantitative (levels of abundance) rather than qualitative (presence/absence of species) changes. A typical example of this was seen in the case of the rose shrimp *Parapenaeus longirostris* with higher abundances in the trawl lane sites. The opposite is true for 2 echinoderm species. The crinoid *Leptometra phalangium* had a lower abundance in the trawl lane 2 and 7 months into the trawling season and differences in abundance during the closed season. The bioturbating echinoid *Brissopsis lyrifera* also had a lower abundance in the trawl lane during the fishing season. The gobiids *Leseurigobius friesii* and *L. suerii* had significantly higher abundances in the control sites during the trawling season (Figure 1). Both of these fish construct shallow surface burrows that could easily be destroyed by the passage of a trawl. On the contrary, the crab *Goneplax rhomboides,* which constructs a relatively deep U-shaped burrow, had increased abundance in the fishing lane during the fishing period.

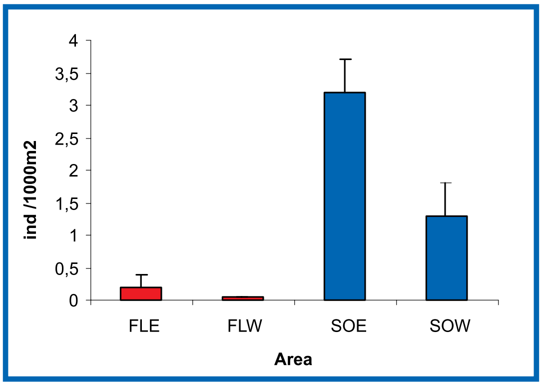

Figure 1. Mean abundances of *Lesueurigobius suerii* from Agassiz trawl sampling during the fishing season (mean with 95% confidence intervals) from Dia Island sampling areas (FLE: fishing lane east, FLW: fishing lane west, SOE: control area east, SOW: control area west). Source data: SMITH & PAPADOPOULOU, 2005.

Damage assessment

As the quality, composition and quantity of discards are gear and ground specific (MACHIAS *et al*., 2001) and damage and survival is species-specific (BERGMANN *et al.,* 2001; COGGAN *et al.,* 2001), quantification of discards alone is a poor indicator of the effects of fishing gear on biological communities. Ground and fishery specific data on damage, survival and fate of discards could indicate shifts in community composition and improve quality of stock assessments. In addition, the use of damage assessment has been proposed as a proxy indicator for fishing intensity and its use and applicability has been examined by several studies.

In Hellas, damage to echinoderms (in terms of broken or torn arms/legs, broken/missing spines, scraped skin or ruptured body) was assessed by COGGAN *et al.,* (2001) during repeat otter trawling in an experimentally impacted lane in the southern Aegean (80-90 m depth with sediments consisting of coarse sand and mud with maerly fragments). The group of echinoderms was chosen due to its high diversity in species, sizes and body forms as well as its dual response (vulnerability to fishing and attraction to discards generated by fishing) evidenced by both short-term declines (e.g. filter feeding *Leptometra phalangium*, SMITH *et al.,* 2000) and increases in densities (e.g. carnivore *Astropecten* spp., TRIBE, 1997).

Results revealed that for all the species observed, damage noted was species' specific depending on body form (armed/spined or not, Figure 2) and structure (soft, hard, flexible). In addition, for some species (e.g. *Centrostephanus longispinus,* Figure 3*),* damage will be size related too, although a wide range of size classes could be retained by the trawl gear (e.g. *Liocarcinus depurator*, Figure 4) certain size classes might be more prone to damage than others. At the two extremes, the crinoids were all damaged (100%) with a high level of seriously damaged individuals (58%), whilst the holothuroids were unaffected by trawling (although lethally damaged through aerial exposure when left on deck for too long). However, although the method has been shown to have some potential its applicability and usefulness as a proxy indicator is questionable as it requires species and area specific knowledge of baseline levels of damage through predation/accidental breakage, as well as survival and recruitment data.

Figure 2: Severely damaged ophiuroid specimen (4 of the 5 arms have been removed from the central disc). Source data: COGGAN *et al*., 2001.

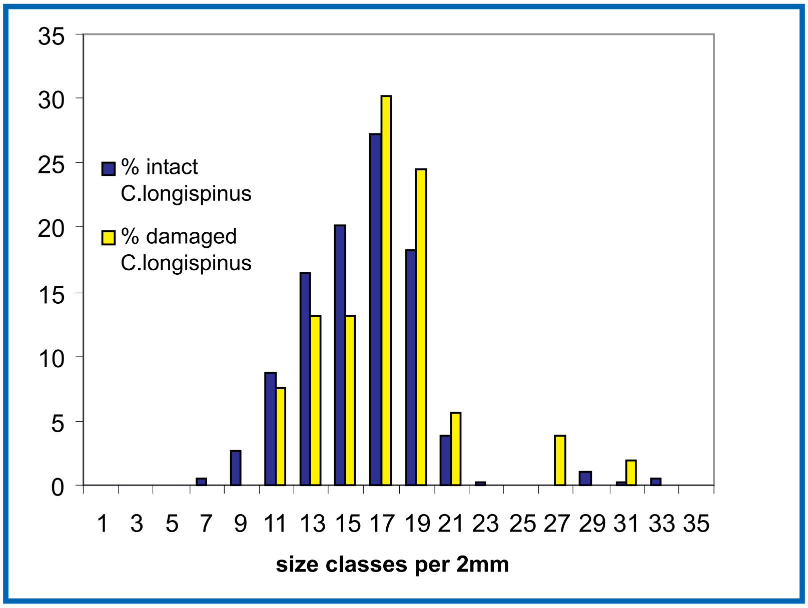

Figure 3: Size frequency histogram (percent per 2 mm size class in body test diameter) for echinoid *Centrostephanus longispinus*, both intact (blue bars) and severely damaged specimens are shown (red bars). Source data: COGGAN *et al*., 2001.

Effects on benthic flora: example from *Posidonia oceanica*

With growing awareness and scientific evidence on the impacts of fishing, in recent years a number of endangered species and habitats are legally protected either through banning destructive gears or by banning fishing activities from certain sensitive habitats. The meadows of the seagrass *Posidonia oceanica*, known as both a fish spawning ground and biodiversity hot spots, is such a habitat. Although very little targeted work has been done on the subject, historical records from faunistic studies and recent work carried out during the "NATURA 2000" project indicate both declines over time and partial degradation of this habitat. *Posidonia* meadows are now largely protected

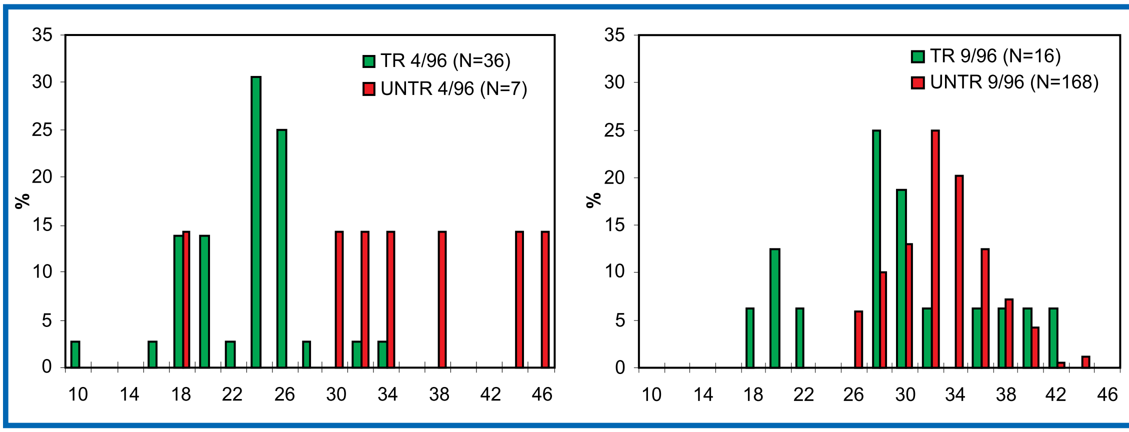

Figure 4: Size frequency distribution of crustacean crab *Liocarcinus depurator* (per 2mm size class in carapace width) caught in the trawl catches of the open (TR) and closed (UNTR) to fishery sites. Study period: 4/96 in fishing season, 9/96 in the closed season for fishing.
Source data: TRIBE, 1997.

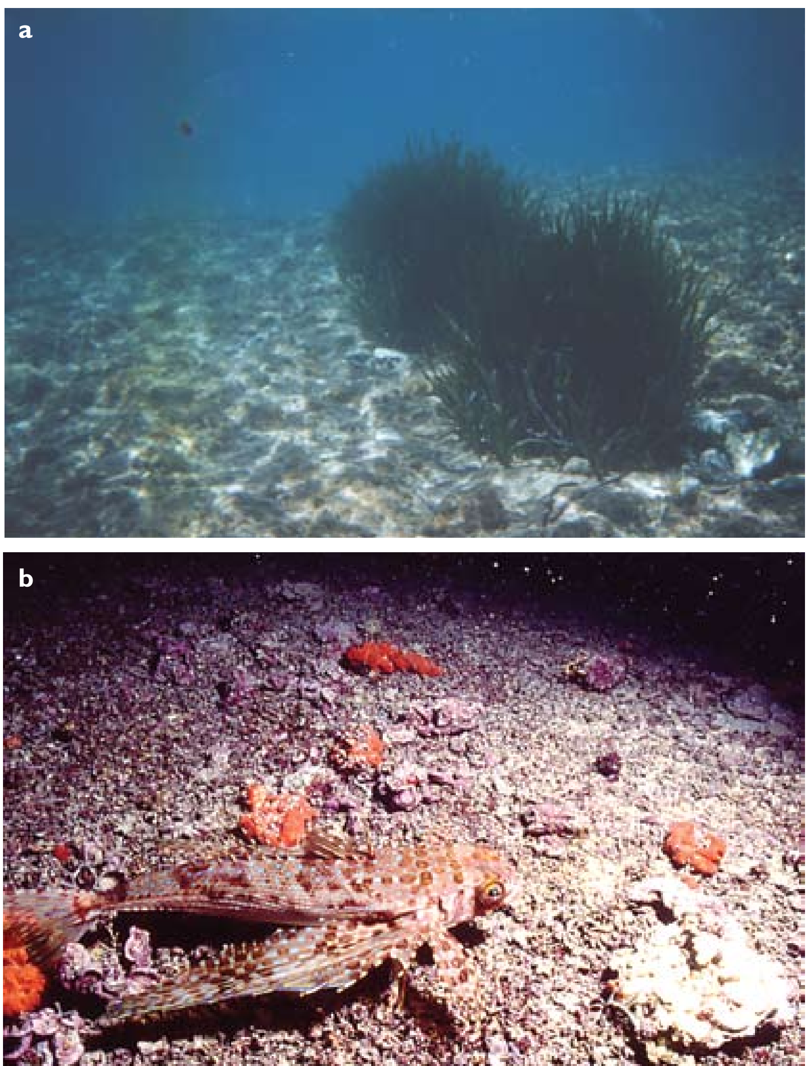

Figure 5: a) *Posidonia* damaged by trawling gear (Photo courtesy: M. SALOMIDI); b) Maerl habitat in Hellas (Photo: S. KATSANEVAKIS).

from trawling (as trawling is forbidden in depths less than 50 m depth or less than 1 or 3 miles from shore) but until recently trawling effects included both removal of the seagrass and its associated fauna (Figure 5), smothering (being covered by re-suspended sediments) and degradation of the water quality (due to sediment clouds created by the passage of the trawls). Another floral habitat impacted by trawling is the coralline algal habitat (Figure 5). A number of crustose, calcareous red algae (Corallinaceae) grow detached in shallow waters on the coasts of NW Europe and in the Mediterranean and accumulate to form large beds of stone-like algae. These are collectively known as "maërl", "coral" or "coral sand". In the past maerl habitats were more protected in Hellas, recently however, increased use of more powerful and rugged gears (dredges, chain mats, rock hoppers) as well as accurate positioning devices and sonars puts this habitat in increasing danger.

Effects at the community level: examples from macrobenthos, megabenthos, hyperbernthos and meiobenthos

Three studies (SMITH *et al.,* 2000, COGGAN *et al.,* 2001, SMITH & PAPADOPOULOU, 2005), from work on a deep commercial trawling ground, reported highly significant differences in megafaunal abundance, biomass and diversity with higher values for diversity and evenness in all the control areas. Although community analyses revealed a major split with treatment (fished vs. control, Figure 6), results on abundance and biomass between studies were mixed, with some of the trawled areas exhibiting more biomass and some of the control areas less abundance. Two projects (FGE project: SMITH & PAPADOPOULOU, 1999, SMITH *et al.,*

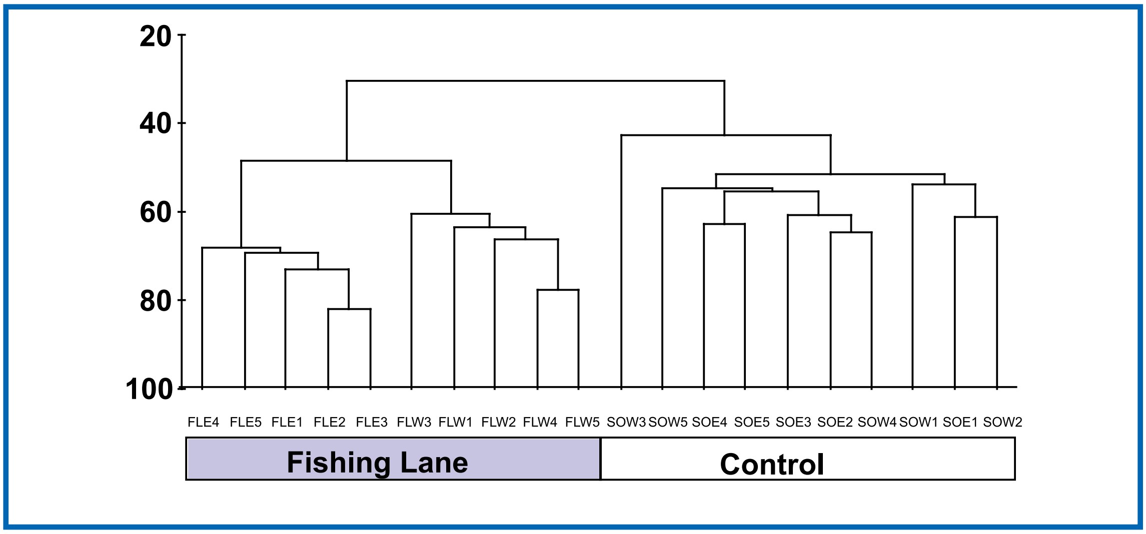

Figure 6: Cluster analysis of all the Agassiz trawl samples (data: abundance/1000 sqm) from Dia Island sampling areas during the trawling season. Samples linked by percentage similarity. (FLE: fishing lane east, SOE: control area east, FLW: fishing lane west, SOW: control area west).

2000, TRIBE project: TRIBE, 1999) have studied the impacts of trawling on macrobenthos (benthic animals larger than 0.5 -1 mm usually sampled by grabs and box corers). The 'FGE' project reported lower macrofaunal species' number, abundance and biomass in a commercial trawl area compared to adjacent non-trawled areas of similar depth (200 m) and sediment type (fine muds). The 'TRIBE' project investigating shallower (60-70 m) trawled and untrawled areas, reported increased species' number and abundance in the trawled areas (Table 2), which were primarily due to sediment type differences (higher values in the coarser 'mixed' sediments of the trawled area). However, a shift seen in the macrobenthic community structure, in the form of an increase in the number of polychaetes and opportunistic macrofaunal group was attributed to trawling activities. The 'TRBIOGEO' project (KOULOURI *et al.,* 2005) investigated trawling impacts on hyperbenthos: these are small-sized bottom-dependent animals, with good swimming abilities and living above the sediment-water interface, such as mysid shrimps, cumaceans, etc. Results have indicated disturbance of the hyperbenthic community to such a degree that it probably increases the vulnerability of some of these animals to their predators. Effects persisted at least a week post-trawling, also including a likely immigration of small organisms to feed on an increased food supply. The 'INTERPOL' (LAMPADARIOU *et al.,* 2005) have investigated among other aspects, the impacts of trawling on meiofauna. The term derives from the hellenic word "meios" meaning smaller and is used to describe very small benthic animals (between 500 μm and 42 μm) living on or within the sediment. Meiofauna has been shown to be more resilient than macrofauna due to their smaller size and higher growth and reproduction rates. In accordance with this, when comparing commercially trawled areas over time (during the open and closed season for trawling) no short-term effects (30 days) were seen on meiofaunal abundance and community structure.

Effects on target species: examples from fish

There are few studies on the impacts of trawling on the target species and their communities. The impact of consecutive trawling has been looked at

Table 2. Example from macrobenthos: Comparison of means of fished (TR: sandy open to fishing area, UNTR: muddy, closed to fishing area) and respective control (E, C) sites by t-test for abundance (N), number of species (S) and community diversity (H'). N.S. denotes no statistically significant differences. Source: TRIBE, 1997.

	TR0-E0	**UNTR0-C0**	**TR3-E3**	**UNTR3-C3**	**TR6-E6**	**UNTR6-C6**
N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S	N.S.	N.S.	E>TR	UNTR>C	E>TR	UNTR>C
H'	N.S.	N.S.	E>TR	UNTR>C	E>TR	UNTR>C

Table 3. Comparative catch composition from trawl and control grounds during the open (April) and closed (September) for fishing season. Source :V. Vassilopoulou (TRIBE, 1997).

	April		September	
	Closed area	**Fished area**	**Closed area**	**Fished area**
Fish	113.8	15.1	157.2	156.2
Mollusca	7	4.2	3.2	7.6
Echinodermata	15.9	4.2	1	4.6
Crustacea	4.5	0.7	3.2	0.2
Ascidia		1.5		
Total (Kg/h)	141.2	25.7	164.7	168.6
Total (%)	84.6	15.4	49.4	50.6

in catches from seasonal experimental trawling in the Pagasitikos Gulf in central Hellas. SMITH & PAPADOPOULOU (1999) reported that, in respect of fish communities, overall species' number and abundance did not show great differences with repeated trawling. The catch composition changed with indications of early removal of gadoids (predominantly bentho-pelagic schooling species) and territorial species or those with smaller mobility ranges (e.g. flatfish) and increases over time in more opportunistic scavenging species that obviously take advantage of damaged fauna or turned over sediments (SMITH *et al.,* 1997). The TRIBE project (TRIBE, 1997) compared a commercially trawled and a control ground during the open and closed season for trawling. In April (7 months into the trawling season), the closed area comprised almost 85% of the total trawl catch in both areas, while in September (at the end of the 4 month closed season for trawling) this proportion dropped to about 50%. The considerable increase of the area open to trawling yield in September which reached 168.5 Kg/h, in relation to the 25.7 Kg/h in April (Table 3) was mainly due to the increased yield of fish species while smaller variations existed in the rest of the major categories that were collected by the trawler and appear in Table 3. An increasing number of recent studies have, however, studied the effects of fishing on fish size and changes in trophic levels. For results see case studies reviewed in Chapter VI.6.

GAPS

Although a number of investigations have been carried out in a variety of biotopes and looking at different faunal aspects, their temporal and spatial span and scale has been limited. Extrapolation of results to the scale of commercial fisheries is still a very difficult task. A few outstanding gaps pose further difficulties in quantifying fishing impacts. These include mostly: lack of precise data on spatial and temporal distribution of the fishing effort of the commercial fisheries and lack of studies on changes in food availability, energy subsidies and the fate of discards.

CONCLUSIONS

Multifaceted and multidisciplinary investigations conclusively point to fishing having an impact on the Hellenic marine environment. Many components are impacted (both negatively leading to a loss of biodiversity and positively with some increases in sea bed biomass reported) with the environment no longer being a 'natural' environment. The area that is affected is a very small percentage of the total Hellenic waters, but it is the most important part in terms of usage and resources. Our scientific knowledge of the ecosystem and the detailed quantifiable impacts of trawling are still less than sufficient to give precise numbers, to be used for management purposes. We should, therefore, use the precautionary approach to the management of impacts on habitats and non-target species and develop new fisheries in a gradual manner, scaled to the knowledge available. In addition to continued reviews of capacity (e.g. limitations on number of vessels and upper limits on vessel power and tonnage) and technical measures (e.g. mesh size restrictions and compulsory use of more selective gears), several other tactics and tools exist. The most important of these is perhaps the creation of "Marine Protected Areas" (i.e. no-take zones, fisheries closures, marine parks as well as wildlife refuges and marine reserves) which have been advocated as both a conservation and managerial tool of central importance in the Ecosystem Approach to Fisheries (STERGIOU, 2002). Although clearly, the choice of location, size and number of MPAs is critical, large-scale marine protected areas will be beneficial in meeting the main objectives of rebuilding overexploited fish populations, preserving habitat and biodiversity and maintaining ecosystem structure (BROWMAN & STERGIOU, 2004).

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V.4. FISHERIES EFFECTS ON BENTHIC HABITATS (AND FLUXES)

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INTRODUCTION

The primary fishing activity affecting benthic habitats is demersal trawling. To a much lesser extent, passive fishing gears (nets, longlines and traps) may also have some impact on the seabed, particularly during retrieval, but these gears have a very small footprint so their impact is very low over the whole ecosystem. Demersal trawls have a large footprint on the seabed and move over large areas, with different parts of the gears in contact, including the trawling wires, doors, ground rope and net (Figure 1).

- Trawl wires bow down to touch the seabed in places, lightly scrape the sediment surface to the order of a few centimetres and may flatten some small topographical features.
- Trawl doors keep the trawl net open and plough the seabed, digging deep furrows up to 40 cm deep and 40 cm wide and throw the excavated sediment on to one side of the trench in a spoil heap of the same dimensions.
- The ground rope, especially if weighted, will dig into the top of the sediment to the order of a few centimetres and will flatten topographical features.
- The net flattens and smoothes out the sediment surface.

Physical contact of the trawl with the seabed causes sediment to be pushed up into suspension. The sediment cloud will remain in suspension with the small grains dropping out initially and gradually the fine grains. This sediment cloud may be dispersed to other areas some distance from the trawling area.

WHERE TRAWLS ARE USED

Trawling takes place throughout Hellas in coastal and shelf waters where the bottom is relatively flat and unobstructed. Current regulations exclude trawling activities in depths less than 50 m or 3 miles from the shore, where shallow waters persist offshore. Operational constraints have limited trawling to depths of approximately 500 m in the central and northern Aegean, although deeper water trawling to target some deeper water species of shrimp and fish, takes place in the Ionian Sea. The area covered between 50-500 m is shown in Figure 2. This area covers a large geographical area, although a significant proportion would be untrawlable due to contours or obstructions. Where the seabed is very steep or rocky there are possibilities of damage to gear and typically a trawler needs an unobstructed tow line of more than 5 miles, although this does not have to be in a straight line. New EU regulations have recently given a deeper limit of 700 m for trawling in the Mediterranean to protect deep water stocks which tend to be more sensitive. Most of

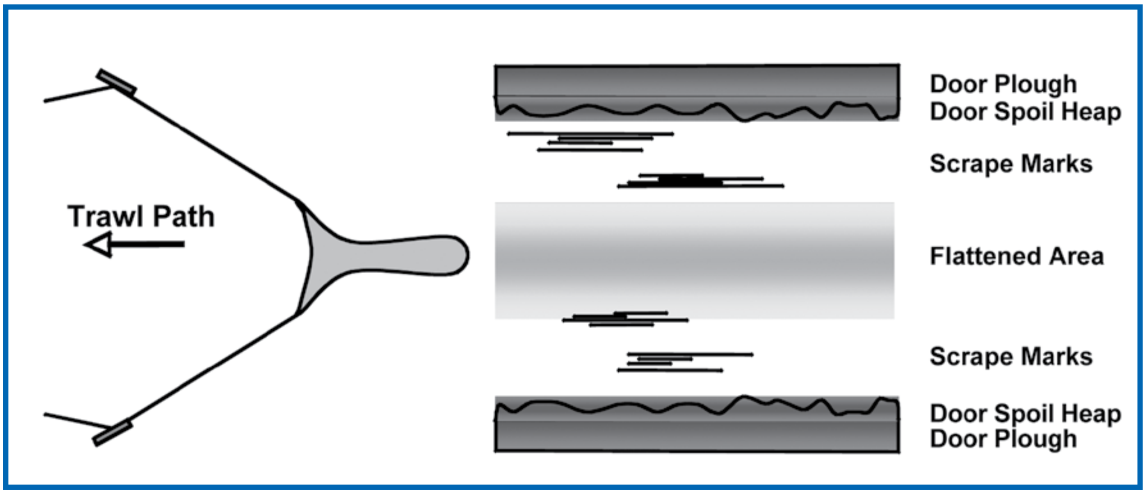

Figure 1. Principal marks on the seabed made from the different parts of the trawl

the trawling activities in Hellenic waters are in the Aegean, primarily in the more eutrophic northern waters and large Gulfs (Saronikos, Thermaikos) where the major demersal stocks tend to be concentrated. In the southern Aegean, trawlers tend to stay in more coastal areas and there is less activity due to the narrower shelf areas and the more oligotrophic nature of the system, limiting fisheries biomass and abundance. Trawling takes place on sedimentary seabeds ranging from soft muds to coarse sands.

STUDIES ON THE IMPACTS OF TRAWLING

A number of research projects have been undertaken investigating trawling impacts in Hellenic waters (Table 1). These projects have been undertaken in the Thermaikos Gulf (Table 1, Study 2), the Southern Evvoikos Gulf (Study 5), the Pagasitikos Gulf (Study 6) and the Bay of Irakleio, Kriti (Studies 1,3,4,6). A commercial trawling ground in the closed and open season (silty clay, 30-90 m depth) was studied in the Thermaikos Gulf. The study in the Evvoikos Gulf compared commercially trawled and untrawled areas with seasonal sampling (muddy-sand, 70 m). The Pagasitikos investigation (silty sediment 80 m) was a before and after experimental impact study. The work undertaken in Kriti has been the most extensive and includes a before and after trawling study (70 m depth, coarse sediment), a simulated trawling study (70-150 m muddy sand) and comparisons between commercially trawled and untrawled areas (200 m, silty sediment). Much work has been undertaken at the latter site (Stud-

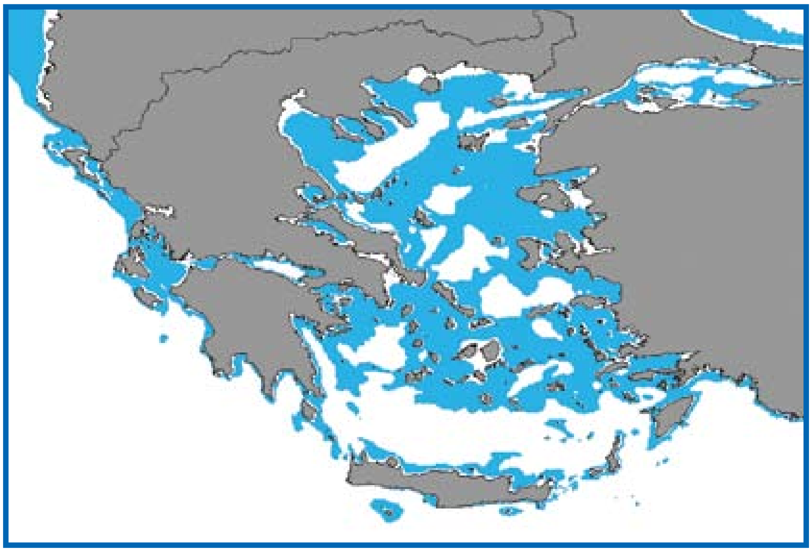

Figure 2: Area of Hellenic seabed between 50-500 m depth that is potentially available for trawling (shaded in blue).

Table 1. Funded research projects on fisheries ecosystem interactions undertaken in Hellas (IMBC: Institute of Marine Biology of Kriti, NCMR: National Centre for Marine Research).

Study	Study Period	Project Title	Contractor	Hellenic Participants	Study Areas
1	2002-04	Cost-Impact: Costing the impact of demersal fishing on marine ecosystem processes and biodiversity. (www.cost-impact.org)	EU DGXII	IMBC	Irakleio Bay
2	2001-03	Interpol: Impact of natural and trawling events on resuspension, dispersion and fate of pollutants. (www.ncmr.gr/interpol)	EU DGXII	NCMR, IMBC	Thermaikos Gulf
3	1999-00	Comparison of rapid methodologies for quantifying environmental impacts of otter trawling. (www.imbc.gr/institute/eco_bio/fge2/OTIP2.pdf)	EU DGXIV	IMBC	Irakleio Bay
4	1999-01	A new method for the quantitative measurement of the effects of otter trawling on benthic nutrient fluxes and sediment biogeochemistry.	EU DGXIV	IMBC	Irakleio Bay
5	1996-97	Trawling impact on benthic ecosystems.	EU DGXIV	NCMR	S. Evvoikos Gulf
6	1993-96	The environmental impact of demersal fishing gears on the marine environment.	EU DGXIV	IMBC	Irakleio Bay Pagasitikos Gulf

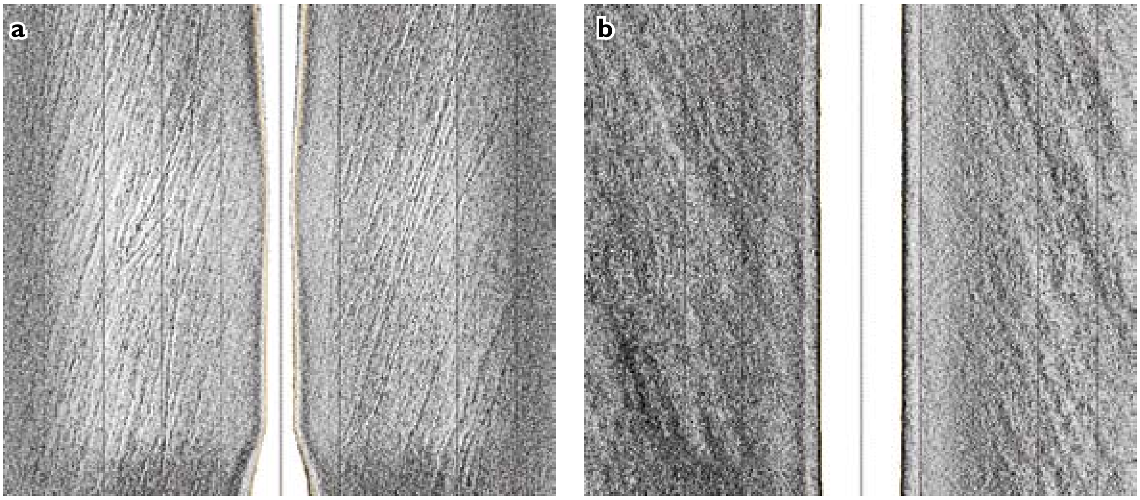

Figure 3: Side scan sonar image of the seabed (200 x 200 m) showing trawl door marks on a) soft sedimentary seabed, and b) coarse sedimentary seabed.

ies 1, 3, 6), where there is a closely defined commercial fishing lane with similar depth untrawled study areas in very close proximity (< 1 km).

IMPACT ON HABITAT

In all sedimentary habitats bottom trawling is responsible for large scale flattening and reduction in spatial heterogeneity. The exception to this is in siltier sediments where trawl door marks may persist, but frequent overpassing might make them unsuitable for colonisation. Trawling removes small structures, whether they are natural (rippling caused by water movement, sedimentary mounds caused by bioturbation mounds, rocks, biogenic structures) or unnatural (rubbish, wrecks, lost items). Trawling may also cause the infilling of natural depressions (rippling caused by water movement, feeding pits, scar marks, burrows). Figure 3 shows side scan images of the seabed affected by trawling. Each image is approximately 200 x 200 m, with the soft sediment seabed showing the seabed heavily incised by trawl doors. In coarser sediments the marks are much more diffuse because the trawl doors have lesser penetration and the sweeping action of the gear is more important. In the southern Aegean, SMITH *et al.* (2003) were able to note the loss of visible structures in trawled areas in both coarse and fine sediments using Sediment Profile Imagery (analysis of images perpendicular to the sediment surface). Loss of spatial heterogeneity leads to a smaller range of microhabitats and in general a decrease in biodiversity. One particular example of this is in maerl beds, which are biogenic structures on the seabed comprised of coralline algae that range from coarse gravel-like sands to small reef structures. In the past, trawlers may have avoided these areas, but with the introduction of northern European trawling adaptations (hoppers and wheels on the ground rope, which allow passage over rougher ground), these grounds are more accessible. Maerl is comprised of very slow growing algae species some of which are very delicate and can be broken up/removed in one pass. Many other individuals are associated with maerl as it can provide a complex 3-dimensional habitat above the sediment. *Posidonia* (seagrass) habitats in shallow waters have been damaged in the past by trawling, but their importance to the ecosystem (biodiversity, oxygen production, nursery grounds) has been understood and these areas are now for the most part protected by the 50m/3 mile regulation.

Various fishing methodologies may in some cases increase the habitat resource on a very small scale through lost gears – a trawl net lost overboard, disposed of trawling wires, lost or torn nets lines and traps. For example, nets in shallower waters may be lost from lost surface ropes or tearing on retrieval. The net will continue to fish for long periods attracting scavengers to feed on the lost catch. In time the net will be fouled with settling hard substrate fauna looking for an anchor. As the weight of fouling builds up the net will gather and sink to the bottom, eventually being totally overgrown. The substrate provided by one net is not particularly large, but over time considering the number of nets used, even with a very small percentage of loss the increase in habitat may be significant.

SEDIMENT PHYSICAL PROPERTIES

As noted previously the passage of the trawl may cause suspension of the sediment and mixing through the surface. This can affect the actual composition of the sediment. In Kriti, SMITH & PAPADOPOULOU (2005) found that trawled sites had a reduced overall median grain size and also made the sediments more homogeneous, compared to nearby control sites that had a larger grain size with much more variability. This may have been due to local settlement of resuspended material. KARAGEORGIS *et al.* (2005) found heavily mixed surface layers in the Thermaikos Gulf that may have been attributable to trawling, although this was confounded by local riverine inputs and the possibility of storm related mixing (shallower waters). The weight of a trawl or parts of a trawl could potentially reduce water content and compact the sediment changing porosity, pore water variables and fluxes. SMITH *et al.* (2003) looking at relative compaction in Kriti did not find any overall effects from trawling and PUSCEDDU *et al.* (2005a) did not find any change sediment water content in the Thermaikos Bay with the onset of the trawling season. Both these negative results may be due to the differential impacts on compaction and mixing over.

RESUSPENSION AND SEDIMENTATION

As previously noted the passage of a trawl over the sediment causes sediment to rise into suspension then gradually drop out. This is more prevalent in softer sediments than in coarser sediments. SMITH *et al.* (2000) have reported the presence of turbidity clouds after the passage of trawl seen both from simple echosounders and through bottom video. Targetted work by de MADRON *et al.* (2005) in the Western Mediterranean have indicated that trawls produce significant resuspension, with sediment clouds several hundreds of metres behind trawls that are 3-6 m high and 70-200 m wide. Suspended sediment concentrations reached 50 mg/l and with flux rates ranging 190-800 g/m^2/s depending on sediment (coarse – silty). However, the particulate load only resulted from the resuspension of less than 1 mm thickness of sediment bed, indicating that a very small fraction of the sediment ploughed by the trawl is injected into the water column. In the Thermaikos Bay investigation in Hellas, PRICE *et al.* (2005) studying particulate and dissolved elements identified a 2-3 fold increase in resuspension between September and October almost certainly due to trawling (the trawling season starts at the end of September and there was no change in riverine and atmospheric conditions) and that the resuspended material was more silty in nature. In the same study PUSCEDDU *et al.* (2005b) noted trawling activities led to a significant increase in suspended particulate organic matter and changes in its biochemical composition with a change to a more refractory nature, (ie. an increase in organic material in the water but less bioavailable).

HEAVY METALS AND POLLUTANTS

COTOU *et al.* (2005) investigating resuspension events (including trawling) in the Thermaikos Gulf noted that these events appeared to be able to exert an influence on the chemical forms of micropollutants; thus on their bioavailability and toxicity. Trawling activities have been associated with the release of various compounds and elements from marine sediments. Over a long period of time, these compounds and elements can sink into and accumulate in the sediment from various sources (normally anthropogenic). In a relatively short period of time, trawls can dig into and turnover the sediment allowing the compounds and elements to be released very quickly back into the water column at concentrations much higher than when they were gradually deposited. This is more likely to happen in new trawling areas, whereas existing trawling areas will be in a greater state of equilibrium unless there is some major change in technique (such as deeper digging gears).

SEDIMENT CHEMISTRY

Sediment chemistry and chemical processes are dependent on sediment type and fabric, fauna dwelling in the sediment and diffusive processes over the sediment. They might easily be modified by changes to the sediment and removal of fauna from trawling. Organic carbon and phytopigments are a very basic measure of richness/food availability in the sediment for the fauna. With extensive sampling in Kriti, SMITH *et al.* (2000) and SMITH & PAPADOPOULOU (2005) were not able to detect differences in organic carbon between stations (multiple control and trawl lane sites) due to trawling. However, in the Thermaikos Gulf, PUSCEDDU *et al.* (2005a) found that sedimentary organic carbon concentrations and other organic variables (such as biopolymeric C concentrations) displayed a significant increase immediately after the initiation of the trawling season. It was suggested that this was related to the uplift from deeper sediment layers caused by trawling.

A change in the composition of the carbon in the surface sediments indicated that trawling activities increased the quality and bioavailability of organic carbon (cf changes in carbon bioavailability in re-suspended sediments)

In the study around Kriti SMITH *et al.* (2000) reported that for most of the year there were no differences between control and trawl lane stations with respect to phytopigments. The exception to this was in November just after the start of the trawling season when phytopigments were significantly higher in the commercial trawl lane stations. SMITH & PAPADOPOULOU (2005) found similar results, but did note that on deep sediment profiles there was a lot more variability in the phytopigment results from the trawl lane area. In the Thermaikos Gulf, PUSCEDDU *et al.* (2005a) did not find any significant changes in phytopigment content of the sediments observed after trawling events.

CHEMICAL FLUXES

Two sets of experiments have been conducted to study the acute and chronic impact of trawling on nutrient fluxes. Both have involved the sampling of sediments from commercially trawled and nearby control areas, the acute study looking at flux differences over 24 hours and the chronic study looking at fluxes over 8-12 days. Results have again been mixed with no reported effects on phosphate and silicate. However, SMITH & PAPADOPOULOU (2005) noted a lesser oxygen uptake but more nitrite uptake in the trawling lane in winter (trawling season) and more ammonia being absorbed in the trawling lane in the summer (closed season) They concluded that there was strong interaction of trawling with the denitrification and reduction process, but this was complicated by both seasonality and the open/closed season for trawling. In an experimental study on coarse sediments SMITH & PAPADOPOULOU (1999) had measured some immediate increases in bottom water silicate immediately after the passage of a trawl.

CONCLUSIONS

Demersal trawls have an evident impact on seabed habitats, at the least as some form of modification and at the worst, complete destruction. Individual impacts on specific physical and chemical parameters are not always clear cut and results from different studies have ranged from significant overall impact effects, effects at certain times or in specific areas, or have been contrary between studies. These results are in the most part due to the complexity of trawling impacts at both the direct and indirect level, as well as the differential impacts of the different parts of the trawling gear. The period when studies are undertaken may also play some part in the results as in Hellas there is an 8 month trawling period with a 4 month closed trawling period. This is complicated further by the seasonal nature of the periods with the closed period in summer, and the open period covering autumn/winter/spring. It is important that studies are undertaken with great care and in incremental stages, where possible removing natural variability as an external factor to have an appropriate number of replicate samples and replicate sampling stations. Direct sampling may also play a role in the future where multiple samples can be taken from specific places in relation to specific trawling impacts.

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V.5. FISHERIES INTERACTIONS WITH CETACEAN SPECIES IN HELLAS

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INTRODUCTION

The Hellenic Seas host a diversity of protected animal species, some of them recognized as threatened globally by international bodies and conventions. Protected marine vertebrate species involve several classes (fish, reptiles, birds, mammals). Three major taxons of the marine mega-fauna of the Hellenic Seas, namely reptiles (sea turtles), pinnipeds (seals) and cetaceans (whales and dolphins) are known to interact with fisheries. We review, herewith the available knowledge regarding six (out of twelve) cetacean species that inhabit the Hellenic Seas (Table 1) and are known to interact with fishing activities. The interaction of fisheries with these species has often a negative impact on either the threaten populations of the protected species, or the fishing activities, or both (Figure 1).

Figure 1: Common bottlenose dolphin found stranded with trammel nets around its caudal fin (Photo: A. FRANTZIS/Pelagos Cetacean Research Institute).

BIOLOGICAL NOTES ON THE CETACEAN SPECIES INVOLVED

(Abundance, distribution, habitat and feeding habits)

There are 12 cetacean species that have been recorded in the Hellenic Seas or in offshore waters surrounding Hellas. Eight of them have resident populations and four have been recorded only occasionally. Six species among those who have resident populations have been found to interact with fisheries (Table 1). The striped dolphin is by far the most abundant species followed by the bottlenose dolphin, the common dolphin, the sperm whale, the Risso's dolphin and the harbour porpoise. These species belong to two ecologically distinct groups, inhabiting the pelagic and the coastal waters respectively.

Table 1. Cetacean species that interact with fisheries in Hellas.

Species	Common name	IUCN status (Mediterranean population)	Fishing gear(s) involved	Interaction involved
Physeter macrocephalus	Sperm whale	Endangered	Pelagic driftnets	Entrapment
Grampus griseus	Risso's dolphin	Data deficient	Pelagic driftnets Longlines	Entrapment
Tursiops trunactus	Common bottlenose dolphin	Vulnerable	Traditional gillnets Trawl nets Aquacultures	Prey depletion Entrapment Gear damage Deliberate killing
Delphinus delphis	Short-beaked common dolphin	Endangered	Purse seiners, Trawler nets, Beach seiners, Trammel and gill nets	Prey depletion Entrapment ? Gear damage? Deliberate killing
Stenella coeruleoalba	Striped dolphin	Vulnerable	Pelagic driftnets Longlines	Deliberate killing
Phocoena phocoena	Harbour porpoise	Endangered	replace with trammel & gill nets	Prey depletion Entrapment ?

The sperm whales and the Risso's dolphins mainly inhabit the waters above the steep "slope", i.e. the end of the continental shelf where depth increases rapidly, but can also be found in further offshore waters. The striped dolphins inhabit the "slope" and pelagic offshore waters as well. Sperm whales are mainly found at depths of 500-1500 m and at distances of 2.5-10 km offshore. The Risso's dolphin are usually found at depths 200-1700 m and distances of 1-32 km offshore. Striped dolphins are found at all depths above 200 m and at all distances beyond the 1st km offshore. On the other hand the common bottlenose dolphin is the most abundant coastal species. It is mainly found over bottoms that do not exceed 250 m depth and usually limited at the first 6 km from the shore. It is common in gulfs and bays of the entire Aegean plateau, where it can be found further offshore in shallow waters in between islands. It is well present in the north Ionian Sea, even in the shallow and closed Amvrakikos Gulf. It is also present in the south Ionian and south Cretan Seas, although only locally along the coasts that run parallel to the Hellenic Trench. The short-beaked common dolphin also inhabits coastal and shallow waters below 200 m deep. It can be found further offshore only in the plateau of the Thracian Sea. A second, distinct ecotype of short-beaked common dolphins inhabits the Korinthiakos Gulf, where this species lives only in mixed pods with striped dolphins, only in deep waters of 500-900 m depth. The short-beaked common dolphins are disappearing very fast, and less than 20 individuals are now left in the entire Ionian Sea. No habitat data are available for the harbour porpoise, which is limited in the north Aegean Sea and mainly in the shallow plateau of the Thracian Sea, although it is believed to inhabit only coastal and shallow waters.

The three pelagic species feed almost exclusively with mesopelagic squids, and therefore, do not come close to fishing nets to feed. The coastal species are feeding mainly or exclusively on fish. When feeding close to the surface, common dolphins prey upon epipelagic schooling fish (sardines and anchovies; *Sardinella aurita*, *Sardina pilhardus*; *Engraulis encrasicholus*). The common bottlenose dolphins have much more opportunistic feeding habits (demersal fish and schooling epipelagic fish), and finally the feeding habits of the harbour porpoise are not well known (sardines have been found in one stomach content).

INTERACTION WITH FISHERIES

Interactions between cetaceans and fisheries include an important number of relationships, and have an impact in both the cetacean populations and the fishing activities. These are summarized in the Table 2 according to Bearzi (2002) slightly modified.

Among the six cetacean species of the Hellenic Seas that are known to interact with fisheries, there is only one species known to have a measurable impact on fishing activity. This is the common bottlenose dolphin (*Tursiops truncatus*), which is known to interact with trammel and gill nets, fish farms (aquacultures) and trawl nets. Fishermen complains concerning gillnet damage probably regard only this species (in theory the short-beaked common dolphin and the harbour porpoise could also feed upon caught fish in trammel and gill nets; however there are no documented cases and anyway, the short-beaked common dolphin faced a dramatic decline in numbers over the past few decades and is now rare in most Hellenic Seas, and the harbour porpoise is an even rarer species). Several common bottlenose dolphins get entrapped in trammel and gill nets in Hellas every year (Figure 2), although there is no estimate of their number. By-catch does not seem to be high enough to threaten local population units, however, if the dolphin numbers continue to decline with the actual rates, even the by-catch numbers may be unsustainable.

Table 2. Main known interactions between cetaceans and fisheries (from BEARZI 2002, modified).

Impact of cetaceans on fisheries	Impact of fisheries on cetaceans
Damage to fishing gear in the form of holes torn in the nets as the dolphins attempt to remove fish	Injury or mortality from retaliatory measures by fishermen who perceive dolphins as a pest
Reduction in the amount or value of the catch as the dolphins mutilate or remove caught fish	Bycatch in fishing gear and direct injury or killing from illegal dynamite fishing
Reduction in the size or quality of the catch as the dolphins' presence may cause fish to flee from the vicinity of the nets	Reduction of food prey availability or changes in food prey composition/distribution caused by overfishing
A real or perceived ecological competition with cetaceans, based on the conviction that dolphins reduce the amount of fish available to fisheries	Modifications in cetacean behaviour leading to emigration, or reduced reproductive rates as a consequence of interactions with fisheries

Figure 2: Common bottlenose dolphin carcass entagled in trammel nets (Photo: N.TSOUKALA/ Pelagos Cetacean Research Institute).

Figure 3: Striped dolphin still alive without caudal fin that was amputated by fishermen (provided by port-police authorities/ archive Pelagos Cetacean Research Institute).

The damage of the fishing gear and secondarily the reduction of the amount of the catch by common bottlenose dolphins interacting with the gillnet fisheries is by far the most important problem, that makes fishermen perceive dolphins (without discriminating among species) as a pest. A direct consequence of this problem is the retaliatory measures by some fishermen. While evaluating the extent of the problems created by this dolphin species to the fisheries, it must be considered that Mediterranean common bottlenose populations have now declined considerably and their numbers are certainly much lower than they used to be a few decades ago. Recent efforts to use acoustic devices that could keep the dolphins away from the nets have not shown to provide a solution, either because they are ineffective, or because they may extirpate dolphin populations from their feeding grounds. Such devices have often been proposed to Hellenic fishermen as "their salvation" for commercial reasons, however, they turned to be inefficient and most importantly, they have not been passed by any control, and no regulations have been established regarding their use.

The interaction of common bottlenose dolphins with trawler nets and fish farms is perceived as a much less important problem to fisheries, since in these cases no damage is inflicted to the fishing gear, and only in the trawler nets case, a limited quantity of fish is "stolen" from the fishermen. The dolphins either follow the trawl net and catch injured fish from the bottom or attempt to remove fish through the net mesh, or in some cases may enter rapidly the net pocket to directly collect fish. So far, there is no published evidence that cetaceans may cause direct damage to Mediterranean aquaculture facilities, however, there are cases of complains reporting stress in farmed fish induced by the dolphin presence and feeding activity in the vicinity of the cages. The dolphins are attracted primarily by the large shoals of fish, mainly boque (*Boops boops*), that have appeared in the vicinity of fish farms due to good feeding conditions.

The striped dolphin, which is by far the most abundant cetacean in the Hellenic Seas, has a pelagic distribution and largely feeds on non-commercial prey species. Therefore, it does not represent a problem to coastal fisheries. However, it is not rare to find stranded specimens of this species either shot or mutilated (Figure 3). The same is valid for the rare and endangered short-beaked common dolphin. These two dolphin species are occasionally killed deliberately by fishermen although they provoke no harm to their fishing activity. Unfortunately, almost no fishermen in Hellas can distinguish between the common bottlenose dolphin and the other two above mentioned species. They called them all "dolphins", they may believe that the two smaller species (striped and short-beaked common dolphins) are calves or juveniles of the larger common bottlenose dolphins, and eventually, they consider them as harmful competitors or as a pest as well. The same problem is probably valid for the Risso's dolphin and the harbour porpoise, however, their scarcity and their escaping behaviour significantly reduces the encounters with fishermen.

Reports of cetaceans caught by longlines are rare, although they do occur (a documented case exists for a couple of Risso's dolphins, caught by surface drifting longline for swordfish and released by the fishermen off Evvoia Island). In other Mediterranean areas dolphins (striped dolphins, Risso's dolphins and common bottlenose dolphins) have been found stranded with hooks in their mouth, or with fishing lines in their larynx, suggesting that in some cases these animals may try to feed on bait or hooked fish. Comprehensive studies on the potential impact of longlines on cetaceans in the Mediterranean have never been conducted. However, this seems likely to represent a minor threat in the basin.

Another fishing activity, which unfortunately remains a common practice in the Hellenic Seas, is the illegal dynamite fishing. The serious negative impact of this fishing method on the fish stocks and the coastal ecosystem in general is certainly significant, although difficult to evaluate. Apart the role it plays in depleting fish stocks upon which coastal dolphin species prey, it may provoke direct physiological damage to cetaceans found in vicinity, or behavioural changes including emigration because of habitat degradation. Apart the coastal species, in some areas along the Helelnic Trench, where big depths are found close to the coasts, pelagic cetacean species including the sperm whale are also suffering from the frequent and unexpected explosions. The level of damage to their hearing or to other vital systems is unknown.

Finally, one of the most important threats for all the pelagic cetacean species, and especially for the endangered Mediterranean sperm whale population, is the deployment of pelagic driftnets. Historically, driftnets were the most significant source of entrapments for cetaceans. Driftnets are large, floating nets made of a mesh of monofilament or multifilament line, deployed in the open sea. In the Mediterranean, driftnets have been used to capture several species of tuna and, currently, mostly swordfish. They can be up 50 kilometers (30 miles) long and hang vertically 20-30 meters from the surface. Left to drift freely, the design of the nets means they are not selective in what they catch, resulting in a high level of bycatch - the catch of non-target species. Because driftnets are generally deployed in the open sea, they are likely to entangle large pelagic species, including whales, dolphins, sharks, turtles, rays and seabirds. The propensity for driftnets to kill so many large animals earned them the nickname "walls of death".

In 1992 the European Community prohibited driftnet fishing in the Mediterranean with nets more than 2.5 km in length, as did the General Fisheries Commission for the Mediterranean (GFCM) in 1997 under a binding Resolution. A total ban on driftnet fishing on large pelagic species by the EU fleet in the Mediterranean entered into force from 1st January 2002; the same decision was adopted by ICCAT by means of a binding recommendation in November 2003.

Although this fishing activity is illegal in the European Union, it still goes on in the international Mediterranean waters, but occasionally in the national Hellenic waters as well. Because driftnets are illegal, states will not admit formally to their use, or are unable to monitor the practice within their waters, and therefore no data on the targeted catch rates or the associated bycatch rates are available for driftnet fisheries. At the peak of driftnetting, an annual bycatch of over 8,000 cetaceans was estimated for Italian Seas alone. These catch rates were undoubtedly unsustainable for the species most affected, including striped and common dolphins, and sperm whales. Between 1986 and 2000, 64 sperm whales in Italy were killed as a result of entrapment in fishing gear, and probably most if not all of these were from driftnets.

In Hellas very few vessels had applied this fishing practice in the past, and it does not seem likely that they continue nowadays. However, foreigner fleets (particularly Italian boats) are still deploying drifnets at least in the Ionian Sea, and seriously threaten the sperm whales (Figure 4), for which the Ionian Sea is an important habitat.

Recently, on May 2005, fishermen off Hellas's Aegean island of Samothrace have found 13 dead striped dolphins, one Risso's dolphin, one shark and some tuna in an illegal abandoned driftnet. The

Figure 4: This sperm whale photographed along the Hellenic Trench has a driftnet around its tail flukes. According to a summary of records from the waters of Spain, France and Italy between 1971-2003, 229 sperm whales were reported as stranded, entangled in fishing gear or carrying entanglement scars.
(Photo: A. FRANTZIS / Pelagos Cetacean Research Institute).

floaters of the driftnet contained Turkish batteries that cannot be found in the Hellenic market and indicated a Turkish origin.

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V.6. FISHERIES INTERACTIONS WITH MARINE TURTLES

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INTRODUCTION

Three species of marine turtles, namely the loggerhead turtle *Caretta caretta*, the green turtle *Chelonia mydas*, and the leatherback turtle *Dermochelys coriacea* are encountered in the Hellenic seas, as well as in the Mediterranean. Of these, the first two reproduce in the Mediterranean and have evolved local populations, while the leatherback turtle is a visitor from the Atlantic. Only *Caretta caretta* is known to nest in Hellas, concentrating about 60% of the total documented nesting of this species in the Mediterranean (MARGARITOULIS *et al.,* 2003a).

Caretta caretta and *Chelonia mydas* are listed as Endangered and *Dermochelys coriacea* as Critically Endangered in the IUCN Red List of Threatened Species. All three species are protected in Hellas by national legislation including several ratified international conventions (e.g. Bern Convention, Bonn Convention, Barcelona Convention) as well as European Community regulations (e.g. CITES) and directives (e.g. 92/43 Habitats Directive).

In Hellas, all species of sea turtles are known to interact with fishing activities, often with a negative impact on either the turtles or the fishing gear, or both.

BIOLOGICAL NOTES ON SEA TURTLES

Sea turtles are a highly migratory species; therefore, they should be examined in a regional context. This is most apparent in the case of a semi-enclosed sea such as the Mediterranean.

1. Caretta caretta

It is a cosmopolitan species, frequenting tropical and temperate latitudes as well as open and coastal waters. The loggerhead populations in the Mediterranean exhibit a certain degree of isolation from the ones in the Atlantic (BOWEN *et al.,* 1993).

Nesting Areas: Nesting in the Mediterranean occurs almost exclusively in the eastern basin, and mainly in Hellas (3 000 nests/yr), Turkey (1 400 nests/yr) and Cyprus (600 nests/yr). According to long-term documented data, the single most important nesting site, and the one with the highest nest density, is Laganas Bay on the island of Zakynthos. Nesting areas in Hellas have been classified, according to specific criteria, as "major" (Kyparissia Bay, Rethymnon, Lakonikos Bay, Bay of Chania), and "moderate" (Koroni, Bay of Messara, Kotychi, Kefallonia, Kos and several others) (MARGARITOULIS *et al.,* 2003a).

Marine Habitats: Loggerhead turtles pass through two ecological stages in their lifetime. During the "oceanic" stage they frequent open waters and feed upon pelagic prey, while during the "neritic" stage they settle in shallow coastal waters and feed upon benthic prey.

It is worthwhile to note that loggerhead turtles, hatched on northwestern Atlantic beaches, enter the Mediterranean Sea through the Straits of Gibraltar, during their oceanic-stage migration. The presence of Atlantic turtles in the western Mediterranean was initially discovered by the frequent captures in surface longlines of juvenile loggerheads, the high numbers of which could not be justified as originating from only the Mediterranean stock; this has been subsequently corroborated by genetic studies. These Atlantic-oriented individuals do not reproduce in the Mediterranean but share the same or adjacent oceanic habitats with juveniles from the Mediterranean stock. Besides the western Mediterranean, another important oceanic habitat, probably hosting juveniles from Hellas, has been recently identified between the southern Adriatic Sea and the northern Ionian Sea.

Large-sized turtles (i.e. in their neritic stage) are usually found in the eastern Mediterranean. This has been determined through frequent captures in bottom trawlers in the shallow waters of the northern Adriatic (CASALE *et al.,* 2004), and the Gulf of Gabès in Tunisia (JRIBI *et al.,* 2004), as was also shown by the post-nesting migrations of adult females which were tagged in Hellas and subsequently captured in these two areas (Figure 1). In Hellas, as derived by the size of turtles captured in fishing gear or found stranded, several areas can be considered as neritic habitats (e.g. Lakonikos Bay, Amvrakikos Bay, Thracian Sea).

2. Chelonia mydas

It has a circumglobal distribution, frequenting mainly tropical latitudes as well as open and shallow waters. Genetic divergence has shown a strong degree of isolation from the Atlantic popu-

Figure 1: Post-nesting movements of loggerhead turtles, tagged in Hellas (Zakynthos and Kyparissia Bay) in the period 1982-2004. From a total of about 3 200 tagged females, 129 (4.0%) have been recovered at distances longer than 150 km from the respective nesting area. Of the recovered individuals, 28% were found in the Gulf of Gabès and 43% in the Adriatic Sea. Arrows are indicative and do not suggest migratory routes.

lations. Nesting in the Mediterranean is restricted to its easternmost part (mainly in Turkey, Cyprus and Syria) with an average number of nests of about 1 200 per year. Satellite tracking has shown that some females nesting in Cyprus migrate to northern Africa during winter. The most important foraging area is found between Turkey and Egypt. However, a foraging habitat for juvenile green turtles has been recently identified in Lakonikos Bay, southern Hellas.

3. Dermochelys coriacea

It is the largest marine turtle and, although its nesting is restricted to the tropical zone, it has the widest latitudinal distribution at sea among all marine turtles. In the Mediterranean this species, appearing in large juvenile and adult size classes, is considered a regular visitor from the Atlantic. By comparing catch rates in longlines, it is derived that the leatherback's occurrence in the Mediterranean is much lower than that observed in the Atlantic. Available data from Hellas indicate that this species appears mainly in the Aegean Sea (MARGARITOULIS, 1986).

INTERACTION WITH FISHERIES

A major threat to marine turtle populations originates from their interaction with fishing activities. Since marine turtles are migratory, interactions with fishing gear in one Mediterranean country may affect sea turtle populations in another. Conservation efforts in a sea turtle nesting area can be undermined by the impact caused by fisheries by-catch on the same population in another area or country.

Thousands of turtles are captured every year in various fishing gears throughout the Mediterranean, including Hellas. However, the mortality rate of the captured turtles is not known. For better clarification of the above, it is useful to differentiate "mortality" into two components: (1) the "direct mortality" which is directly observed at gear retrieval, and (2) the "delayed or post-release mortality" which occurs after the release of a captured turtle. In contrast to the easily determined "direct mortality", the "delayed mortality" is extremely difficult to assess. Indeed, although most captured turtles are alive at gear retrieval (and usually released alive immediately or soon after), it is very difficult to determine how many of these will die because of damage incurred by this interaction. As reported in more detail below, death to a turtle released after capture can occur many days, weeks or even months, after a fisheries' interaction.

In addition to the mortalities caused by the interaction alone, turtles may be intentionally killed or injured by fishermen. There are several reasons for this behaviour. Sometimes turtles are seen by fishermen as competitors for fish. Longline fishermen may kill them to recover expensive hooks. Furthermore, they can be killed because of prejudice, ignorance or superstition, as well as revenge because of the damage caused to fishing gear. From a sample of 524 turtle strandings found along the

Figure 2: Loggerhead turtle with healed injury on head, inflicted intentionally after its capture in gill nets (© ARCHELON).

coasts of Hellas, over 23% had injuries presumably inflicted intentionally by fishermen (KOPSIDA *et al.,* 2002). Also, from a sample of 226 injured turtles admitted to ARCHELON's Rescue Centre in Glyfada, 34% suffered from head trauma (Figure 2) in most cases deliberately inflicted after capture in fishing gear (PANAGOPOULOS *et al.,* 2003).
Relevant data from sea turtle rescue centres can provide a general idea of the proportion of affected turtles because of fisheries' interactions. During the 10-year period 1997-2006, 441 injured turtles were admitted to ARCHELON's Rescue Centre in Glyfada. Of these, 306 (69.4%) bore signs of fisheries' interaction (i.e. ingested hooks or lines, intentional blows, entanglement in nets). The annual percentage of the fisheries' induced injuries ranged from 59.4% to 78.9% (Figure 3).
Another important factor of fisheries' impact on turtle populations stems from the size class of the affected turtles. It has been shown that large-sized turtles have a greater reproductive value than small-sized ones. Therefore, fishing gears used mostly in shallow waters (e.g. beach seines, trawls, static nets), frequented by the large-sized "neritic" specimens, have a greater impact on turtle populations than those used in open waters (e.g. drifting longline), frequented by the small-sized "oceanic" specimens, even if the latter gears catch more turtles.
The fishing gears with a major impact on sea turtles in the Mediterranean, and most probably in Hellas, are the drifting longline, the static gill net, the bottom trawler and the beach seine. The impact caused to turtles by these gears is briefly described below.

Drifting longline

This gear is responsible for the highest number of turtle captures in the Mediterranean and, according to the available data, also in Hellas. Several tens of thousand captures occur every year in the Mediterranean (CAMIÑAS, 1988; GEROSA & CASALE, 1999; DEFLORIO *et al.,* 2005), and LEWISON *et al.* (2004) estimated at least 60 000-80 000 turtle captures per year mainly in the western Mediterranean. An onboard observer study in Hellenic drifting longlines during 1999 and 2000 estimated the total loggerhead captures to be 1 145 (in 1999) and 5 474 (in 2000) (KAPANTAGAKIS & LIOUDAKIS, 2006). A similar study in the Ionian Sea provided an estimated total capture, by the Italian longline fleet, of 1 084 turtles (in 1999) and 4 447 turtles (in 2000) (DEFLORIO *et al.,* 2005). The vast majority of turtles captured in drifting

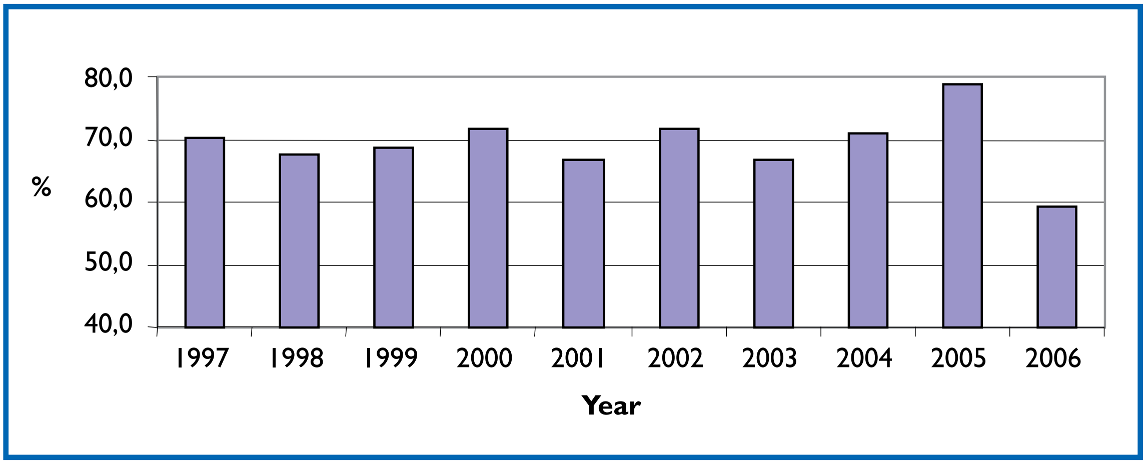

Figure 3: Annual percentage of turtles bearing signs of fisheries interaction (e.g. ingested hooks, entanglement in fishing lines and nets, intentional blows) from the ones admitted to ARCHELON's Sea Turtle Rescue Centre in Glyfada, during the period 1997-2006 (total number of admitted turtles: 441).

Figure 4: Juvenile loggerhead turtle hooked in drifting longline (© ARCHELON).

Figure 5: Fisherman releasing juvenile green turtle found alive in static gill nets (© ARCHELON).

longlines are *Caretta caretta* with very few *Chelonia mydas* and *Dermochelys coriacea*. Turtles captured in drifting longlines are usually released by fishermen by cutting the branch line, without hauling the turtle onboard. Therefore, in most cases released turtles go away with an ingested hook and a piece of nylon line (Figure 4).

Turtle mortality in drifting longlines

Many factors influence the overall mortality induced by longlines, making its assessment rather difficult. Direct mortality in longlines is relatively low (zero in DEFLORIO *et al.,* 2005; about 5% in KAPANTAGAKIS & LIOUDAKIS, 2006), but delayed mortality is probably very high. About half of the 200 turtles which were caught by the Italian longline fleet in the Ionian Sea had hooks that could not be removed and remained deeply embedded in the digestive track (DEFLORIO *et al.,* 2005). Two independent studies on hooked turtles, hosted at rescue centers in the Mediterranean, showed mortality rates of 34% (AGUILAR *et al.,* 1995) and 33% (FREGGI & CASALE, 2006). It is interesting to note that a considerable proportion of "delayed" mortality is caused by the line itself which may cause lethal damage to the intestine, especially if the line is held in place by an anchored hook. Affected turtles are unable to digest food; they gradually become debilitated and subsequently die of starvation.

Static gill net

There are several types of this kind of set nets. In the Mediterranean and in Hellas, these gears are operated by numerous and widespread small-scale and artisan fishermen, and therefore, it is very difficult to determine their overall impact on turtles (Figure 5). Nevertheless, circumstantial evidence and the assumed high overall fishing effort suggest that turtle captures in this fishing gear may be very considerable.

Turtle mortality in static gill nets

A turtle captured in these nets usually drowns as it is not possible, in most cases, for it to swim to the surface to breathe. Available data indicate a very high direct mortality rate, usually higher than 50% and even over 90% (see review of CASALE *et al.,* 2005). In Hellas, turtle mortality in static gill nets has not been assessed but it is suspected that it might be similar to that estimated for drifting longlines. If a turtle is found alive in a static net, fishermen try to release it by cutting the nets; otherwise the nets can be severely damaged. Thus, released turtles may go away wrapped in pieces of nylon nets, which sometimes cause necrosis of their flippers (Figure 6) as well as other problems. Moreover, this gear seems to draw the largest portion of intentional killings or attempts at it, as derived from anecdotal evidence and interviews with fishermen, as well as from injured turtles admitted to rescue centres (KOPSIDA *et al.,* 2002).

Figure 6: Treatment of flipper necrosis due to entanglement in fishing lines (© ARCHELON).

Bottom trawler

An onboard observer study estimated 4 300 loggerhead turtle captures per year by the Italian trawler fleet in the northern Adriatic Sea (CASALE *et al.,* 2004), which is an important foraging area for turtles nesting in Hellas (Figure 1). Similarly, in the Gulf of Gabès off Tunisia, another important foraging area for turtles nesting in Hellas (Figure 1), about 5 500 turtles are captured per year by the Tunisian trawl fishery (JRIBI *et al.,* 2004). After a two-year study onboard Hellenic trawlers, in the Thracian Sea (northern Aegean) and the Ionian Sea (Gulf of Patras, western Gulf of Corinth, Echinades islands), the total turtle captures have been estimated at 0-418 captures/yr (Thracian Sea) and 0-448 captures/yr (Ionian Sea); the wide range being attributable to the small number of turtles caught (MARGARITOULIS *et al.,* 2003b). It is interesting to note that both species (*Caretta caretta* and *Chelonia mydas)* were captured at trawling depths of less than 50 m. All captured turtles were alive and, following measurements and tagging, were released. The usual practice of trawl fishermen in Hellas is to release captured turtles immediately by throwing them overboard. However, as it will be shown in the following section, this practice is not always the appropriate one.

<u>Turtle mortality in bottom trawlers</u>

Mortality of turtles caught in bottom trawlers depends largely on haul duration, which varies according to different factors (e.g. target species, sea bottom, type of vessel). Longer haul durations may increase: (1) the proportion of dead turtles in the net (direct mortality), and (2) the proportion of turtles in a comatose state, caused by apnea. It is important to note that comatose turtles thrown overboard usually die because they are unable to swim and therefore cannot reach the surface to breathe (delayed mortality). Trawl fishermen can substantially reduce this type of "delayed mortality" by keeping comatose turtles onboard and allowing them to recover before releasing them. Indeed, in the northern Adriatic Sea CASALE *et al.*, (2004) estimated 9.4% of direct mortality and 43.8% of maximum potential delayed mortality (assuming that all comatose turtles would die). In the above mentioned two-year study in Hellas, zero direct mortality and no comatose turtles (i.e. no delayed mortality) have been observed, probably a result of short haul durations (ranging 68-185 min) (MARGARITOULIS *et al.,* 2003b).

Beach seine

This gear is used in shallow water and therefore, it has a considerable impact on large-sized "neritic" turtles, especially in certain areas of Hellas (e.g. Lakonikos Bay). The threat from this gear was more serious in previous years, due to the large number of these vessels. However, the gradual withdrawal of this type of fishing gear will certainly ease the pressure imposed on turtles.

Figure 7: Public release of injured turtle after its rehabilitation at the Rescue Centre (© ARCHELON).

CONSERVATION EFFORTS AND PROPOSALS

The many incidents of injured marine turtles reported in Hellas have prompted ARCHELON to establish a Sea Turtle Rescue Centre in Glyfada, Attica, in cooperation with the local Municipality. The Centre has a capacity to simultaneously treat 25 turtles under the supervision of a specialized veterinarian. The Centre receives about 44 turtles per year (Figure 3), of which about 50% are successfully rehabilitated and released (Figure 7).

Injured turtles are brought to the Rescue Centre thanks to a nationwide Stranding Network, comprised of public services (mainly Coast Guard stations), NGOs and concerned citizens.

Both the Rescue Centre and the Stranding Network were greatly improved by relevant LIFE-Nature projects, co-funded by the European Commission. These projects also included cooperative actions with fishermen in known "hot spot" areas, such as Lakonikos Bay, Amvrakikos Bay and Kriti. The most recent of these projects, entitled "Reduction of mortality of *Caretta caretta* in the Hellenic seas", covered the entire country with emphasis in western Hellas and Kriti where, due to the high incidence of turtle captures, two First-Aid Stations were established. Further, the collection and analysis of more stranding data provided the opportunity to identify some additional "hot spot" areas (e.g. Messiniakos Bay, Thracian Sea, Argolikos Bay). Special public awareness events were organized in these areas aiming at sensitising fishermen, local authorities and schoolchildren. It is useful to note that in the context of this project about 30 Memoranda of Understanding (MoU) have been signed by local Fishermen's Associations. The MoU, drafted in consultation with a fishermen's association, includes among others, the need to compensate fishermen who suffer damage or loss of gear by turtle interactions.

It is clearly understood that some mitigation measures are needed to lessen turtle by-catch during fishing activities. It is also understood that fishing activity is a major economic and recreational resource. With these prerequisites in mind, UNEP's RAC/SPA (Regional Activity Centre for Specially Protected Areas), which coordinates the implementation of the Action Plan for the Conservation of Marine Turtles in the Mediterranean (adopted by all Mediterranean countries through the Barcelona Convention), has published a booklet with instructions for fishermen towards reducing turtle mortality during or after a turtle's capture. The booklet has been translated in several Mediterranean languages, including Hellenic. In addition to this, ARCHELON has issued a number of leaflets, brochures, and posters for fishermen and relevant authorities in Hellas providing instructions on how to release captured turtles from various fishing gears.

Drawing from the above instructions, as well as from similar examples in non-Mediterranean countries (e.g. Australia, USA), we suggest the following actions to be implemented as a simple fundamental approach towards the assessment, and the reduction of turtle by-catch and associated mortalities in fishing gears used in Hellas:

- Assessment of turtle mortality rates in static gill nets
- Reduction of intentional killings or attempts
    Design and implementation of educational programmes directed towards small-scale fishermen, with emphasis on static gill nets.
    Evaluate progress through the national Sea Turtle Stranding Network and specific surveys in fishing ports.
- Mitigation of delayed (post-release) turtle mortality in trawlers and longlines
    In trawlers: comatose turtles should remain onboard until they are able to swim.
    In longlines: fishermen should cut the branch line as close to the turtle's mouth as possible, without hauling the turtle onboard.

Since marine turtles use different habitats and migrate across national boundaries during their life-cycles, any conservation effort should have a strong regional component. This is particularly evident for the semi-enclosed Mediterranean Sea, which is surrounded by 21 nations with different cultures, religions and needs, and where important populations of endangered marine turtles reproduce, forage, migrate and interact with various fishing gears. It is apparent that long-term conservation of these species in the Mediterranean is not an easy endeavour that can be undertaken by one or few countries but it requires well coordinated regional efforts. Moreover, marine turtles are also affected by many of the problems that humans are causing to the marine environment. Therefore, actions for the conservation of marine turtles contain a substantial potential for a positive impact on marine ecosystems, and reinforce international cooperation towards a rational management of marine habitats.

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V.7. MEDITERRANEAN MONK SEAL *MONACHUS MONACHUS* AND FISHERIES: CONSERVING BIODIVERSITY AND MITIGATING A CONFLICT IN HELLENIC SEAS

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INTRODUCTION

As the awareness of the integral importance of marine mammals in healthy aquatic ecosystems has increased in recent years, so has the interest in all aspects of the lives of these animals, both by the general public and in the scientific and management communities. It has also become evident that a number of human activities, fisheries included, threaten their survival and their habitats. Numerous studies have tried to evaluate the extent of marine mammal and fisheries interactions. Most of these studies have focused on the operational interactions, i.e. the accidental entanglement or mortality of marine mammals in fishing operations and the damage caused by marine mammals to fishing gear. Several species or populations of marine mammals may be threatened with extinction or severe depletion from such interactions. In contrast, relatively fewer studies have addressed the possible biological aspect of such interactions, i.e. the competitive interactions between marine mammals and fisheries for food and fishery resources (NORTHRIDGE, 1991).

In the Mediterranean Sea a characteristic and a widely publicized example of such an interaction is the case of the Mediterranean monk seal, *Monachus monachus* (Figure 1), with coastal fisheries. The Mediterranean monk seal is one of the 33 extant species of Pinnipeds and belongs to a genus that inhabits exclusively subtropical and temperate waters. Population numbers declined dramatically in the past century and the species is currently considered "critically endangered" by the World Conservation Union (IUCN) (IUCN, 2000).
Historically, the Mediterranean monk seal occupied a wide geographical range. More recently, however, monk seals have disappeared from most of their former range, with the most severe contraction and fragmentation occurring during the last century. The species is now mainly confined to two surviving populations, one occupying the Atlantic coast of northwest Africa, and the other,

Figure 1: Mediterranean monk seal in the Aegean Sea (© MOm/V. Paravas).

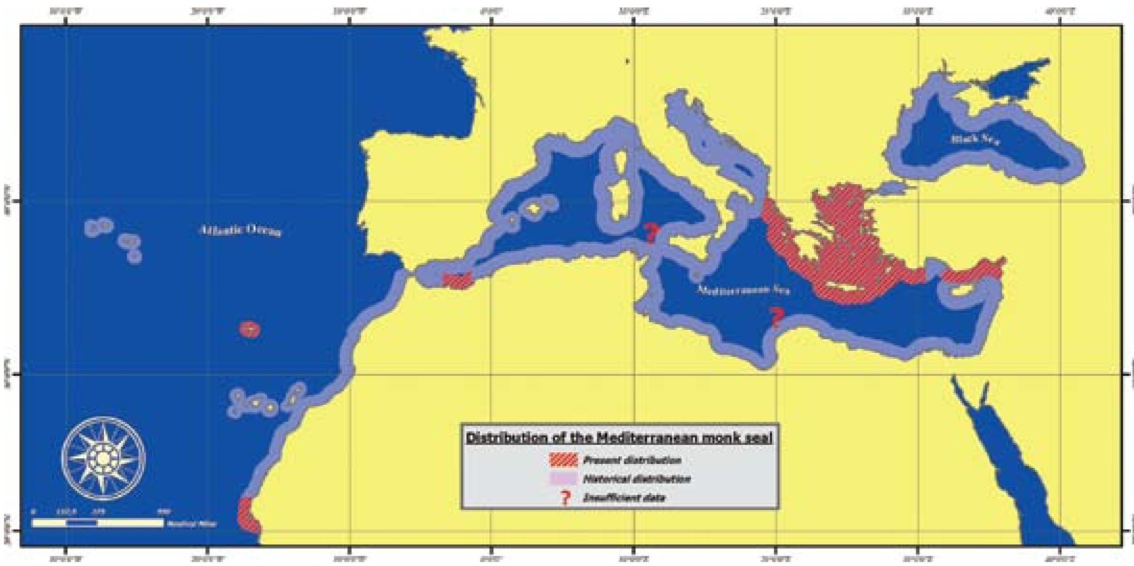

Figure 2: Mediterranean monk seal distribution (© MOm).

the northeastern Mediterranean (Figure 2). The shy and reclusive nature of the species and the inaccessibility of its habitat have precluded accurate population estimations. Conventional wisdom, however, suggests that fewer than 600 individuals survive (REIJNDERS *et al.,* 1997).

Although their relative importance and intensity may vary from region to region, a consensus of scientific opinion holds that the following – often inter-relating – factors are the main threats to the survival of the species (REIJNDERS *et al.,* 1997):

a. Habitat loss and deterioration (including increased pup mortality caused by pupping in unsuitable locations)
b. Deliberate killing (mostly by fishermen)
c. Accidental death due to entanglement in fishing gear
d. Lack of food and depressed physical condition as a result of overfishing
e. Lack of international coordination and funding of conservation and management actions
f. Stochastic events (i.e. disease epidemics, cave collapses, oil spills, toxic algae blooms or other)

Threats b, c and d are directly linked to interactions with the fishing industry and are considered here in more detail:

- <u>Deliberate killing</u>: Although the Mediterranean monk seal was hunted commercially for its oil and skin until the late Middle Ages, population collapse eventually brought an end to such exploitation. Deliberate killing of surviving individuals has continued by fishermen, angered over damaged nets and 'stolen fish' (JOHNSON & LAVIGNE, 1999). More recently, fish farm operators have also come into conflict with monk seals that raid their facilities, particularly where adequate protective netting has not been installed (GÜÇLÜSOY & SAVAS, 2003).
- <u>Entanglement in fishing gear</u>: Accidental entanglement in fishing gear has been postulated to have posed a major threat to the Mediterranean monk seal and was considered to have played an important role in the extirpation of the species from several parts of its former range. However, recent evidence from the Eastern Mediterranean shows that the relative importance of entanglements may have been overestimated (ANDROUKAKI *et al*., 1999). Entanglement is not restricted to a specific type of fishing gear. Unlike pelagic species, however, monk seals appear to be most vulnerable to entrapment in static gear and discarded nets in coastal areas (PANOU *et al*., 1993).
- <u>Overfishing</u>: Although research on the cause and effect of this threat has not been carried out systematically, and consequently, only circumstantial evidence is available, overfishing has been considered to have had a negative effect on monk seal populations in several areas (SALMAN *et al.,* 2001, GÜÇLÜSOY *et al.,* 2003).

THE MEDITERRANEAN MONK SEAL IN HELLAS: STATUS, DISTRIBUTION AND FISHERY-RELATED THREATS

Information on the abundance and distribution of Mediterranean monk seals in Hellas from ancient and classical times indicates that the species was abundant and distributed throughout the entire country (JOHNSON & LAVIGNE, 1999). As was the case throughout the species range, monk seals in Hellas experienced intense human pressure, especially in the 20th century. Already by the 1970s MARCHESSAUX and DUGUY reported the monk seal population in Hellas to be restricted mainly to the southern part of the mainland of the country and to the remote islands and islets of the Aegean and Ionian Seas and to number 260-360 individuals (MARCHESSAUX & DUGUY, 1977). One has to keep in mind, however, that such estimates were not based on the systematic monitoring of the species.

In order to fill critical gaps in the knowledge of the species status, an integrated research and conservation programme was initiated in 1990 by MOm/ Hellenic Society for the Study and Protection of the Monk seal (a non-profit, non-governmental organization). Key objectives of the programme were to evaluate the distribution and abundance of Mediterranean monk seals within Hellas and identify and mitigate threats to the species' survival. Systematic research efforts focus on:

- Carrying out field surveys throughout the country in order to evaluate habitat availability, suitability and use, especially in relevance to breeding sites.
- Establishing and operating a Rescue and Information Network (RINT) that receives information on monk seal sightings from the entire country and responding to cases of emergency (rescuing orphaned pups, treating animals exposed to oil spills, etc.).
- Monitoring local monk seal populations in key areas of the species distribution.
- Monitoring mortality causes by carrying out necropsies on dead seals reported to the RINT.

The main results of the last 20 years of research, regarding the species' distribution and abundance, can be summarized as follows:

a) The species is still widely distributed throughout Hellas, showing a preference for secluded and inaccessible parts of the coastline (ADAMANTOPOULOU *et al.*, 1999) (Figure 3).

b) More than 560 suitable monk seal shelters have been identified throughout the country. Ninety-nine of these shelters are considered to be suitable for pupping, while the rest are suitable only for resting (MOm 2007).

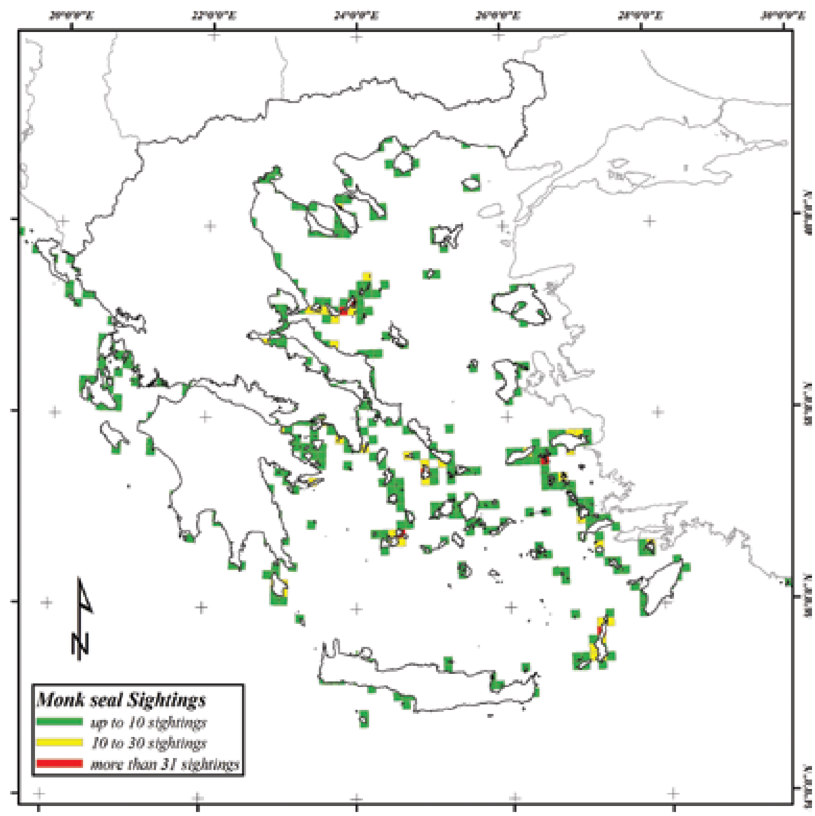

Figure 3: Distribution of Mediterranean monk seal sightings in Hellas (1990 - 2005) (©MOm).

c) Seals are capable of covering considerable distances within the country and diving up to 125 m (DENDRINOS *et al.*, 2007), but they remain usually within the 200 m isobath.

d) Important colonies of the species have been identified in the Northern Sporades archipelago (DENDRINOS *et al.*, 1994), at the island complexes of Kimolos-Polyaigos and Karpathos-Saria (MOm 2005a) and in the Ionian Sea (PANOU *et al.,* 1993, WWF & Archipelagos, 1999).

e) The monk seal colony in the Northern Sporades archipelago is the most important of its kind in the Mediterranean. Up to date, 52 adult individuals have been identified, while the annual birth rate has increased since monitoring efforts started, and currently numbers eight pups per year (DENDRINOS *et al.,* 1994, 1999).

f) Population estimates for the island complexes of Kimolos-Polyaigos and Karpathos-Saria are

Figure 4: Mediterranean monk seal pup (© MOm/P. Dendrinos).

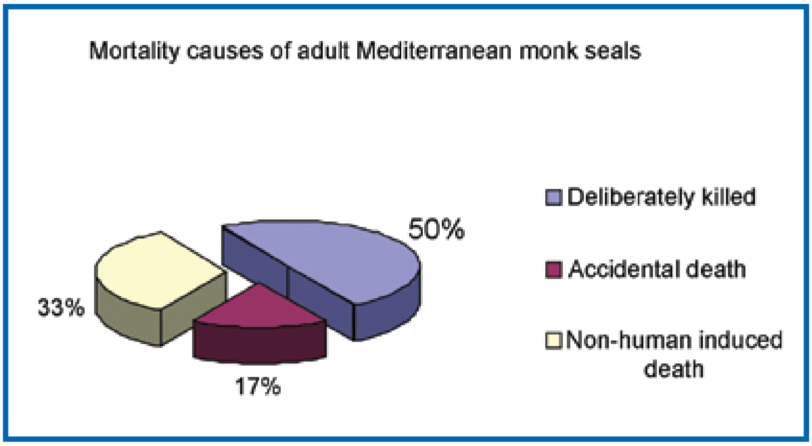

Figure 5: Mortality causes of adult Mediterranean monk seals based on necropsy results (1986 – 2005) (© MOm).

46 and 23 individuals, respectively, while annual birth rates are estimated to be 7.9 and 3.7 pups (Figure 4), (MOm, 2007). In the Ionian islands important breeding populations are found in Zakynthos, Kephalonia and Ithaki (PANOU *et al.,* 1993, WWF & Archipelagos, 1999).

g) A conservative minimum estimation of the Mediterranean monk seal population in Hellas lies at 170 adult individuals (MOm 2007).

With respect to evaluating the fisheries-related threats to the species in Hellas, MOm's research efforts indicate the following:

1. Based on the results of more than 90 necropsies and on information received through the Rescue and Information Network, deliberate killing is the most frequent cause of non-natural death for the species in Hellas. Especially adult individuals are affected, as they are considered to be a threat to the livelihood of fishermen and aqua culturists. Approximately 50% of adult monk seals found dead in Hellas were deliberately killed (Figure 5), while juveniles and newborns were killed less frequently (i.e. 36% and 7%, respectively) (ANDROUKAKI *et al.,* 1999).
2. Accidental entanglement and death through drowning was also found to be a serious threat to the survival of the species in the country. It affects mainly inexperienced individuals, such as juveniles and pups (ANDROUKAKI *et al.,* 1999).
3. The effects of overfishing on the Mediterranean monk seal in Hellas have been difficult to assess so far. Circumstantial information has associated this threat, with an increase in the frequency of attacks by seals on fishing nets and with abnormal feeding incidents (PANOU *et al.,* 1993, KARAVELLAS *et al.,* 1996).

CONSERVATION OF THE MEDITERRANEAN MONK SEAL IN HELLAS

The fact that Hellas hosts the largest breeding population of the Mediterranean monk seal in the world, dictates the concentration of conservation efforts within the country. It has further attracted the attention of the international conservation community, making the protection of this species a key conservation issue. Even though conservation efforts began in Hellas in the early 1970s, it was not until much later that a concrete conservation strategy with distinct priorities was formulated (ARCHIPELAGOS & MOm, 1996). This strategy, which was adopted also by the national authorities, calls for a series of actions, such as protection of habitats, research, rehabilitation, awareness campaigns, etc., that aim at mitigating the major threats for the survival of the species.

Protecting key breeding habitats

A key priority in the conservation of the Mediterranean monk seal in Hellas during the last 15 years has been the protection, through the establishment and effective operation of protected areas, of key breeding habitats of the species. A major achievement towards this goal has been the establishment in 1992 of the National Marine Park of Alonnisos, Northern Sporades (NMPANS) in the northwestern Aegean Sea. The NMPANS is one of the largest protected areas in the Mediterranean Sea and constitutes the only area in Hellas, where conservation measures for the protection of the monk seal and of the local fish stocks have been actively enforced, with substantial results (MOm 2005b, 2007) (BOX 1). A number of additional sites of importance for the species, such as the islands of Milos, Kimolos, Polyaigos, Karpathos, Saria and Samos in the Aegean and Zakynthos, Kephalonia and Ithaki in the Ionian Sea, have also been proposed as protected areas to the Hellenic State. However, up to date, little progress has been made towards the effective protection of these areas.

Tackling the seal- fisheries conflict

In order to improve the conservation status of the European Union's largest population of the critically endangered Mediterranean monk seal, found in Hellas, it is imperative to mitigate the negative consequences of the interactions between the seals and the fishery sector. In the long-term, this can be achieved by mitigating at the same time the negative consequences to both, the seals (i.e. decreasing the overall mortality rate of the species) and the fishery sector (i.e. decreasing the loss of income through the implementation of socio-economic and technical measures or by providing incentives).

A key obstacle in achieving this objective is the lack of adequate data on the exact nature, extent

BOX 1. A MONK SEAL-FISHERY PILOT STUDY IN COLLABORATION WITH THE FISHERMEN OF ALONNISOS

In order to understand the nature and extent of fisheries-related threats to the critically endangered Mediterranean monk seal a questionnaire survey was carried out in the National Marine Park of Alonnisos, Northern Sporades (NMPANS). The questionnaire was designed to collect information on the size and nature of the fishing sector, the marine fauna of the NMPANS, the seal-fisheries interactions and their effect on the fishery sector, as well as proposals for possible solutions. One quarter (n=26) of the Alonnisos fishermen operating in the Park were interviewed. The results indicate that fishing in the NMPANS is coastal and low scale. The marine mega fauna of the area is rich, both in terms of species diversity and population size. Various species of dolphins and monk seals are observed frequently within the Park and are reported to cause damages to the fishermen (Figure 6). Although such damage does affect fishing gear and fish catches, it is not considered by the fishermen as the key problem for their livelihood. Based on their opinion, overfishing and illegal fishing practices are the main threats to their activities and most of the solutions proposed were related to stricter enforcement of the legislation and the promotion of sustainable fishing practices. These results are indicative of the change in the attitude of local fishermen towards marine species, especially within protected areas. This is further evident by the fact that during the last 15 years, no deliberate killing of monk seals has been recorded within the NMPANS (DENDRINOS *et al.,* 2006).

Figure 6: Characteristic "three-hole" damage caused by Mediterranean monk seals to static fishing gear (© MOm/V. Paravas).

and intensity of the interactions between monk seals and the fishing industry at both the national and international level. During the last two decades, MOm's and other researchers' work (e.g. PANOU *et al.,* 1993) provide a detailed account of the status and distribution of the Mediterranean monk seal in Hellas and of the effect of this interaction on the seal population. In contrast, information on the impact of the species on fisheries is scarce. The few studies (PANOU *et al.,* 1993, DENDRINOS *et al.,* 2006) that have investigated this issue have all been quite limited in their duration and geographical range (Box 1). Their conclusions, therefore, cannot be easily extrapolated to a national scale.

Recently, a new initiative has been launched, aiming at assessing the intensity and consequences of the seal-fishery interactions in a comprehensive manner at a national level and at developing a concrete action plan with specific measures to mitigate the consequences of the interaction. This initiative (the MOFI Project), supported by the LIFE financial instrument of the European Commission and by the Hellenic Ministries of Environment, Agriculture and Mercantile Marine, aims at examining monk seal-fisheries interactions at three interrelated levels:

- The two most important monk seal breeding sites in Hellas (the NMPANS in the Northern Sporades archipelago and the island complex of Kimolos-Polyaigos): In these two areas the actual intensity of the seal-fishery interaction, relative to the fishing effort, will be measured. This will take place in close collaboration with local fishermen.
- At 7 "hot spot" areas (areas with intense seal-fishery interactions that have been selected through the analysis of currently available data on monk seals and fisheries): In these areas open interviews with artisanal fishermen and aquaculture operators will provide information on the extent and effects of the seal-fishery interactions, as well as, on possible solutions proposed to resolve the existing conflict.
- At a national level: Questionnaires to artisanal fishermen and fishery related services will provide information on the overall distribution of the seal-fishery interaction, while stomach content analysis from samples collected throughout the country will enable, for the first time, the determination of the species' feeding preferences. In addition, mortality causes of the species will be monitored and by responding to reports of monk seal strandings, animals needing emergency care will be rescued and treated, leading to a reduction in the species' mortality.

Based on the results of these activities and on the existing international experience, and in close consultation with all relevant stakeholders, an Action Plan with measures to mitigate the seal-fishery conflict will be elaborated and presented to the relevant national authorities. The objective of this Action Plan is to include specific, feasible and ready for immediate implementation, measures and to reach the maximum possible consensus among key stakeholders (fishermen, aquaculture owners, competent authorities and environmental organizations) so as to be integrated within the current national fisheries and nature conservation policies.

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CHAPTER VI

MANAGEMENT TOOLS / STRATEGIES

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INTRODUCTION

Whenever a common natural resource is insufficient, meaning that its use by one user implies reduced opportunities for its use by others, some form of management is required. Private property does not require management in the same sense because the owner is responsible for the care of the property, and, any failure in this care does not in principle affect other people (WILSON *et al*., 2007).
Fisheries' management is just one of a whole group of activities by which people have tried to address the problem of common interest. The problem itself has been recognized from the ancient times:

> *For that which is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest; and only when he is himself concerned as an individual. For besides other considerations, everybody is more inclined to neglect the duty which he expects another to fulfill; as in families many attendants are often less useful than a few. Each citizen will have a thousand sons who will not be his sons individually but anybody will be equally the son of anybody, and will therefore be neglected by all alike. (From Aristotle's "Politics", written c.a. 350 BC)*

Fisheries' management is today often referred to as a governmental system of management rules based on defined objectives and a mix of management means to implement the rules, which is put in place by a system of monitoring control and surveillance (http://en.wikipedia.org/wiki/Fisheries_management). Modern fisheries' management is most often based on biological arguments where the idea is to protect the biological resource in order to make a sustainable exploitation possible.
Fisheries' management is based on the development and use of tools and strategies which enable assessment of the resources, exploration of options within specific management procedures with an evaluation of trade-offs between various objectives, taking also into account the robustness of the assumptions and risks involved.
The current chapter presents, not only information on the various tools/strategies that are used or can be potentially used for the management of the Hellenic Fisheries' Resources, but it also provides information on the research carried out for the development of new approaches aiming to face the specific needs of the Hellenic fisheries.
The papers discuss a variety of management tools/strategies starting from the traditional single species approaches and going towards more sophisticated ones such as the ecosystem and precautionary approaches and Bayesian risk assessment. Finally, information is provided on the existing management systems including examples on the various effort control rules and technical regulations applied to specific fisheries, as well as on tools, such as the marine protected areas, which focus on ecosystem sustainability.

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George Tserpes

VI.1. ARTIFICIAL REEFS

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GENERAL OVERVIEW

Artificial reefs (A.R.) are an ancient invention, originating from the coastal regions of the Pacific Ocean. Even then, the observation of marine organisms gathering and flourishing in those primitive wooden structures resembling a reef was quite common. This old technique was rediscovered quite recently, about 40 years' ago. Second-hand industrial products such as vehicles, electric devices and other metallic constructions with complex surfaces were used in the dawn of artificial reef use. Nowadays, however, artificial reef are made of natural rocks, concrete or steel elements that aim to strengthen the bases of these sensitive natural marine ecosystems (Figure 1).

Productive artificial reefs aim to upgrade total fishing production and are seen to exist all around the globe. Among others, one of the main goals set in an attempt to establish an artificial reef include the improvement of fishing quantities of the targeted zones. There are obvious ecological advantages in their use, since the ecosystem is allowed to slowly build up by itself based on the morphological advantages of the artificial structures. Hence, these reefs are rightfully considered an important tool in the integrated management of the coastal environment.

Local areas and communities have much to profit from an artificial reef. The local ecosystems are enriched with young fish and the value of commercial stocks rises. The possible upgrade of local tourist activity due to these reefs must also be taken into account.

The main outcome of the well-being of an artificial reef is the increase of total biomass of the area through the attraction of more species of fish and more marine organisms. This results from the very attractive physical and biological conditions produced by these reefs that aim to minimize mortality of the species. The reefs are also responsible for upgrading the coastal ecosystems through the increase of local biodiversity. The decrease of the erosion caused by wave action in the coastal zone is also an important factor to outline and this is especially beneficial in highly eroded areas due to the construction of dams and other anthropogenic interventions.

When constructing an artificial reef, there are several factors related to the increase of fishing activity in the zone that should be examined.

Firstly, an artificial reef can alter the local distribution of biomass, abundance of fish or of any other commercial organism in the area near the reef. The increasing result in the indigenous fishing activities is directly due to the upgraded availability of the fish. However, in order to preserve the increasing trend in availability, it is imperative that a management plan is used in order to adjust the fishing efforts inside reef territory and thus, maintain species' availability. In order for management plans to be successful they should be integrated, taking into account sensitive factors such as socio-economics

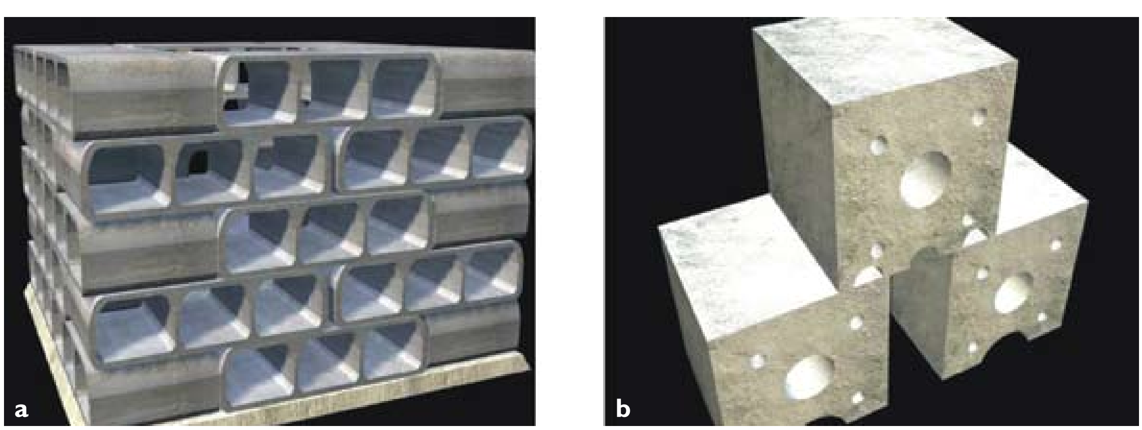

Figure 1: Artificial structures used in the pilot project at Fanari in the Thracian Sea. French (a) and Italian type (b) elements.

Figure 2: Species fished around the artificial reef of Fanari during the final phase of monitoring. The hard substratum species prevailed.

and other social problems, apart from the standard ecological and biological study that needs to be performed.

Secondly, the creation of a reef not only causes species massing in a defined area, but also increases the fished quantities. In this case, with the same fishing effort, there is far better efficiency. The increase of fished biomass is largely caused by the smaller natural mortality observed in the local fish populations since the artificial reef provides a safer and more sheltered environment. Combining the physical advantages of the reefs associated with their morphology, with the enrichment of certain fish species that are strategically chosen, results in even more positive results.

By a quick look through the relative international literature, examples of both of the above occasions can be found. Combining these reports with the scientific experience gained throughout the years, it can be easily concluded that artificial reefs can produce an outstanding result as far as fish production is concerned. The percentage reported in literature is usually around 5-20% from the total local fish production according to the type of the artificial reef being used (Figure 2).

However, there are some extreme examples that show a 400% increase. This increase is a result of many factors. For instance, the technical characteristics of the reef and the natural features of the selected area are very important. In many cases different building materials or altered structures create different results, attracting the relative species on each occasion. Also, increased fish production is observed mainly in areas with no natural reefs near the artificial environment. Areas with many natural obstacles, extensive rocky grounds, having unstable substrate or large inflow of floating material are judged as not suitable.

The main characteristics of the local fishing production have to be taken into account. A large number of factors is considered in each area in order to obtain the proper scientific knowledge in order to decide which species can be enriched by an artificial reef. Common species in the Mediterranean Sea are species of the family *Sparidae, Serranidae, Labridae, Scorpaenidae, Carangidae* and *Scombridae*.

Before the creation of an artificial reef, each part of the area would need to be examined oceanographically and biologically. The success of the reef depends largely on the study made by the performed studies.

Natural and artificial reefs should not co-exist, except in the case where there is a need to observe and make comparisons between them. Also since over-fishing can exterminate even the best yield results from an artificial reef, it is important to emphasize the importance of enforcing a management plan right after the reef is constructed to minimize time loss. The final receiver of the project's results should be the nearest coastal fishing association or cooperative who would have to take over its management. This partly ensures that the local communities keep their interests focused on the maintenance of the reef.

Both the Japanese and the Mediterranean experience on the artificial reef matter, shows the artificial reefs to be excellent tools in fisheries' management, allowing the management of the local fishing effort, differentiation of the fishing methods, new methods of aquaculture, management of the local biological resources and finally the increase in fish production.

ARTIFICIAL REEFS IN THE MEDITERANNEAN

During the 1960s in some areas of the Mediterranean, the first efforts of artificial reef construction were made by the sinking of crashed cars in areas with illegal fishing problems, but no scientific observations were performed. In 1974, the first scientifically designed artificial reef was set up in the Adriatic Sea, by the Institute of Fisheries and Technology of Ancona (Italy), and consisted of 12 pyramids and 2 sunken boats (BOMBACE, 1981). In the years after, more artificial reefs were made in Italy, both in the Tyrrhenian and Adriatic Sea. In the Ligurian Sea, an artificial reef was completed between 1980 – 1985 in the Marconi Gulf (ORSI RELINI *et al.*, 1986). Relative actions took place also in Sicily in the Gulf of Castelamare.

In France, there have been many efforts for the construction of an artificial reef in Palavas (1968) skeletons of cars were used, old tyres and cube stones, giving a total of 400 cubic meters. In the beginning of 1980, in the Mediterranean Sea around Nice, 200 cubic meters of cube stones were used for the creation of another artificial reef. In Spain, during the last eight years many artificial reefs were built, aiming mainly for the protection of fishing from trawls. Today more than 50 artificial reefs exist all over the Spanish shores and at the same time, a management committee has been formed which watches over the newly constructed reefs as well as the progress of the older ones.

In Hellas the Fisheries' Research Institute (FRI), part of NAGREF, together with the former Institute of Marine Biology of Crete, participated for the first time in the construction of artificial reefs in 1997, when the Ministry of Agriculture issued a call for financial tenders, assigned to the consortium with the construction and monitoring of a pilot project aiming to demonstrate the utility of these structures for the coastal zone management. The reef was built by cube-shaped concrete blocks arranged in pyramids (ANTONIADOU *et al.*, 2001). The first problems encountered were mainly of a political nature since the long-term benefits of an artificial reef were difficult to explain to the local fishermen and the building costs were high (DOUNAS *et al.*, 2000).

The project commenced at the end of 1997 with the preliminary assessment which was focused in the marine area of Fanari in the prefecture of Rodopi. After approximately one year, in the middle of 1999, the construction of the artificial reef was completed with the laying of the artificial structures. The artificial reef is continuously being monitored since then by a number of scientific devices as well as by the specialized team of divers-biologists of the FRI who has undertaken the task of visual inspection.

The data that were being recorded comprised of the hydrographic characteristics of the area, the nutrients that are being accumulated or trapped by the artificial reef structures, the successive colonization of these structures by the large number of flora and fauna species, but mainly the colonization of the artificial reef by important species, commercial or not, of fish and invertebrates.

From the beginning of the artificial reef operation, immediately after the laying of the artificial reef structures, the divers team detected schools of fish which have begun to circulate around the artificial reef area, proving in this way that the fish, or at least some species of fish, instinctively are attracted by anything that differentiates the sea bottom offering them even elementary opportunities of sheltering and/or protection from predators.

Because the artificial reefs were laid in the middle of October, the first winter of monitoring passed without encouraging results, since the low temperatures in the area during the winter dissuade the dramatic colonization of the artificial reef by seaweeds and invertebrates, the presence of which is regarded as prerequisite for the attraction of fish who need them as a source of energy.

However, there were some species of fish like *Pagelus acarne* (axillary sea bream), that have settled there from the first day following the laying of the artificial reef, and have not abandoned it since leading us, after two years of monitoring, to record an increase of the species' presence by eight times in relation to the period before the construction of the artificial reef. This particular species has attracted other larger predators in the area, such as the *Seriola dumerili* (greater amberjack) which although they are not fished, they are recorded by the divers' visual inspection and the video recordings in equally increasing numbers.

Other species that colonized the area during the first spring following the laying of the artificial reef was *Diplodus vulgaris* (common two-banded sea bream), the abundance of which increased four times after a year of monitoring. *Trisopterus minutus capellanus* (poor cod) is another example. Its presence in the artificial reef was a surprise since it was believed until today that the species prefer to colonize in muddy environments. Other species for which a substantial increase was recorded were *Serranus scriba* (painted comber) which exhibited an increase of 700%, *Boops boops* (bogue), *Zeus faber* (John Dory), *Loligo vulgaris* (common squid), *Sepia officinalis* (common cuttlefish) and *Scorpaena* sp. (scorpion fish), with an recorded increase in their abundance that ranges between 100-500%. From the experimental samplings, a total of 101 species were recognized in the reef area, with 10 newly fished species (SOPHRONIDIS *et al.*, 2001). Seasonal differentiation in species' abundances was found to be present between seasons (KALLIANIOTIS *et al.*, 2003).

During the monitoring period and via laboratory analyses, it was discovered that the biocommunity of the area was gradually evolving and that a special substrata emerged on the artificial reef structures created by seaweeds, bivalves, ascidians and polychaetes in a continual succession of species and assemblages, an evolution process that is being continued until today.

The biological equilibrium in the rhythm of colonization was reached at the end of 2003, when the largest number of species was recorded since the construction of the artificial reef and the area that surrounds it. In 2005, the reef was observed to provide a steady basis for local fisheries, particularly for the species *Octopus vulgaris*, *Sepia officinalis*, *Penaeus kerathurus* and *Solea vulgaris* (ARGYRI & KALLIANIOTIS, 2005). The monitoring of the artificial reef continued until the end of 2004, five years after the laying of the artificial elements. At the end of the project the consortium proposed to the Regional Fisheries Office a management plan which focused on the future utilization of the artificial reef, not only for scientific purposes but for production purposes as well. This is considered to be the most difficult phase of the project, since the supervision of the area as well as the maintenance of the structures, have to be assigned to a private sector body, such as a fishing association.

In the area of the artificial reef, a prohibition of fishing activities has been issued from the beginning, that included all fishing gears, but in the future the specifications of the gears that are going to be used within the area of artificial reef, have to be described and included in the relevant management plan.

However, during and after the end of the monitoring phase we observed some negative phenomena mainly due to the gathering of a vast number of fishing vessels in the area, following the positive impression that the initial monitoring results gave, regarding the abundance of species in the artificial reef Despite the prohibition of fishing activities in and within two nautical miles radius around the artificial reef, many fishermen ignored it and were laying their fishing gears around the artificial reef and even sometimes inside the zone of absolute protection, where theoretically the environment has to be permanently left intact.

In the future, the artificial reef will attribute the best results only if its importance for the fisheries stocks as well as for the potential income for local fishermen, become comprehensible.

After 2002, FRI alone or jointly with HCMR has undertaken the feasibility studies of four additional artificial reef, namely in Kalymnos, in Ierissos, in Maliakos Bay, and that on the coasts of Pieria, while HCMR has undertaken the study of the artificial reef of Messolongi and Preveza. In any case, the consortium suggested the implementation of innovative technology, applying therefore, the experience gained from its participation in the realization of the first pilot plan in Fanari and the advances made by other teams abroad.

The artificial reefs are expected to play an important role in the management of the coastal zone in Hellas as is the case on a global scale, since they offer a steady point of reference in marine areas where it is difficult to appoint any element of ownership. In addition, they create an artificial ground for a combined concentration of marine species within a protected marine environment. With the enforcement of appropriate management, mixed systems of fishing and tourist activities of the areas as well as special forms of aquaculture can be applied and these can act in favour of small local communities which are still dependent on fisheries, and which for the benefit of our country should continue plying their traditional fishing activities.

CRITERIA FOR THE SELECTION OF SUITABLE AREAS

Suitable areas have to be chosen according to a clear methodology, examining various factors that will probably affect the project. For the selection of the installation position, it is necessary that areas with large trawling activities are excluded.

Among the most basic criteria that need to be taken into account are the substrate type, the sea depth, physical and chemical parameters, the existence of natural reefs, the protection of zones from over-fishing and others.

For the maximization of the biological development of the artificial reef, according to the preset goals, it is necessary to take into account the physical and chemical parameters of the selected area. With the fulfillment of the preliminary study the definition of the nature of the substrate as well as the hydrology of the water column must be carried out where the artificial reef will be installed.

ELEMENTS IN THE STUDY FOR THE CONSTRUCTION AND INSTALLMENT OF AN ARTIFICIAL REEF

For the proper and effective function of an artificial reef, the design would have to be based on biological, economical and mechanical demands, so that the suggested system would increase its productivity to the maximum fulfilling, at the same time, the goals of its manufacture.

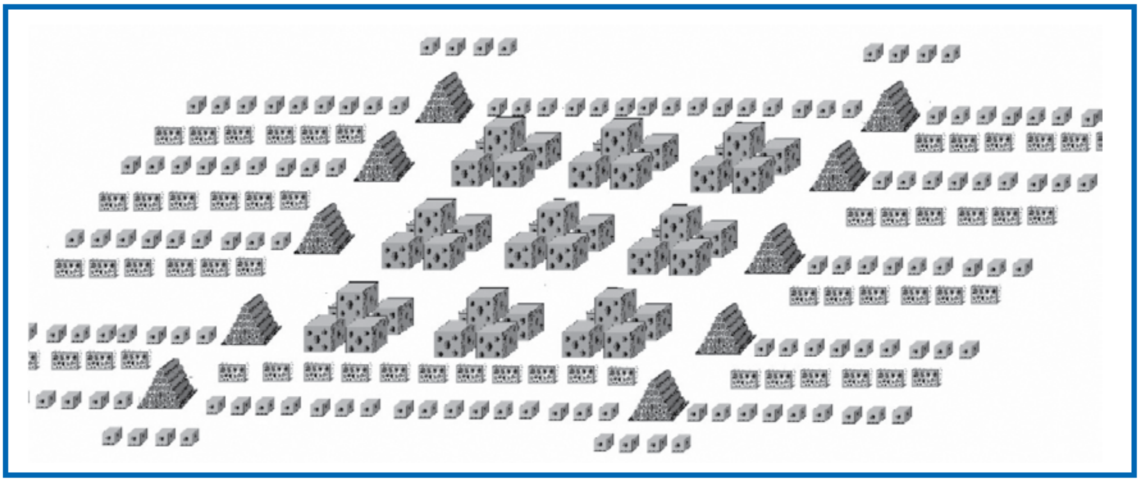

Figure 3: An artificial reef plan using four different types of elements, aiming to increase the complexity of the structure.

The artificial reef must be designed in a way to make food availability easier to both the transferring species and the species remaining settled in the surrounding zone. The various sections of the artificial reef must be formed in a way to help the feeding and settling of the more commercial species. The maximization of the population's abundance is the confirmation that the artificial reef was designed according to the special requirements of the "target" species or their habitat (Figure 3).

Apart from the evolution of its biological dimension, the artificial reef must be designed in a way to make possible tourist development in the zone. The amateur fisheries are usually directed to different species than the professional fishermen and as a result, this reef plan must be adjusted accordingly to take them into account as well. Also, the construction plan must be designed properly to prevent the damage of professional and amateur fishing equipment since many fishers will select the reef areas as their base.

The artificial reefs increase the attraction of fish, but also they can be designed to prevent trawl fishing and increase the fish production of these areas. The limitation or total ban of trawl fishing in an area surrounding an artificial reef, allows the strengthening of fishing with static gears and the increase of local fishermens' involvement.

MATERIALS USED FOR THE CONSTRUCTION OF ARTIFICIAL REEFS

European and Japanese scientists are leaders in the research of the study of structural material used in the construction of artificial reefs and the use of concrete has become more widely accepted by European manufacturers. The most common block used is made of concrete; it can be cubic or cylindrical with round or triangular openings. The use of second-hand materials for the construction of artificial reefs has obvious economical significance but the impact on the environment should be carefully evaluated.

The use of old tyres for the construction of artificial reefs has provoked many discussions and many different opinions have been given about the issue. The common opinion in Europe is that these materials are thought to carry dangerous toxic substances during their time in the sea and for this reason their use is not seen as positive.

Shipwrecks are often suggested for artificial reefs and also for scuba-diving activities. In the United States 80% of the underwater A.R. (MC GURRIN, 1989) are comprised almost exclusively of shipwrecks or other second-hand industrial construction materials. Yet, no research has been made on the suitability of shipwrecks for artificial reef areas and thus their proper value remains unknown. Old boats should be carefully cleaned of all harmful material such as copper and remaining fuel before their use. It is important to point out that wooden fishing boats are considered unsuitable as far as the shallow water areas of the artificial reefs are concerned, since the chances of them being crushed by strong wave activity are high.

EVALUATION OF THE ARTICICIAL REEF EFFICIENCY

There are two basic problems when starting preparations for a commercial-use artificial reef. The first concerns the time at which the artificial reef will be ready for fishing activities; secondly, the determination of maximum fishing effort and the rel-

Figure 4: Colonization of the artificial reef in Fanari. Large crustaceans have created their shelter at the base, while other species used the flat areas.

Figure 5: Position of existing and programmed artificial reefs in the Hellenic Seas.

evant constant fish production of the artificial reef. These issues cannot be answered initially, in areas where no artificial reef has been constructed in the past. They can be answered during the second phase of construction, a phase that co-exists with the scientific and technical monitoring of the artificial reef.

It is difficult to calculate the fish production an artificial reef can produce, because this depends on the nature of the management plan that will be enforced.

The observation of fishing exploitation is done with experimental fishing. This type of fishing has to be constant from the beginning of installation of the A.R, so that it can be related to the trends of fishing indicators present, and to quantify the influence of commercial fishing inside the artificial reef area. The artificial reef projects serve also management purposes by making the creation of marine protected areas possible.

Future research regarding artificial reefs should focus on the importance of the surrounding habitat, reef size and the seasonality of certain factors such as the improving of recruitment, the growth of juvenile fish and spawning success. Still, the optimization of the design is a priority. More effective block styles would have to be discovered and the cost-effectiveness of the structures improved.

Other than that, apart from preventing trawling, the importance of predation and shelter on early species' recruitment would have to be evaluated carefully in each case (Figure 4). Proper shelter provided by the artificial reef complexity can decrease predation and thus help the stability of fish populations in the area. The distance between reef blocks is also important since structures with the same complexity have different fish assemblages depending on how far they are from each other. Finally, standard methods of monitoring are needed to help gather concrete evidence on the artificial reef success and give the project a solid statistical certainty.

The artificial reef in the Thracian Sea was a pilot project, aiming at monitoring the effects on the environment and also the impact on local fisheries. The Hellenic National plan for the artificial reef included the creation of three more reefs, in Ierissos Bay, in Kalimnos and in Preveza. At present, new projects are being planned in order to start the construction of more artificial reefs., for example, on the coast of Pieria, in Mesolonghi and the Gulf of Kavala (Figure 5).

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VI.2. FISHERIES MANAGEMENT AND MARINE PROTECTED AREAS

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INTRODUCTION

The idea of using protected areas for the recovery or protection of fish stocks dates back more than 100 years (GARSTANG, 1900). The use of models for evaluating the effect of closed areas on yield-per-recruit extends back to the classic work of BEVERTON & HOLT (1957); these models are still in use (e.g. GUENETTE *et al.*, 1998). However, the stimulus for the establishment of marine protected areas (MPAs) in many parts of the world was the need for better management of coastal and marine environments and their initial objective was to protect biodiversity and to conserve ecosystems (Box 1) by reducing anthropogenic impact (ALLISON *et al.*, 1998). Closed areas to fishing for the protection of coral reefs and coastal zone closures for the protection of nursery areas have been widely used at a national level throughout the world (e.g. VASSILOPOULOU & PAPACONSTANTINOU, 1999). Throughout the years the significance of MPAs for the protection of exploited stocks, or at least of part of their life history, gained attention and became more important. There has been much recent interest in the potential of MPAs as an alternative and easily enforced fishery management tool that could reduce the likelihood of anthropogenic disturbance on marine exploited populations and their habitats (ROSENBERG, 2001; ROBERTS *et al.*, 2001; SUMAILA, 2002; BROWMAN & STERGIOU, 2004a; SMITH *et al.*, 2006).

WILLIS *et al.* (2003) calculated the (cumulative) number of theoretical, empirical and review articles on marine reserves (MRs) published in the primary literature (Figure 1 in WILLIS *et al.*, 2003). They observed an exponential increase in published material concerning marine reserves for the period 1990-2001. A similar citation analysis based on Scopus (www.scopus.com; using "marine protected areas" and "marine reserves" as keywords, access date: 13 February 2007) showed that the (absolute) number of articles published in primary literature on MPAs and MRs increased exponentially between 1995 and 2006 as well as the articles on ecosystem-based fisheries' management for the same period (TSIKLIRAS & STERGIOU, unpublished data). The similarities in the trends of the two series suggest that these two ideas were evolved under the same intellectual environment. Ecosystem-based management (e.g. BROWMAN & STERGIOU, 2004a), which is nowadays gaining increasing support, partly relies on - or is related to - the temporal or permanent exclusion of specific areas from all or some fishing activities.

BOX1. Definitions

Different terms have been proposed and applied by various authors and at various locations for the definition of marine protected areas. Although, the terminology might change depending on the level of protection and the management scheme of each marine ecosystem (IUCN 1994), there is a general agreement (LUBCHENCO *et al.*, 2003a) on the definition of the term Marine Protected Areas (MPAs) in the literature: areas of the ocean designated to enhance conservation of marine resources through legal protections from disturbance, harm, and/or fishing (LUBCHENCO *et al.*, 2003b). Most MPAs allow some low-impact activities such as sport fishing and/or some forms of commercial fishing, while prohibiting heavy-impact ones such as trawling, dredging, drilling for oil, etc. Some MPAs include temporary or seasonal closures that have been designated to provide temporary protection from fishing pressure (e.g. spawning and nursery areas, other critical life history periods). MPAs can be designed for different levels of use including no access areas, permitted areas, seasonally closed areas, and fishing gear restricted areas.

For the purposes of this chapter, we consider an MPA to be an area with legal boundaries in which fishing is prohibited for all or some species, or particular fishing gears are not allowed. The marine reserves (also known as 'no-take zones') are included in our approach because they are a special category of MPA in which no fishing activity is allowed. Marine Reserves (MR) are defined as marine areas completely protected from all extractive and destructive activities (i.e., "*all biological resources are protected through prohibitions on fishing and the removal, disturbance, or harm of any living or non-living marine resource, except when necessary for monitoring or research to evaluate reserve effectiveness*": LUBCHENCO *et al.*, 2003b).

Globally, MPA size varies from 0.01 km^2 (Red Coral Reserve, Monaco and Doctor's Gully Fish Reserve, Australia) to 344,000 km^2 (the Great Barrier Reef Marine Park, Australia), with a global mean and median value of about 1,000 km^2 and 16 km^2, respectively (MCCLANAHAN, 1999). The continuously increasing number of MPAs includes only 0.01% of the global fishing grounds (RUSS & ZELLER, 2003). Theoretical and modelling research concludes that maximum benefits to the fisheries are associated with protected closures of around 20-40% of the fishing grounds (GELL & ROBERTS, 2003). Nowadays, fisheries' science should target the abandonment of any fishing activity for 20-30% of the fishing grounds (ROBERTS *et al.*, 2005).

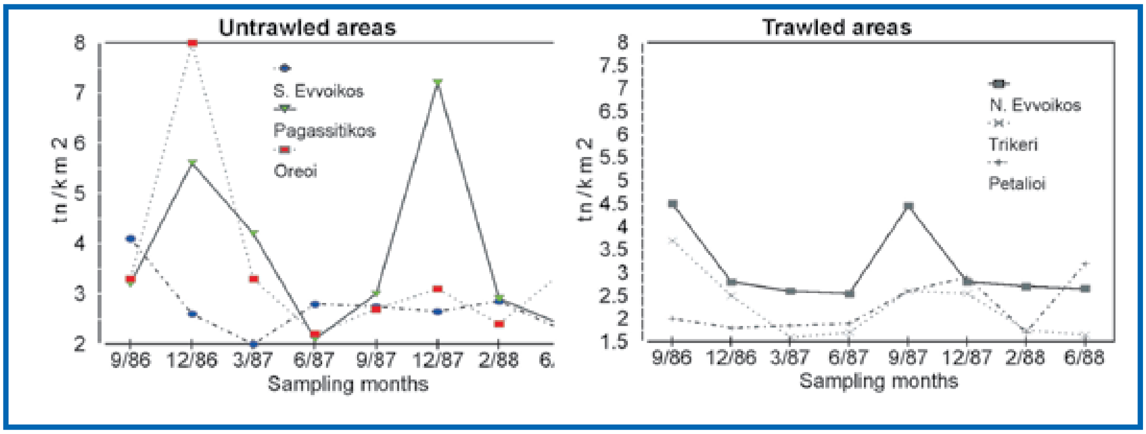

Figure 1: Total biomass (in t/km^2) of fish stocks in three trawled and three adjacent protected from trawling areas in the central Aegean Sea, Hellas (VASSILOPOULOU & PAPACONSTANTINOU, 1999).

MPAS AND FISHERIES MANAGEMENT: BENEFITS

In this chapter we assembled and summarized the results on the effects of MPAs on fisheries and ecosystems from eleven articles referring to the Mediterranean (Table 1). These studies showed that the establishment of MPAs enhanced population and somatic growth, and allowed the undisturbed nursing of juvenile fish and their successful recruitment into the adult population (Table 1). Following their increase in density and biomass, adult fish often dispersed (emigrated) to adjacent waters and fisheries' catches increased (Table 1). Finally, the population of the non-targeted by the fishery species generally remained unchanged (Table 1).

In addition, according to two recent reviews, MPAs showed higher levels of biomass (90%), density (63%), size (80%), and diversity (59%) compared to control sites for all species combined (in 89 studies reviewed by HALPERN, 2003) and higher biomass, density, abundance and body size of fishes and invertebrates within the protected areas when compared to fished zones or to time periods before protection (more than 20 studies reviewed by GELL & ROBERTS, 2003). Finally, a review on the Mediterranean MPAs showed a general increase in abundance of most exploited fishes after the protection and an increase in their mean size in several cases (SÁNCHEZ LIZASO *et al.*, 2000).

The way that species with different life history strategies respond to habitat protection varies depending on the population characteristics of each stock. Species with "fast" (*sensu* DENNEY *et al.*, 2002) life history strategies (short generation time, small size, high fecundity, short lifespan and early maturation) are more likely to respond quickly and recover (HALPERN & WARNER, 2002). This category includes several small pelagic fishes and the invertebrates. On the other hand, recovery may take longer for species with slow life history strategies i.e. long generation time, longer lifespan and late maturation (RUSS & ALCALA, 2004). Within an MPA, a portion of the exploited population is permanently protected from fishing mortality and so are non-targeted species by the fishery. These structural changes and improvement of fish populations within the MPA may in turn benefit intensively exploited fisheries outside the MPA (ROBERTS *et al.*, 2001) by dispersal of fish depending on the moving ability and reproductive rates of the stocks (HILBORN *et al.*, 2004). Hence, the benefits of the MPAs are distinguished in those inside the MPA (biomass and reproductive potential increase, and ecosystem protection) and in those benefiting the neighbouring fishing grounds (dispersal of eggs, larvae, juveniles and adults).

Biomass increase and emigration to surrounding fishing grounds

VASSILOPOULOU & PAPACONSTANTINOU (1999) compared three pairs of adjacent trawled and untrawled areas in the central Aegean Sea and observed that fish biomass was generally higher in protected (untrawled) than in non-protected (open to trawling) areas (Figure 1). The increase in the somatic biomass and density of fish within the MPA will result in fish dispersing (emigrating) from the MPA to the adjacent fishing grounds either by random diffusion (BEVERTON & HOLT, 1957) or by 'spillover' of larvae or adult fish (MCCLANAHAN & MANGI, 2000; ROBERTS *et al.*, 2001). This adult 'spillover' is attributed to density-dependent processes, i.e. fish leave the MPA as density, and thus competition for resources, increases within the reserve. The extent of adult

Table 1. A list of selected original articles from the Mediterranean Sea showing the effects of marine protected areas (MPAs) on species, ecosystems and fisheries.

Location	MPA establish-ment	Time of study	Result	Source
Banyuls-Cerbère, NW Mediterranean	1974	1980	Species richness and diversity did not differ. Higher densities and larger sizes of fish species within the reserve.	BELL, 1983
Scandola, Corsica, NW Mediterranean	1975	1988-1992	Higher mean density and biomass of fish (*Dicentrarchus labrax*, *Sparus aurata*, *Epinephelus marginatus*, *Sciaena umbra*) in rocky substrata than the other sites.	FRANCOUR, 1994
Carry-le-Rouet, NW Mediterranean	1987	1995	Increase in abundance of demersal fishes by 25%. The abundance of large-sized fishes was higher by 50%. Mean size of *Serranus cabrilla* and *Coris julis* increased inside the MPA.	HARMELIN *et al.*, 1995
Banyuls-Cerbère, NW Mediterranean	1974	1992	Species abundance decreased inside the reserve and maintained outside. Six fish species vulnerable to fishing were more abundant inside the reserve and 4 were more abundant outside. Large-sized fish were more abundant inside the reserve.	DUFOUR *et al.*, 1995
3 pairs of trawled-untrawled areas, Aegean Sea	-	1986-1988	Total biomass was higher in the untrawled areas compared to the trawled ones. In some cases the mean length of the European hale (*Merluccius merluccius*) the main target species of the trawling fishery was higher in the untrawled than in the trawled areas.	VASSILOPOULOU & PAPACONSTANTINOU, 1999
Castellammare, NW Sicily	1989 (ban of trawling for 9 years)	1993, 1997	Eight-fold increase of total biomass. The abundance of eleven target species (nine fish and two cephalopods) increased by a factor of between 1.2 and 497. Eight years after trawl banning, the distribution of several species expanded and these species were observed at greater depths than previously.	PIPITONE *et al.*, 2000
Castellammare, NW Sicily	1989 (ban of trawling for 9 years)	1987, 1989, 1994, 1998	Mean size of monkfish (*Lophius budegassa*) increased. The abundance of three target species (*L. budegassa*, *Merluccius merluccius*, *Mullus barbatus*) also increased. The trophic level of the species did not show any size related differences.	BADALAMENTI *et al.*, 2002
Trieste gulf, N. Adriatic	1991 (three MPAs)	1998-2001	The species' composition and fish density did not differ between the MPA and the non-protected area. However, only a few commercially exploited fishes inhabited these areas.	LIPEJ *et al.*, 2003
Miramare, N. Adriatic	1986	2002-2003	More fish taxa inside the protected than in fished areas. Most targeted fish species had higher density (e.g. *Sciaena umbra*, *Dicentrarchus labrax*, *Sparus aurata*, *Diplodus vulgaris*, *D. sargus* and *D. puntazzo*) and/or size (e.g. *S. aurata* and *D. annularis*) at the protected than fished areas.	GUIDETTI *et al.*, 2005
Cinque Terre, Ligurian Sea	1997	2003	Larger in size individuals of targeted species inside the MPA compared to the fished zone.	TUNESI *et al.*, 2006
Cote Bleue Marine Park, south French coast	1983 (1995)	1995, 1998, 2001	The abundance of larger-sized, demersal, exploited fishes (*Diplodus* spp., *Serranus* spp., *Symphodus* spp.) was highest inside than outside the MPA. This was not the case for small-sized or unfished species.	CLAUDET *et al.*, 2006

"spillover" from the MPA largely depends on fish mobility (HILBORN *et al.*, 2004) which has to be in an intermediate range in order to achieve both the accumulation of biomass within the MPA and the level of "spillover" that may lead to enhanced yields at surrounding fisheries (MICHELI *et al.*, 2004; PALUMBI, 2004). The absolute gain in biomass for the fishery itself from the "spillover" however, has to be balanced against the direct loss due to the closure itself and is difficult to estimate (HART, 2006).

Increase in reproductive potential

Body size is very important in fish ecology because it determines the susceptibility of an individual to predation and to fishing as well as its reproductive potential (e.g. WOOTTON, 1998). Size is inversely related to the likelihood of predation, while it is exponentially related to the reproductive potential, i.e. the number of oocytes produced per spawning female (BIRKELAND & DAYTON, 2005). MPAs act as refuges for the early planktonic stages and the juveniles that are susceptible to high predation and fishing (for juveniles), the latter leading to recruitment over-fishing. Avoiding recruitment over-fishing will at least allow the recruitment into the adult population and sexual maturation (e.g. FAUNCHE *et al.*, 2002). Additionally, MPAs offer the females greater chances of surviving to larger sizes (e.g. JAWORSKI *et al.*, 2006) and hence producing more offspring. The protection of juvenile fish and spawning females ensure higher reproductive success and undisturbed recruitment into the adult stock (GELL & ROBERTS, 2003) that will subsequently increase the biomass and body size of the stock (e.g. BEUKERS-STEWART *et al.*, 2005).

Ecosystem protection

Fishing can alter the structure of the trophic web by selectively removing commercially important large-bodied species (PAULY *et al.*, 1998; LAW, 2000) and the extended use of some fishing gears (e.g. trawls and dredges) by damaging or even destroying the seabed and associated life forms (JENNINGS & KAISER, 1998). The effect of fishing includes reduction in biomass and size of benthic and targeted organisms, biodiversity loss and subsequent community changes in species composition and interactions (for a review see JENNINGS & KAISER, 1998). Additionally, fishing in nursery grounds may remove small-sized immature individuals and fishing in spawning sites may remove pre-spawners. The selective removal of high-trophic level, large-bodied fishes by fishing (SADOVY, 2001), which are more fecund and produce higher-quality eggs (BIRKELAND & DAYTON, 2005), decreases the reproductive potential of the stock (CONOVER & MUNCH, 2002). The absence of fishing will gradually restore the biomass balance between targeted (mostly predators) and non-targeted species (mostly prey) (WILLIAMSON *et al.*, 2004) and within the trophic web.

SCEPTICISM AND UNCERTAINTIES

Although, the beneficial effects of MPAs are repeatedly stressed (Table 1; GELL & ROBERTS, 2003), MPAs have not been more widely used because there is some disagreement on whether MPAs will be any more effective in managing the marine resources than traditional practices (ROBERTS *et al.*, 2005). There is also scepticism on several issues, such as the location, design, number and size of MPAs. Regarding the MPA design and their use as effective management and conservation tools, BROWMAN & STERGIOU (2004b) suggest that the member-vagrant hypothesis (ILES & SINCLAIR, 1982) together with the Large Marine Ecosystem (SHERMAN & DUDA, 1999) or the 'biogeochemical provinces' (LONGHURST, 1998) concept provide the framework within which the design, area and number of MPAs can be defined. A coupling of fisheries' science with oceanographic and ecological aspects is a necessary step for effective ecosystem management through the MPAs (BROWMAN & STERGIOU, 2004b). Another important issue is the revenues to the fishers that will lose part of their income (BALMFORD *et al.*, 2004). A detailed response to the various concerns and other "myths" is provided in ROBERTS *et al.* (2005).

MPAs clearly benefit habitat-specific reef-associated fish (e.g. ZELLER & RUSS, 1998) and crustacean species (LANGLOIS *et al.*, 2006), and they are the only tool that can effectively protect sensitive habitats such as coral-reefs or seagrass meadows. Sedentary species, such as sea scallops, and benthic fish with restricted mobility will also benefit from the exclusion of fishing activities (HERMSEN *et al.*, 2003). These stocks will recover quickly inside the MPA (GELL & ROBERTS, 2003). Yet, the recovery of the fisheries of the wide-ranging, long-lived commercial species such as hake (*Merluccius merluccius*) and cod (*Gadus morhua*), which are subjected to the higher fishing pressure, is slower (MURAWSKI *et al.*, 2000) and may take decades (PALUMBI, 2004). The stocks of highly migratory species such as sharks and tunas could also be protected through the protection of their spawning sites and nursery grounds (GELL & ROBERTS, 2003).

PROTECTED AREAS IN HELLENIC WATERS

Coastal closures

One category of MPAs similar to the 'plaice-box' (PIET & RIJNSDORP, 1998) that has been implemented in Hellenic coastal waters is the prohibition of trawling within 2 nm from the coast (or in waters shallower than 50 m) and of purse-seining

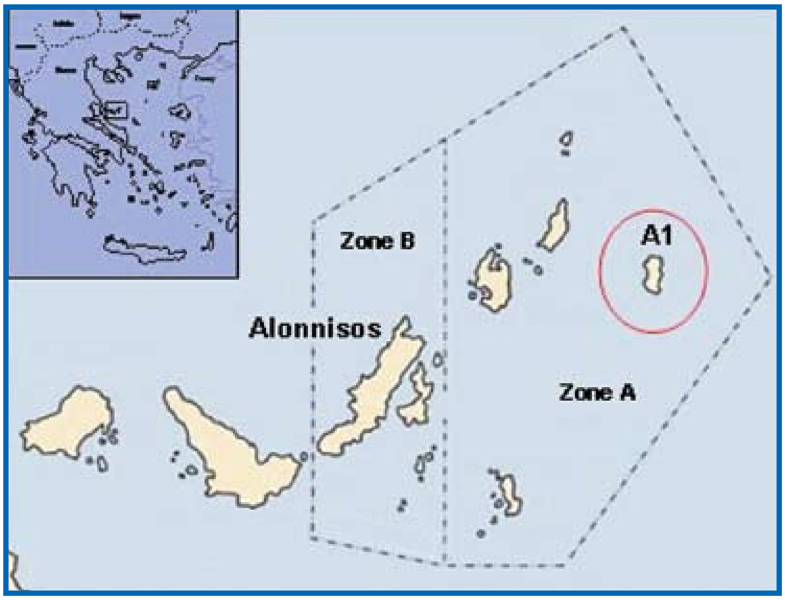

Figure 2: Map of the National Marine Park of Alonnisos, Northern Sporades Islands (NMPANS), northern Aegean Sea, Hellas showing the two main zones (Zones A and B) of protection (dotted lines) and the only no-fishing zone A1 (solid red line).

within 300 m from the coast (or in waters shallower than 30 m). The spatial closure of coastal waters from trawling is extended to 3 nm from the coast at river mouths and may exclude entire enclosed areas (e.g. the Pagasitikos Gulf in central Aegean Sea), with clear benefits for the fish biomass (see above; VASSILOPOULOU & PAPACONSTANTINOU 1999) (Figure 1). This set of regulations was enforced in the late 1980s aiming towards the protection of the coastal zone including the seagrass (*Posidonia oceanica*) meadows, the nursery areas and/or spawning grounds of several fish species. Although it was considered as a valid management scheme, it was proven ineffective because it would not protect the entire life cycle of the stocks (STERGIOU *et al.*, 2000). Fishers are always trawling at the margins of these closures often violating the prohibition by entering the closed zones. In any case, by the time the juveniles leave the coastal zone and recruit into the parental open-sea stock they were already subjected to heavy fishing mortality. Narrow closures that are parallel to the coastline are thus ineffective in the sense that they are focused on the protection of nursing juveniles but exclude, for instance, the spawning females. In contrast, wide closed bands perpendicular to the coast allow for a more holistic protection of the stock provided that the life history patterns are known (spawning and nursery grounds, habitat, migrating routes, etc.) (STERGIOU & POLLARD, 1994; STERGIOU *et al.*, 2000). The latter can be easily achieved by constructing life-history visualization plots based on already published data (ZELLER & PAULY, 2001) on a species by species basis.

The National Marine Park of Alonnisos, Northern Sporades Islands

The National Marine Park of Alonnisos, Northern Sporades Islands (NMPANS) was established in 1992 and is protected under the 519/92 Presidential Decree. It consists of one populated (Alonnisos) and five uninhabited islands and 22 small islets and the marine area among them (Figure 2). Although the size of the NMPANS appears to be 2200 km^2, which ranks it by far the largest in the Mediterranean Sea (BADALAMENTI *et al.*, 2000) the NMPANS is not fully functional. It has been divided in two large zones (A: zone for the protection of nature, and B: zone of special regulations; Figure 2) and then further subdivided in thirteen terrestrial and marine areas (details are not shown in Figure 2) with varying levels of protection. Only one small marine area (covering the 3 nautical mile perimeter of a small island) has been designated as a no-fishing zone (Zone A1: Figure 2). In the remaining marine areas, fishing (small scale coastal, trawling, seining including sport fishing) is allowed and subjected to the same temporal and spatial regulations enforced by the national law which applies to the entire Hellenic fleet. The NMPANS was initially established, among other aims, "for the protection of the world's largest population of the monk seal (*Monachus monachus*)" which was endangered. Until recently, its operation has been a matter of conflict among the local fishers, the management body and the non governmental organization *MOm,* which is based in Alonnisos and involved in monitoring the monk seal population.

RECOMMENDATIONS FOR THE USE OF MPAS IN HELLENIC SEAS

The establishment of an MPA and appropriate control site(s) is a long process involving several steps (summarized in Figure 3) and may require a plethora of scientific and socio-economic data prior to its design. Hence, the design of MPAs should consider species' life histories, community structure and interactions, ecosystem condition, oceanographic processes, habitat quality, and local socio-economic factors (GUENETTE *et al.*, 1998; LARGIER, 2003; FIELD *et al.*, 2006; HALPERN *et al.*, 2006). Prior to the establishment of an

MPA, adequate sampling across all trophic levels of the candidate sites should be performed, complemented with sampling to appropriate control sites, which are needed for statistical comparisons with similar habitat characteristics (Box 1 in GELL & ROBERTS, 2003). After the MPA establishment, long-term sampling and monitoring is required to assess the effect of the protected area on the ecosystem itself and on neighbouring fishing grounds and distinguishing from the effect of natural processes (Figure 3). Further evaluation of existing MPAs and the investigation of experimental ones over appropriate time spans will provide insights for number, size, shape, running costs, selection and distribution of MPAs (HALPERN, 2003; SALE *et al.*, 2005).

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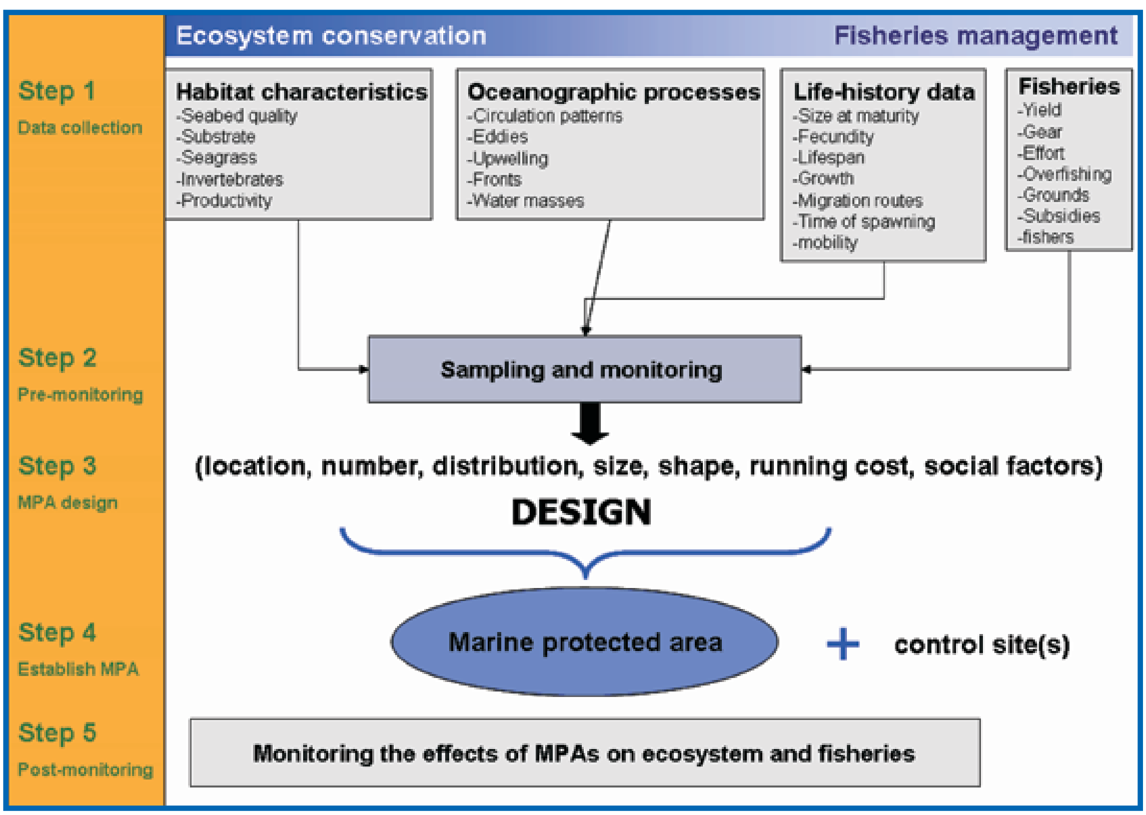

Figure 3: A synthesis showing various steps towards ecosystem conservation and fisheries' management through MPAs. The five steps required for the design, establishment and monitoring of an MPA and the characteristics/criteria within the five steps are based on several authors (ROBERTS *et al.*, 2001; GELL & ROBERTS, 2003; BROWMAN & STERGIOU, 2004a; PALUMBI, 2004; HALPERN *et al.*, 2006).

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VI.3. SINGLE - MULTISPECIES MANAGEMENT

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In theory, fisheries' management can be approached in two fundamentally different manners: (a) a holistic approach that uses the entire ecosystem as its starting point; and (b) a single-species approach that focuses only on the species of interest, providing advice which does not take into account the rest of the ecosystem (MACE, 2001).

Holistic approaches are supposed to take into account fundamental aspects of ecosystem structure (e.g. trophic interactions). Thus, it is apparent that such approaches represent the "real world" more effectively. Further, as most fisheries are multi-species, it is expected that multi-species management approaches would be most appropriate in the majority of cases (COCHRANE, 1999).

However, due to the complexity of most marine ecosystems, approaches that attempt to model the system as a whole encompass several uncertainties. Apart from the sum of the single species uncertainties, additional uncertainty arises through the poorly understood biological interactions between most of the stocks. WARD (2000) identified several "gaps and uncertainties" in the process of deriving marine ecosystem sustainability indicators for Australia's marine ecosystems. Among others, he identified problems related to: (a) limited ecological knowledge; (b) limited scientific understanding of credible cause-effect environmental issues; (c) the synthesis and aggregation of data; and (d) implementation issues (i.e. case study trials, reference sites and interpretive models.

Even relatively simple multi-species approaches that try to model prey-predator relationships are in several cases problematic, as they lack sufficient data, so as realistic as they may be conceptually, they may not adequately represent the ecosystem because of their incompleteness. In addition, trophic food webs are usually extraordinarily complex and depend not only on predation and competition among species for a variety of prey, but a host of other factors including climatic conditions, and physical properties of the marine environment.

Although there are tools which allow simulation of dynamic change in a food web with multiple exploited components, balancing exploitation rates between different fleets harvesting different components requires judgements on complex and often conflicting socio-economic issues (COCHRANE, *et al.*, 1998). Such complexities and uncertainties pose difficulties in defining operational objectives (e.g. target reference points) and performance measures. As a consequence, single-species approaches prevail in the existing management systems and they form the core of management advice. Current fisheries' management depends on stock assessments to estimate population parameters of the focal species from the age or length structure of past catches, biomass of past catches, past fishing effort, and fishery independent surveys (HILBORN & WALTERS, 1992). Typically, fisheries' scientists formulate potential management actions based on assessment estimates and provide them to managers, who weigh their socio-political consequences in deciding which to implement.

EU FISHERIES

In the EU Atlantic waters, one of the most common management methods is the imposition of the total allowable catch (TAC) on fishing for focal species. Other management actions include technical measures and effort limitations. Apparently, existing management systems are not directly considering ecological bio-indicators or any other ecological side-effects of fishing. Adoption of multi-species approaches would allow the modification of the TACs of individual species based upon the removal of other components in the food web. This means that instead of setting simple reference points related to single populations, it is also needed to refer to limits and targets related to conservation of ecosystem components, structures, processes and interactions (Figure 1). An immediate implication of this is that the complexity of the system we are considering increases and the number of objectives and the conflicts between those objectives increases substantially. This expansion in uncertainty and complexity is not, however, a consequence of adopting multi-species or ecosystem based management, it is the result of recognising and attempting to consider the full complexity and uncertainty that have always been there, but that we have previously ignored.

The Hellenic fisheries, similarly to most Mediterranean fisheries, are managed through input control rules, and technical regulations established in the frames of the EU Common Fisheries Policy (CFP) for the Mediterranean. According to FAO (2002),

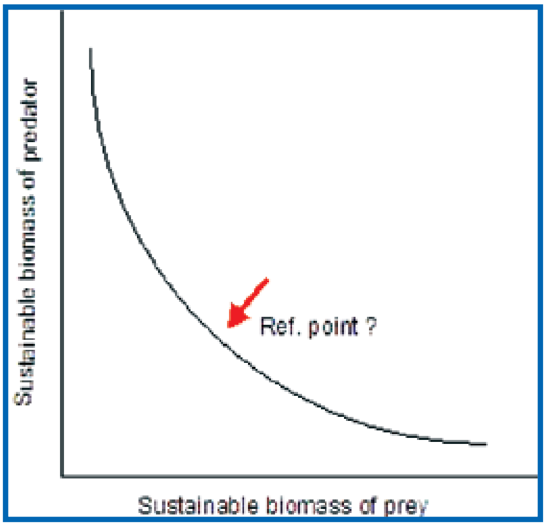

Figure 1: Hypothetical position of a biomass reference point in the case of multi-species assessment including a simple prey-predator relationship.

input controls are restrictions put on the intensity of fishing activities and equipment used for fishing. Thus, input controls refer to the number and size of fishing vessels (capacity), the duration of their operation (activity) and consequently, to the product of capacity and activity, i.e. the fishing effort. Technical regulations include indirect methods of effort limitations, such as spatiotemporal closures, which reduce fishery input, and minimum landing size regulations and gear restrictions which control the catch resulting from a given effort.

Although there are technical measures, such as minimum landing size regulations, which are focusing on the conservation of specific commercially important species, most of the existing input controls rules and technical regulations are more globally oriented. A typical example is the ban of bottom trawling within 3 miles of the coast or in depths less than 50m (whatever comes first) which protects sensitive near-shore habitats, such as soft substrates and rocky reefs, serving as nursery ground for several marine organisms. In that sense it can be said that fisheries' management includes a multi-species or even ecosystem dimension. However, the above measures are not originating from multi-species model estimates but they are empirical, based on general knowledge on species biology and ecology.

The assessments presented in the General Fisheries Commission for the Mediterranean (GFCM), which is the responsible body for managing the demersal and small pelagic resources of the basin, are typical single species assessments that are focusing in few target species (see GFCM-FTP site *(ftp://cucafera.icm.csic.es/pub/scsal)*, for details). In the same line are the assessments of the large pelagic fish stocks (tunas and swordfish) carried out by the International Commission for the Conservation of Atlantic Tunas (ICCAT).

However, the Scientific Advisory Committee (SAC) of GFCM has invited putting more emphasis on a holistic approach to fisheries' management especially through taking into account the multi-species character of most shared fisheries (FAO, 2003). In the same line is the FAO Code of Conduct for Responsible Fisheries (FAO, 1996), which highlights the importance of multi-species approaches to fisheries' management. This will require assessing more stocks caught in the same fisheries as well as strengthening coordination and integration of activities among the different Sub-Committees. It will also require ensuring that advice derived from stock and environmental assessments be translated into fisheries' management advice that take into account the socio-economic impacts of measures being suggested.

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VI.4. PRECAUTIONARY APPROACH AND REFERENCE POINTS IN HELLENIC FISHERIES MANAGEMENT

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INTRODUCTION

Principle 15 of the Rio Declaration of the UN Conference on Environment and Development (Rio de Janeiro, 1992) states that: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation."*

The *FAO Code of Conduct for Responsible Fisheries* and the *Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and management of Straddling Fish Stocks and Highly Migratory Fish Stocks* developed several concepts relating to precautionary approaches in fisheries, including:

a. actions to manage and conserve fisheries resource should be applied using a precautionary approach;
b. absence of adequate scientific information should not be used as a reason for postponing or failing to take measures;
c. specific targets and limit reference points appropriate to precautionary approaches should be determined and established;
d. the level of uncertainty in status and risk associated with actions should be encompassed into strategies;
e. enhanced data are required to decrease or lessen restrictive actions.

A precautionary approach to assessment and analysis requires a realistic appraisal of the range of outcomes possible under fishing and the probabilities of these outcomes under different management actions. The precautionary approach to assessment would follow a process of identifying alternative possible hypotheses or states of nature, based on the information available, and examining the consequences of proposed management actions under each of these alternative hypotheses. This process would be the same in data-rich and data-poor analyses. A precautionary assessment would, at the very least, aim to consider: (a) uncertainties in data; (b) specific alternative hypotheses about underlying biological, economic and social processes, and (c) calculation of the theoretical response of the system to a range of alternative management actions.

REFERENCE POINTS IN PRECAUTIONARY FISHERY MANAGEMENT

The last few years have seen a major proliferation of action on the formulation of reference points (RPs) to achieve precautionary fishery management goals. A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries' management (FAO, 1995).

Two types of precautionary reference points should be used: *conservation, or limit, reference points* and *management, or target, reference points* (FAO, 1995). Limit reference points (LRP) set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points (TRP) are intended to meet management objectives.

More precisely: a *limit* (LRP) is a conservation reference point based on a level of biomass (B_{limit}) or a fishing mortality rate (F_{limit}) that should be avoided with high probability because it is believed that the stock may be in danger of recruitment overfishing or depensatory effects if the reference points are violated. However, if the stock falls below the limit biomass or if fishing mortality exceeds the limit F, this does not necessarily imply that the fishery must be shut down. If a stock exceeds the limit fishing mortality, reductions in fishing mortality are required as quickly as possible; if the stock falls below the limit biomass, a rebuilding plan with a specific time horizon may be required. The level chosen to represent "high probability" depends on the severity of the consequences of the violation. F_{MSY} is probably the most appropriate fishing mortality-based limit reference point. Other potential candidates for limit fishing mortality rates include (FAO, 1995): (i) reference points from yield per recruit analysis (e.g. Fmax), (ii) reference points from spawning biomass per recruit analysis (e.g. F5%, F10%, F20%). Potential candidates for limit biomass levels include: B_{MSY} ,

B_{limit} = 20% B_0. B_{MSY} may be a better rebuilding target than B_{limit}, because this will enhance the probability of rebuilding the age structure as well as the biomass of a previously-depleted stock.

A *target* (TRP) is a management objective based on a level of biomass (Btarget) or a fishing mortality rate (F_{target}) that should be achieved with high probability on average. This generally means that the probability of exceeding the reference point should be around 50%. Targets should be set sufficiently far away from limits so that they result in only a low probability that the limits will be exceeded. Fishing mortality-based targets have tended to assume more importance than biomass targets (except that the latter may be used as targets of rebuilding plans) because while fishing mortality rates can theoretically be controlled by setting quotas, it is expected that biomass will fluctuate around the corresponding biomass target.

A *threshold* is a level of biomass (B_{thresh}) or a fishing mortality rate (F_{thresh}) between the limit and target reference points that serves as a "red flag" and may trigger particular management actions designed to reduce fishing mortality (FAO, 1995). Of the four combinations of limit/ target and fishing mortality/ biomass-based reference points, the most important reference points are targets based on fishing mortality rates (F_{target}) and limits based on biomass levels (B_{limit}). Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.

PRECAUTIONARY APPROACH IN HELLENIC FISHERIES

The precautionary approach is yet to be applied to the Hellenic fisheries' management system. In the past, marine protected areas (MPA) have been suggested as potential reference points helping to implement precautionary fisheries in Hellas (VASSILOPOULOU & PAPACONSTANTINOU, 1999). Here we utilized: a) data on hake fishery/stock and b) a population model describing the dynamics of the hake stock in order to evaluate alternative fisheries' management strategies/scenaria. The output was in the form of performance measures and their corresponding reference points. The performance measures being numerical descriptions of the likely future effects of the alternative management options taking into account uncertainty about the current status of the fishery and its future behaviour. Typical examples of performance measures examined were the realization that the biomass will fall below some threshold level (B_{MSY}) during a management period, the expected catch over that period, the expectation that the harvest rate will rise above a threshold level (hr_{MSY}).

The fishing mortality rate, which generates maximum sustainable yield (MSY), i.e. F_{MSY}, is usually regarded as a minimum standard for limit reference points. For stocks, which are not over-fished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a pre-defined threshold. For over-fished stocks, the biomass and harvest rate (hr), which would produce maximum sustainable yield, could serve as rebuilding targets. The simplest management strategies were tested here, consisted of fixing either a TAC (i.e. catch control rule) or a fishing mortality rate, F (or harvest/effort control rule, hr) for a given period. At present TAC is not a management measure included in the Hellenic fisheries' management system of demersal resources. However, it was decided to examine a TAC-harvest policy, as it is easy to envisage a management scenario aiming at restricting total catches below a certain level. In the case of effort control scenario, the associated harvest control rule consisted of setting a harvest rate, hr, each year based on the most recent estimate of fishing mortality (or hr). However, alternative strategies were also envisioned, in particular strategies utilizing a multi-annual basis. In such management scenaria gradual changes in fishing mortality were anticipated, from a given current value of hr to the target hr_{MSY}. These kinds of strategies were able to achieve the desired target while, at the same time, avoiding abrupt changes in fishing mortality and therefore, in successive TAC values. Thus, it was considered particularly useful to examine rebuilding strategies on a multi-annual basis. The performance of management control rules (harvest rate or TAC-based policy) was evaluated using deterministic approaches.

Reference points (RPs) were generated to describe the status of the stock and the fishery relative to the management objectives, and to permit comparisons to be made between the experimental treatments tested. Such RPs are generally used to compare the relative performance of management procedures and not to make explicit predictions about the fishery system.

Currently the harvest rate (hr) practised on hake stock by the fishery lies well above the level that

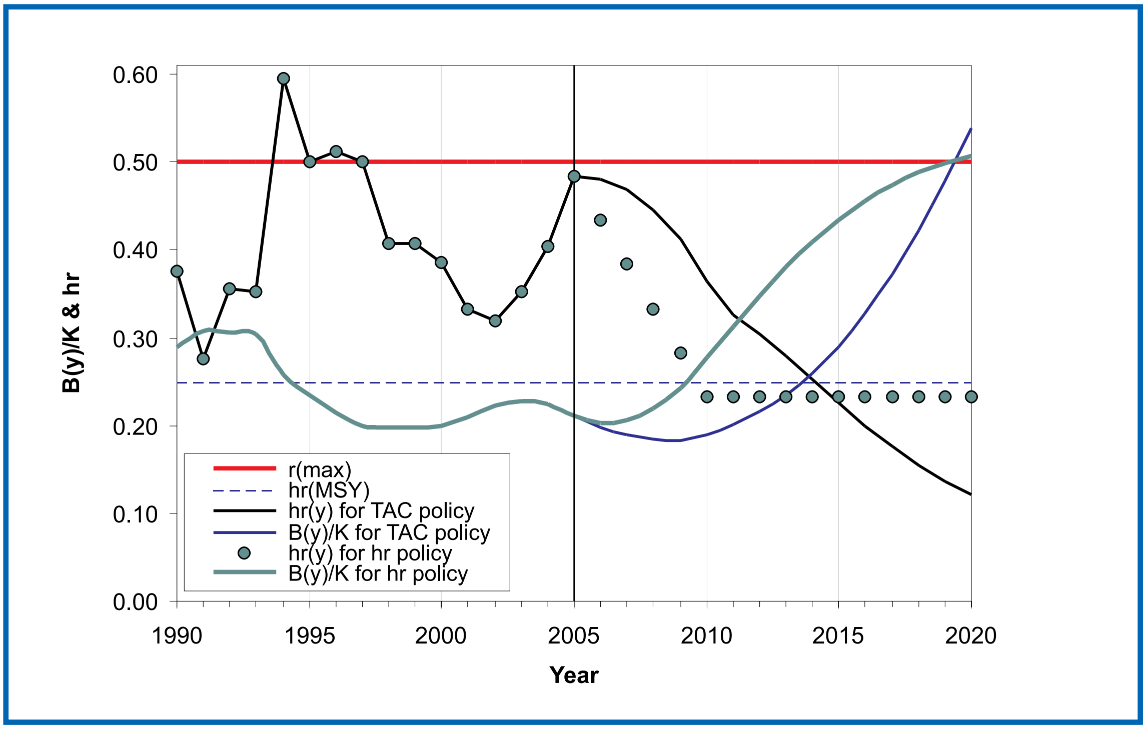

Figure 1: Deterministic results from TAC-policy and hr-policy scenaria in the Hellenic fisheries' management system and corresponding references points. Schaefer surplus production model applied to hake stock for the period 1990-2005. Projection period 2006-2020. B(y)/K: ratio of stock biomass each year relative to long-term average value for unexploited biomass K, $hr_{(MSY)}$: harvest rate at MSY, $r_{(max)}$: maximum rate of exploitation.

corresponds to maximum sustainable yield $hr_{(MSY)}$ (Figure 1). Furthermore, during the mid 1990's the harvest rate exerted on the stock exceeded the maximum rate of exploitation $r_{(max)}$. For the period 1990-2005, the total hake biomass (By) sustained was low (between 0.2-0.3) compared to the long-term average unexploited biomass K (or B_0).

The TAC-policy management scenario included a progressive reduction of 200 tons until 2010 (for a 5-year period) and a fixed total catch after that. Under this catch control rule the harvest rate of the hake fishery requires 9 years to reach the target $hr_{(MSY)}$. The hake biomass remains at low levels up to 2010 and then eventually increases reaching the 0.5 of the virgin biomass in 15 years, i.e. 2020. The hr-policy management scenario accounted for an annual 5% reduction of harvest rate (hr) that corresponded to an 8% reduction in fishing mortality (F) for the next 5 years. For the period 2011-2020, the hr and F were fixed to a level that does not exceed those, which correspond to maximum sustainable yield (hr_{MSY} and F_{MSY}). Under this effort control rule, the interannual change in stock biomass was higher than that observed under the catch control rule. The difference between the green and the blue lines in Figure 1 is indicative of the surplus hake stock biomass produced under the alternative fisheries' management scenaria tested here.

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VI.5. BAYESIAN RISK ASSESSMENT IN HELLENIC FISHERIES MANAGEMENT

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INTRODUCTION

Modern fisheries' management has seen many more failures than successes. These failures led to the realization of the importance of incorporating into advice some expression of uncertainty associated with it (FRANCIS & SHOTTON, 1997). FAO (1995) defined *uncertainty* as the "incompleteness of knowledge about the state of processes (past, present and future) of nature" and *risk* as "the probability of something undesirable happening".

Risk assessment is the formulation of advice for fisheries' managers in a way that conveys the possible consequences of uncertainty (FRANCIS & SHOTTON, 1997). Six types of uncertainty have emerged as important sources of risk in a fisheries' setting: those associated with process, observation, model, estimation, implementation and institutions (FRANCIS & SHOTTON, 1997). *Process* uncertainty is defined as the underlying stochasticity in the population dynamics such as the variability in recruitment. *Observation* uncertainty originates from the process of data collection (e.g. inadequate data collection systems and deliberate misreporting), through measurement and sampling error (as we observe a sample and not the entire population). *Model* uncertainty is due to the lack of complete information on the population and community dynamics of the system. Usually fisheries' scientists and managers use mathematical models, i.e. a conceptual set of equations describing (or at least attempts to) how populations and fisheries change over time. Lack of information in building such models causes: a) structural uncertainty (e.g. shape of Stock/Recruit relationship), b) parameter (e.g. is Natural Mortality M 0.2 or 0.3) uncertainty, and c) error structure uncertainty. *Estimation* uncertainty is linked with the process of parameter estimation (that requires data and model) and as such is derived from some or all of the three above types. *Implementation* uncertainty refers to the extent of successful implementation of management policies. *Institutional* uncertainty relates to problematic interaction of interested parties (scientists, fishers, economists, etc.) composing the management process (FRANCIS & SHOTTON, 1997).

Nowadays, there is a consensus that scientific advice to fishery managers needs to be expressed in probabilistic terms to convey uncertainty about the consequences of alternative harvesting policies (Mc ALLISTER *et al.*, 1994). A statistically rigorous and conceptually straightforward approach to account for and reduce uncertainties arising from data analysis and thus providing such advice is Bayesian decision analysis (PUNT & HILBORN, 1997; Mc ALLISTER & KIRKWOOD, 1998). Although Bayesian statistics are computationally more demanding than frequentist analogues, their use in fishery stock assessment is steadily gaining momentum. Bayesian methods allow parameters to be treated as random variables rather than as fixed values and thus explicitly account for uncertainty in the statistical modelling, as well as providing a more intuitively obvious interpretation of resulting probabilities.

In this paper, a non-equilibrium Bayesian surplus production model (BSP) has been implemented to the assessment of European hake (*Merluccius merluccius*) in Hellenic waters. A Bayesian decision analytic framework for evaluating alternative fishery management procedures that could be applied to the Hellenic fishery of hake has been developed and presented.

APPLICATION OF BAYESIAN RISK ASSESSMENT IN HELLENIC FISHERIES

Methodology: Bayesian Surplus Production Model

The Schaefer Surplus Production Model used here has been widely applied in fisheries' stock assessment (HILBORN & WALTERS, 1992; PUNT, 1993) for a variety of reasons. The model is mathematically simple and has relatively few parameters to estimate (the intrinsic rate of increase, *r*, and carrying capacity, *K*):

$$B_{y+1} = B_y + r\, B_y(1-B_y/K) - C_y$$

where B_y is the stock biomass in year y and C_y is the catch biomass at that year. The model parameters can be estimated by fitting the model to data that are often available, relative abundance indices. Furthermore, the model appears to provide good approximations of fish population dynamics in a wide variety of situations (PUNT, 1993). An important assumption of the model is that maximum surplus production (MSY) occurs at one half of *K*. Catch per unit effort (CPUE) is assumed to be directly proportional to abundance.

A reparameterisation of the model after MEYER & MILLAR (1999) enabled the implementation within WinBUGS framework by turning the model into a Bayesian state-space surplus production model through incorporation of process randomness. Non-equilibrium Bayesian surplus production models (BSPs) have simpler data requirements because they apply age-aggregated population dynamics models that incorporate the essential density-dependent features of population dynamics and generally require fewer untestable assumptions when the model is fitted to data. BSPs may provide increased reliability over non-Bayesian surplus production models because they permit the incorporation of demographic data into the estimation of SP model parameters to permit more reliable and accurate estimation (Mc ALLISTER *et al.,* 2001). Bayesian surplus models can thus offer a credible alternative to age-structured methods for the evaluation of stock status, maximum sustainable yield (MSY) based reference points, and evaluations of the potential consequences of alternative TAC or other types of age-aggregated harvest control policies.

Estimation uncertainty can be reduced with the application of informative Bayesian prior probability density functions (pdfs) for model parameters (Mc ALLISTER *et al.,* 1994). Here, probability density functions (pdfs) were used to express *a priori* uncertainty in the values of the estimated model parameters, such as the virgin population biomass (B_0) of the population and the parameters of the Surplus Production model (*r, K, q, M, F*). One of the key parameter inputs to this model was the stock size relative to carrying capacity in the first year of the model (B_0/K). This was derived algebraically from the logistic model surplus production function as a function of the long-term average harvest rate prior to the initial year of the model (h_0) and the intrinsic rate of increase

(r): $B_0/K = P_0 = 1 - h_0/r$.

<u>Step 1</u> included the identification of the alternative management procedures to evaluate. A changing catch policy scenario (TAC-policy) keeping the effort constant was evaluated. The tested catches were varying fractions of the 2005 reported catch of hake (NATIONAL STATISTICAL SERVICES OF GREECE, NSSG). Projections were done for a five-year period from 2006 to 2010.

<u>Step 2</u> identified the indices of policy performance. The output was in the form of performance measures and their corresponding reference points. The performance measures being numerical descriptions of the likely future effects of the alternative management options take into account uncertainty about the current status of the fishery and its future behaviour. The indices used to evaluate policy performance included the following:

(a) the posterior expected value for the ratio of stock biomass each year, *By,* to carrying capacity, *K,* (*E*(*By*/*K*)) in the projected period (2006-2010),
(b) the probabilities that the stock size in the projected period (2006-2010) will be larger than the stock size in 2005 ($P(By > B05)$),
(c) the probability that there will be no overfishing in the final year (2010) of the simulation, i.e., that stock biomass in 2010 is larger than 25% of *K*,
(d) the probability that there is no overfishing in the current year (2005), i.e., that stock biomass in the current year is larger than 25% of *K*,
(e) the probability that the harvest rate in 2005 (hr_{2005}) is larger than 1.5 times the MSY-harvest rate ($P(hr_{2005}>1.5hr_{MSY})$),
(f) the probability that the harvest rate in 2010 (hr_{2010}) is larger than 1.5 times the MSY-harvest rate ($P(hr_{2010}>1.5hr_{MSY})$),
(g) the probability that the hr/hr_{MSY} in the current year (2005) is larger than a factor of 1, ($P(hr_{2005}>hr_{MSY})$ and
(h) the probability that the hr/hr_{MSY} in the final year (2010) is larger than a factor of 1, ($P(hr_{2010}>hr_{MSY})$.

<u>Step 3</u> calculated the joint and marginal posterior probability distributions for model parameters and stock biomass in each year, as well as other management quantities such as the ratio of stock biomass in each year, By, to B_0 or *K*.

In <u>step 4</u> the potential consequences of alternative management actions were evaluated. This was achieved by randomly sampling values for model parameters from the joint posterior probability distribution obtained in the previous step and using these values to project the model into future years (here 2006-2010).

Monte Carlo projection is a way of dealing with uncertainty in evaluating management options. If there were no uncertainty, the model could produce, for each alternative management option, a single exact description of the future of the fishery. Because there is uncertainty, the method of Monte

Table 1. Biological reference points and posterior probabilities from Bayesian analysis on hake stock for the period 1990-2010. Results of Markov Chain Monte Carlo (MCMC) simulations (200 000 sims). MC error < 5%.

Performance measures	Mean Probability value (st.dev)
The probability that there is no overfishing in the current year (2005), i.e., that stock biomass in the current year is larger than 25% of K.	0.70 (0.45)
The probability that there will be no overfishing in the final year (2010) of the simulation, i.e., that stock biomass in 2010 is larger than 25% of K.	0.54 (0.49)
The probability that the hr/hr_{MSY} in the current year (2005) is larger than a factor of 1.5.	0.49 (0.50)
The probability that the hr/hr_{MSY} in the final year (2010) is larger than a factor of 1.5.	0.17 (0.37)
The 2005 hr being larger than 2 times the hr_{MSY}	0.08 (0.27)
The 2010 hr being larger than 2 times the hr_{MSY}	0.06 (0.25)
The probability that the hr/hr_{MSY} in the current year (2005) is larger than a factor of 1.	0.90 (0.28)
The probability that hr/hr_{MSY} in the final year (2010) is larger than a factor of 1.	0.45 (0.49)

Carlo projection produces a large number (more than 1000) of alternative possible futures for the fishery for each management option. Each of these possible futures ("realizations") is a description of how the fishery might develop as a result of that option (FRANCIS & SHOTTON, 1997). In the present Bayesian fishery assessment, the Monte Carlo approach used for estimating multidimensional posteriors was the Markov Chain Monte Carlo (MCMC) method. The MCMC method implemented was based on iterative Markovian updating schemes for estimating posteriors and sampling entailed a random walk over the posterior probability surface (PUNT & HILBORN, 1997) More explicitly, 200 000 Markov Chain Monte Carlo simulations were run. The sensitivity of the marginal posterior distributions was tested for the key model parameters, for example, *r, K, M, q, F* and the maximum sustainable yield (MSY = $rK/4$) to alternative prior distributions for *r*. Finally, the distribution and expected value of each performance measure was evaluated.

Results - Discussion

The potential consequences resulting from the TAC-policy management scenario are shown in Table 1. The results of the Bayesian approach to hake stock assessment were generated from 200 000 Markov Chain Monte Carlo (MCMC) simulations. The mean probability for a range of performance measures and corresponding biological reference points alongside their standard deviation is given. The estimated Monte Carlo error (MC error) remained always lower than 0.05%. A number of intriguing findings emerged from the Bayesian Risk Assessment analysis:

1) There is a 30% probability (risk) that the hake stock in the current year 2005 is overfished. In other words, there is a 30% chance that the 2005 hake stock biomass is less than 25% of the carrying capacity, *K*.
2) There is a 46% risk that the hake stock in 2010 will remain over exploited and overfished.
3) The existing harvest rate of the hake stock, i.e. hr_{2005}, has a high risk (49%) of being larger than 1.5 times the harvest rate that corresponds to the maximum sustainable exploitation of the stock or MSY level, i.e. hr_{MSY}.
4) Following the adoption of the changing catch policy scenario, the harvest rate of the hake stock in 2010, i.e. hr_{2010}, has a lower risk (17%) of being larger than 1.5 times the harvest rate that corresponds to MSY level, i.e. hr_{MSY}.
5) There is a 90% risk that the existing harvest rate of the hake stock, i.e. hr_{2005}, is larger than the harvest rate that corresponds to MSY level, i.e. hr_{MSY}.
6) Under the catch policy scenario introduced, the risk that the harvest rate of the hake stock in 2010, i.e. hr_{2010}, will be larger than the harvest rate that corresponds to MSY level (hr_{MSY}) is greatly reduced. More precisely the risk drops from 90% in 2005 to 45% in 2010 (50% reduction).

In Figure 1 the harvest rate each year (hr) relative to the MSY harvest rate (hr_{MSY}) is shown. For a sustainable exploitation of the stock the hr/hr_{MSY} ratio should always remain lower than 1. The harvest rate implemented since 1990 always exceeded the hr_{MSY}. The changing catch policy scenario introduced after 2005 resulted in a reduction of harvest rate. However, the stock remained over exploited. This implies that a more severe catch policy scenario is required to rebuild the stock from its current level.

In Figure 2 the annual stock biomass relative to *K* is shown. The results (Table 1, Figure 2) suggest that the stock is very low relative to carrying capacity, currently at about 30%. The hake stock has been heavily fished down since the early 1990s. Probabilistic estimates of 5% and 95% confidence intervals are also presented. The former indicate that, for the projection period, there is about a 5% risk that stock biomass will drop below the values shown, e.g. there is a 5% chance that the By/K will be below 0.13 in 2010. The latter suggest that there is about a 95% risk that the stock biomass will rise above the values shown, e.g. in 2010 there is a 95% probability that the By/K will be above 0.55.

Scientific advice to fishery managers needs to be expressed in probabilistic terms to convey uncertainty about the consequences of alternative harvesting policies (Mc ALLISTER *et al.,* 1998). In this paper, a Bayesian risk assessment methodology was presented and applied to Hellenic fisheries. Informative prior probability distributions (*priors*) were used for *r, K, q, M, F*. This procedure could be easily implemented in any other fisheries/stock. The risk assessment approach was applied to a hypothetical situation to evaluate the potential consequences of catch control rules when a biomass dynamic model is fitted to catch rate data. Effort control management options can also be tested. The most astonishing result was that despite the substantial reduction of the proposed allowable catch by 2010 (almost by half its 2005 value) the hake stock remained heavily depleted. Evidently, stronger probing policies alongside more stringent harvest control management procedures will be required to restore the stock to sustainable levels of exploitation. The probabilistic modelling methods applied here have taken uncertainties into account and provided estimates of biological risks of alternative catch-policy options. This may serve as a basis for providing precautionary fishery management advice. Future management procedures should be designed to lower the risk of high harvest rates and to promote stock recovery when stock size is low thus, reducing the risk of over exploitation.

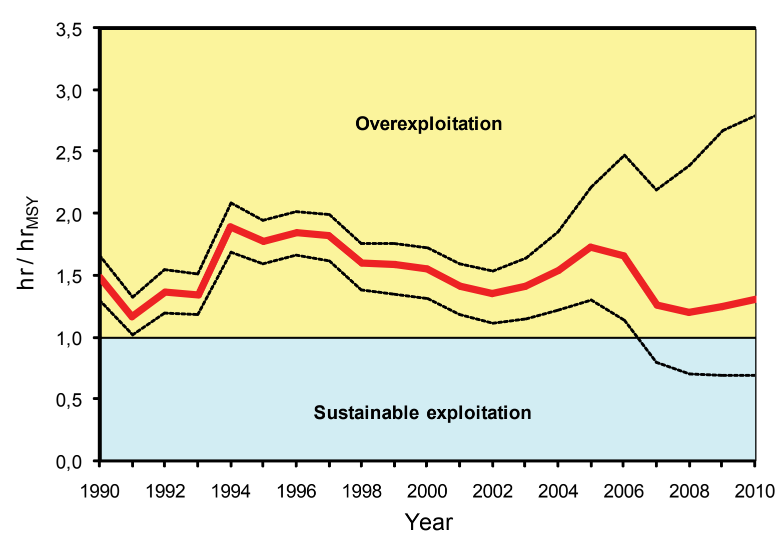

Figure 1: Posterior means of annual harvest rate (hr) relative to the harvest rate that corresponds to Maximum Sustainable Yield, MSY, (hr_{MSY}). Five-year projection period: 2006-2010. Dotted lines represent upper 90% and lower 10% posterior probabilistic estimates of intervals.

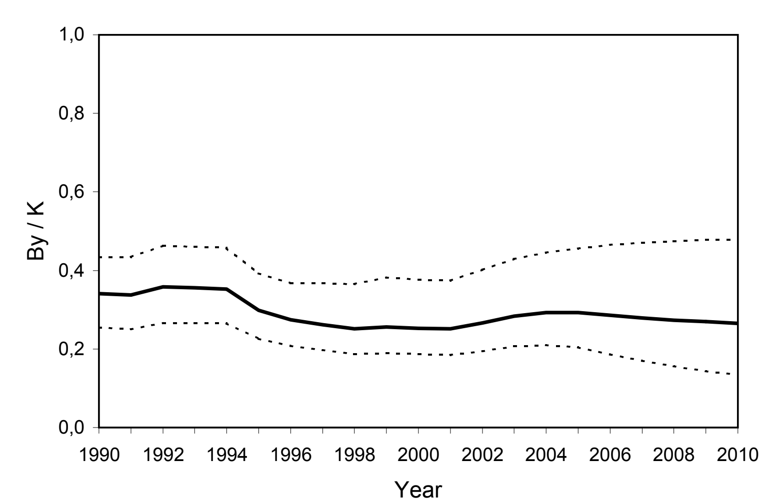

Figure 2: Posterior medians for annual stock biomass (*By*) relative to carrying capacity *K* between 1990 and 2010 (solid line) and 95% posterior probability intervals (dashed lines).

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VI.6. FISHERY AND BENTHIC INDICATORS TO EVALUATE THE EFFECTS OF FISHING IN HELLENIC WATERS

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INTRODUCTION

Fisheries by their nature are dependant upon, and can profoundly influence, the aquatic environment. Their dependence on the environment relates primarily to the overall health of the coastal and marine ecosystems and is thus vulnerable to both anthropogenic influences, such as a decline in water quality from pollution, as well as temporal variations in the cycling of natural processes. Fisheries' exploitation can also have a major impact on the aquatic environment through the reduction of wild fish populations. This may not only affect the exploited/targeted populations but also non-target species through trophic interactions or competition. Fisheries' activities can also have direct or indirect impacts on marine and coastal habitats, which may have further consequences for maintenance of the integrity of marine life, including biodiversity.

The Common Fisheries Policy (CFP) provides *the* framework for European and national fisheries management activities. The Action Plan on environmental integration into the CFP (COM(2002)186) contains guiding principles, management measures and a work programme, to move towards an ecosystem approach to fisheries' management. The overarching principles of the latter approach are an extension of the conventional principles for sustainable fisheries development to cover the ecosystem as a whole. The main implication is the need to cater both for human, as well as ecosystem, well-being. This means conservation of ecosystem structures, processes and interactions through sustainable use. Among the immediate steps that should be taken in moving towards ecosystem-based management in fisheries are in consultation with all legitimate stakeholders and interest groups to agree upon objectives for each ecosystem, and to recognize and address potential conflicts and inconsistencies in those objectives. As a part of setting the objectives, sustainability indicators need to be established for each ecosystem. In effect, indicators can be valuable tools for tracking change, identifying problems and monitoring implementation of policies and results. A robust set of informative indicators will help policy- and decision-makers to evaluate the performance of management measures, as well as to ensure accountability to the public through regular information. Moreover, the development of a system of indicators is envisaged to monitor the change from the 'old' to the 'new' CFP. These indicators are to assess to what extent the reformed CFP is on the right track towards integrating environmental protection requirements.

The role of indicators in supporting management and reporting has already been clearly identified by the EC [SEC(2004)29[1] and SEC(2004)892][2]. According to the Sub Group on Research Needs (SGRN) of the Scientific Technical and Economic Committee for Fisheries (STECF), indicators that might support the environmental integration process into fisheries can be used (1) to describe the pressures (fishing effort, fishing mortality, frequency of disturbance, etc.) affecting the environment, the state of the environment (abundance and status of populations, etc.) and the response of managers, (2) to support management decision making and (3) to track progress towards environmental integration. [SEC(2005)[3]].

A preliminary set of indicators on the integration process as proposed by STECF is presented in Annex1.

The Mediterranean fisheries are highly diverse in terms of species and fishing gears used. Bottom trawling fisheries are essentially multi-species, and they are carried out in a wide range of depths and affect different bottoms and communities. Bottom

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[1] SEC(2004)29 *Ad hoc Expert Group on Indicators of environmental integration for the common fisheries policy*. Commission Staff Working Paper. Brussels, October 2003. 8.1.2004 http://europa.eu.int/comm/fisheries/doc_et_publ/factsheets/legal_texts/docscom/en/sec_2004_573_en.pdf

[2] SEC(2004)892 *Developing a system of indicators of environmental integration for the Common Fisheries Policy*. Commission Staff Working Paper Brussels, 29.06.2004 http://europa.eu.int/comm/fisheries/doc_et_publ/factsheets/legal_texts/docscom/en/sec_2004_892_en.pdf

[3] SEC(2005) *Report of the SUBGROUP ON RESEARCH NEEDS (SGRN) on data collection: environmental integration and move towards an ecosystem approach* Commission Staff Working Paper Report of The Scientific, Technical And Economic Committee For Fisheries Brussels 11-14 July, 2005 http://stecf.jrc.cec.eu.int/events_list.php?sg=SGRN

trawl fleets predominate in many Mediterranean fisheries. The high profitability of this fishing practice is largely due to its low selectivity with respect to sizes and species caught and to the high harvests generated (Chapter VII: Gear selectivity). Trawlers have dramatic effects on the ecosystem including physical damage to the seabed and the degradation of associated communities, the overfishing of demersal resources, and the changes in the structure and functioning of marine pelagic and benthic ecosystems derived from the depletion of populations and the huge amount of bycatches and associated discards (Chapter V.2). The latter underlines the necessity to gather relevant information and develop indicators contributing to track the impact of trawling on stocks, communities and finally the ecosystem.

During the last decade HCMR has been involved in the development of appropriate indicators to monitor fisheries' impacts on the marine ecosystem through its participation in European Environment Agency (EEA) fora[4 5 6]. Moreover, in the framework of the INDECO (Development of Indicators of Environmental Performance of the Common Fisheries Policy, STRP 513754)[7] project quantitative indicators for the impact of fishing on the ecosystem state are being identified and their applicability is assessed, in parallel with continued efforts towards the development of operational and ecological models (e.g. COST-IMPACT project) to assess fisheries' impacts at the ecosystem level and for scenario testing. Finally, in the project INDENT (INDicators of Environmental iNtegration, FISH/2004/12)[8], numerical values to indicators of environmental integration were attributed and interpreted, while gaps in data/information were determined.

As a paradigm of the results achieved so far through our involvement in the development of environmental indicators to monitor fisheries' impact on the marine ecosystem, a case study for the Aegean Sea on the impact of trawling on demersal fish assemblages is provided as well as a summary of additional work on the impact of trawling on benthic communities in Hellenic waters.

USING FISHERY INDICATORS TO EVALUATE THE IMPACT OF TRAWLING ON DEMERSAL FISH ASSEMBLAGES IN THE AEGEAN SEA - CASE STUDY

The objective of this study was to provide assessments of fishery indicators based on data derived through a monitoring programme of observers recording catches (landed and discarded part of the catch) on-board commercial trawlers during an eleven years period from 1995 to 2005 in the Aegean Sea. Such information contributes to our knowledge on the state of demersal fish assemblages in eastern Mediterranean waters.

Based on these data, and by pooling the species data, the mean length, mean weight, as well as the mean maximum length and the mean trophic levels of the Aegean demersal fish assemblages were calculated. All possible trends in the indicators' time-series were extracted through General Linear Model Analysis of Variance (GLM ANOVA) with SPSS v.11 for Windows. Power analysis has been used to assess the power to detect trends in the aforementioned indicators (TRENKEL & ROCHET, 2003). Power calculations demonstrate whether indicators provide feedback to managers on the timescales over which progress in relation to objectives might be assessed. If power is low, and it takes many years of monitoring to detect a relevant trend, then the monitoring program and/or indicator may need to be modified. Graphs of power versus sample size (in years) were produced for the evaluation of the indicator's performance.

Mean length and weight

Values of mean length and weight per haul were calculated and time-series graphs of the two indicators for the Aegean demersal assemblages are shown in Figure 1. Although both series appeared to have a negative trend, this trend was not significant ($P>0.05$) and its power was found to be very low (about 0.055). Power analysis was then conducted to evaluate the utility and robustness of mean size (length and weight) of fish as indicators of the exploitation status of the Aegean assemblages. Results showed that in all cases larger sampling sizes were needed to detect smaller changes (Figure 2). For example, at a power level of 0.8 a 1% rate of change of the mean needs more than 27 years, while 11 years are enough for a 5%

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[5] Jaako Pöyry Infra (Soil & Water), 2003. *Development of Preliminary Indicators of Environmental Integration of the Common Fisheries Policy*; Contract No FISH/2002/08

[6] Joint Fisheries Working Group

[7] INDECO Final analysis and evaluation of INDECO Indicators :http://www.ieep.eu/publications/pdfs/indeco/Final_%20analysis_INDECO.pdf

[8] INDENT final Report: http://ec.europa.eu/fisheries/publications/studies/indent_2006.pdf

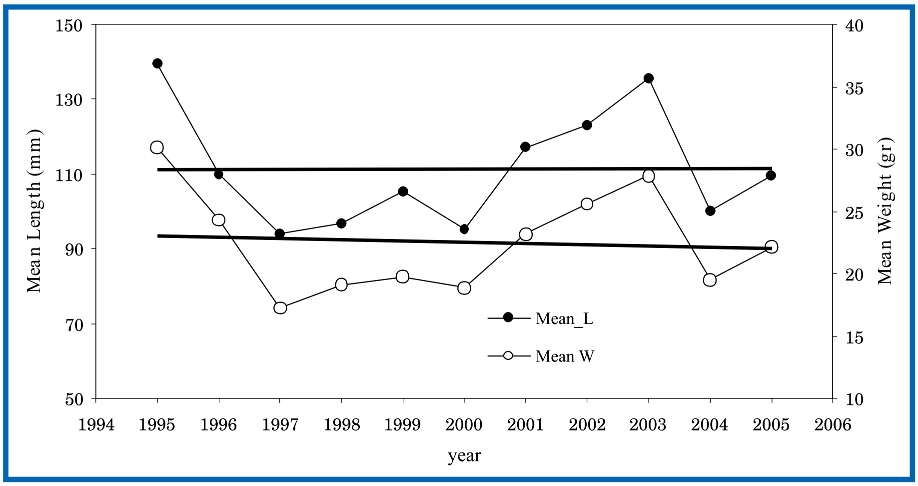


Figure 1: Time-series of the size indicators (mean length and weight) in the Aegean Sea, along with their linear trendlines against year (from 1995 to 2005).

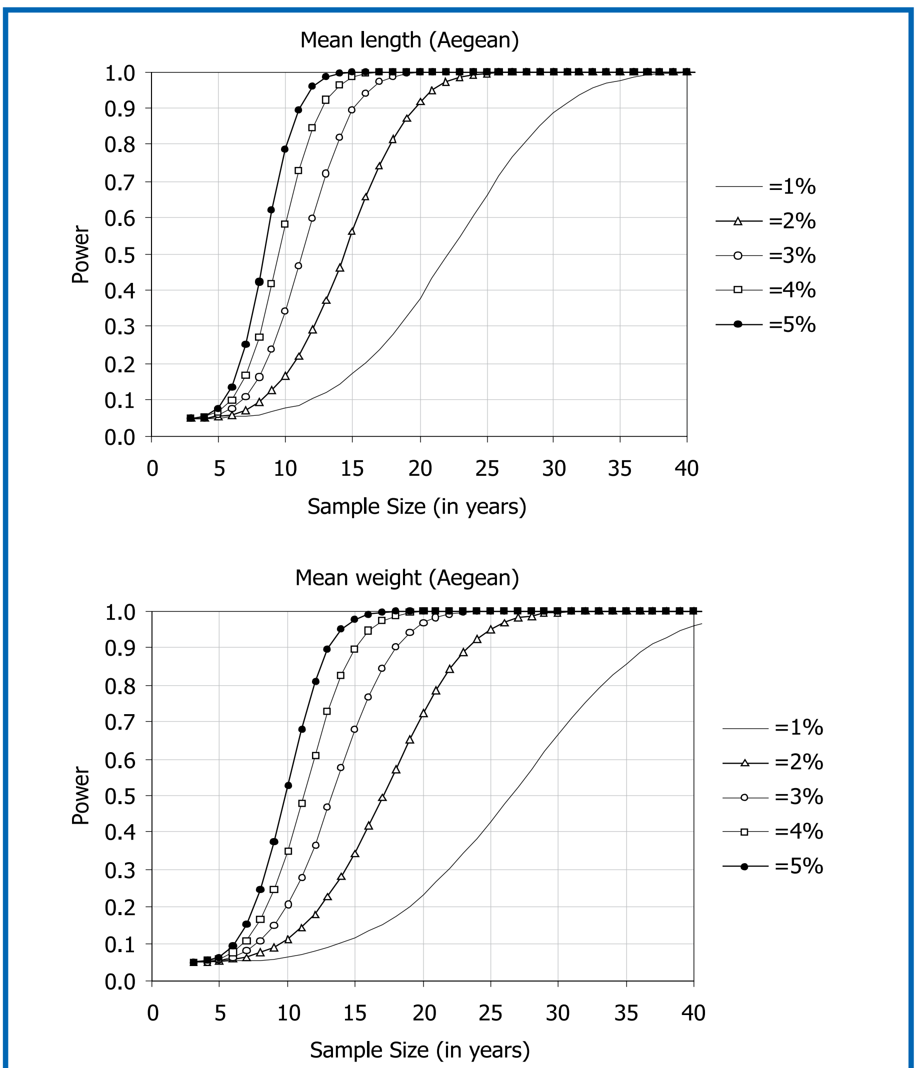


Figure 2: Power versus sample size (in years) of the size indicators (mean length and weight) time-series in the Aegean Sea. The hypotheses tested a detection of a linear trend (in terms of absolute value of slope) ≤ 1%, 2%, 3%, 4% and 5% of the mean value of the series.

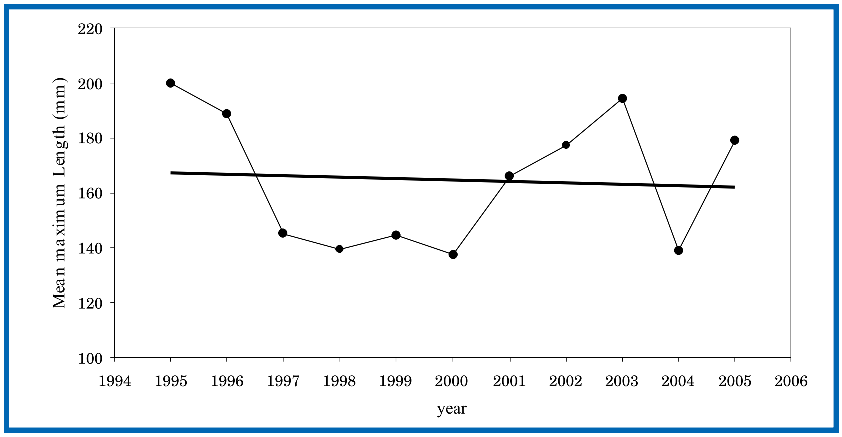


Figure 3: Time-series of the mean maximum length in the Aegean Sea, along with linear trendlines against year (from 1995 to 2005).

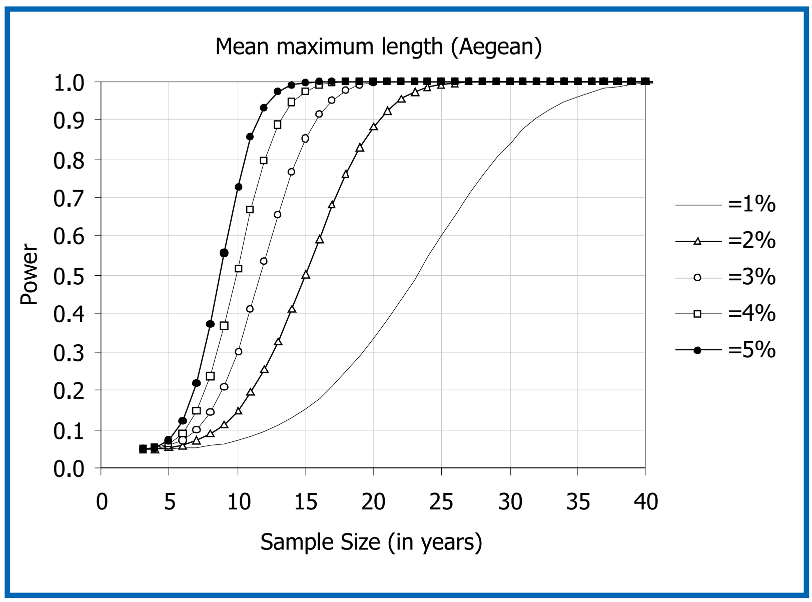


Figure 4: Power versus sample size (in years) of the mean maximum length time-series in the Aegean Sea. The hypotheses tested a detection of a linear trend (in terms of absolute value of slope) ≤ 1%, 2%, 3%, 4% and 5% of the mean value of the series.

rate of change. Comparing the performance of the two size indicators it is obvious that mean length is more powerful than mean weight in terms of detecting a linear trend.

Mean maximum length

Values of mean maximum length per haul for the Aegean fish assemblages were calculated and the respective time-series is given in Figure 3. This indicator's time-series appeared to follow the exact same pattern as the mean size indicators. The negative trend that also appears is again non-significant (P>0.05) and has a very low power (0.05). From Figure 4, where power versus sample size (in years) is illustrated, a similar performance of this indicator to that presented by average size is observed, suggesting once again that larger sampling sizes (i.e. more years) are needed to detect smaller changes.

Mean trophic levels (TL)

Values of mean trophic levels per haul for the Aegean fish assemblages were calculated and the respective time-series is provided in Figure 5. Mean trophic level indicator values ranged between 3.59 and 3.77, appearing to follow more or less the same pattern as the mean size and mean maximum length indicators. Again a negative trend appears, but this trend is also non significant (P>0.05) and presents a very low power (0.05). The application of power analysis, however, suggested that a much smaller sampling size is needed to powerfully detect a change (i.e. at a power level of 0.8 a 1% rate of change of the mean needs about eight years) indicating the utility and robustness of this indicator to detect a linear trend (Figure 6). Based on this indicator and on the steadily decreasing trend of TL values in the last 50 years, PAULY *et al.* (1998) described the existence of a global "fishing down marine food webs effect" (FDMFW), also verified in the Mediterranean and the Aegean (TUDELA, 2004; STERGIOU, 2005).

Summing up, average size indicators appear to provide indications about existing trends in the state of the demersal fish assemblages in the Aegean Sea. Our results suggested, however, that for powerful detection of a relatively small change (<2%) a sample exceeding 20 years is needed. On the other hand, mean trophic level appearing to offer powerful detection of possible trends with smaller sampling sizes seems to constitute a more useful indicator. The present study based on data of a rather limited spatio-temporal coverage could be considered as indicative and has a preliminary role, while long-term retrospective analyses are needed to interpret trends and values correctly, and to avoid shifting baselines. Any change in the temporal dynamics or trajectory of an indicator must be interpreted in the light of other, complementary indicators, as well as general ecological knowledge.

USING BENTHIC INDICATORS TO EVALUATE THE IMPACT OF TRAWLING ON BENTHIC COMMUNITIES IN HELLENIC WATERS

The effects of trawling on benthic communities are the subject of heated debate; the generality of trawl effects on the ecosystem with respect to gear and habitat types is poorly understood. In order to quantify the effects of trawling on benthos two approaches are usually employed. A Before/After (B vs A) experimental design which provides information about the short-term effects (immediate to a few months) and a Control/Impact (C vs I) design which provides information on the long-term effects.

Four trawl impact studies can be used as indicator case studies. The first three were conducted in the sea of Kriti (S. Aegean) at a trawling lane before, during and after the trawling season and a suitable control area (FGE Project TR/MED93/012, OTIP Project EC 98/017, COST-IMPACT Q5RS-2001-00993) and the fourth in the Central

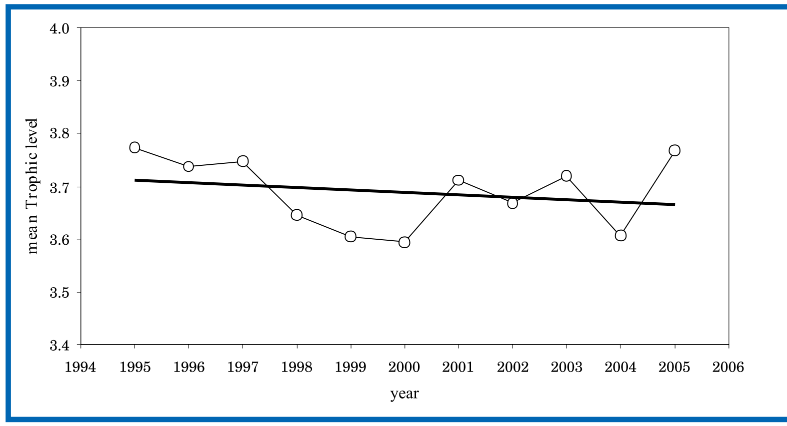


Figure 5: Time-series of the mean trophic level in the Aegean Sea, along with linear trendlines against year (from 1995 to 2005).

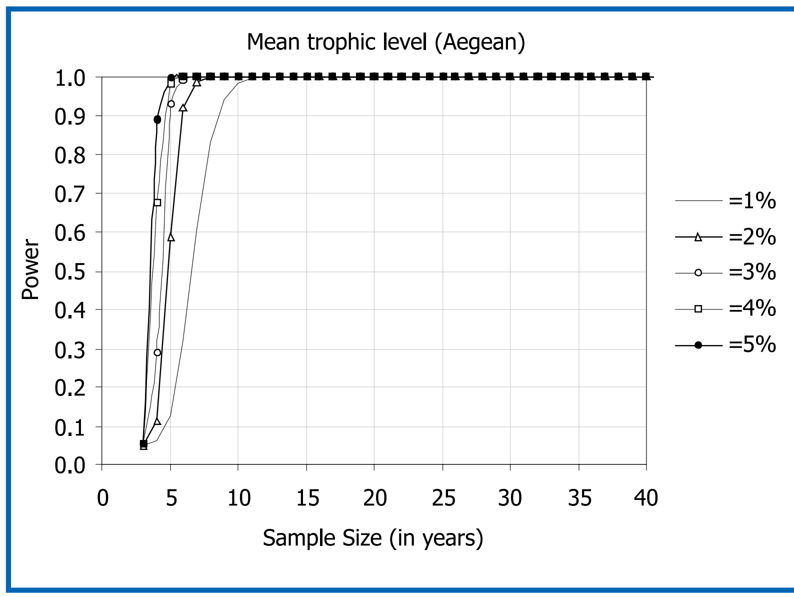


Figure 6: Power versus sample size (in years) of the mean trophic level indicator time-series in the Aegean Sea. The hypotheses tested a detection of a linear trend (in terms of absolute value of slope) ≤ 1%, 2%, 3%, 4% and 5% of the mean value of the series.

Aegean, South Evvoikos (area closed to trawlers) and Petalioi Gulf (open to trawlers) (TRIBE Project 95/014), using experimental trawling when necessary. Fishing effort (intensity) was higher in the C. Aegean (Petalioi Gulf) than in S. Aegean.

Indices of community structure

Regarding the megafaunal communities (larger animals>2mm living on or burrowing in or attached on the seabed), measurements of species number (S), Abundance (N), Diversity Shannon

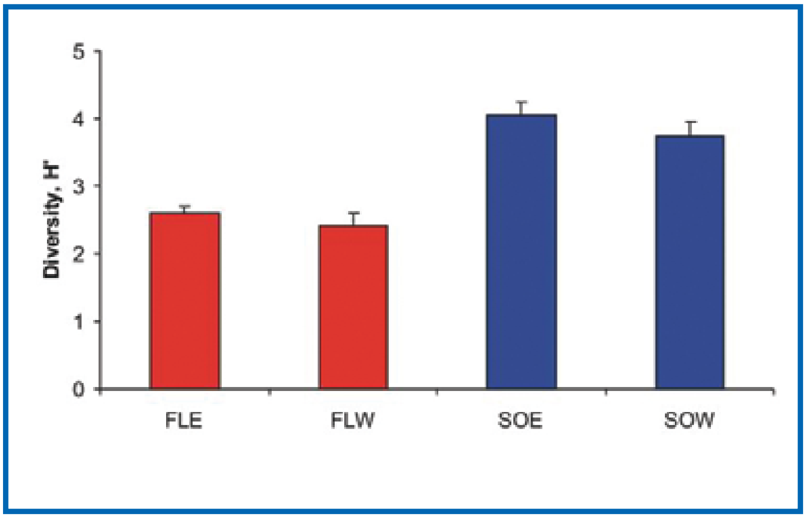


Figure 7: Mean megafaunal diversity H' (Shannon-Wiener) from winter Agassiz trawl sampling during the trawling season (mean and 95% confidence intervals, FLE: fishing lane east, SOE: control area east, FLW: fishing lane west, SOW: control area west). From SMITH & PAPADOPOULOU, 2005

Wiener (H), and Evenness (J) indicators, can reveal the impact of trawling on benthos but not consistently.

Diversity (H), is the indicator consistently revealing such impact; a lower overall diversity in the trawl lane stations and in experimentally trawled stations has been determined in all the studies conducted in the Sea of Kriti (SMITH *et al*., 2000, COGGAN *et al.,* 2001; SMITH & PAPADOPOULOU, 2005: Figure 7).

On the other hand, using the abundance of megafaunal species (N) as an indicator, the impact of trawling on the megafaunal benthic ecosystem could not be consistently demonstrated as different studies produced inconsistent results. The same was true when the megafaunal biomass or Abundance-Biomass Comparison curves were considered.

Generally speaking, the findings of fishing impacts' studies have not been very consistent (COLLIE *et al*., 2000), but detecting fishing effects will depend on the indicator used (e.g. diversity or abundance), the scale of sampling (KAISER, 2003), the intensity

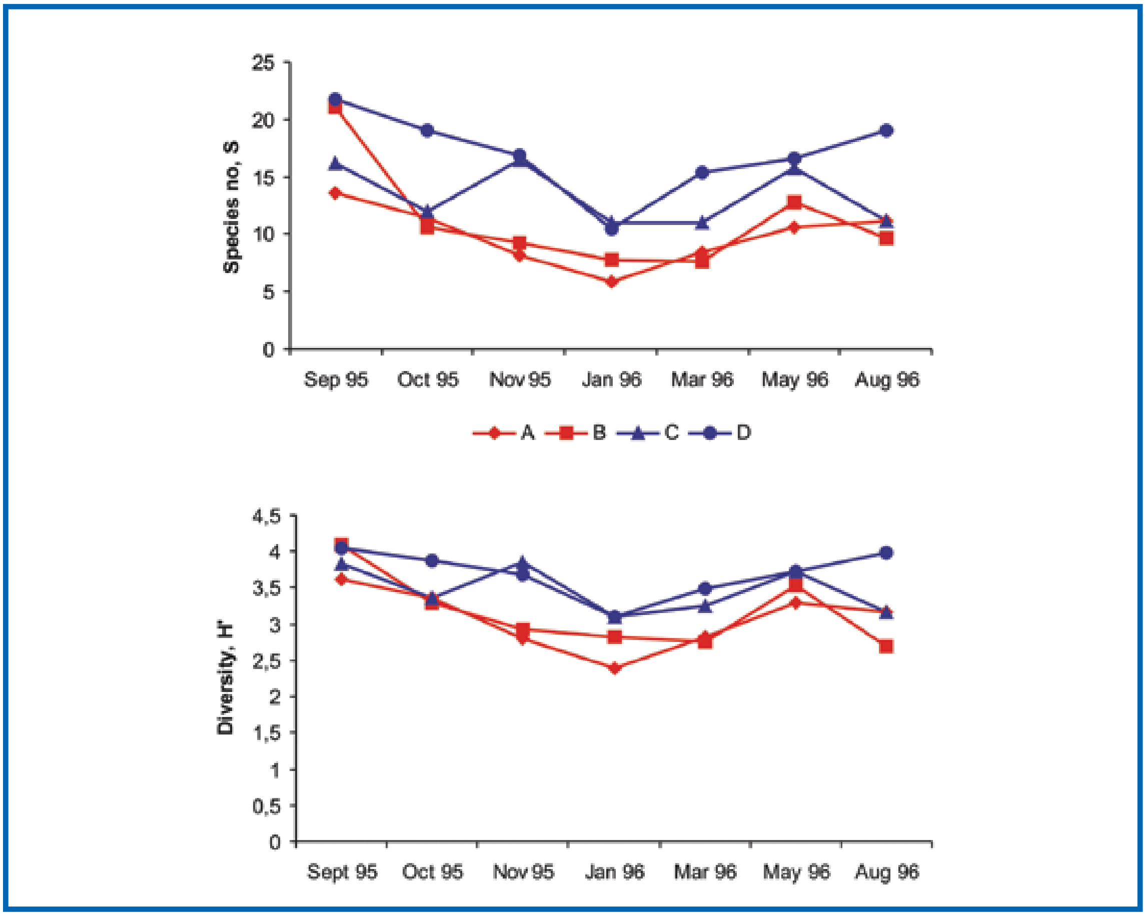


Figure 8: Mean number of Species (S) (top) and Jhannon Wiener University (H) (bottom) of macrofauna in the South Aegean by month (SMITH *et al.,* 2000) (A & B in the trawl lane, C & D control, October to May in trawling season).

of fishing effort as well as the patchiness in the distribution of the fauna and the effort.
Regarding the macrofaunal communities (small animals living on the seabed or in the sediment), measurements of species number (S), Abundance (N), Diversity Shannon Wiener (H), and Evenness (J) and biomass indicators of various functional or taxonomic groups, revealed higher overall diversity species number and abundance along with lower evenness in the control stations in the study conducted in the Sea of Kriti (SMITH *et al.*, 2000) demonstrating the impact of trawling on the whole benthic ecosystem (Figure 8); the opposite was reported in the Central Aegean study (Figure 9) (TRIBE Project 95/014).
The 'typical response' to fishing pressure not reported in the later study was attributed to differences in the sediment type of the two areas (shallower coarser sediments in the trawled area). However, even in this case, the revealed increase in the number of polychaetes and opportunistic macrofaunal groups, often a sign of environmental disturbance, was presumably the result of trawling activities (Figure 10) (TRIBE, 1997).

Functional groups and Indicator species
Depending on their morphology and ecology, benthic species exhibit different responses to trawling: some species will be removed and easily damaged (such as the fragile low motility crinoid *Leptometra phalangium*) while others may be attracted (such as scavenging hermit crabs or sea stars) or unaffected (such as deep burrowing crabs).
Functional changes have been recorded with elimination of the target species and of sessile (or discretely mobile) species vulnerable to sediment re-suspension and enhancement of the tolerant scavengers and opportunistics (TRIBE, 1997; SMITH

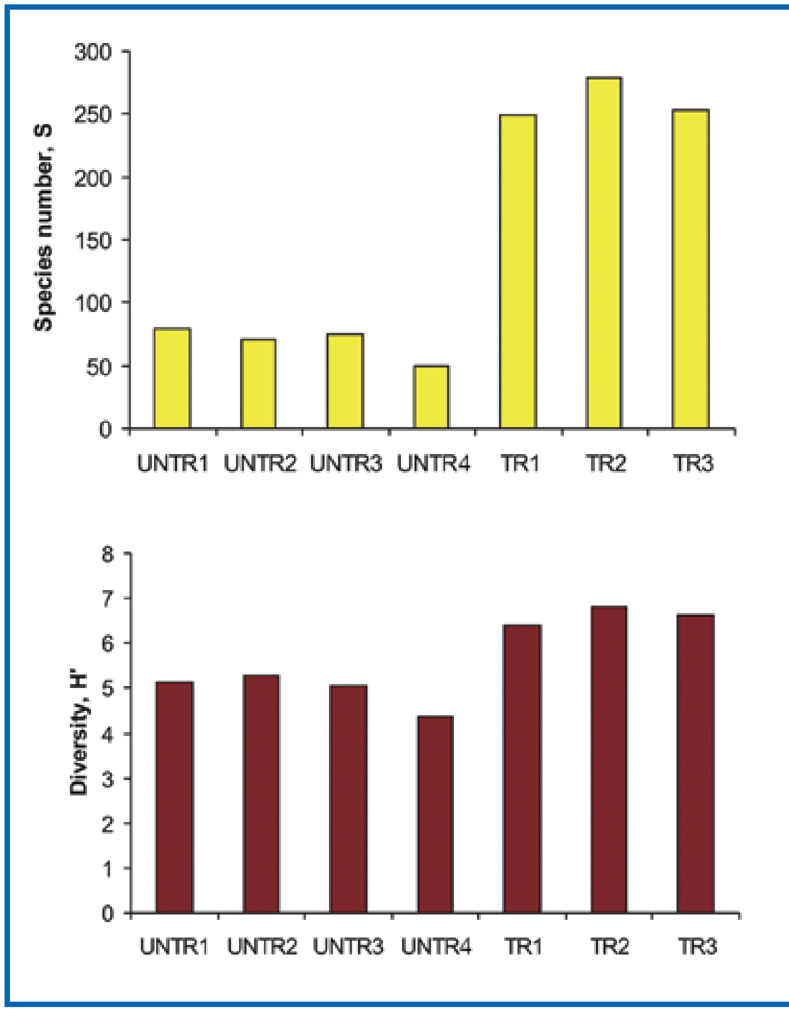


Figure 9: Species' number (S) (top), and Shannon Wiener Diversity (H') (bottom) of macrofauna in Central Aegean (TRIBE, 1997). (Stations UNTR 1, 2, 3, 4 and TR 1, 2, 3 in closed and open for trawling areas respectively).

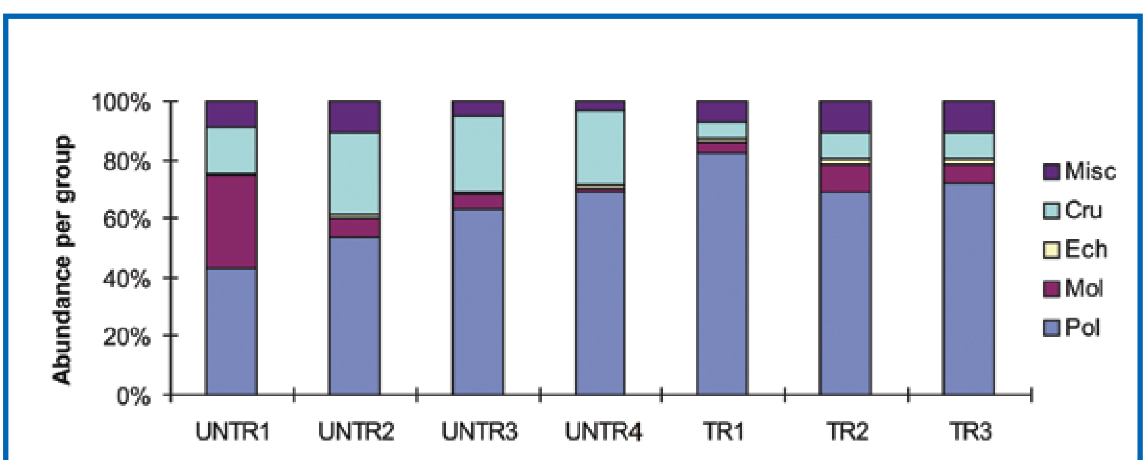
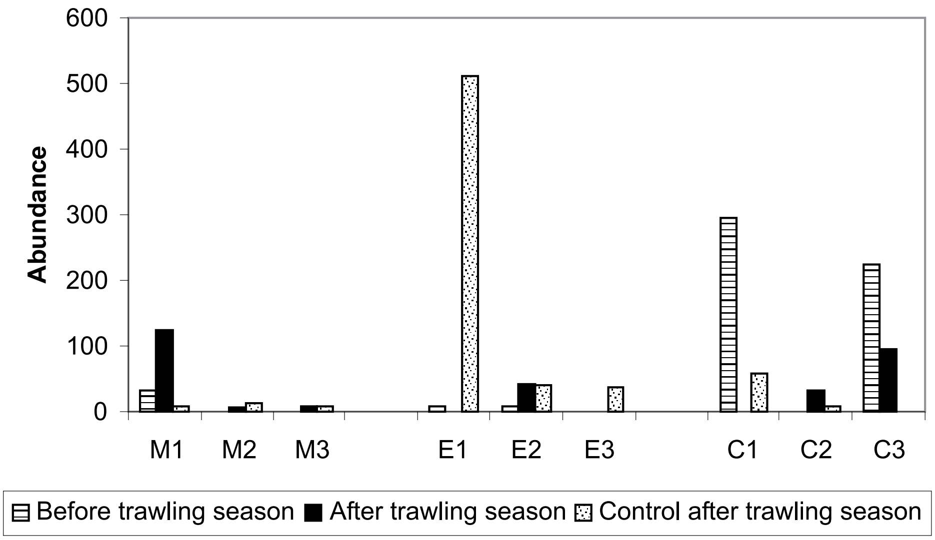
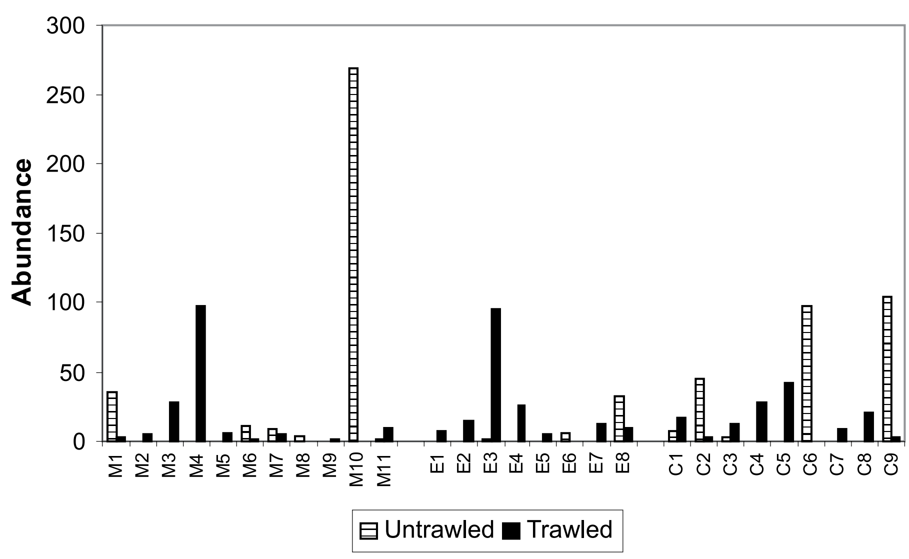


Figure 10: The percentage contribution of abundance of macrobenthic groups (TRIBE, 1997). (Stations UNTR 1, 2, 3, 4 and TR 1, 2, 3 in closed and open for trawling areas respectively).



M1.*Aporrhais serresianus*; M2. *Scaphander lignarius*; M3. *Abra longicallus*
E1. *Leptometra phalangium*; E2. *Ophiura texturata*; E3. *Stichopus regalis*
C1.Parapenaeus longirostris; C2.Alpheus glaber; C3. Solenocera membranacea

Figure 11a: Impact of otter trawling on dominant megafaunal species, South Aegean, (SMITH *et al.*, 2000).



M1. *Acanthocardia echinata;* M2. *Aequipecten opercularis;* M3. *Aporrhais pespelecani;* M4. *Bolinus brandaris;* M5. *Cardida aculeatea;* M6. *Cassidaria echinophora;* M7. *Eledone moschata;* M8. *Illex coindefii*
M9. *Laevicardium oblongum;* M10. *Loligo vulgaris;* M11. *Ostrea edulis*
E1. *Antedon mediterranea;* E2. *Astropecten aranciacus;* E3. *Astropecten irregularis pentacanthus;* E4. *Cidaris cidaris;* E5. *Echinaster sepositus;* E6. *Leptopentacta tergestina;* E7. *Ophiura ophiura;* E8. *Stichopus regalis*
C1. *Dorippe lanata;* C2. *Goneplax rhomboides;* C3. *Liocarcinus depurator;* C4. *Paguristes eremita;* C5. *Pagurus excavatus;* C6. *Parapenaeus longirostris;* C7. *Pilumnus* sp.; C8. *Pontocaris cataphractus;* C9. *Squilla mantis*

Figure 11b: Impact of otter trawling on dominant megafaunal species, Central Aegean, (TRIBE, 1997).

et al., 2000; COGGAN *et al.,* 2001) (Figure 11a and 11b). In addition megafaunal epifaunal predators and both macro- and mega-faunal suspension feeders were found in significantly higher numbers in trawl lane and control stations respectively (SMITH & PAPADOPOULOU, 2005).

Although existing findings exhibited consistent trends, and shown potential for use as ecological indicators, the selection of a suitable *Indicator group or species* will require in depth knowledge of its functional ecology and will be site specific (making between site comparisons difficult).

Summing up, simple whole-community descriptors such as macrobenthic or megabenthic diversity or abundance indices, although equally challenging and demanding in expertise, have less potential for use as ecological impact indicators compared to indicator species or body size indicators (mean length or size spectra). Unfortunately, very little work has been done in Hellas on either body size indicators or more complex linked state (of an ecosystem component or attribute) and pressure indicators, i.e. pressure indicators that account for both frequency of disturbance (pressure) and capacity for recovery and state indicators that have a clear link with fishing pressure (HIDDING *et al*., 2006).

CONCLUSIONS

Developing benthic indicators to study the impact of trawling on the benthic communities and ecosystem have often been hampered by the lack of control (unfished) areas to conduct experimental trawling. Although a number of investigations have been carried out in a variety of Aegean areas and biotopes (e.g. with different depth, sediment type etc), as the response to fishing impacts will vary with environmental variables, most investigations regard the disturbance of small experimental areas for extrapolation of results to the scale of commercial fisheries to be a very difficult task. The lack of large spatial and historical time-series datasets is also critical.

In the case of Rishens indicators used to evaluate the impact of trawling on demersal fish assemblages in the Aegean Sea, although the case study presented here has a preliminary / demonstration role, both indicators (mean length and mean trophic level) examined have shown potential and significant predictive power. Of the two, mean trophic level appears to offer powerful detection of possible trends with smaller sampling sizes and to constitute a more useful indicator. Long-term data analyses are required to determine trends at an initial stage and reference limits at a later stage but fortunately, existing historical datasets are continually "updated" by contemporary annual data collection through the National Data Collection Regulation Program, complying with the requirements set out by Council Regulation (EC) 1543/2000 (DCR).

The development of environmental indicators to study the effects of fisheries on the Hellenic marine ecosystem requires further systematic and comprehensive work as currently such development is based on case studies limited both on a temporal and spatial scale. Despite wide realization of the need to protect the marine environment, halt biodiversity loss and reduce discards and a recently rapidly increasing number of policy initiatives and conventions adapting the Ecosystem Approach to Fisheries (FAO, 2003), progress in the development of suitable indicators to support an EAF is still quite limited worldwide (JENNINGS, 2005).

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ANNEX I

Preliminary set of indicators on the integration process proposed by STECF for the 2005 environmental integration scheme.

Policy Area	Policy questions	Proposed indicators for 2005 report	Second-order indicators
Conservation (of species and habitats)	Are fisheries sustainable in respect of individual fish species?	Proportion of commercial stocks that are within safe biological limits.	Relative abundance of a set of populations that are not regularly assessed but which are decreasing in number.
	Are fisheries sustainable in respect of fish communities?	Average size (length and weight) in the community.	Mean trophic level. Biodiversity indicators. Mean maximum length.
	Is the impact of fisheries on marine habitats and nonfish marine species sustainable?	Trends in abundance of sensitive benthos species.	Area coverage of highly sensitive habitats.
	Is aquaculture getting more environmentally sound?	Total aquaculture production and total area occupied by aquaculture installations.	Eco-efficiency of aquaculture. Potential impact of aquaculture, and particularly on the impact of reared fish (such as salmon) escaping from fish farms, on the genetic structure of wild (fish) populations. Effluent water quality.
Structural measures	Are the structure and organisation of the fishery sector supportive of environmental goals?	Effective fishing capacity (adjusted fishing effort) and its spatial and temporal distribution.	Structural support and proportion allocated to promote environmental friendly fishing practices.
	Is the CFP contributing to good fishing practices?	Mapping of effort distribution over the sensitive areas. Use of environmentally friendly gears.	Oil consumption as a proxy for CO_2 production. Unwanted by-catches of protected species and discards
Policy Area	**Policy questions**	**Proposed indicators for 2005 report**	**Second-order indicators**
Market measures	Are there market measures that respond to demand patterns?	Initiatives to support eco-labelling and use of eco-labels and similar awards. Amounts of fish taken out of the market and/or traded on secondary (intervention) conditions.	Share of fish produced (or consumed) that are eco-labelled. Size of the European market for fish. Proportion of landings covered by catch plans. Changes in consumer preferences in relation to environmental issues.
Horizontal measures	Are the structure and organisation of the fishery inspection sector supportive of environmental goals?	Number of inspections per landing. Number of infringements over number of inspections.	Level of imposition of punishment.
	Is stewardship of stakeholders increasing?	Attitudes and awareness of stakeholders towards CFP environmental goals.	Number of violations (assuming that inspection is efficient).
	Is scientific understanding of complex environmental issues improving in research as well as is the integration of the scientific advice to decision taking.	Total quantity of funds allocated to relevant research and distribution of research funds.	Scientific advice in decision Making. Policy makers' performance.

CHAPTER VII

RESEARCH

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RESEARCH

INTRODUCTION

Fisheries research provides the basis for a rational, scientific approach to the management of living marine resources that allows their sustainable exploitation.

Broadly speaking, research in fisheries can:

- provide scientifically sound information and data to support fishery conservation and management;
- contribute to efforts to reduce by-catch and adverse effects of fishing on essential fish habitats and protected species;
- promote efficient harvest of target species;
- provide scientific information and data to increase long-term economic and social benefits from the living marine resources;
- improve the fishery information management system;
- improve the effectiveness of external partnerships with fishers, managers, scientists, conservationists, and other interested groups to build a balanced approach to meet common fisheries goals.

The current chapter focuses on the research carried out in Hellas to support the rational exploitation of the fishery resources. Such research provides information that helps to refine population estimates, define essential fish habitats (EFH), mitigate the effects of fishing on protected marine organisms and improve exploitation patterns.

The papers deal with a variety of scientific topics including:

- studies on specific species and fisheries, aiming to provide information on the species biology, distribution and dynamics as well as on their fisheries;
- surveys aiming to provide data to support fisheries' independent assessment methods;
- gear selectivity studies aiming to improve resource exploitation patterns;
- methods to identify EFH;
- application of remote sensing and GIS techniques to fisheries, and
- population genetic studies aiming to identify stock structure and boundaries.

The results that are presented are coming from numerous international and national projects, mostly accomplished by HCMR scientists.

George Tserpes

VII.1A. FISHERIES INDEPENDENT ASSESSMENT METHODS: ACOUSTICS

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GENERAL PRINCIPLES OF ACOUSTICS

Acoustics is the science of sound; the theme of fisheries' acoustics is a subject area that refers to hydroacoustic techniques applied to fish detection and fish abundance measurement. The use of hydroacoustics for underwater detection was initially applied for naval undersea warfare but the detection and qualitative assessment of fish abundance has also been an important component of commercial fisheries since World War II. Nowadays acoustic instruments, such as echosounders or sonars, are used to locate fish and monitor gear performance in commercial fisheries. Acoustic methods are applied in fisheries' research to estimate the abundance of fish stocks and record fish behaviour and distribution. Acoustic assessments of fish stocks are becoming increasingly important in the management of many commercial fish stocks (FREON & MISUND, 1999). In Hellas, acoustic methods are being applied for the stock assessment of small pelagic fish since the end of the 1980s as well as for the study of fish behaviour.

The basic function of an echosounder starts with transmission of a high voltage pulse to the transducer which converts the electrical energy to sound pressure that radiates spherically. If the sound wave impacts an object (e.g. fish, plankton or the bottom), which has a density different than that of the surrounding water, a certain amount of the echo wave is reflected and the back-scattered echo is detected by the transducer. The reflected energy is stronger as the difference of density between the object and the water increases. The transducer converts the pressure wave into electrical energy, which is amplified and filtered by the echosounder receiver and gives an output signal that can be measured, visualized and provides information on the target that reflected the echo energy.

The application of acoustics on fisheries' science is based on the aforementioned property of the echo. Although the mean fish density is close to the water density, fish skeletal structures (solid) and swimbladder presence (gas) strongly reflect an echo, because its densities are much higher or much smaller than the water density. The gas in the swimbladder is responsible for more than 90-95% of the total echo reflection. Fishes that lack this organ, such as the Atlantic mackerel *Scomber scombrus*, reflect an echo that is only the 1/10 that of a comparable size swimbladdered species (MISUND, 1997).

The key parameter for acoustic estimations is the quantity of the echo reflected by one (1) fish. This parameter is measured by the Target strength (TS). The TS is a logarithmic measure of the proportion of the incident energy which is back-scattered by the target, expressed in decibels (McLENNAN & SIMMONDS, 1992). The greater the TS, the stronger the back-scattered echo relative to the transmission. The back-scattered echo is directly related to the size of the surface that reflects the echo, i.e. to the size and shape of the fish's swimbladder. Specifically it is related to the size of the geometric projection of the swimbladder to the horizontal surface (cross-section) i.e. the surface that the echosounder "perceives".

As the swimbladder is the anatomical and biological background of the sound reflection, the TS is affected by a series of biological and behavioural parameters that affect the size, the shape and the orientation of the swimbladder. The projection of the swimbladder to the horizontal level depends on (ONA, 1990; McLENNAN & SIMMONDS, 1992; MACHIAS & TSIMENIDES, 1995; 1996):

- The species.
- The size of the fish (bigger fish – bigger swimbladder).
- The orientation of the swimbladder inside the fish.
- The orientation of the fish in relation to the sea level. A change in the vertical orientation with the fish body tilted slightly upwards or downwards, may easily result in a reduction of the cross-section by a factor of 100 (FOOTE, 1980).
- The intestine organs in the vicinity of the swimbladder, mainly lipid tissue, gonads and stomach contents. In sardine *Sardina pilchardus* the volume and the swimbladder cross-section changes mainly in relation to gonad volume and the total lipid content (MACHIAS & TSIMENIDES, 1995; 1996).
- The type of the swimbladder (physostomous

fish reflect one order of magnitude lower than physoclystous fish).

- The vertical position of the physostomous fish in the water column.

The TS is related to the cross-section with the equation

$$TS=10\log_{10}(\sigma/4\pi);$$

where TS is the Target strength in decibels, σ is the acoustic cross-section and its unit is the reciprocal of meters squared, and

$$\sigma= S*(I_b/I_i);$$

where S is the surface that reflects the echo (i.e. the cross-section of the swimbladder), I_b is the intensity reflected by the target back in the direction of the transducer and I_i is the incident intensity impacting on the target (McLENNAN & SIMMONDS, 1992).

Although the echosounder measures the echo in db, the parameter actually used in calculations is the acoustic cross-section which is expressed in m^2. The concept of logarithmic units may seem strange but is common with fields such as electrical engineering (McLENNAN & SIMMONDS, 1992). To calculate the acoustic cross-section equivalent to a given target strength the formula is $\sigma=4\pi 10^{(TS/10)}$.

It is obvious that the swimbladder cross-section (and consequently TS) could not be estimated as a deterministic, but as a stochastic parameter (i.e. as magnitude with an average value and a variance). It has been found that a very good approximation of this stochastic parameter could be obtained by regressing the TS with the $\log_{10}$ of the total length (L) of the fish in cm. In other words, TS=a log L-b; where a, b are species specific constants and a ≈ 20.

Measurement of target strength

Measurements of TS could be made

- on insonified tethered fish;
- with cage measurements on single fish or fish schools that are being sampled acoustically;
- histological, by measuring the swimbladder cross-section (ONA, 1990, MACHIAS; & TSIMENIDES, 1995,1996);
- *In situ***,** based on field measurement of fish.

In practice *in situ* experiments are performed by recording target strength measurements over a period of time within a particular layer or school of fish that it is trawled. Target strength frequencies as well as the length frequencies of the fish species caught are displayed as a histogram. The size modes of fish species from the trawl catch are regressed to the modes of the target strength histogram.

In cases where no other species' specific equations have been estimated, FOOTE (1987) has recommended the use of the general equations TS=20logL-67.5 for the physoclistous and TS=20logL-71.9 for the physostomous fish, based on regression results of *in situ* measurements of TS.

USING ACOUSTICS FOR STOCK ASSESSMENT

The main principle of stock assessment by means of acoustics is rather simple (Figure 1): If we know a) the total echo from a particular species, and b) the echo that an average-sized fish specimen of this species reflects, then an estimation of the fish abundance could be obtained. In addition, knowing the length – weight relationship the estimation of the total biomass can be accomplished. By all means, the calculations and the statistics applied for stock assessment in an area are much more complicated than simply dividing and multiplying numbers.

An optimum practice for stock assessment requires a series of data that should be collected through an efficient sampling design. Specifically, a standard procedure requires:

- a well-designed cruise including predetermined transects to collect echo data;
- a well-calibrated echo sounder;
- the knowledge of a Target strength equation that relates the TS with the fish size;
- the partitioning of echo into species;
- a representative length frequency distribution of each species and a good estimation of the mean fish length regarding the fish sub-populations in the surveyed area;
- an estimation of the length – weight relationship in order to convert the abundance of fish into biomass;

and finally, the calculations should be estimated for the entire area.

ACOUSTIC SURVEY DESIGN, SURVEYED AREAS IN THE HELLENIC SEAS

The survey design is the key issue for the stock assessment. A well-designed survey is the basis for high accuracy and precision of the estimations. Furthermore, a good survey design should take into account the peculiarities of the population (i.e. population density, spatial characteristics, location of fish near boundaries) and the biological characteristics of the species (i.e. plankton or fish, diel migrations, schooling behaviour) that we are investigating.

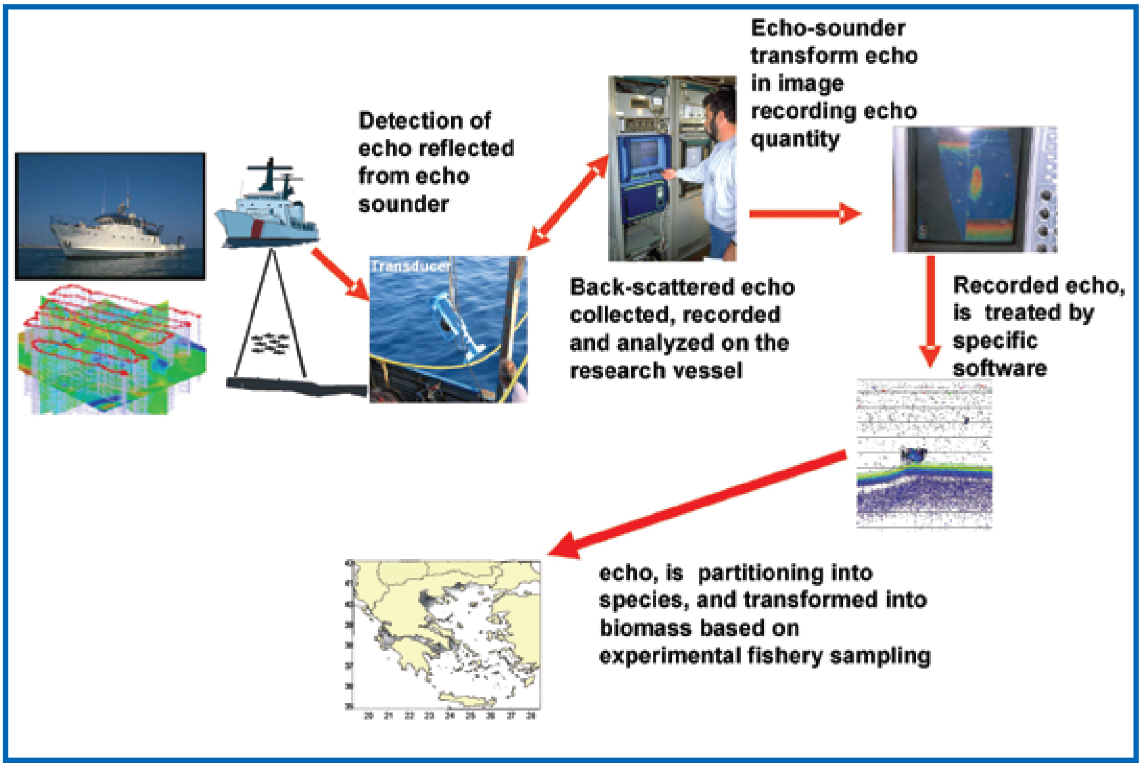

Figure 1: Outline of the methodology followed by the stock assessment by means of acoustics.

Ideally, the entire distribution area of a fish stock must be surveyed if a reliable acoustic abundance estimate has to be obtained. The issues taken into consideration include: time and money availability for the collection of acoustic data as well as the geographical features of the surveyed area (i.e. islands, coastlines, enclosed areas). In addition, the biological and ecological characteristics of the target species could imply the need for different sampling intensity from place to place. So, the cruise track could be decided in advance (i.e. pre-planned regarding the number of transects and the transect spacing, when targeting a good estimate of fish abundance) or adjusted on the basis of observations made during the survey (i.e. adaptive sampling by increasing the number of transects when detecting fish concentrations which might be exploited for commercial fishing).

Cruise track design regarding fish stock assessment includes line transects usually parallel (random or equidistant) and perpendicular to the coastline, or zigzagged in a triangular manner, (MISUND, 1997; Figure 2) when the transect length is small (e.g. small closed gulfs). Transect spacing should be decided on the basis of objective criteria, such as population density, reducing the transect spacing where the fish density is higher that the average.

The acoustic sampling takes place continuously along transects, consequently there is a need to define a sampling unit to use for calculations. The length of the cruise track along which measurements should be integrated to give one sample (i.e. Elementary Distance Sampling Unit-EDSU) should be defined for echo integration and it should be

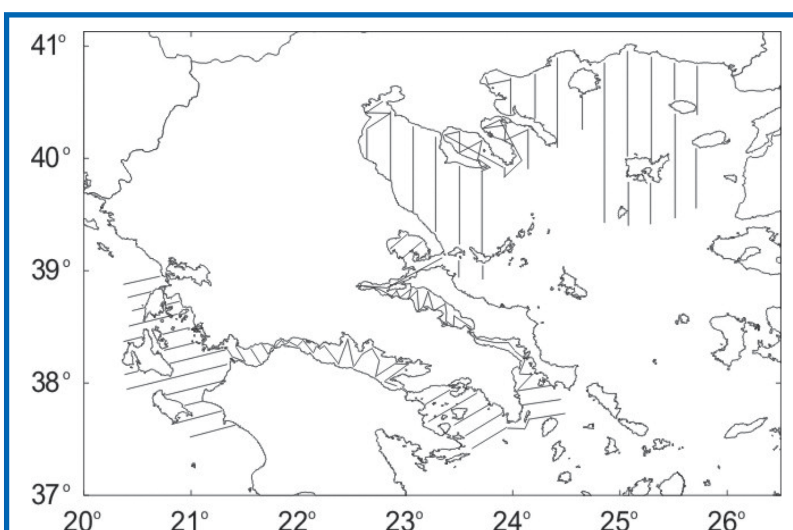

Figure 2: The cruise track design of acoustic transects in the Hellenic Seas.

large enough so that the acoustic data may reasonably considered as a set of independent random samples (McLENNAN & SIMMONDS, 1992). In an acoustic survey the EDSU is usually one nautical mile, but other units (e.g. 0.5nm, 1Km, 2nm, etc.) could also be used.

Acoustic surveys regarding stock assessment of small pelagic fish that have been applied in the Hellenic Seas could give a good example of the different alternatives for survey design due to the peculiar topography of the Hellenic Seas. The survey design was generally based on BAZIGOS 1974 and TSIMENIDES *et al.*, 1989 as shown in Figure 2. The first acoustic surveys in the Hellenic Seas have been conducted in the northern Aegean Sea in 1987-1988, in the central Aegean Sea in 1989-1990 and in the southern Aegean Sea in 1991, all aiming towards the study of the echo-distribution of small pelagic fish assemblages (TSIMENIDES, 1989; TSIMENIDES *et al.*, 1995a, 1995b). Later surveys in 1995-2001 were focused on the estimation of biomass of anchovy and sardine in the northern Aegean Sea and the coastal areas of central Aegean and Ionian Seas in the framework of various European and National projects (MACHIAS *et al.*, 1996; 1997; 2000a,b; 2001; MARAVELIAS *et al.*, 1997; GIANNOULAKI *et al.*, 2001; 2002; 2004a). Acoustic surveys regarding stock assessment of small pelagic fish have been consistently applied since 2003 within the framework of the National Fishery Data Collection (GIANNOULAKI *et al.*, 2006a).

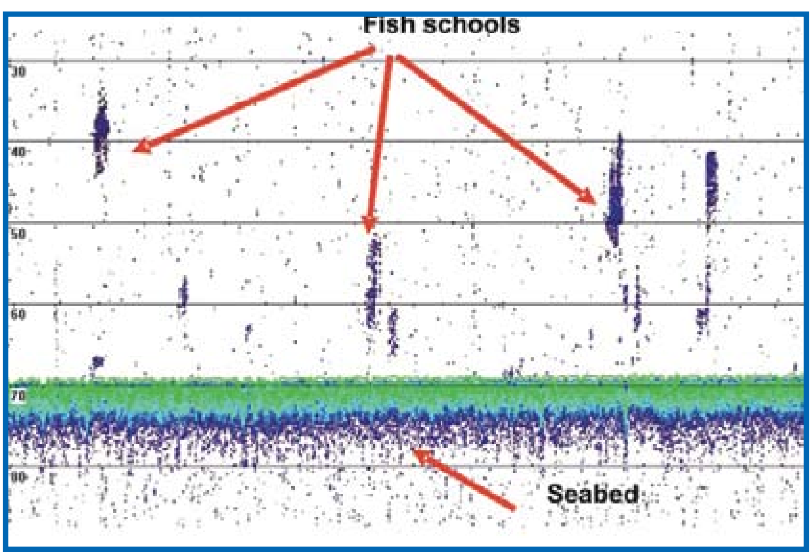

Figure 3: Typical echogram of a split beam echosounder where fish schools and seabed, are shown.

Calibration

The type of echosounder used in the early Hellenic surveys was dual beam and in the latest a split beam. Specifically, the R/V PHILIA was used, equipped with a EK 500 Simrad echosounder 38kHz, a Biosonic Dual Beam echosounder 102 Model 120 kHz and a most recently adapted Biosonic Split Beam DTX echosounder at 38 and 120 kHz. Supplementary to these scientific echosounders, a single beam Furuno echosounder at 38 and 15 kHz has been used as well as a Scanmar RX echosounder. The latter is placed into the opening of a trawl net and serves for scrutinizing the fish catch during trawling. Acoustic data analysis is performed using the SonarData Echoview software.

Calibration of the echosounder is required before and during each echo survey. The need for calibration derives from the systematic deviation of the measurements from the expected ones. These deviations are associated to structural or industrial features, the age of the equipment, the time interval between two surveys and the maintenance of the equipment and could result in highly biased measurements, especially regarding assessment estimations.

In order to overcome this problem the echosounders are regularly calibrated using the standard sphere method suggested by FOOTE (1987). The TS of this standard sphere is known, so the deviation of the equipment is calculated and could be taken into consideration for measurement corrections.

Species identification, echo partitioning into species

The next problem that should be resolved is to identify the echo that derives from fish and subsequently, the partitioning of this echo into fish species. Specifically, the examination of an echogram reveals a number of obvious features such as the seabed or "echo traces" resulting from one or more biological objects (e.g. single fish, fish schools, plankton aggregations, Figure 3) or other, inanimate sources (e.g. oceanographic discontinuities, submerged objects) in the water column (REID, 2000). Therefore, we need to characterize and classify each of these "objects" from an echogram, determine fish and discriminate fish targets into fish species. The basis of school discrimination is the targeted fishing of specific schools in order to identify the species that comprise it, comparing with the school images recorded in the echograms and assign echo traces into species. This is a standard protocol during an acoustic survey and any time that a new or unknown aggregation or type of schools are met, identification with trawling is required. The knowledge of the fish school characteristics obtained by this repetitive sampling could be standardized through several procedures (McLENNAN & SIMMONDS, 1992; REID, 2000; REID *et al.,* 2000).

Echo Trace Classification (ETC) as this process is called, is based on a set of descriptors such as positional (i.e. position in time and space), morphometric (i.e. the shape, height, perimeter, size of a fish school) or energetic (i.e. the acoustic energy of the fish school) or other biological and ecological characteristics such as, time of day, position in the water column, school density as well as the spatial and temporal autocorrelation of fish schools. This is usually accomplished through image processing algorithms or software applied to digital echogram data (REID, 2000). The commercial software SonarData Echoview is routinely used for analyzing the Biosonic Split Beam DT-X echosounder of 38 kHz and 120 kHz data from the Hellenic hydroacoustic surveys that uses the SHAPES algorithm (GOETZEE, 2000) for school identification.

Furthermore, based on school characteristics from acoustic surveys held in the Thermaikos Gulf, a non-commercial software package for ETC has been developed by GEORGAKARAKOS & PATERAKIS (1993) called "School", that processes the EK 500 Simrad acoustic data, provides automatic school and species classification using image processing methodologies and Artificial Neural Network Methods (GEORGAKARAKOS & HARALABOUS, 1993; HARALABOUS & GEORGAKARAKOS, 1996).

Allocation to fish species and size

Two more questions that we have to answer in order to transform echo into fish biomass concern:

- "The mean size of each fish species", in order to apply the target strength equation.
- "The fish mean weight", in order to transform total echo into fish biomass.

This sort of biological information is obtained by the trawl sampling during the survey. Along with echo sampling, a representative trawl sampling at high fish concentrations is required to achieve a good estimation of the length frequency distribution, the mean length as well as the length - weight relationship ($W=aL^b$) of each species. These parameters usually vary between sub-areas of the surveyed region. The mean length is used for calculating the mean TS, the mean cross-section and for transforming the echo into number of fish. The length – weight relationship is used to transform the number of fish into biomass. The mean length of a certain species is estimated as follows:

$$f_j = \frac{\sum_{k=1}^{M}\left(\frac{n_{jk}}{t_k}\right)}{\sum_{k=1}^{M}\left(\frac{N_k}{t_k}\right)}$$

where f_j is the mean frequency of fish at length class j; n_{jk} is the number of specimens at length class j at haul station k; N_k is the total number of fish for the particular species at haul station k; t_k is the duration of the haul at the station k and M is the number of haul stations (McLENNAN & SIMMONDS, 1992).

Echo integration, Echo transformation into fish biomass

In order to estimate fish biomass, the first step is to apply echo trace classification in order to estimate echo abundance (expressed as Nautical Area Scattering Coefficient in m^2/nm^2) for each species and subsequently, produce an integrated echo per each EDSU (i.e. 1 nautical mile). The echo partitioning could be achieved either by classification of the schools into different species as described earlier, or by reduction of the trawl catch into species in the cases of unknown or mixed species schools. According to the second approach the mean echo integral of species i, is given by the equation:

$$E_i = w_i \sigma_i \frac{E_m}{\sum w_i \sigma_i}$$

where w_i is proportional to number or weight of the species i, σ_i is the mean cross-section of species i and E_m is the mean echo integral of the mixed echo.

The density of targets of the species i (F_i) is estimated as $F_i = (K/\langle\sigma_i\rangle)\, E_i$, where K is the calibration factor, $\langle\sigma_i\rangle$ is the mean cross-section and E_i is the Echo integral after partitioning into species (McLENNAN & SIMMONDS, 1992). The $\langle\sigma_i\rangle$ was calculated for the mean total fish length according to the equations $\langle\sigma_i\rangle = 4\pi \sum_{é} f_i 10^{TS/10}$, where f_i is the corresponding length frequency distribution of the species as deduced from the fishing samples.

The next step is to determine the total abundance in the surveyed area. This makes necessary some assumptions, the most important is considering the observed densities along each cruise track representative of a given area around each transect. The abundance Q_k in a sub area k (i.e. a set of transects defining an elementary statistical sampling area), is calculated from the average density within each sub-area according to the equation:

$$Q_k = A_k \sum_i F_i / N_k,$$

where F_i is the density of the targets in i sample; A_k is the surface of each elementary statistical sampling area and N_k are the number of transects sampled in A_k.
The variance V was estimated as

$$V=\sum_i (AF_i-Q_k)^2/[N_k(N_{k-1}-1)]$$

Further to an unbiased estimation of the abundance, the last step is to obtain the most precise estimation. The prior or post stratification of the investigated region into sub-areas, where within each sub-area the variance is minimized, ensures the highest accuracy of the estimations. The total abundance Q_t and its variance are obtained by adding up the results for each region $Q_t=Q_1+Q_2+\ldots$, and $V_t=V_1+V_2+\ldots$. Standard error of Q_t is the square root of V (McLENNAN & SIMMONDS, 1992).

APPLICATION OF GEOSTATISTICS TO FISHERIES ACOUSTIC SURVEYS

The procedure described up to this point in one aspect ignores the spatial-autocorrelation of fish abundance. However, in acoustic cruises data are collected continuously along transects and the spatial auto correlation between them is present and should be modelled. Geostatistics is an appropriate tool for examining the autocorrelation of data (PETITGAS, 1993) and have been widely applied during the last years in fisheries' science. Two steps are generally distinguished in a geostatistical analysis (RIVOIRARD *et al*., 2000):

- the structural analysis which aims in describing and modelling the spatial structure of the variable by means of a structural tool i.e. a variograms, and
- the use of this structure for an evaluation problem (e.g. make a map or compute global abundance with its associated variance).

In fisheries' science these tools are used to analyse the fish spatial distribution and therefore, to optimise the design of sampling schemes and estimate the variance of the fish stock total abundance (PETITGAS, 1993; 1997; MARAVELIAS *et al.,* 1996, MARAVELIAS & HARALABOUS, 1995; BARANGE & HAMPTON, 1997). Intrinsic geostatistics (i.e. where the spatial structure of a variable can be described independently of the geometry of a certain domain, ISAAKS & SRIVASTAVA, 1989) were applied to study the spatial structure of small pelagic populations in the Hellenic seas (MARAVELIAS *et al.,* 1997; GIANNOULAKI *et al.,* 2003; GIANNOULAKI *et al.,* 2004b; 2006b). Intrinsic methods, are based on the variogram as the basic tool for measuring the spatial structure of a variable (e.g. fish echo abundance) allowing for the determination of which spatial scales (small or large scale) are most responsible for the overall variance. Results of geostatistical analysis should be taken into account in order to obtain the best design for an unbiased estimate of the abundance and a minimum variance estimate or a best map of the distribution. For example, in cases where fish density distribution is anisotropic, depending on direction, a line transect survey design should place the group of transects in the direction of the greatest rate of change. Furthermore, spacing in parallel transect should be less than half the transect length; otherwise for shorter distances a zigzag design should be preferred (RIVOIRARD *et al.,* 2000).
Geostatistical methodology applied to make a map or compute global abundance with its variance is called kriging (ISAAKS & SRIVASTAVA, 1989). Kriging is an interpolation estimation method that allows the estimation of the density at an unknown point. It uses algorithms that apply weights when interpolating between known points in order to minimize the estimation variance and assess fish abundance (Figure 4). Weights used, are determined by the spatial continuity as expressed in the variograms model applied.

ADVANTAGES OF DIRECT ASSESSMENT METHODS

An important characteristic for the assessment and management of anchovy and sardine is their short life-span. The bulk of the individuals found in the sea are up to three years old. This feature results in a high dependence of abundance and composition of the stocks on the *in year* successful recruitment. As a result these fish stocks exhibit large fluctuations in population size which varies inter-annually, implying a stronger dependence to environmental conditions in respect to other species.
So, because of all these features catches at age analysis based on VPA like assessments offer little value because the landings are not representative to the age structure of the population at sea and the use of catch per unit effort (CPUE) information, particularly in the absence of fishery-independent methods, is questioned because the

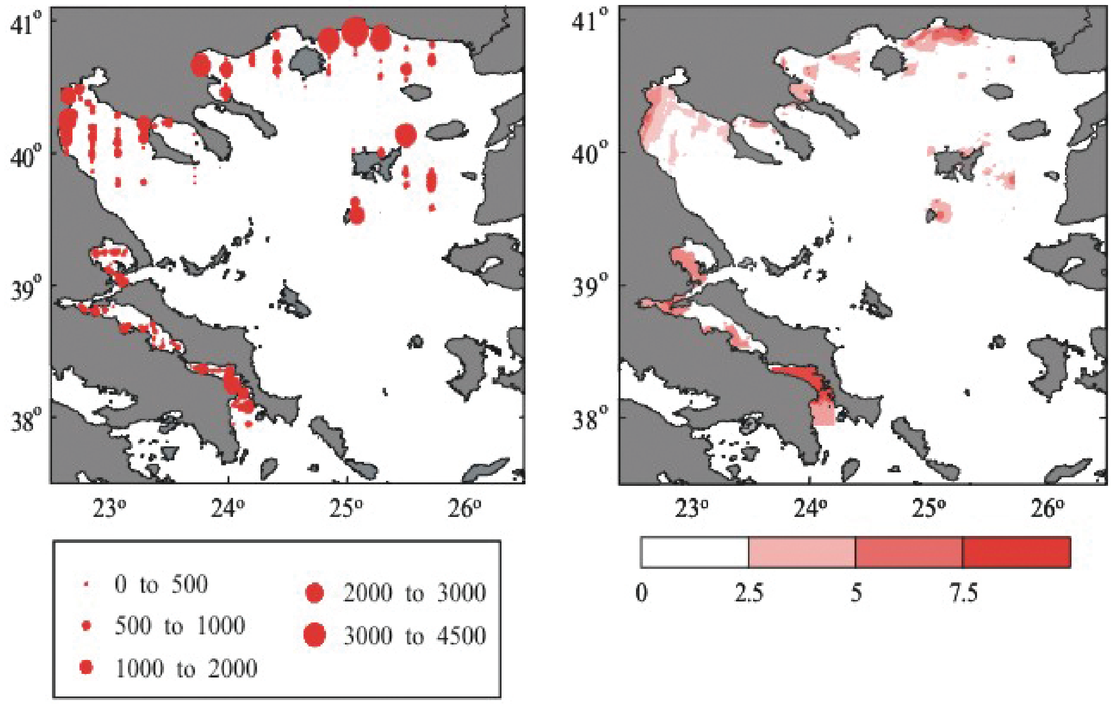

Figure 4: Anchovy. Echo distribution (in NASC) in Hellenic waters based on point map (left) and echo distribution (ln NASC) based on kriging interpolation method (right).

schooling habits of pelagic fish suggest CPUE may not reflect stock abundance. Particularly, in Hellas, where the small pelagics are exploited legally only by the purse-seine fleet and pelagic trawl fishery is banned, there is a bias towards large specimens in landings (see MACHIAS *et al.,* in this volume), implying the need for *in year* monitoring of the stocks through fisheries' independent techniques (e.g. acoustics; Daily Egg Production Method) and science-based management.

One of the weaknesses of the direct methods is the absence of effective reference points for management decisions. For example, the most common reference point of the acoustic method is the *in year* minimum estimated biomass. Therefore, VPA techniques combined with assessments from fishery independent surveys is a very promising approach to overcome problems that derive from both techniques. The data from acoustic surveys can be used to provide information on biomass at-age and numbers at age that can be subsequently used to assess the stocks through an Integrated Catch at Age analysis (PATTERSON & MELVIN, 1996).

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VII.1B. FISHERIES INDEPENDENT ASSESSMENT METHODS: DAILY EGG PRODUCTION METHOD

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The spawning stock biomass (SSB) of an exploited species is an important variable in the management of fisheries. Egg production surveys provide a method of estimating SSB independent of any data on commercial catches and have become very important because of increased demands for fishery-independent information (HUNTER & LO, 1993).

The Daily Egg Production Method (DEPM) is an ichthyoplankton-based method for estimating the SSB of pelagic schooling fish like anchovies and sardines. The method is applicable to batch-spawning species with indeterminate annual fecundity and was developed in the late 1970s by staff of the Coastal Division of the Southwest Fisheries Science in La Jolla, California (LASKER, 1985). Since then, it has been applied to a variety of small pelagic stocks in different ecosystems around the world as well as the Atlantic mackerel (ALHEIT, 1993; HUNTER & LO, 1993, 1997; PRIEDE & WATSON, 1993). The number and kind of applications continue to increase. Besides biomass

Table 1. DEPM spawning stock biomass estimates (SSB, in t) for anchovy and sardine in the Hellenic Seas. Coefficients of variation are given in parentheses.

Region	Year	Species	Month	SSB	Sources
NE Aegean Sea	1993	Anchovy	June	14 002 (0.34)	1, 2, 3, 4
	1995			10 282 (0.22)	5, 6, 3, 4
	2003			17600 (0.220)	7
	2004			6251 (0.247)	7
	2005			16038 (0.205)	8
NW Aegean Sea	1993	Anchovy	June	9 030 (0.38)	1, 2, 3, 4
	1995			8 948 (0.36)	5, 6, 3, 4
	2003			22442 (0.316)	7
	2004			16548 (0.320)	7
	2005			4496 (0.256)	8
Central Aegean Sea	1999	Anchovy	May-June	6 273 (0.435)	9, 10, 4
Central Ionian Sea	1999	Anchovy	June	5 588 (0.331)	9, 10, 4
Central Aegean Sea	2000	Sardine	December	16174 (0.521)	11, 12, 13, 14
Central Ionian Sea	2001	Sardine	January-February	3652 (0.282)	11, 12, 13, 14

[1]TSIMENIDES *et al.* (1995),[2]SOMARAKIS & TSIMENIDES (1997),[3]SOMARAKIS (2005),[4]SOMARAKIS *et al.* (2004), [5]TSIMENIDES *et al.* (1998),[6]SOMARAKIS *et al.* (1997),[7]SOMARAKIS *et al.* (2005),[8]SOMARAKIS *et al.* (2006B), [9]MACHIAS *et al.* (2000),[10]SOMARAKIS *et al.* (2002a),[11]MACHIAS *et al.* (2001),[12]SOMARAKIS *et al.* (2001),[13]SOMARAKIS *et al.* (2002b),[14]SOMARAKIS *et al.* (2006a).

estimation, the application of DEPM provides a regional time-series on important biological variables of fish stocks, which can lead to new insights into their reproductive biology, particularly when such variables can be compared among species and stocks or habitats and seasons (ALHEIT, 1993, SOMARAKIS *et al.,* 2004, 2006a).
The DEPM is based on the simple model:

$$SSB = P_0 A / (R / W) S F$$

where SSB is the spawning biomass for area A, P_0 is the daily egg production at age 0-day per unit sea surface area, W is average weight of mature female, S is the fraction of mature females spawning per day (spawning frequency), F is the batch fecundity (number of eggs produced per female per spawning event), A is area size and R is the female fraction of the biomass (weight-specific sex ratio). Up to 2001, the DEPM had been applied experimentally to different anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) stocks in the Hellenic Seas but since 2003, it has been used regularly for the yearly assessment of the northern Aegean Sea anchovy stock (Table 1).
The application of DEPM requires two concurrent surveys: (a) a plankton survey for the calculation of daily egg production and spawning area, and (b) an adult survey for estimating the parameters W, R, F and S (Figure 1). In the Aegean Sea, a combination of research-vessel and commercial-fleet adult samples (from purse seiners) is used in an effort to allocate more samples in areas where stock density is higher. Details on sampling designs and estimation of egg and adult parameters and their variances can be found in SOMARAKIS *et al.,* (2002, 2005, 2006b).
The plankton, hydrographic and pelagic trawl sampling is carried out onboard the research vessel PHILIA. Standard vertical plankton tows are made using a WP2 plankton-net and vertical profiles of temperature, salinity and fluorescence are sampled with CTDs.
Adult samples are processed in the laboratory and female gonads are used to estimate batch fecundity and spawning frequency. The latter parameter is the most laborious since it involves the histological analysis of large numbers of ovaries (Figure 2). Anchovies spawn at around midnight in June. After the release of eggs, cell layers, that surrounded eggs during their growth, are left in the ovary and identified in histological sections as irregular structures, known as postovulatory follicles (POFs). The POFs start to degenerate soon after spawning and can be used to assign fish as to the date of spawning, based on time of sampling and degree of degeneration. Hence, the fraction

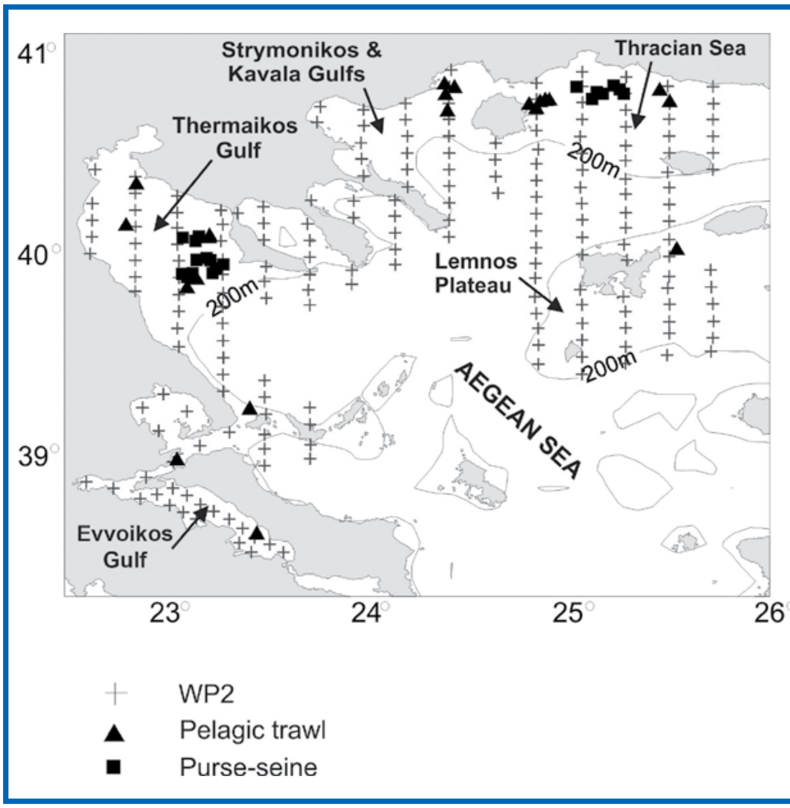

Figure 1: Anchovy DEPM survey, June 2004. Egg sampling stations (WP2 vertical tows) and adult fishing locations. A combination of experimental pelagic trawl samples and commercial purse seine samples are used for adult parameter estimations.

of females spawning each night can be reliably estimated.
From the plankton and hydrographic sampling, data required for the estimation of the daily egg production are gathered but also important information on the location and persistence of spawning grounds (Figure 3). For example, from the yearly DEPM applications to the northern Aegean Sea anchovy stock since 2003, three main spawning aggregations have been identified: (a) The Thracian Sea aggregation, distributed in waters that receive the direct influence of the Black Sea water (Figure 3), (b) the Thermaikos Gulf aggregation, inhabiting the semi-enclosed and productive Thermaikos Gulf, and (c) the north Evvoikos Gulf aggregation, with fish located in a highly enclosed area, also known to be productive. These three areas are likely to exhibit discrete retention mechanisms for larval anchovy because of hydrological (e.g. the Samothraki Gyre in the Thracian Sea, NIKOLIOUDAKIS *et al.,* 2005) and topographic characteristics (i.e. high land enclosure). Such features are important

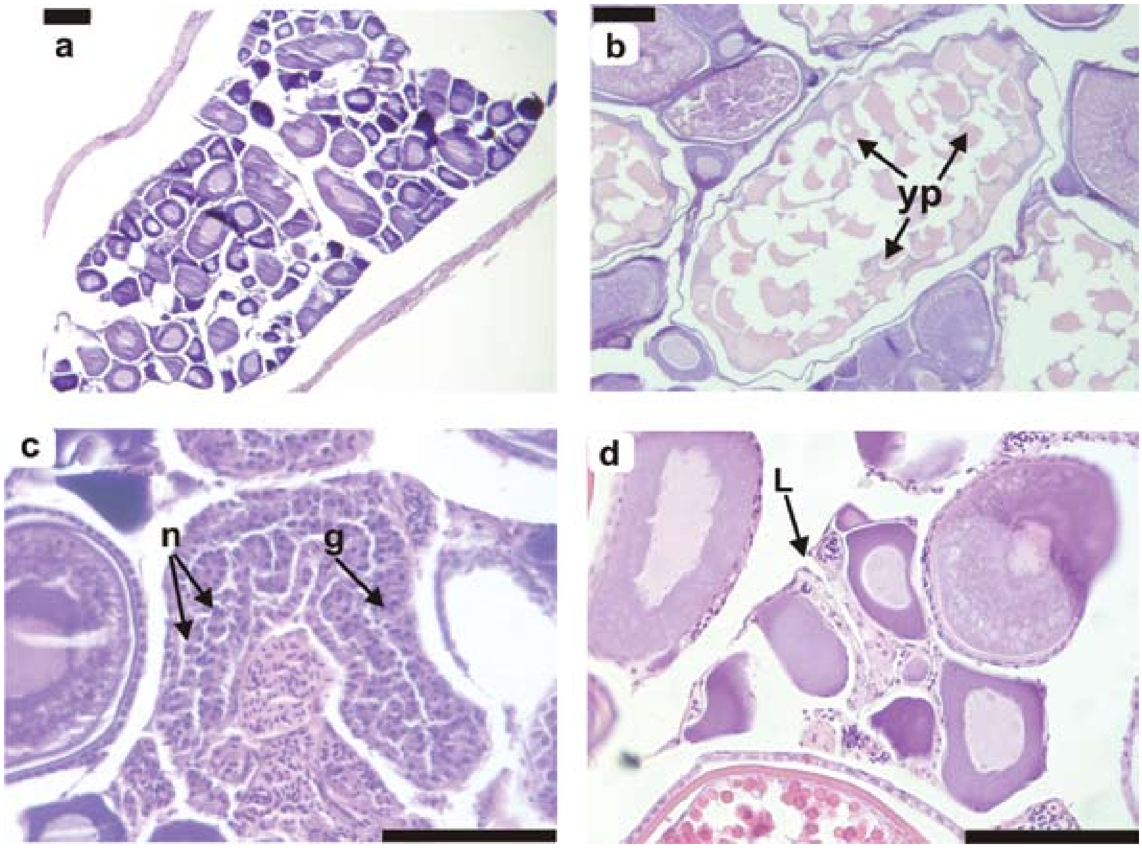

Figure 2: Spawning frequency (the fraction of females spawning each night) is determined with histological methods based on the degree of degeneration of postovulatory follicles (POFs) in relation to time of spawning, time of collection and water temperature. (a) Inactive anchovy gonad. (b) Hydrated oocyte; Hydrated gonads are used for the estimation of batch fecundity. (c) A postovulatory follicle (POF) immediately after spawning (midnight). (d) A degenerating POF of about 24-hrs old. yp: yolk plates. n: nuclei. g: granulosa cells. L: lumen. Black bar: 0.1 mm.

for stock structure and population integrity.

Data from DEPM surveys can help in improving our understanding of the mechanisms by which environmental changes could modulate the reproductive biology and subsequent survival of early life history stages of small pelagic fish. The characterization of suitable spawning habitats (Figure 4) and further investigations on their response to physical forcing will greatly improve our understanding and predicting ability of fluctuations of the stocks.

Estimates of anchovy reproductive parameter accumulated from the DEPM surveys in the Hellenic Seas show high inter-annual and inter-regional variability (Figure 5). This is true for the whole Mediterranean Basin (SOMARAKIS *et al.*, 2004) and has been attributed to spatial and temporal (seasonal/inter-annual) variability in biological production. Egg production can directly be affected by recent and current food intake, as suggested for the NE Aegean Sea stock: When comparing June 1993 and

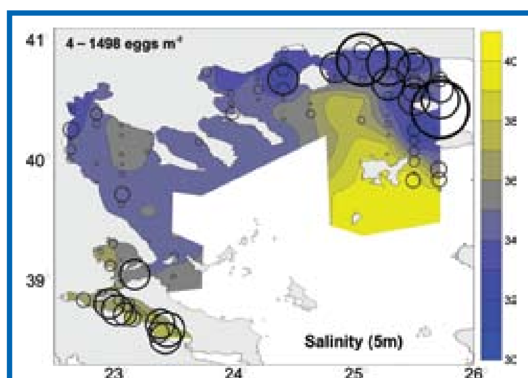

Figure 3: Anchovy DEPM survey, June 2004. Distribution and abundance of anchovy eggs (discs, proportional to abundance) in relation to surface salinity. Most eggs were found in the low salinity (<34) Black Sea waters over the Thracian Sea continental shelf (eastern part of the surveyed area).

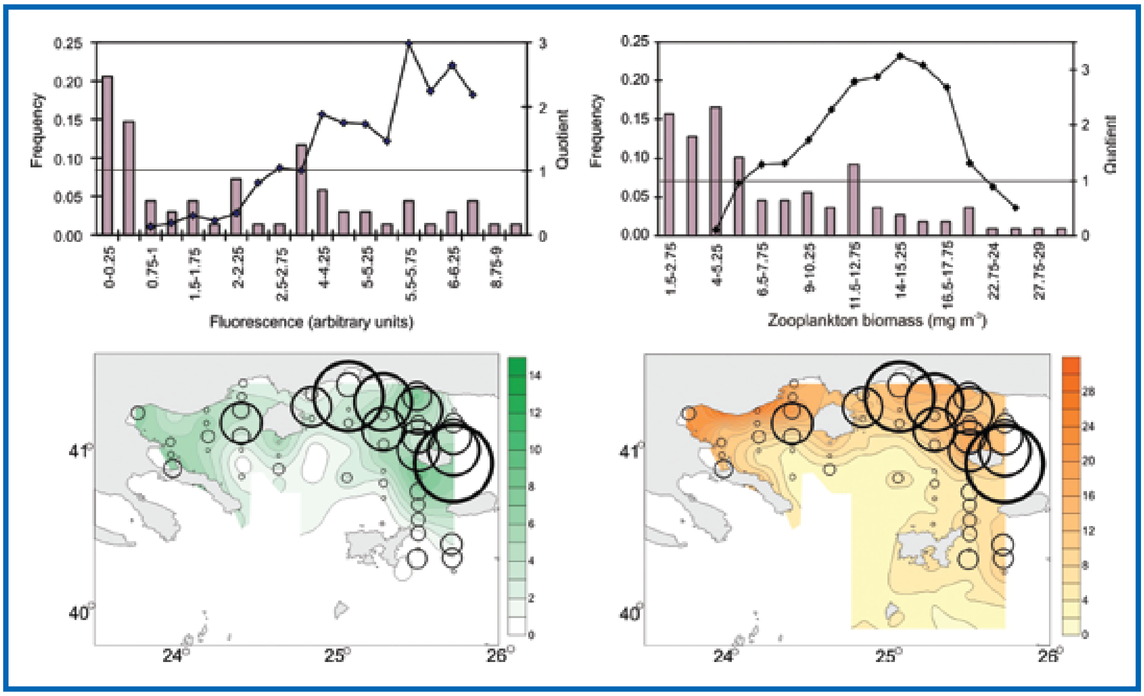

Figure 4: Anchovy DEPM survey, June 2004. Upper panel: Quotient analysis for egg abundance in relation to Chl-α concentration (fluorescence) and mesozooplankton biomass. Histograms are variable distributions. Lines are quotient curves. Horizontal lines indicate a unit quotient value; quotient values above this indicate positive selection and below this indicate negative selection (SOMARAKIS *et al.,* 2006a). Lower panel: Abundance of anchovy eggs (discs) in relation to horizontal distribution of fluorescence and zooplankton biomass. Spawning anchovies select the low salinity Black Sea waters (see also Figure 4) which are rich in food for both adults and their offspring.

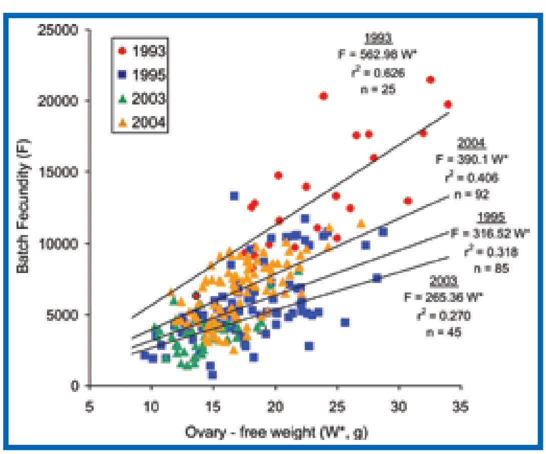

Figure 5: Batch fecundity (number of eggs produced per spawning) – on – ovary free weight relationships for different DEPM applications to the NE Aegean anchovy stock. Anchovy adult parameters, such as batch fecundity, show marked interannual variability that has been attributed to trophic conditions (SOMARAKIS, 2005).

June 1995, SOMARAKIS (2005) showed that adult food availability (mesozooplankton) was higher in 1993, when waters were significantly cooler and fresher, and concurrently, female anchovies were in better condition, producing numerous eggs at a higher spawning frequency (short inter-spawning interval). These observations were consistent with a ration-related reproductive tactic in European anchovy.

In examining the correlation between the estimates of the daily egg production and respective estimates of daily specific fecundity for anchovy stocks in the Mediterranean, Bay of Biscay and upwelling areas (SOMARAKIS *et al.,* 2004), a significant isometric relationship emerges for European anchovy applications (Mediterranean and Bay of Biscay) (Figure 6a). In upwelling areas, the daily egg production estimates are relatively high for a narrow range of generally low daily specific fecundities. Furthermore, there is a strong linear relationship between spawning stock and spawning area for anchovy in European waters which does not differ significantly between the Bay of Biscay and the Mediterranean Sea (Figure 6b). These two relationships imply a density dependent use of the spawning habitats by anchovy in European waters

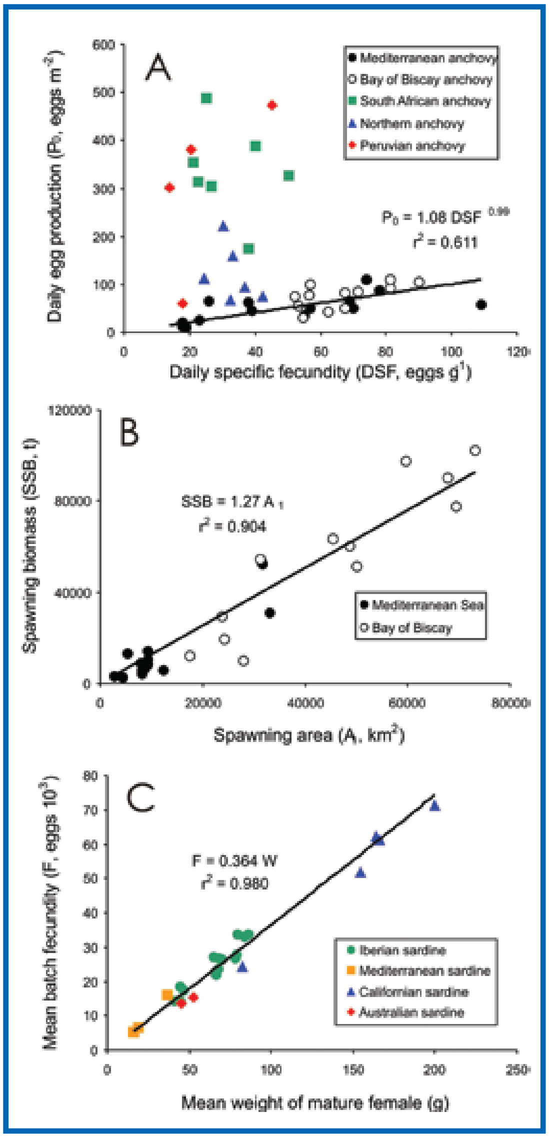

Figure 6: Examples of meta-analysis of parameters from DEPM applications on anchovies (*Engraulis*) and sardines (*Sardina* and *Sardinops*) around the world. (a) and (b): anchovies. (c): sardines (redrawn from SOMARAKIS *et al.,* 2004 and 2006a).

(SOMARAKIS *et al.,* 2004).

A similar meta-analysis of DEPM parameters for *Sardina* and *Sardinops* stocks around the world (SOMARAKIS *et al.,* 2006a) reveals a highly significant linear regression between mean batch fecundity (F) and mean weight of mature female (W) (Figure 6c). The strength of the observed relationship suggests that batch fecundity of the average mature female in the population is mainly a function of its size, regardless of stock, subspecies, species or genus. Furthermore, the relationship implies that, during the peak of the spawning season, mean relative batch fecundity (F/W) is fairly constant for sardine in all ecosystems around the world. In other words, the weight-specific fecundity of a 16g sardine (genus *Sardina*) in the extremely oligotrophic eastern Mediterranean Sea is, on average, very similar to a 200g sardine (genus *Sardinops*) in the California current system.

FUTURE DIRECTIONS

The application of DEPM is believed to greatly improve stock assessment and our understanding of fundamental processes acting on population variability of small pelagic fish in the Hellenic Seas. The aims of future work are directed towards:

- The use of DEPM spawning stock biomass estimates for the northern Aegean anchovy stock accumulating in recent years to tune suitable stock assessment models for the yearly evaluation of the status of the stock. This will be a step forward, improving scientific advice and the management of this important fish resource of the eastern Mediterranean.
- The use of time-series on the distribution and abundance of pelagic fish eggs to characterize and predict spawning habitats and daily egg production in relation to the physical and biological environment. The GIS and satellite technology and the application of advanced modeling techniques are expected to substantially help in this effort.
- The use of all physical and biological data collected during the DEPM surveys to improve our understanding of the factors that control reproductive effort of anchovy and sardine in the Mediterranean Sea. The variability observed in reproductive parameters of the stocks is markedly high and likely to significantly affect recruitment and population variability of pelagic fish in the Mediterranean.

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VII.1C. FISHERIES INDEPENDENT ASSESSMENT METHODS: VIDEO

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INTRODUCTION

The crustacean *Nephrops norvegicus* (scampi, Norwegian lobster, Dublin Bay prawn, karavida) is found on muddy bottoms from 80 - 600 m depth. In the Mediterranean it is one of the most important commercial crustacean species of the mixed demersal fishery for shrimp (*Parapenaeus longirostris*) and hake (*Merluccius merluccius*). It is primarily fished through trawling, although there are some very localised fisheries using traps and nets.

Traditional analytical stock assessment methods rely on analysis of long-term trends in fishery data, particularly, length and age-based assessments. The assessments require detailed data (e.g. population structure, age, recruitment, mortality) and make a number of assumptions (e.g. homogeneity of stock, equal capture availability, year to year normalised behaviour). The data must be provided by port sampling (amount and size structure of landings), at-sea observations on commercial vessels (catch and discards) and research cruises. These types of data collection are quite limited in Hellas especially the landings and observations due to the lack of infrastructure, diffuse nature of landings and the nature of management (non-quota based).

Fishery independent surveys, have become an increasingly useful tool in the assessment of *Nephrops* stocks in northern Europe (ANON, 2001). One such method is the use of a towed underwater TV. This method exploits the fact that individual *Nephrops* live in recognisable burrow structures that can be identified and enumerated, thus resulting in quantified video estimations of burrow density. A burrow structure or complex consists of two or more openings linked by sub-surface tunnels with at least one wide opening angled in from the surface. The video methodology depends on adequate sampling of the ground (e.g. stratified random sampling), accurate burrow recognition, and a satisfactory strategy for counting burrows. With knowledge of the extent of the *Nephrops* ground, numbers and biomass can be estimated for the whole ground.

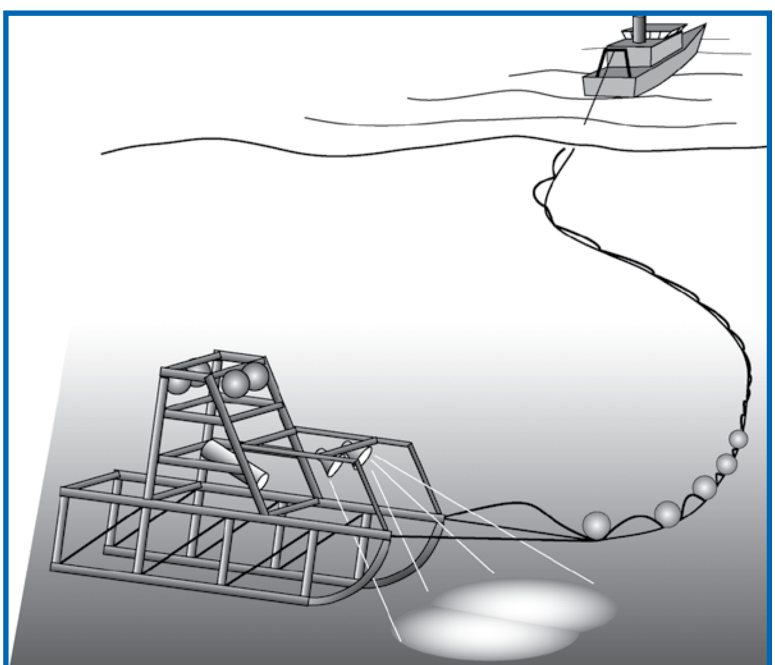

Figure 1: Towed underwater video sled used for estimates of *Nephrops* densities.

METHODS

Estimations of *Nephrops* densities are made from video recordings along the seabed (Figure 1). The video sled used was a modern Marine Laboratory design (SHAND & PRIESTLY, 1999). The sled has a low light sensitive camera, mounted facing obliquely forward with integral lighting. The camera view is precalibrated against the seabed by filming a measured grid attached to the front of the sled before the start of operations. The sled was towed from the stern of the research vessel on a trawl warp (12 mm) to which the electrical cables of the camera and lights were attached by quick release ties. Video recordings are made continuously from the time the sled touches the seabed. Position of the towing vessel is recorded every 5 minutes (GPS position) and the output from the TV camera was recorded on videotape (S-VHS), together with a time signal. The distance covered during each 5-minute section could be calculated and with the calibrated fixed view, the area viewed could also be calculated. A trained observer is able to identify individual *Nephrops* burrows (Figure 2) and the density of burrows can, therefore, be estimated. Whilst it is not always easy to identify occupied burrows, the presence of an individual in the opening or a well maintained entrance indicates current occupation. Burrow entrances

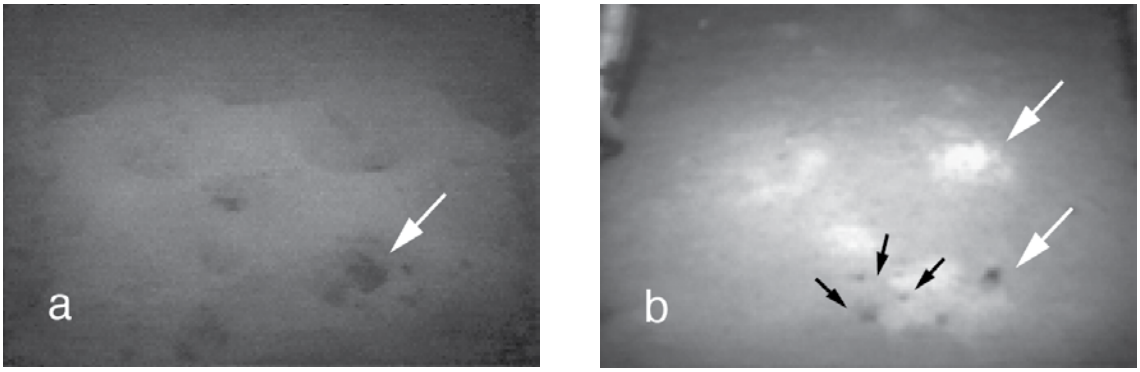

Figure 2: *Nephrops* burrows: a) Pagasitikos Bay, 86 m. *Nephrops* burrow visible (white arrow) in front of *Cepola rubescens* burrows; b) Skiathos, 450 m, white arrows mark opening of small *Nephrops* burrow next to burrow of *Calocaris macandreae* (black arrows).

that show erosion or collection of material (sediment detritus, litter, etc.) are less likely to be occupied. Mean burrow densities can be calculated in a specific area by averaging sequential 5 minute sections. If a trawl is conducted in the area, the average size and weight of individual Nephrops can be estimated. Density estimates in an area can, therefore, be converted into total weights within a known geographical area (Nephrops ground). Additionally, error limits can be applied considering different levels of burrow occupation (e.g. 100, 75% occupation).

RESULTS

The video sled methodology has been used in three separate campaigns (Table 1) over the last decade. The latter two campaigns were targetted studies to develop the technique for Hellenic waters. The 1996 study (published in SMITH *et al.,* 2003a), looked at a number of *Nephrops* populations in the northern Aegean, at both low and high density. Densities were variable between grounds with similar intermediate densities observed in Limnos, Thasos, Skyros and Skiathos, high densities in Mytilini and Pagasitikos and very low densities in Evvoikos (Figure 3). There was a strong correlation found between Nephrops abundances estimated from video counts and from trawl estimates (r^2=0.8098, P<0.005). Video counts were found to be higher than the trawl counts, especially at the higher density grounds, whilst at the very low density grounds (Evvoikos), the values were closer. Burrow distribution over the ground was either random or aggregated.

During the latest study, repeat sampling was carried out in the Pagasitikos Bay at a number of sampling stations (reported in SMITH *et al*., 2003b). This allowed contour diagrams of density estimates to be made for the bay during different seasons (Figure 4). The results showed that there was seasonal variability across the bay, in particular, very low estimates for February 2000. Other observations on video during this period included many areas of seabed covered with a detrital flux and in a few areas bacterial mats, implying low oxygen. During the period of the study there were 22 small fishing vessels fishing *Nephrops* in the Bay. Integrating the total density of *Nephrops* in the Bay and relating this to landings indicated that annual removal by the fishermen was 1.5-2% of the stock.

DISCUSSION

The methodology for a fisheries independent stock assessment of *Nephrops* by towed underwater video has been approved by ICES and is in routine use in northern European waters (BAILEY *et al.,* 1993, ANON., 1994, TUCK *et al.,* 1997, Marrs *et al.,* 1998, TUCK *et al.,* 1999). The technique has been extended and proven for Hellenic waters (SMITH *et al*., 2003a, 2003b). It was noted in the results that video counts were found to be

Table 1. Studies undertaken in Hellas on the fishery independent stock assessment of *Nephrops*.

Area	**Purpose**	**Project Reference**
W. Skyros Island	Technique Proving	ANON, 1994
Mytilini, Limnos, Thasos, Skyros, Skiathos, Pagasitikos, N. Evvoikos	Technique Testing	MARRS *et al*., 1996
Pagasitikos Bay	Seasonal stock assessment	SMITH *et al*., 2001

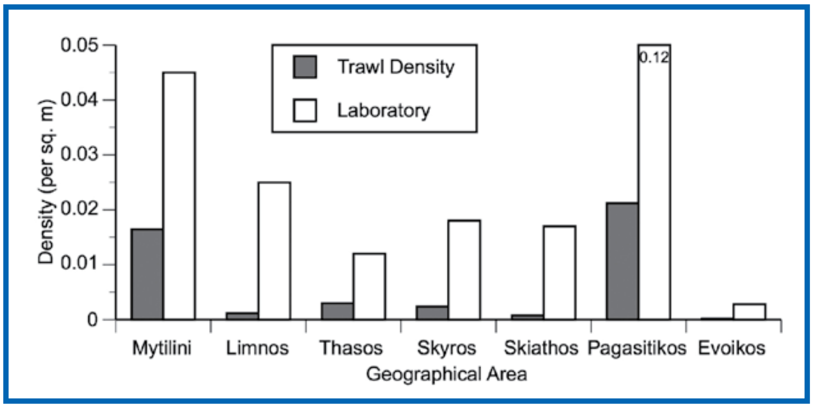

Figure 3: Density of Nephrops on different trawl grounds in the northern Aegean from trawl estimates and video counts.

higher than trawl counts. Trawl counts were only done from one trawl per area so the variability of this parameter is not known. However, the video counts are, in all probability, more accurate as trawl catch estimates are based on those individuals that are caught and a significant part of the population may still be present but not available due to their burrowing lifestyle. Their catchability also depends on daily light/dark cycles in shallower waters (more individuals on the sediment surface at night), seasonality (more individuals at the surface during the summer) and reproductive cycles (females remain more in the burrow over winter when carrying eggs). The video technique is highly dependent on the skill/experience of the observer in being able to identify a *Nephrops* burrow complex (burrow recognition keys given in MARRS *et al.*, 1996) and ascertain if it is occupied. Detailed occupancy criteria have, however, been defined based on diving and casting work (MARRS *et al.*, 1996). To cover the possibility of operator error, results are normally given as two values, reflecting 100% and 75% burrow occupancy. The technique also depends to a certain extent on the spatial and density distribution of the *Nephrops* population, so the estimates should be based on a comprehensive sampling programme.

GAPS IN KNOWLEDGE

The technique has been reasonably well proven for density estimates, however, more work needs to be done to understand the variability across *Nephrops* grounds (distributions and occupancy) and also to relate the size of the burrow structure

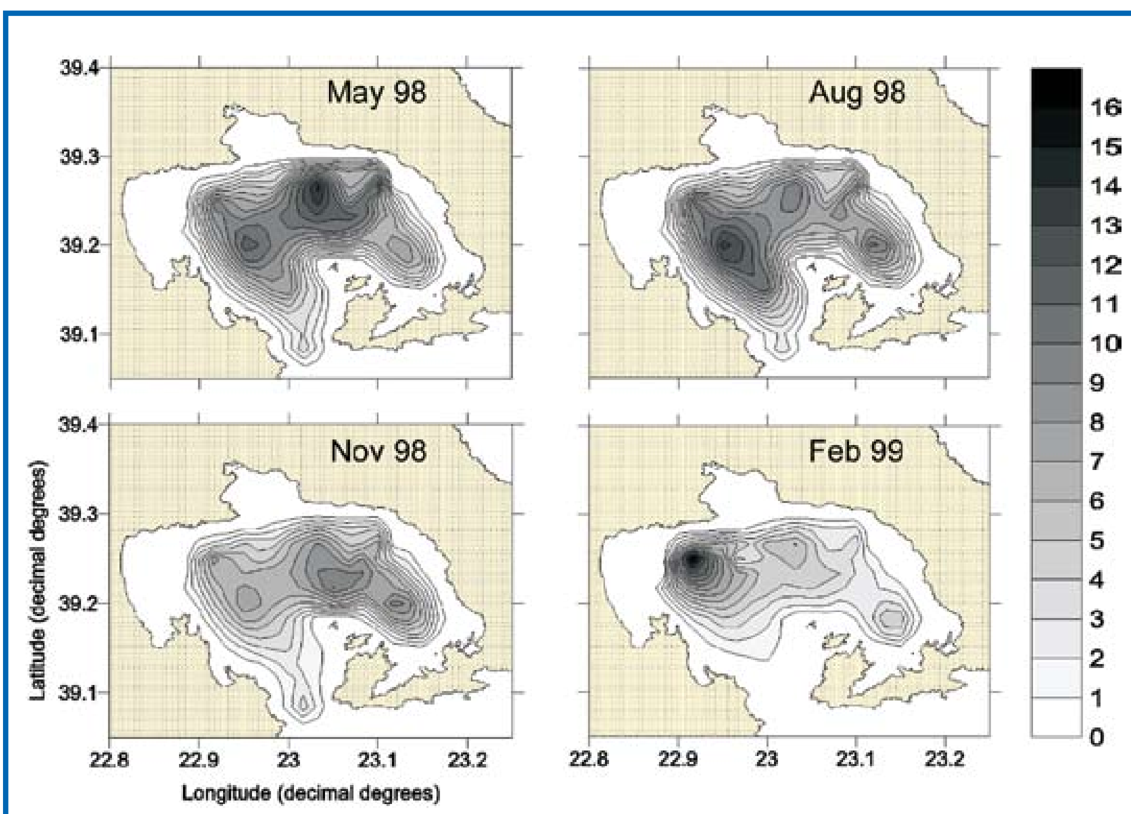

Figure 4: Contour plots of *Nephrops* burrow density (mean density of *Nephrops* burrows 100 m^{-2}) across Pagasitikos Bay over time. Darker shading represents higher densities (SMITH *et al.*, 2003).

to the size of the individual inside. There is also an interest to try and automate the system of estimation with computer recognition and counting of the video material. This is perhaps more relevant to those areas where there is statutory use of the method for stock assessment (northern European waters), it would free the need for expert observers and be more objective, but would be very difficult to accomplish.

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VII.1D. FISHERIES INDEPENDENT ASSESSMENT METHODS: DEMERSAL SURVEYS

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TRAWL SURVEYS AND THEIR IMPORTANCE FOR MONITORING POPULATION TRENDS IN THE MEDITERRANEAN

The objectives of trawl surveys are either the exploration of an area in terms of the distribution and relative abundance of fishes, the commercial feasibility of various gear and fishing methods, or the stock monitoring and resource appraisal (SAVILLE, 1977). Demersal trawl surveys form also an integral part of the fish stock assessment process.

Trawl surveys designed to monitor changes in the distribution, abundance, and structure of multispecies fish populations over a period of years, usually include the use of standardized trawl gear and regular annual or seasonal sampling over the entire region inhabited by the targeted fish stocks, taking into account their migration patterns. The principal objective of monitoring surveys is to help assess the effects of fishing on the stocks by providing quantitative measures of the fluctuations in the relative abundance and structure (age and length) of major stocks, which are free of the many sources of bias inherent in commercial fishery statistics (GROSSLEIN, 1969), such as misidentification, discarding and misreporting.

An important advantage of monitoring surveys is the completeness of catch records. Commercial vessels often discard many species and especially small fish (pre-exploited sizes), whereas research vessel surveys can provide information on the total species' composition and size range available to the trawl. Cod-end fine mesh liners are used in demersal surveys, resulting in the catch of small individuals and small species not normally caught in commercial gears. Predictions of recruitment to the major commercial stocks can often be made from trawl surveys, as well as a much more complete evaluation of production potential and composition of the total fish biomass (GROSSLEIN *et al*., 1980). Surveys can also provide valuable information on the relation between fish distribution and environmental factors. Finally, trawl surveys can provide a wide variety of important biological data (e.g., size distribution, maturity, spawning season and areas, scales or otoliths for age and growth studies, stomach contents), which may not be available from commercial fish landings (GROSSLEIN & LAUREC, 1982).

In the Mediterranean, the main demersal fisheries are localized on narrow continental shelves along the coasts. Experiences during the last decades in this area have shown that it was difficult to obtain a global estimate of the demersal resources from fishing activity, especially due to the very large dispersion of the landing places, the important diversity of the gears and species caught and the scarceness of reliable statistics (FARRUGIO *et al*., 1993; PAPACONSTANTINOU & FARRUGIO, 2000). Commercial fishing practices change in response to market demand as well as to weather conditions or fish availability, and therefore, commercial catch-per-unit-effort data seldom provide reliable indices of absolute population abundance. In addition, changes in commercial gears and fish detection methods occur from time to time, resulting in changes in catchability, which are difficult to measure. Properly conducted trawl surveys on research vessels are free of such biases because they use strictly standardized trawls and fishing methods, and because trawling is done at random (or systematic) pre-selected locations. Many demersal resources in the Mediterranean are considered as heavily or over-exploited (PAPACONSTANTINOU & FARRUGIO, 2000). To support the sustainability of these fisheries, through the application of a common fishery policy in the Mediterranean, there is need for standardised information on the status of these resources. Such information can be provided through trawl surveys that follow a standardized sampling scheme.

Though bottom trawl surveys are in many cases a necessary supplement to commercial fishery statistics, they cannot provide information on the size and composition of the commercial catch, which is critical to any stock assessment. However, some indicators of the fishing impact on fish populations and communities can be estimated from time series data of scientific surveys (e.g. population abundance and average length, community total biomass and number, average length and weight, size spectrum), and the trends in these indicators can be utilised for management advice (ROCHET *et al*., 2005). In addition, in cases that

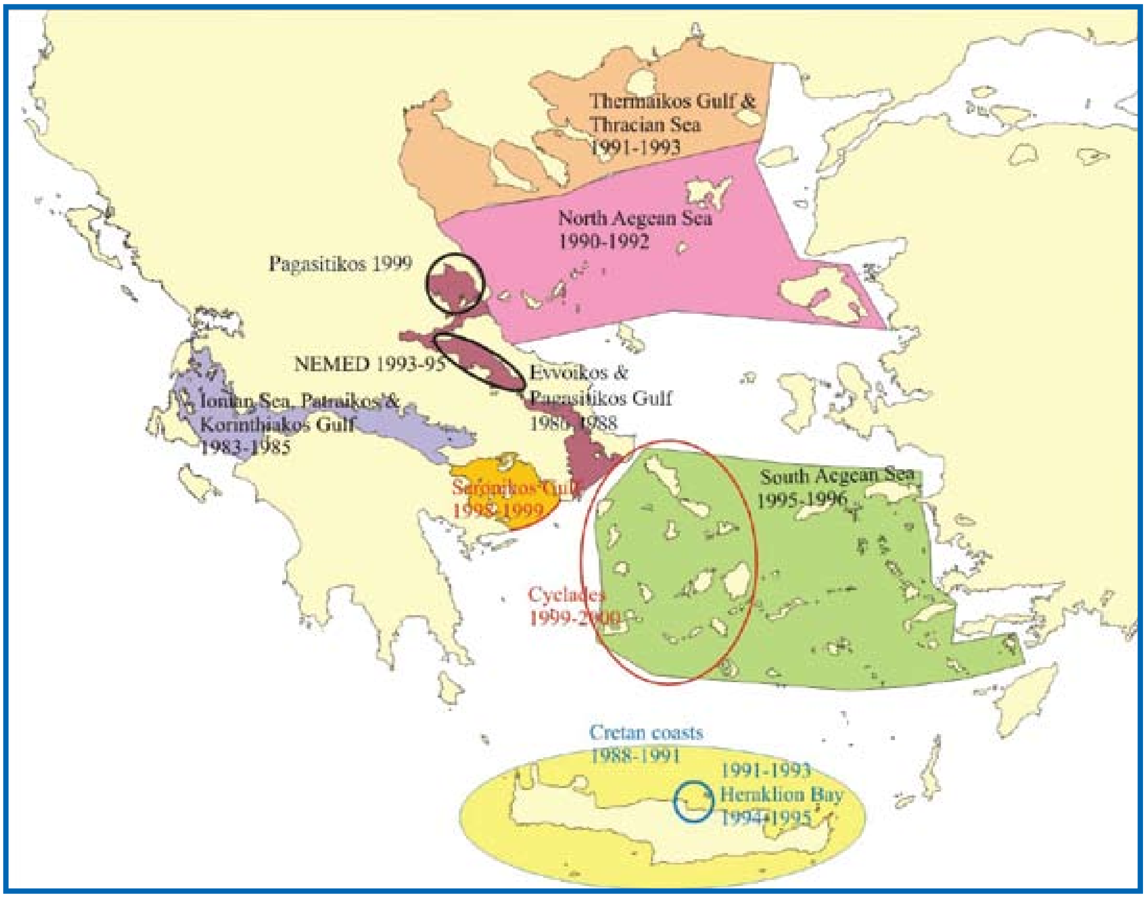

Figure 1: Map showing the areas studied during the regional trawl survey projects carried out by the different institutes in Hellenic waters. (Black letters: programmes of NCMR, Blue letters: programmes of IMBC, Red letters: programmes of LFTA).

the available data from commercial fisheries are sparse and their reliability is questioned, survey data are essential for the accomplishment of stock assessment studies. This is a very important issue for most of the Mediterranean commercial fisheries, where long-term monitoring projects are generally lacking. In any case, care must be taken to make the best use of available resources in a proper mix of sampling commercial catches and conducting trawl surveys.

REGIONAL EXPERIMENTAL TRAWL SURVEYS CARRIED OUT IN THE HELLENIC SEAS

The demersal fisheries' resources of different areas of Hellenic waters were initially investigated in the framework of various trawl survey programmes of limited duration (mostly two years long with seasonal or monthly samplings). During these programmes data were collected on the abundance, biology, ecology and population dynamics of the commercially important and the most abundant demersal species (Table 1). The state of the stocks was assessed using mostly the yield per recruit approach.

More specifically, these trawl survey projects carried out by the different Hellenic Institutes are the following (Figure 1):

- 1983-1985: Dynamics of demersal fish populations in Korinthiakos and Patraikos Gulfs and the Ionian Sea. NCMR/Greek Ministry of Agriculture.
- 1986-1988: Dynamics of demersal fish populations in Evoikos and Pagassitikos Gulfs. NCMR/Greek Ministry of Agriculture.
- 1988-1991: Study of the demersal fish species in the coasts of Crete. IMBC/ Greek Ministry of Agriculture.
- 1991-1993: Study of the demersal fish species in the Heraklion Bay. IMBC/ Greek Ministry of Agriculture.
- 1994-1995 Pelagic benthic coupling in the Eastern Mediterranean Sea, Mediterranean targeted project I (CINCS) Demersal fauna of Iraklion Bay, Crete. IMBC/EC CT-94-0092)
- 1990-1992: Investigation of the abundance

Table 1. Summary of the data collected during the different regional trawl survey programs carried out in the Hellenic Seas.

Area-Programme	Duration	Sampling periodicity	Depth (m)	Target species	Parameters estimated	References
Ionian Sea, Korinthiakos & Patraikos Gulfs	2 years: 1983-1985:	Seasonal	<400	*Merluccius merluccius* *Mullus barbatus* *Pagellus erythrinus* *Micromesistius poutassou*	Abundance-CPUE, lfd, age-growth, length-weight relationship, reproduction-fecundity, diet, Z-F-M-E	24, 25
Evvoikos & Pagasitikos Gulfs	2 years : 1986-1988	Seasonal	<250	*M. merluccius* *Mullus barbatus* *P. erythrinus* *Pagellus acarne* *M. poutassou* *Trisopterus minutus capelanus* *Nephrops norvegicus*	Abundance-biomass, lfd, age-growth, length-weight relationship, reproduction, diet, Z-F-M, MSY, Y/R	28
Coasts of Kriti	4 years: 1988-1991	Seasonal	<350	15 fish species	Distribution, abundance indices, age-growth, Z, F	11, 20, 21, 22, 23, 37, 38, 39, 40
Irakleio Bay	2 years: 1991-1993	Monthly	<350	15 fish species	Distribution, abundance indices, age-growth, diet, Z, F	11, 20, 21, 22, 23, 37, 38, 39, 40
Irakleio Bay, Cretan Sea	2 years: 1994-1995	Seasonal	50-1000	Demersal resources	Distribution, abundance, lfd	12
N. Aegean Sea	2 years : 1990-1992	Seasonal	<550	14 species (fishes, cephalopods, crustacean)	Abundance-biomass, lfd, age-growth, length-weight relationship, reproduction, diet, Z-F-M, Y/R	26
Thermaikos Gulf & Thracian Sea	2 years : 1991-1993	Seasonal	<450	16 species (fishes, cephalopods, crustacean)	Abundance-biomass, lfd, age-growth, length-weight relationship, reproduction, Z-F-M, Y/R	30
Evvoikos Gulf - NEMED	2 years : 1993-1994	Monthly	<350	*N. norvegicus*	Lfd, growth, reproduction-fecundity, diet, genetics, trawl selectivity, Y/R	2, 35

(continued)

Table I (continued)

Area-Programme	Duration	Sampling periodicity	Depth (m)	Target species	Parameters estimated	References
S. Aegean Sea	2 years : 1995-1996	Seasonal	<650		Abundance-biomass, lfd, age-growth, length-weight relationship, reproduction, diet, Z-F-M, Y/R	29
Pagasitikos Gulf	1 year: 1999	Seasonal	<100	*M. merluccius* *Mullus barbatus* *P. erythrinus* *Pagellus acarne* *Lophius budegassa* *Zeus faber* *Dentex maroccanus*	Abundance-CPUE, lfd-age distribution, reproduction, Z-F-M	4
Saronikos Gulf	1 year: 1998-1999	Monthly	<200	9 species (fishes, cephalopod)	Distribution, abundance-CPUE, lfd, reproduction, growth, Z-F-M, Emax/Ecur	13, 14, 15, 16, 17, 18, 19, 41
Kyklades	1 year: 1999-2000	Bimonthly	<450	9 species (fishes, cephalopod)	Abundance-CPUE, lfd, reproduction	14, 19

and distribution of demersal stocks of primary importance to the Greek fishery in the North Aegean Sea. NCMR/ EC MA-1-90.

- 1991-1993: Stock assessment of the demersal fisheries stocks with commercial importance in the Thermaikos Gulf and Thracian Sea. NCMR/EC ΕΠΕΤ/ΣΠΑ.
- 1993-1994: *Nephrops norvegicus*: Comparative biology and fishery in the Mediterranean Sea (NEMED). ICM-NCMR/EC MED/92/008
- 1995-1996: Development of Greek Fisheries: assessment of demersal fish stocks of commercial importance in the S. Aegean Sea. NCMR/EC ΕΠΕΤ II/ΕΚΒΑΝ.
- 1999: Development of an integrated policy for the sustainable management of the Pagassitikos Gulf. ANEM-NCMR/Greek Ministry of Environment.
- 1998-1999: Study of fish stocks in the Saronikos Gulf. Laboratory of Fisheries Technology and Applications of the Greek Ministry of Agriculture.
- 1999-2000: Study of fish stocks in the Cyclades Islands. Laboratory of Fisheries Technology and Applications of the Greek Ministry of Agriculture.

MEDITS PROGRAMME

The MEDITS programme (International bottom trawl survey in the Mediterranean) was organized with the instigation of the European Commission (Directorate of Fisheries, 1993), to support the Common Fishery Policy in the Mediterranean. Thus, a standardized observation network on demersal resources of the area was developed. The objective was to contribute to the fisheries' monitoring system in the Mediterranean by organizing regular large-scale bottom trawl surveys and producing assessments of the demersal resources to serve as references for their sustainable management. The programme began in 1994 with four partner countries (Spain, France, Italy and Hellas) and the surveys have been conducted along their coasts. From 1996, almost all the Adriatic Sea was covered with the additional participation of Slovenia, Croatia and Albania. Since 1999, the south of the Alboran Sea has been included in the survey programme with the Moroccan contribution, and the waters around Malta have been surveyed since 2000. In 2005, the participation of Cyprus permitted the expansion of the surveyed area around its coasts.

The surveys in Hellenic waters are carried out by three teams: 1) Institute of Marine Biological

Resources (IMBR)/HCMR-Athens in the Ionian Sea and the Argosaronikos area, 2) IMBR/HCMR-Kriti in the Southern Aegean Sea and 3) Fisheries Research Institute (FRI)/ NFAD- Kavala in the Northern Aegean Sea. IMBR of Athens undertakes the National Coordination of the project. The international coordination is ensured by the Coordination Committee, which is composed of the national coordinators of each country, and by the Steering Committee, which is constituted of the regional coordinators.

At the beginning of the project common standardized sampling protocols were adopted by the partners. The protocols included the design of the survey, the sampling gear (feature and handling), the information to be collected and the management of the data (i.e. data format, standardized analyses). The "Manual of protocols" agreed by the Steering Committee of the project was distributed to the participants before the first survey. This manual, which was published later to ensure its distribution (ANON., 1998), has been established from different experiences and particularly from those of the IBTS Group (ICES, 1992). The protocols were amended when necessary in the following years.

The bottom trawl surveys cover all the trawlable areas of the shelves and upper slopes, from 10 to 800 m depth. The sampling area is stratified by depth (strata: 10-50 m, 50-100 m, 100-200 m, 200-500 m, 500-800 m) with random distribution of hauls within each stratum (Figure 2). The same haul positions were kept each year. Haul duration is fixed to 30 min at depths less than 200 m and 60 min at depths higher than 200 m. The sampling gear is a bottom trawl designed for this purpose (IFREMER-Sète) with a codend stretched mesh size of 20 mm (Figure 3). All surveys take place in summer. As much as possible, the same vessel was used every year in each area. A list of 36 common target species was defined taking into account their commercial importance, their accessibility to a bottom trawl and their potential interest as biological indicators in the different areas. Collected information on each of these species (26 fishes, 6 cephalopods and 4 crustaceans) includes the total number of specimens, total weight, length frequency distribution and sex (including stage of sexual maturity according to the MEDITS protocols) (Figure 4). The total number and weight is also recorded for a complementary list of 22 species (19 fishes, 1 cephalopod and 2 crustaceans).

The raw data are stored in computer files by each team in charge of the survey in each area using standard exchange formats, which include five standard file types: TA (haul data), TB (catches by haul), TC (biological parameters), TD (temperature

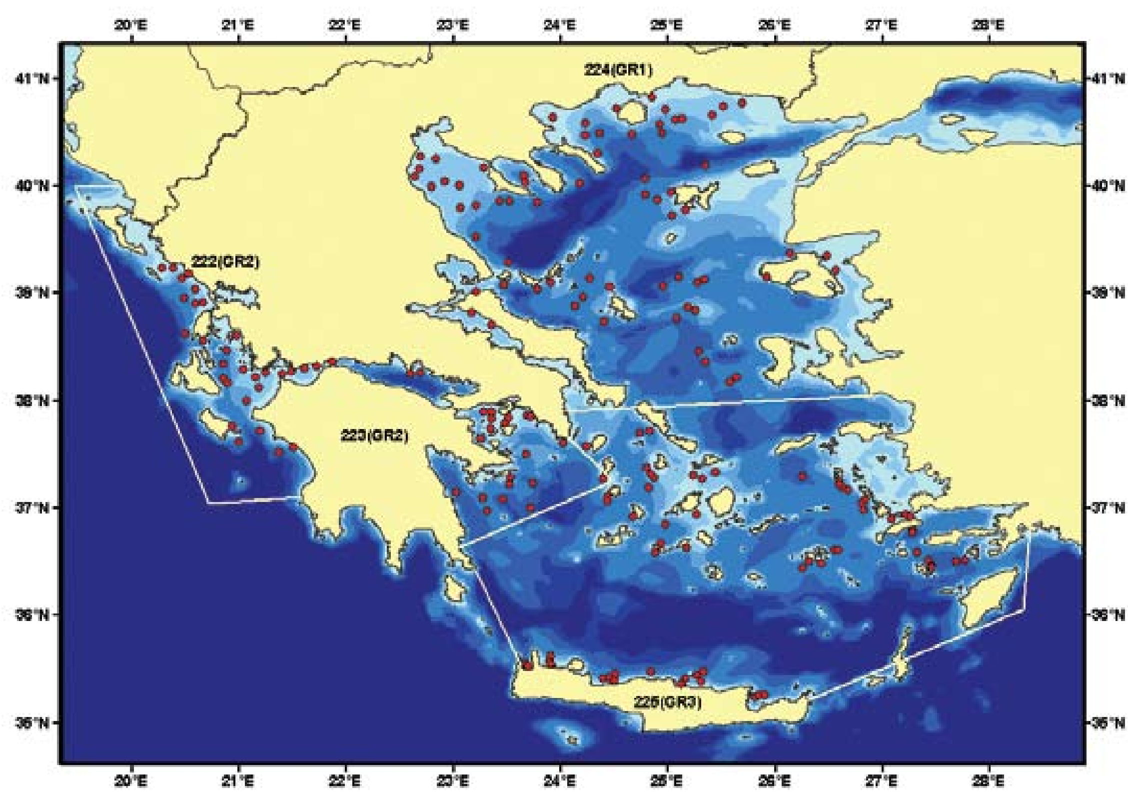

Figure 2: MEDITS-GR programme's study areas with sampling stations.

data) and TR (stratification scheme). An automatic checking of the data is done by each partner using specific software developed for this purpose (SOUPLET, 1996a). The data were regrouped for a second validation at an international level (IFREMER- Sète) until 2001 or at a national level, after the incorporation of MEDITS in the National Projects for Data Collection 2002-2006 (EC regulation 1543/2000). The standard analyses produced every year include biomass and abundance indices (in kg/km^2 and number of specimens/km^2) and length frequency distributions by target species and stratum. The analyses are made using specific software (SOUPLET, 1996b), which was included later in the MEDITS Data Management System (EC/NCMR Contract No 96-016).

Furthermore, specific results obtained from the project concerning the properties of the fishing gear and the biology and ecology of the species caught in each area were presented during an international symposium held in Pisa in 1998 (BER-

Figure 3: Sampling gear designed for the surveys of MEDITS programme.

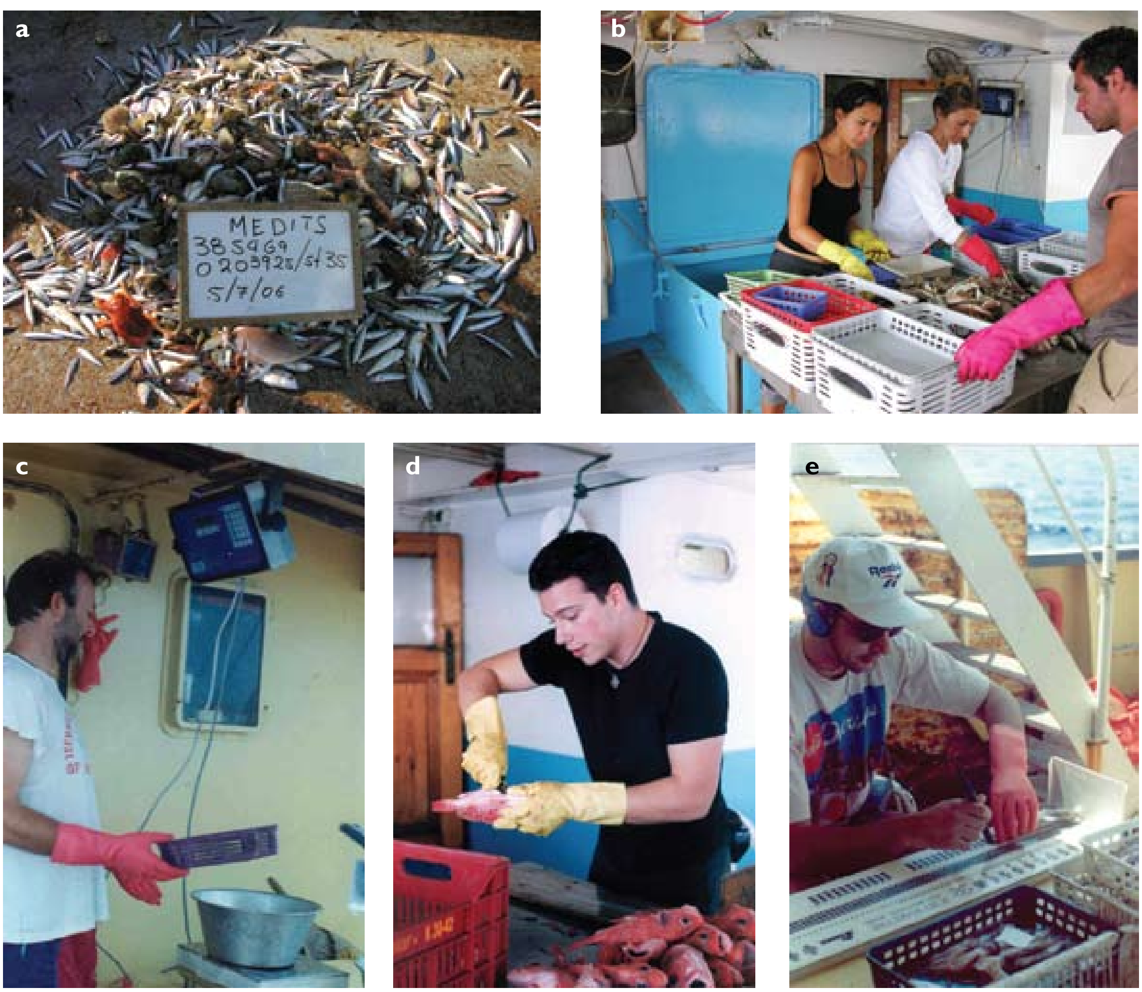

Figure 4: Scheme of the work on board per haul: a) collection and b) sorting of the different species caught, c) weighing per species, d) examination of sex and maturity of target species and e) length measuring.

TRAND & RELINI, 2000). An additional analysis of the MEDITS data obtained until 1999 was made in the framework of the project SAMED (Stock assessment in the Mediterranean- EC/SIBM Contract No 99/047). A special issue of the journal Scientia Marina was also devoted to a series of articles concerning spatial and temporal trends of the MEDITS target species and other contributions based on this programme (ABELLÓ *et al.*, 2002). In the framework of the MEDITS 2000-2001 project three sub-tasks were defined in order to study the following subjects using the data obtained until then: species assemblages, nursery areas and statistical analysis of temporal trends. Finally, in 2004, a MEDITS working group was organized with the aim to (1) select sets of indicators relevant to assess population and fish communities in the Mediterranean, (2) apply them to the whole MEDITS series in order to evaluate their potential as assessment tools and (3) produce preliminary assessments. A meeting of the group was held in Nantes (France) in March 2005 for a first data analysis and discussion. Specific software was developed to perform all calculations and produce the relevant figures (ROCHET *et al.*, 2004). During a second meeting held in Kavala (Hellas) in April 2006 amendments were made on the indicators and it was decided to produce a scientific report. During the same meeting further ways of exploitation of the MEDITS data time series were explored in order to contribute to the stock assessment of the Mediterranean demersal resources.

CONCLUSIONS

Regional programmes are useful for monitoring the demersal resources of specific areas and follow the seasonality of their biological parameters. However, their usually short duration supposes the steady state of the stocks and does not permit the observation of their trends during the years. On the other hand, an extended internationally standardised trawl survey programme of long duration like MEDITS, although it loses in detail (seasonality, specific areas), is indispensable for the study of the dynamics of the stocks in a large spatial and temporal scale especially in the Mediterranean, where long-term monitoring surveys are lacking and commercial fisheries statistics data are poor. A further exploitation of the results obtained during MEDITS and a combination with those obtained from other sources, especially with the different fishery data collected in the frame of the UE-DCR, will improve our knowledge on the fisheries resources and will be useful for the CFP.

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VII.1E. FISHERIES INDEPENDENT ASSESSMENT METHODS: TAGGING

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INTRODUCTION

Tagging in fisheries is a procedure of capturing fish, marking them with some kind of distinguishing tag, releasing them into the sea and recovering data on them.

Tagging of fish started a few centuries ago (ROUNSFELL & EVERHART, 1953). Since these early attempts, which were scattered and unorganized, tagging of fish developed very slowly. Before the 20th century, tagging experiments were carried out mainly on salmon, sea trout, plaice and cod, using primitive tags, like incisions or cutting holes in their fins. Large scale tagging was only carried out after 1919 on several of the major commercial demersal fishes (JAKOBSSON, 1970).

The main goals of tagging operations are the investigation of migration patterns, growth rate and fishing mortality. The need or desire to gain information on fish migration was without doubt responsible for the initiation of all the earlier tagging experiments. Examination of the migration patterns is very important, not only for the study of fish biology, but also for population dynamics and management, as they are related to the identification and mixing of the stocks and their spatiotemporal distribution.

Tagging experiments have so far provided the only opportunity of measuring the growth of individual fish in their natural state over a precisely known period of time. This method was particularly valuable during the early stages of marine biological studies especially for the confirmation of age estimations based on the annual rings of bony structures and scales. However, more specific issues related with growth rate can be investigated through tagging experiments, such as possible spatial-temporal variability in growth patterns.

Regular planned tagging experiments on certain fisheries can give estimates on fishing and even natural mortality of the targeted fish population. Additionally, estimates on the stock availability to the fishery can be obtained.

TAGS AND TAGGING TECHNIQUES

The key elements of tagging operations are: a) the capturing, tagging and releasing of the fish in the most appropriate way, b) the recovery of the tagging information.

The tagging design is always related to the main objectives of the study carried out. During the capturing, tagging and releasing of the fish, it is important to use a way of capture that is not harmful for the fish. The tagging operation should be completed in a few seconds. While the tagging occurs the fish should be kept in the most comfortable conditions, depending on the species. Also, applicators and tags should be disinfected before use.

The recovery of the tagged information is usually achieved through fisheries, so the existence of a fishery for the specific species is important, in order to have opportunities for recoveries. An extended advertising campaign to the people involved in the fishery of the species gives the opportunity to maximize the chances for reporting recaptures.

Other important factors to be considered are: the tag shedding rate, i.e. the rate of detached or destroyed tags before the recapture of the fish and the tagging mortality, (the percentage of tagged fish that die after their release, due to handling during tagging). If significant shedding or tagging mortality is not accounted for, it can result in substantially fewer tagged fish than are thought to be available for recapture. Failure to account for tagging mortality can result in a negative bias in estimates of exploitation rate and positive bias in estimates of population size.

During the past years a large number of different tagging techniques have been used. Their success has varied and the types used extensively are now relatively few. Nowadays, three main types of tags are used for fish tagging: conventional, chemical and electronic tags.

Conventional tags are mostly plastic external tags, in various shapes: spaghetti-like, labels, collars etc. (Figure 1), which are attached to the fish's body by darts or hooks and have numbers and other information on them. In some cases, *chemical tags* are used together with conventional tags. Chemical tags are usually injected into the fish's flesh and

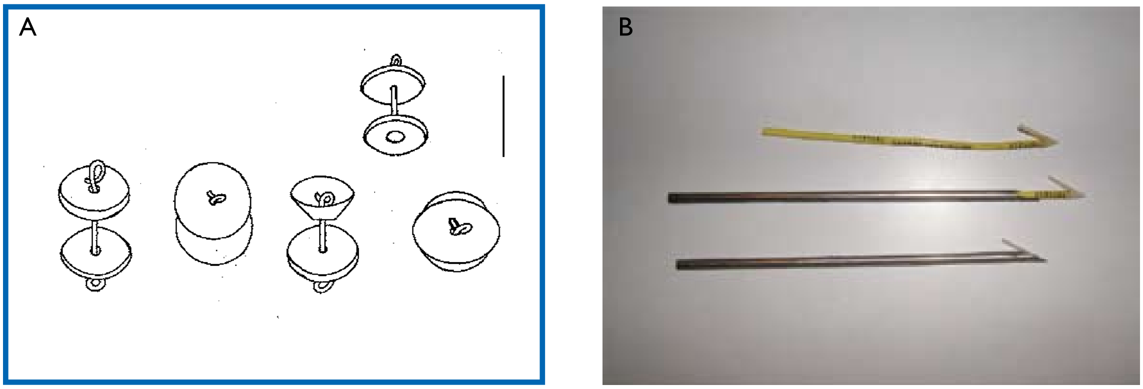

Figure 1: A: Button and disk tags, B: "Spaghetti-type" conventional tags and applicators.

mark some parts of the fish's body. For example, an oxytetracycline injection has been used in tuna tagging experiments. It is incorporated into the hard parts of the fish and form marks which can be seen under ultraviolet light, when the fish is recovered (WILD & FOREMAN, 1980).

Development of new technologies helped the improvement of tagging. New types of tags, the so-called *"electronic tags"* have been employed in tagging experiments in recent years:

- *Acoustic tagging* has been used successfully to study the fine scale movement, thermal physiology and behaviour of individuals of a number of migratory species (CAREY & LAWSON, 1973; LAURS *et al.,* 1977; DIZON *et al.,* 1978; CAREY & OLSON, 1982; YONIMORI, 1982; HUNTER *et al.,* 1986). Acoustic studies primarily focus on collecting data from a single fish equipped with the ultrasonic tag.
- The *archival tags* or data storage tags have been used to study marine mammals and other migratory species' movement and behaviour (DELONG *et al.*, 1992, BLOCK & STEVENS, 2001). Archival tags are basically miniature computers incorporating microprocessors, memory and a suite of environmental and physiological sensors (Figure 2). They have sensors capable of measuring variations in light, depth and temperature and data can be collected over many years. Archival tags would fill the gaps existing between the very short-term and detailed data collected by acoustic tracking studies and the single points of release and recapture provided by the conventional tagging. Some serious limitations remain, as recapture and return of tags depend on fishermen.
- The *pop-up satellite tags* have been mainly employed in order to solve the problem of the low recovery rates of conventional and archival tags for many highly migratory species (tunas, billfish). The tags were designed to be attached externally to the fish, released at a programmed time, float to the surface and then transmit to ARGOS satellites. The ARGOS satellites serve to both uplink data and calculate the end point location. If the tag remains attached to the fish for all of the time between attachment and pop-off, it provides a fisheries-independent

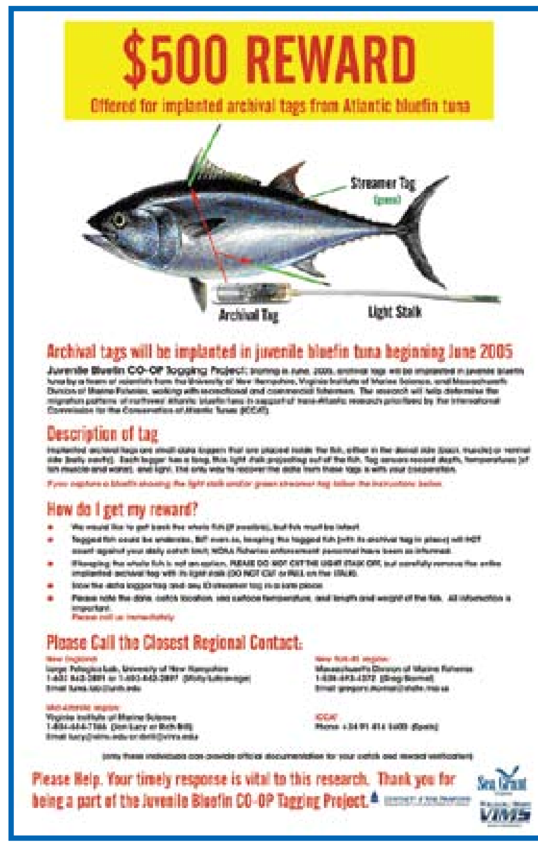

Figure 2: Poster advertising a tagging campaign on juvenile bluefin tuna, with archival tags.

measure of the straight –line distance travelled from the point of tagging (BLOCK *et al.,* 1998; LUTCAVAGE *et al.,* 1999). The most appealing and important feature of this type of tags is the capability of delivering data on movement and behaviour completely independent of fisheries. However, the recovery rate of the tag data is still rather low.

TAGGING EXPERIMENTS IN HELLENIC FISHERIES

Tagging on large pelagic species

Most of the tagging experiments conducted in the Hellenic Seas were concerned with large pelagic fish: bluefin tuna, albacore and swordfish. As these species are highly migratory and the same stocks are exploited by several national fleets it is essential that the conservation measures taken are followed by all fleets involved in these fisheries. Information on the rate of mixing of the different stocks is essential for the implementation of stock assessment studies and proper management measures. Tagging operations could help the clarification of such aspects and so far, they have demonstrated a certain mixing of the west and east Atlantic-Mediterranean bluefin tuna stocks. However, further tagging has been recommended by the International Commission for the Conservation of Atlantic Tunas (ICCAT) in order to reach conclusions on the amount of mixing and identify the migration pattern of the stocks. Most of the large pelagic tagging campaigns are conducted under the auspices of ICCAT and tagging data are compiled in a common database.

A) Tagging operations on large pelagic fish were first carried out in the Hellenic Seas during 1991-1992, in the framework of the European project "Studies on Large Pelagic Fish Stocks by means of Tagging" (DGXIV/91/11). During this tagging campaign 3 738 fishes were totally tagged in several Mediterranean areas and 754 of them were also injected with oxytetracycline. Most of the tagged animals were bluefin tuna (2 338), 1 181 were albacore and 219 were swordfish.

Tagging cruises for albacore and juvenile swordfish were carried out in Hellenic Seas. Sixty-five swordfish and 17 albacore were tagged through the tagging campaign. Twenty-five of the tagged swordfish were also injected with tetracycline. The fish were tagged with conventional "spaghetti-type" tags, provided by ICCAT. The tagging data were reported to the ICCAT secretariat and were included in the tagging database. An advertising campaign was also launched to fishermen and port authorities through posters and circulars.

B) In the framework of TUNASAT (1998-2000), an

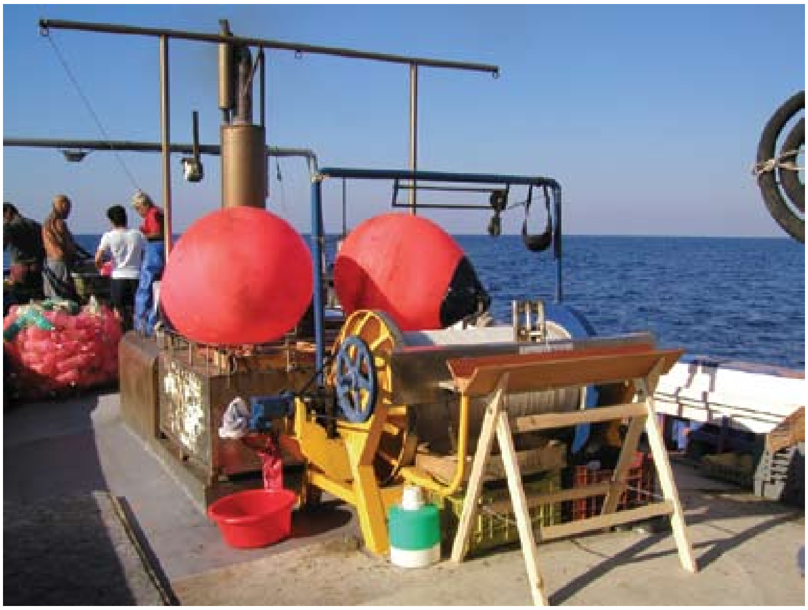

Figure 3: Commercial swordfish-fishing boat involved in the tagging operations in the south Aegean Sea. (Photo: P. PERISTERAKI).

EU-funded research programme, tagging with electronic "pop-up" tags took place in the Mediterranean Sea. During these tagging operations a total of 84 bluefin tunas were tagged and 12 of them in the Aegean Sea. Although the overall return rate was low (31.3%) and most of the tags deployed popped up in the same area, results showed that most of the tags were detected in areas of high productivity. Only two of the tags were detected in distant areas of the NW Atlantic (DE METRIO *et al.,* 2002).

C) A new tagging campaign for large pelagic species started in 2004 in the framework of the Hellenic Fisheries Data Collection Project and it is planned to cover the period 2004-2007. The aim of the project for 2004 was to carry out tagging on juvenile bluefin tuna in the eastern Mediterranean. Tagging operations were carried out during October to December in the N. Aegean, around the Halkidiki Peninsula and in the S. Aegean, around Kalymnos Island and north of Kriti. Small surface drifting long-lines were used for the fish capture. Those of the captured animals that were in good condition were measured on the deck of the boat in a cradle (Figures 3, 4), then tagged by conventional "spaghetti-type" yellow tags (Figure 1) and released into the sea. Date, time and geographical coordinates of the capture location were recorded (Figure 5).

In 2005 the aim of the Hellenic campaign was to tag juvenile swordfish in the eastern Mediterra-

Figure 4: Captured and tagged juvenile swordfish being measured in a special cradle on deck. (Photo: P. PERISTERAKI).

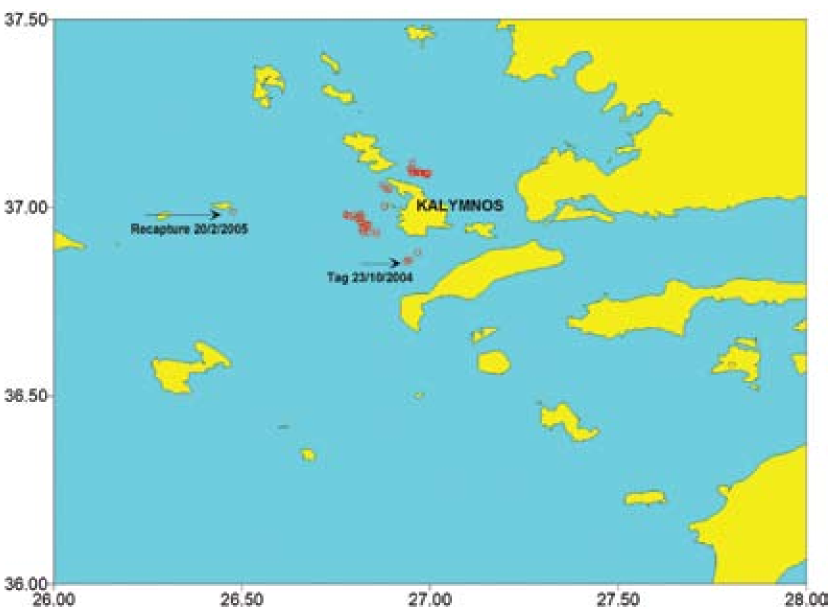

Figure 5: Tagged fish (red circles) around the Kalymnos Island (Dodecanese) during the 2004 tagging campaign (Source: HCMR, Fisheries Data Collection Programme 2002-2006).

nean. Tagging operations were carried out during October to December, in the S. Aegean Sea, at areas around the Dodekanisos and Kyklades islands and Kriti (Figure 6). The same tagging techniques as the previous year were applied. During the tagging operations 183 swordfish and two bluefin tunas were totally tagged by yellow "spaghetti-type" conventional tags and released into the sea. Capture rate for swordfish was estimated at 5.1 individuals/fishing day and the tagged fishes were 4.3 individuals/fishing day. Lengths of tagged fishes ranged from 44 to 120 cm for swordfish.

In order to maximise the chances of recovering data on the recaptures, the tagging campaign was advertised to fishers and harbour authorities through posters, T-shirts, and circulars (Figure 7). Moreover, every reported recapture is awarded.

The Hellenic tagging campaigns have been realised according to the plans agreed during the annual meetings of the "European Tuna Tagging Planning Group", a tagging coordination committee formed in the framework of the EU National Fisheries Data Collection Programmes. Continuation of the tagging campaign is expected on an annual basis. For the immediate future the Planning Group has proposed annual tagging of about 450 juvenile swordfish with conventional tags, in the Mediterranean (150 in Hellenic Seas) and electronic tagging for a small number of adult swordfish and giant bluefin tunas. The release and recapture details are officially reported to ICCAT.

Tagging on *Nephrops norvegicus*

In crustaceans growth is a non-continuous process with molts separated by intermolt periods. During each molt the old exoskeleton sheds and the animal grows very quickly, before the new exoskeleton hardens. Studies on moulting frequency and periodicity as well as growth is especially difficult due to the lack of hard parts (such as otoliths in fish) where age can be registered. The NEP-GM ("Growth and natural mortality of Nephrops norvegicus, with an introduction and evaluation of creeling in Mediterranean waters", SMITH *et al.*, 2001) EU Project studied various biological parameters of *Nephrops norvegicus* in the area off Skyros and in Pagasitikos Bay. Growth studies, carried out in Pagasitikos Bay, were based on the mark-recapture technique and external tagging with the use of streamer tags, which remain in place throughout the moulting process. The moulting frequency studies were based on additional internal tagging with the use of biological implant tags which form a cyst that records the moulting cycles (in a way analogue to that of otolith rings). Approximately 6 000 Nephrops were caught alive and undamaged by trapping, tagged (5 000 with external tags and 1 000 with both external and internal tags) and subsequently released alive with a recapture rate of 35%. Although the rate of return was high, a large number of returns did not show a growth increment (i.e. were caught too early by local fishermen targeting the release area). However, significant estimates were made for animals with release periods greater than one year (1year ± 2 months, 305-425 days). Some animals were returned with release days between 525 and 765 days but in low numbers to allow statistical analyses. Annual growth increment of 2-6 mm cephalothorax CL was seen for male Nephrops with females showing smaller increments. Growth increments are dependent on moulting, which for female Nephrops in Pagasitikos Bay was noted to be annual, after hatching their eggs and related to the extended spawning season recorded. Male moulting was not seasonal, with animals moulting at variable times (juveniles moulting more than once and old individuals once per year). Growth estimates parameters (Linf and K) were in general similar to those calculated from trawl based studies (and the length frequency distribution methods) elsewhere in the Mediterranean. Some differences were noted between Aegean sites with, for example, the Evvoikos population having a lower growth rate than that of the Pagasitikos Bay (MYTILINEOU *et al.,* 1998; SMITH *et al.,* 2001).

Figure 7: Poster advertising the Hellenic large pelagic fish tagging campaign.

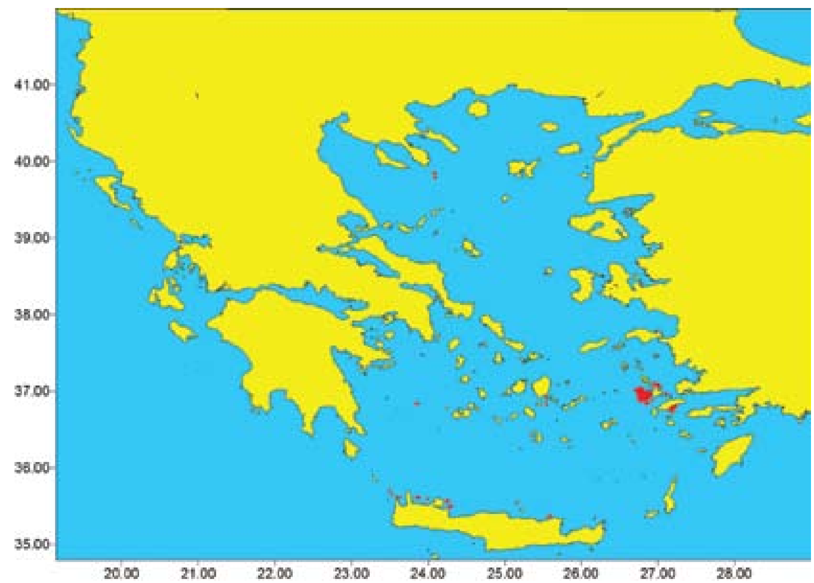

Figure 6: Position (in red) of the tagged swordfish in the Hellenic Seas, during the 2005 tagging campaign (Source: HCMR, Fisheries Data Collection Programme 2002-2006).

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VII.2. GEAR SELECTIVITY

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INTRODUCTION

Fish or in broader terms marine organisms, represent an important food source for humans since the Paleolithic Age. During that time, primitive humans were catching and collecting marine organisms using their hands or simple tools made from stone and wood, being able to reach only the shallow waters of lakes and rivers. Later on, they started using fishing gears, harpoons or baskets, during the Neolithic period nets, and even later with the introduction of metal tools, more complicated hooks. In fact, all fishing gears that fishermen use nowadays represent complicated versions of primitive hooks or nets. With the advent of technology and the construction of larger, faster and better equipped vessels (for fishing, navigation and catch storage) fishermen are now able to expand their activities. Depth and distance from the coast are no longer limiting factors and almost all aquatic ecosystems that shelter commercial species are being fully exploited.

Most aquatic ecosystems include a variety of commercially exploited species (fish, cephalopods, decapods, shellfish, etc). Fishing grounds contain heterogeneous assemblages in terms of species and size distribution that are not equally vulnerable to any fishing method. Selection can mean any process that causes the probability of capture to vary, with the characteristics of the target populations, whereas selectivity is a quantitative expression of selection (LUCAS *et al.*, 1960).

Figure 1: Gill net fishery in Pagasitikos Gulf (2005).

SELECTIVITY OF FISHING GEARS

The selectivity of a given fishing gear can be described in terms of:

- species selectivity (related to the number of species caught). Fishing gear is characterized by high species' selectivity when the catch comprises of a small number of species.
- size selectivity (related to the size of the specimens of each species). Fishing gear shows high size selectivity when the larger individuals of a population or a restricted number of length classes are caught.

Primitive gears were highly selective both in terms of species and size. By using the harpoon, it is possible to catch one fish per attempt, so this gear can be characterized as the ultimate selective gear. Passive gears (trammel nets, gill nets, combined nets, traps, long lines, etc.) on the other hand, are less selective because they catch more than one species and a restricted range of length classes per species. However, they are still regarded as a highly selective gear. Towed and surrounding fishing gears (bottom trawlers, beach seiners and purse seiners) are of low size selectivity because they catch everything above a certain size, encountered in the towing path and inside the net, respectively. However, certain métiers show high species' selectivity, e.g. each haul of the purse seine consists of low number of species.

Selectivity of passive gears

Fish get caught in different ways by the different fishing gears. In a gill net (Figure 1), according to BARANOV (1914) the fish can be caught in the following ways: wedged (held tightly by a mesh around the body), gilled (prevented from backing out of the net, by a mesh caught behind the gill cover) or tangled (held in the net by teeth, maxillaries or other projections without necessarily penetrating the mesh). Small fish can swim through

Figure 2: Nephrops trap fishery in Pagasitikos Gulf (2005).

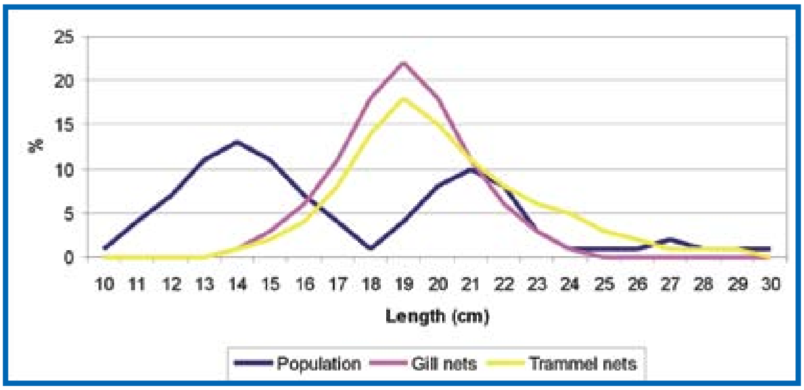

Figure 3: Hypothetical example of length distribution of the population, of the gill net catch and of the trammel net catches.

the meshes and escape, whereas large individuals cannot penetrate the mesh. Trammel nets fish in a similar way. The main difference, between trammel nets and gill nets is that the former are able to catch big fish by trammeling or pocketing (when the fish pass through one mesh in the outer panel, meets the inner net with small mesh size and makes a "pocket" by passing through the mesh of the opposite outer panel) (LOSANES *et al.*, 1992; FABI *et al.*, 2002). Trammel nets are, however, less species and size selective than gill nets resembling in many instances trawl cod-ends (STERGIOU *et al.*, 2006; ERZINI *et al.*, 2006)

In hook and line fisheries, the hook size defines the size of the fish. As the hook size increases, the possibility of catching smaller fish decreases. Long line species and size selectivity is also high. From a recent study comparing the European hake *Merluccius merluccius* trawl, gill net and long line fisheries in Hellas, the long line size selectivity was found to be considerably higher (ARGYRI *et al.,* 2007).

In trap fisheries (Figure 2), the trap selectivity is a function of the mesh size (shape and size), the entrance opening (position, shape and size) and the soak duration (time the trap is left on the seabed). Behavioural aspects may also affect trap selectivity. If a large predator is caught in the trap it may keep other fish/invertebrates from entering the trap and if prey species are already in the trap they may act as live bait attracting others. Although traps of various types have been historically used in Hellas, today such methods are rarely used. Top entry basket-type traps maybe used in shallow, generally rocky, areas for fish, pots are used for octopus and baited traps with side entrances are presently used for the scampi *Nephrops norvegicus* and the lobster *Palinurus elephas*. In the *Nephrops* trap fishery the basic principle of the technique is to attract the target species into the body of the trap, providing an easy entry coupled with a difficult exit. Attraction is undertaken with the use of bait, normally oily/salted fish that have a long lasting and strong underwater smell. Selectivity is achieved principally through the mesh size of the trap body, but also on the size and placement of the "ramp-like" trap entrances. The correct-sized species can enter through the entrance, but cannot escape through the mesh side walls.

The length frequency distribution of the gill nets and of the trammel nets is not reflecting usually the length frequency distribution of the fished population as a result of the selectivity of the gear. A hypothetical example is given in Figure 3. Trap catch length frequency would also follow the same pattern, with almost all of the smaller undersized fish and invertebrates escaping and most of the catch, comprising of mid-range/large specimens and few very large ones (SMITH *et al.,* 2007).

The species' selectivity of these gears (in one specific métier) is always high, since they are usually fixed on the seabed waiting for the fish to come to the net or attracting the fish with the bait and their practical operational range is restricted. Generally, these gears are targeting one species or a small group of species and consequently the catch comprises of a small number of species. In the gill net fishery in the Ionian Sea (Figure 4), the proportion of blackspot sea bream (*Pagellus bogaraveo*) was 90%, whereas the accumulative proportion of the five more abundant species was 98% (PETRAKIS *et al.,* 2001). In the sole (*Solea vulgaris*) métier the proportion of the target species was 60% (Figure 5) (ANON., 1998).

Trap selectivity is extremely high with respect to the target species of *Nephrops* and also in terms of by-catch. During a seasonal monitoring of the shallow commercial trap fishery in the Pagasitikos Gulf (70-90 m depth), a total of 34 species were recorded in the catch. However, only four species were caught in great quantities (*Nephrops norvegicus*, the fish *Spicara flexuosa* and *Trisopterus minutus capelanus* and the crab *Liocarcinus depurator*). During deep-water trap trials off Mytilini island (500 m depth), a total of 13 species were caught, but only two species were found in large quantities (*Nephrops norvegicus* and the shrimp *Parapenaeus longirostris*). The targeting nature of this gear is pointed out when comparing catches made by different gears in the same area, where *Nephrops* consisted of 71-86% of the trap catches (Figure 6), 2-14% of the net catches and 2-17% of the trawl catches (PAPADOPOULOU *et al.,* 2007).

The targeting nature of the deep-water long lining for hake is also highlighted by the dominance of the target species in the catch, with *Merluccius merluccius* comprising 78-97% of the catch. The rest of the catch consisted of a few other species, mainly Scorpanidae and the greater forkbeard *Phycis blennoides* (ARGYRI *et al.,* 2007). However, shallow-water long lining has lower species' selectivity. The diversity of the catch is high, although not as high as that of the gill nets (STERGIOU *et al.,* 2002). Both species' selectivity and commercial/total catch ratios are much higher for static gears when compared to active gears, such as trawls or beach seines (STERGIOU *et al.,* 2002; PAPADOPOULOU *et al.,* 2007; SMITH *et al.,* 2007).

Selectivity of towed and surrounding gears

The most common towed or surrounding fishing gears in Hellas are the bottom trawlers, the purse seiners and the beach seiners.

In bottom trawling, the vessel is moving; towing the gear on the bottom and everything along the path of the tow goes inside the gear (Figure 7). Small fish can escape through the meshes from various parts of the gear and the cod-end. As they grow, the proportion of the escapees is reduced and after a certain age or size, there are no escapees. Each single tow consists of more than one target species with significant variations among them in length composition and in body shape. In the

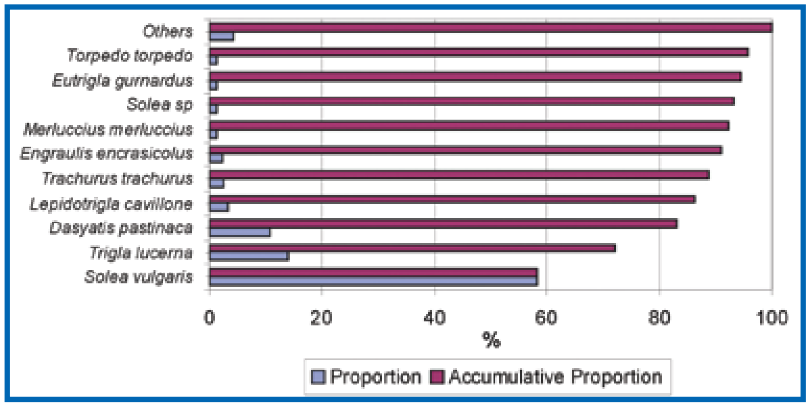

Figure 4: Catch composition (by number) in *Pagellus bogaraveo* gill net métier in the Ionian Sea.

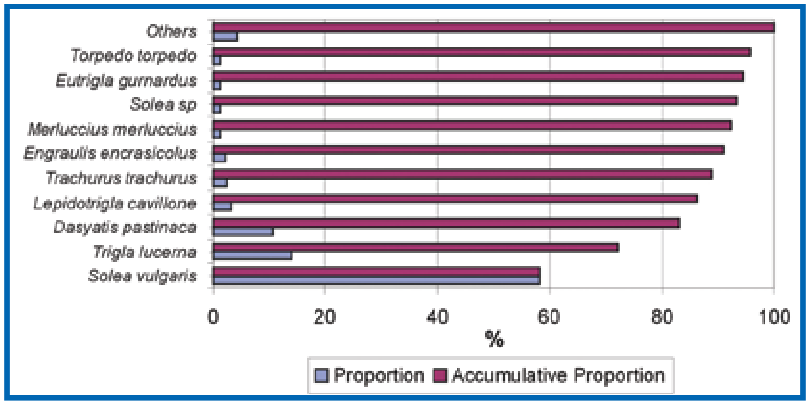

Figure 5: Catch composition (by number) in *Solea vulgaris* gill net métier in the Amvrakikos Gulf.

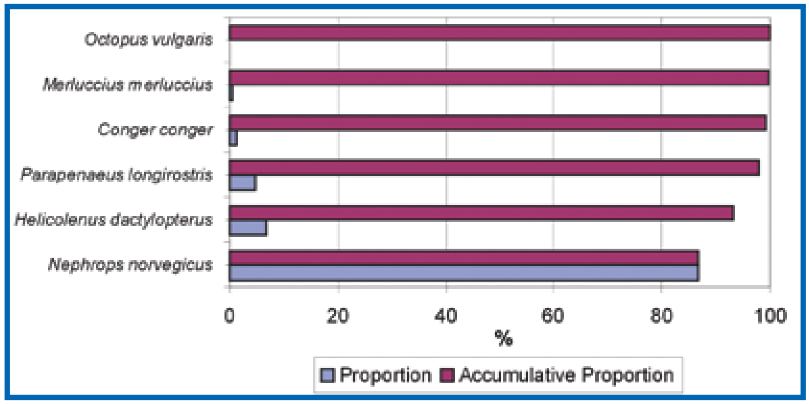

Figure 6: Catch composition (by number) in *Nephrops norvegicus* trap métier in the Aegean Sea.

Mediterranean, where the nature of this fishery is multi-species and many of the commercial species are of small size, the legislated opening of the mesh is small compared to the one in use for the sam e fishery in the Atlantic or other areas.

The length frequency distribution of the catch, after the length where the possibility of capture is 1, is the same as of the fished population, whereas for

Figure 7: Bottom trawl fishery in Pagasitikos Gulf (1999).

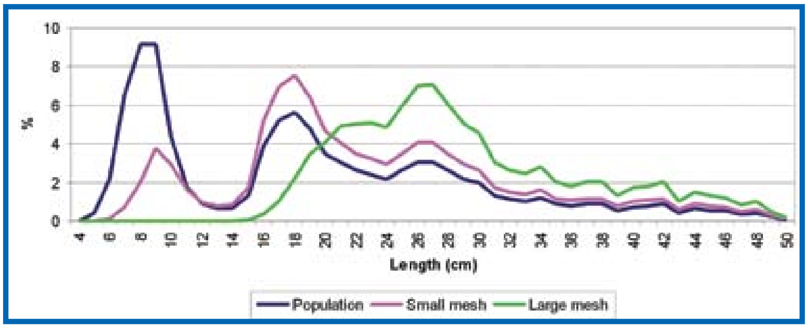

Figure 8: Hypothetical example of length distributions of the population and of the catches of two different mesh sizes in the cod-end of bottom trawl.

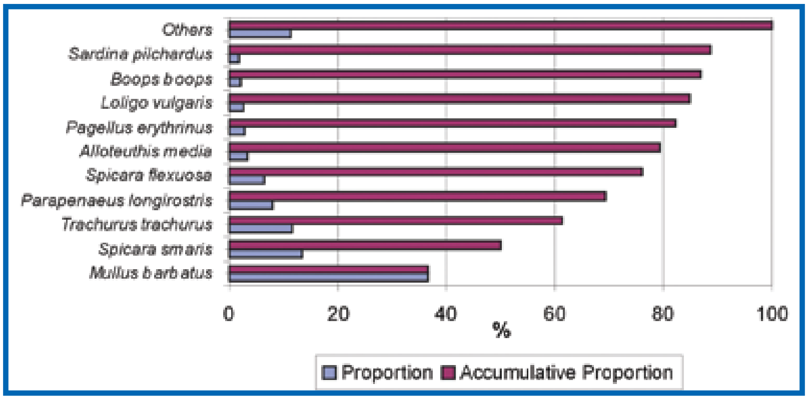

Figure 9: Bottom trawl catch composition in shallow waters in the Ionian Sea (IMAS-FISH data).

smaller fish the length distribution of the catch is affected by the selectivity (Figure 8). It is obvious that as the mesh opening decreases, so does the size selectivity of the fishing gear and the length distribution of the catch resembles that of the population.

The species' selectivity of bottom trawling is very low as well. The duration of each tow varies between 0.5 and 6 hours. The operational range of the gear in every single tow varies according to the duration. A considerable number of species belonging to all the categories (fish, cephalopods, decapods) is caught in each tow (Figure 9, Figure 10). Thus, the catch composition consists of many species. We emphasize here that by the term catch, we mean everything that comes onboard and not only what is landed. In shallow waters, where the catch is dominated by *Mullus barbatus* and *Spicara smaris*, the five more abundant species comprise 76% of the catch; whereas in deep waters the proportion is lower (61% of the catch). The proportion of the "others" in both cases is considerable.

Purse seiners operate during the night using lights in order to aggregate small pelagic fish, or during the day targeting migratory species. The opening of the mesh size of the net in the night purse seiners is very small and not size selective at all in practice. The main excuse for its use is that the fishermen want to avoid the fish getting meshed because it is very difficult and time consuming to clear the net (Figure 11). However, no selectivity or gear operation behaviour experiments have been conducted in Hellas or the Mediterranean, related to this gear. On the other hand, the purse seine can be characterized as species' selective gear. The catch in each haul comprises of a very small number of species (less than five-six species), usually dominated by one single species.

Boat seiners are working during the daytime in coastal waters (Figure 12). The main target species (at least in some fishing areas) is *Spicara smaris*, a small-sized species. As a result, the mesh size in the cod-end is very small and the gear not size selective. In addition, due to the high coastal biodiversity, the catch comprises of many species and the species' selectivity of the gear is low as well. However, in some fishing grounds one or two species dominate the catch.

SELECTIVITY CURVES

Gill and trammel net selectivity curves

For each specific mesh size of a gill net or of a trammel net there is (for each species) a length class where the possibility of a fish being caught is maximum (optimum length, L_o). The mathematical presentation is a bell shaped curve, falling to 0 in

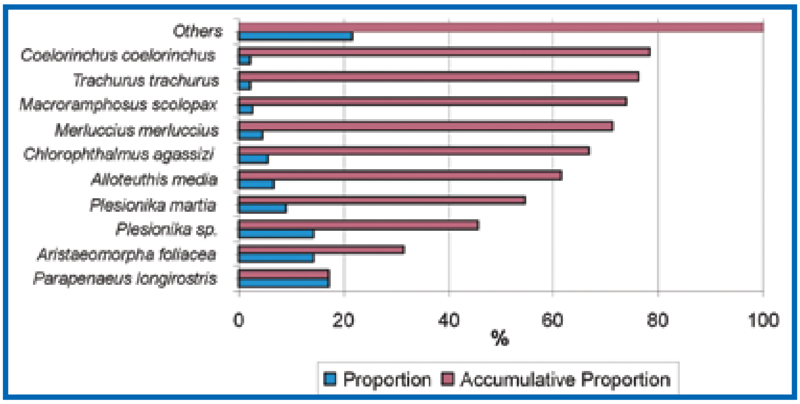

Figure 10: Bottom trawl catch composition in deep waters in the Ionian Sea (IMAS-FISH data).

Figure 11: Purse seine fishermen as they clean the nets of the meshed fish. Port of Volos, Spring 1999.

Figure 12: Boat seine in Syros island (2001).

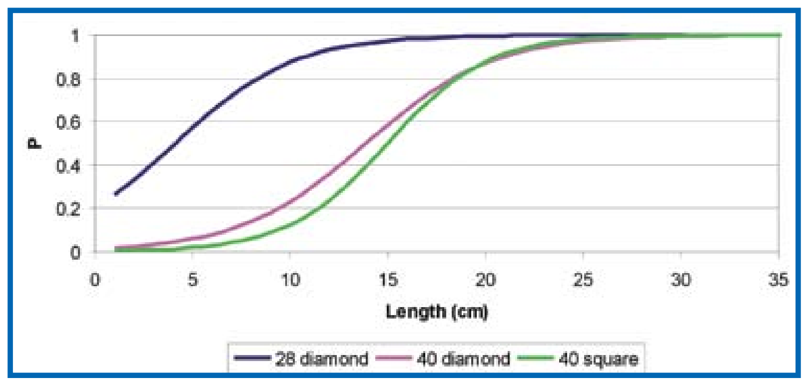

Figure 13: Selectivity curves for *Merluccius merluccius* for three different cod-end mesh sizes.

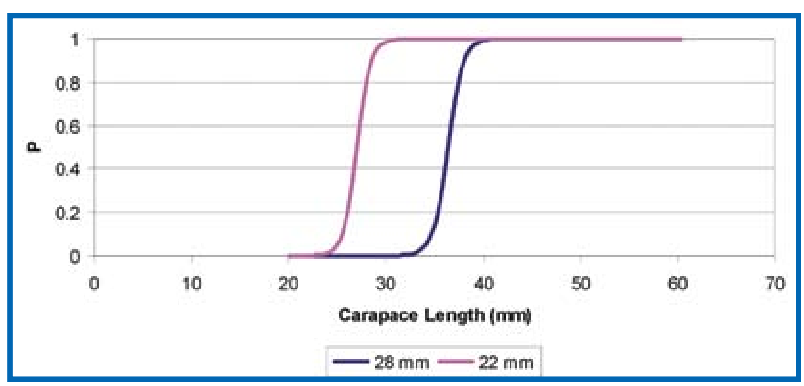

Figure 14: Selectivity curves for male *Nephrops norvegicus* for two different trap mesh sizes.

the both sides of a maximum, where the value in the L_o is equal to 1. There are several methods of estimating the selectivity of gill nets. One of the most popular is the method introduced by HOLT (1963). The probability of capture for each length class according to HOLT (1963) is calculated from the following equation:

$$P=\exp[-(L-L_o)^2 / (2\ SD^2)]$$

Where P= probability of capture in each length class

L= length class

L_o=length at which the probability of capture is maximum

SD=common standard deviation

While there is a general consensus on the form of the selectivity curves for gill nets, this is not true for trammel nets and a number of additional modelling approaches (including logistic type models, see next section) have been used (ERZINI *et al.,* 2006).

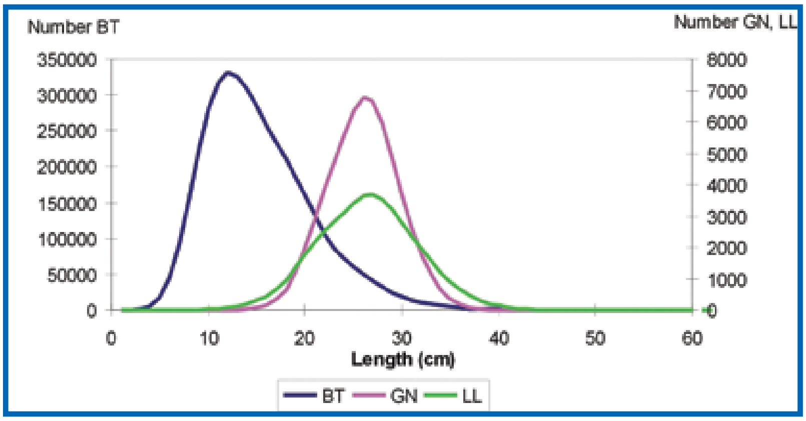

Figure 15: Length frequency distribution for L_{50}=10 cm (BT=bottom trawl, GN=gill net, LL=long line).

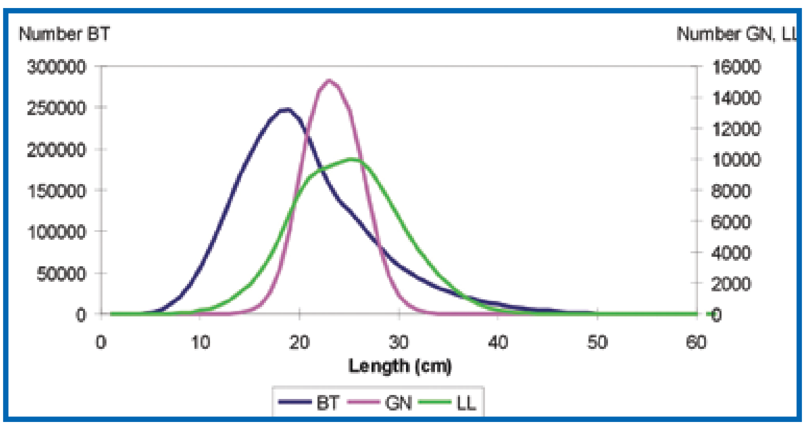

Figure 16: Length frequency distribution for L_{50}=15 cm (BT=bottom trawl, GN=gill net, LL=long line).

Cod-end and trap selectivity curves

The cod-end and trap selectivity curves are described by the logistic function curve (FRYER, 1991):

$$p = \frac{e^{(v_1+v_2 l)}}{(1+e^{(v_1+v_2 l)})}$$

Where, V_1 represents the intercept and V_2 the slope of the curve after applying a logit transformation and the L_{50} (the length where the probability of a fish to be caught is 0.5) can be estimated from the expression:

$$L_{50} = -\frac{v_1}{v_2}$$

Although trap selectivity is more complicated than gill net or trawl selectivity, sharing a number of similarities and differences, the trawl model of selectivity is also usually used for traps due to similarities in escapement through the meshes (Figure 13, Figure 14). As with trammel nets and traps there is no clear consensus on the form of the selectivity curve for hooks on long lines and both gill net and trawl type selection models have been used in hook selectivity studies (ERZINI *et al.,* 1996).

EFFECTS OF SELECTIVITY ON EXPLOITATION PATTERNS

Key parameters for fisheries' management include the selectivity of fishing gears, fishing effort, access to the fishing grounds and resources, etc. An increase in the mesh size of the cod-end leads to an increase in the L_{50}. As a result, fishing mortality of the young fish will be reduced because more fish will escape through the mesh. The fish will be caught at a larger size, so in the long-term the catch is expected to increase. In addition, the spawning stock is expected to increase because more fish will reach the size or the age of reproduction.

In order to realize how selectivity affects the exploitation patterns, let us consider a hypothetical example: a certain number of juvenile fish of a new year class are recruited (5 000 000 individuals) and during their life they are exploited by bottom trawl, gill nets and long lines. When the fish are very small there is no fishing mortality, because all of them can pass even through the mesh of the bottom trawl, which is the less selective gear. As they grow, they start getting caught by the bottom trawls and later on by the gill nets and long lines. Simultaneously, losses due to natural mortality are observed.

Suppose that the L_{50} of the cod-end in use for this species is 10 cm. The length frequency distribution of the catch of each gear will look like the one in Figure 15.

By maintaining all the parameters constant (fishing effort, mesh size, gear dimensions, fishing method, etc.) and using a cod-end with a larger mesh size that will increase the L_{50} for the species from 10 cm to 15 cm, the length frequency will look like the one in Figure 16. The Yield per Recruit (Y/R) would also increase from 75 to 110 g and the total catch weight from 305 to 418 tones (Table 1, Table 2).

Improving the selectivity of fishing gears, through changes in mesh size and shape and other gear modifications, such as the use of escape or separator panels, turtle exclusion devices or a deterrent for dolphins and seabirds, is also of paramount importance in the reduction of discards and by-catch mortalities. With trawls producing the bulk of discards and 44% of total trawl catch being discarded at sea (MACHIAS *et al.,* 2001), further developments are certainly needed in order to improve trawl mesh selection (GRAHAM & FERRO, 2004) in the Mediterranean.

Table 1. Estimated values for L_{50}=10 cm.

	Average length (cm)	Total Number	Total weight (mt)	Y/R (g)
Total catch	17.78	4 050 446	305	75
Bottom trawl catch	17.49	3 882 816	282	3
Gill net catch	23.77	75 215	9	122
Long line catch	25.04	92 415	14	155
Mortality losses		955 688		

Table 2. Estimated values for L_{50}=15 cm.

	Average length (cm)	Total Number	Total weight (mt)	Y/R (g)
Total catch	21.22	3 795 944	418	110
Bottom trawl catch	20.97	3 539 036	382	108
Gill net catch	23.82	115 927	14	123
Long line catch	25.25	140 982	22	158
Mortality losses		1 207 526		

SUMMARY TABLES WITH SELECTIVITY PARAMETERS

Gill nets			
Species	Mesh size	L_o (mm)	References
Diplodus annularis	34 mm	87.9	PETRAKIS & STERGIOU, 1995
	38 mm	98.2	
	42 mm	108.6	
	46 mm	118.9	
Mullus surmuletus	34 mm	121.6	
	38 mm	135.9	
	42 mm	150.2	
	46 mm	164.5	
Pagellus erythrinus	34 mm	106.6	PETRAKIS & STERGIOU, 1996
	38 mm	119.2	
	42 mm	131.7	
	46 mm	144.2	
Pagellus acarne	34 mm	110.4	
	38 mm	123.4	
	42 mm	136.4	
	46 mm	149.4	
Mullus barbatus	34 mm	132.6	
	38 mm	148.2	
	42 mm	163.9	
	46 mm	179.4	
Spicara flexuosa	34 mm	130.2	
	38 mm	145.5	
	42 mm	160.8	
	46 mm	176.1	
Pagellus bogaraveo	60 mm	207.5	PETRAKIS *et al.*, 2001
	68 mm	235.2	
	80 mm	276.7	
	88 mm	304.3	
	90 mm	311.2	
	100 mm	345.8	

(continued)

Trammel nets

Species	Mesh size	L_o	References
Citharus linguatula	44	164.4	CHILARI *et al.*, (in preparation)
	56	209.3	
	72	269.1	
	80	299.0	
Diplodus vulgaris	44	140.0	
	56	178.2	
	72	229.1	
	80	254.6	
Merluccius merluccius	44	339.8	
	56	432.4	
	72	556.1	
	80	617.8	

Traps

Species	Mesh size	L_{50} (mm)	References
Nephrops norvegicus male	22 mm square	27.1	SMITH & PAPADOPOULOU, 2007
	28 mm square	36.3	
Nephrops norvegicus female	22 mm square	27.3	
	28 mm square	36.4	

Cod-end

Species	Mesh size	L_{50} (cm)	References
Merluccius merluccius	28 mm diamond	4.16	PETRAKIS & STERGIOU, 1997
	40 mm diamond	13.79	
	40 mm square	15.10	
Micromesistius poutassou	28 mm diamond		
	40 mm diamond	21.17	
	40 mm square	16.96	
Trisopterus minutus capelanus	28 mm diamond		
	40 mm diamond	13.73	
	40 mm square	11.85	
Lepidorhombus boscii	28 mm diamond		
	40 mm diamond	10.32	
	40 mm square	8.50	
Lepidorhombus boscii	32 mm diamond		POLITOU *et al.*, 1997
	40 mm diamond		
	48 mm diamond	9.85	
	52 mm diamond	11.84	
Micromesistius poutassou	32 mm diamond	4.10	
	40 mm diamond	13.23	
	48 mm diamond	14.21	
	52 mm diamond	16.14	
Trisopterus minutus capelanus	32 mm diamond	4.90	
	40 mm diamond	8.73	
	48 mm diamond	10.12	
	52 mm diamond	12.77	
Nephrops norvegicus	28 mm diamond	22.82*	STERGIOU *et al.*, 1997
	40 mm diamond	24.05*	

(continued)

Cod-end			
Species	Mesh size	L_o	References
Nephrops norvegicus	32 mm diamond		MYTILINEOU *et al.,* 1998
	40 mm diamond	17.83*	
	48 mm diamond	20.06*	
	52 mm diamond	20.53*	
Argentina sphyraena	20 mm diamond	11.95	CHILARI *et al.*, 2007
Boops boops	20 mm diamond	14.79	
Mullus barbatus	20 mm diamond	12.37	
Pagrus pagrus	20 mm diamond	10.28	
Spicara flexuosa	20 mm diamond	13.44	
Sardina pilchardus	20 mm diamond	14.37	
Spicara smaris	20 mm diamond	14.52	
Trachurus mediterraneus	20 mm diamond	14.66	
Trachurus trachurus	20 mm diamond	14.11	
Lepidotrigla cavillone	20 mm diamond	7.61	
Chlorophthalmus agassizii	20 mm diamond knotted	12.24	
	20 mm diamond knotless	10.81	
Merluccius merluccius	20 mm diamond knotted	12.32	
	20 mm diamond knotless	10.44	
Serranus hepatus	20 mm diamond knotted	8.99	
	20 mm diamond knotless	8.51	
Trisopterus minutus capelanus	20 mm diamond knotted	12.00	
	20 mm diamond knotless	9.79	
Dentex macrophthalmus	20 mm diamond knotted	10.78	
	20 mm diamond knotless	9.89	
Pagellus erythrinus	20 mm diamond knotted	11.88	
	20 mm diamond knotless	10.41	
Alloteuthis media	20 mm diamond	4.39**	
Illex coindetii	20 mm diamond	7.43**	
Octopus vulgaris	20 mm diamond	5.22**	
Loligo vulgaris	20 mm diamond	5.00**	
Parapenaeus longirostris	20 mm diamond knotted	19.60*	
	20 mm diamond knotless	16.40*	

* Carapace Length in mm, ** Mantle Length in cm

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VII.3. ESSENTIAL FISH HABITATS

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INTRODUCTION

The term "habitat" in the marine context is considered as a spatial entity and region with diffused and changing boundaries that are characterized by certain life-sustaining conditions. These regions provide fish populations with the optimum biological and environmental conditions for their survival and reproduction and constitute essential habitats for fish that otherwise cannot normally reproduce and grow to maturity.

Marine fish depend on healthy habitats to survive and reproduce. Throughout their life-cycle fish use many types of habitats including seagrass, salt marsh, coral reefs and rocky inter-tidal areas among others. Various activities on land and in the water constantly threaten to alter, damage or destroy these habitats, resulting in insufficient space for fish to carry on naturally with larval survival, growth and maturity. For example, the dependence of a species on seagrass beds for reproduction makes seagrass beds an essential habitat for that species in its specific reproduction life stage. Thus, proper designation of Essential Fish Habitat (EFH) is a highly important spatial measure in any management of fishery resources.

In this unit, the term "Essential Fish Habitat" (EFH) is defined and explained, efforts on EFH identification and mapping are presented, surveys of damaged habitats are shown and measures for EFH protection are proposed for the Hellenic Seas.

DEFINITION OF EFH

Essential Fish Habitat (EFH) is characterised by an aggregation of abiotic and biotic parameters that are suitable for supporting and sustaining fish populations during all stages of their life cycle. A single species may use many different habitats throughout its life to support breeding, spawning, nursery, migration, feeding and protection from predators. EFH encompasses those habitats necessary to ensure healthy fish growth as well as sustainable fisheries.

The term "Essential Fish Habitat" was initially introduced by the US Congress in 1996. EFH is defined as 'those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity', a definition that includes the physical, chemical and biological properties of marine areas and the associated sediment and biological assemblages that sustain fish populations throughout their full life cycle (DOC, 1997). Species EFH include different possible status of a habitat (e.g. potential, effective, realized) as moving fish species usually do not occupy their whole distribution area every year exactly in the same conditions. Thus, EFH mapping requires continuous monitoring of fisheries' resources and updating of existing EFH maps in order to depict the environmental changes that affect species' distributions as well as the extent of different habitat use.

In the European Communities, the term EFH was only recently and indirectly introduced during the ongoing reforming of the Common Fisheries Policy (CFP) through the concerted approach to protecting species' habitats through the Habitat Directive (CEC, 1992), declaring fisheries' protection zones through the Marine Strategy Directive (CEC, 2006), thus introducing the spatialization approach in fishery management under the CFP (CEC, 2001). To this end, the Commission of the European Communities (CEC) has funded a variety of research initiatives that aim to identify and map EFH for commercial fishery resources and propose spatial measures for the facilitation of the new concepts under the CFP.

IDENTIFICATION OF EFH IN HELLENIC WATERS

The identification of EFH is based on scientific information. In fact, latest calls for new and effective management policies (Agenda-21 1992, Fisheries Agreement 2002) require scientific information as the basis of any new management scheme of natural resources. Such information has been accumulated during the last decades for many commercially important fish species through biological and genetic research and organised in life history reports for each species. These reports are often freely available through worldwide online archives and databases, such as FishBase, CephBase, ICES and FIGIS.

Species' life history reports include information on current and historic stock sizes, stock assessments, geographic range and periods and location of major life history stages. In addition, information on the habitat requirements is provided

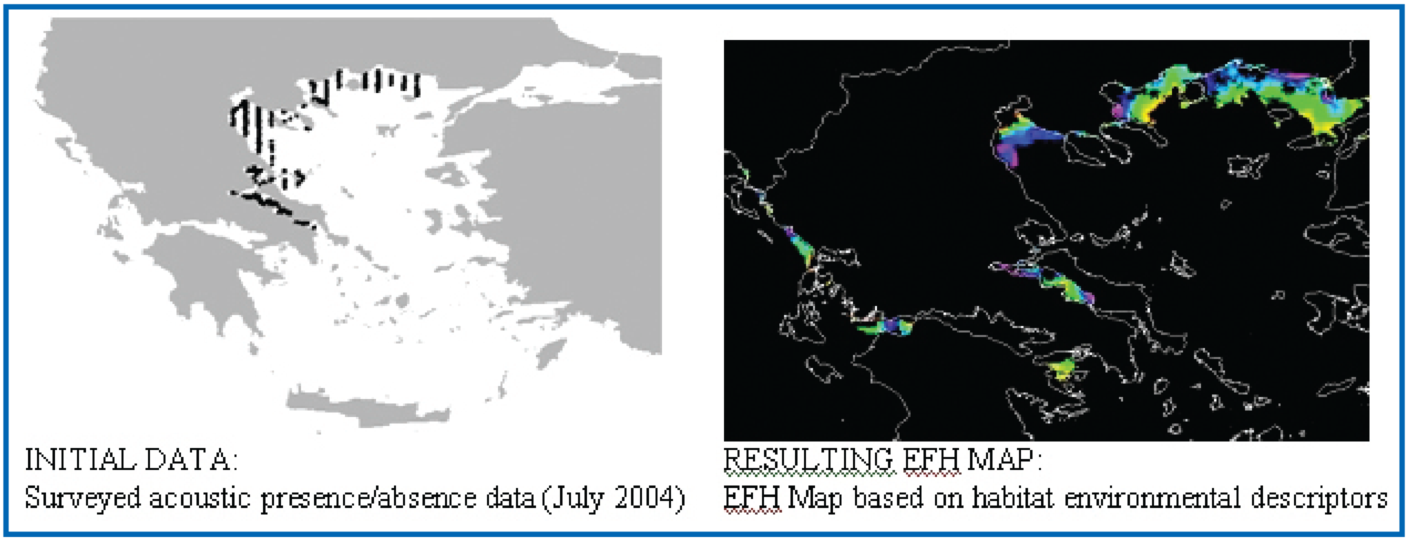

Figure 1: Calculation of EFH areas for European anchovy in Hellenic waters during July 2004. Environmental satellite data are analysed with surveyed acoustic data through GAMs and GIS procedures. EFH areas show anchovy's preferred environmental conditions in temperature, chlorophyll and salinity.

for each life history stage, including the range of habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality and productivity. Specifically, these data provide information on species type (e.g. benthic or pelagic), species preferred living ranges of temperature and salinity, recruitment periods, spawning periods and characteristics (e.g. preferred spawning sediment types and spawning temperature and depth ranges), migration habits, maximum depth of species occurrence, etc. Species' life history data may be viewed as the starting point for spatial analysis and modelling of EFH through new technologies such as Geographic Information Systems (GIS) and Remote Sensing (RS). Species' life history data are inserted into GIS as constraint parameters in the analysis of remotely sensed environmental and surveyed fisheries' data, providing integrated output on seasonal areas that are important in various stages of species life cycles. Thus, the geographic distribution of species' life history data is revealed in a spatiotemporal scale (VALAVANIS, 2002). Specific spatial and temporal patterns on species resources dynamics (e.g. spawning/nursery grounds, aggregation areas, feeding grounds) are identified and mapped with the use of GIS, RS and statistical analysis of scientific information.

The Institute of Marine Biological Resources coordinates the first CEC-funded initiative towards the identification and mapping of EFH in the Mediterranean Sea. This European effort, with participant research institutions from Spain, France and UK, aims to develop the methods and tools in order to provide EFH maps for commercially important fish species and propose spatial measures for EFH protection. This initiative, called EnviEFH (Environmental Approach to Essential Fish Habitat Designation), introduces the latest advances in EFH mapping. Through integrated analysis of species life history data using RS, GIS and statistical functions, EnviEFH is starting to produce EFH maps that are based on monitored data and scientific methods.

The main approach of EFH identification of commercial fisheries' resources in Hellenic waters is based on the integration of environmental protection requirements of EFH. Species prefer certain ranges of water properties in order to successfully breed, spawn and grow. Based on combined analysis of surveyed fisheries' data (e.g. acoustic biomass or experimental trawling) and satellite or surveyed environmental data (e.g. temperature, chlorophyll, salinity), environmental ranges for each water property are calculated through application of certain statistical methods such as Generalized Additive Models (GAMs). For example, EFH mapping for European anchovy (*Engraulis encrasicolus*) in Hellenic waters in summer is based on acoustic biomass surveys (Figure 1). Resulting EFH areas for anchovy are characterised by simultaneous environmental ranges in temperature 22.5-25.13°C, chlorophyll 0.346-2.744mg/m^3 and salinity 38.0-38.7‰ (GIANNOULAKI *et al.*, 2005, 2006). Similarly, EFH areas for short-finned squids (*Illex coindetii*) are based on environmental descrip-

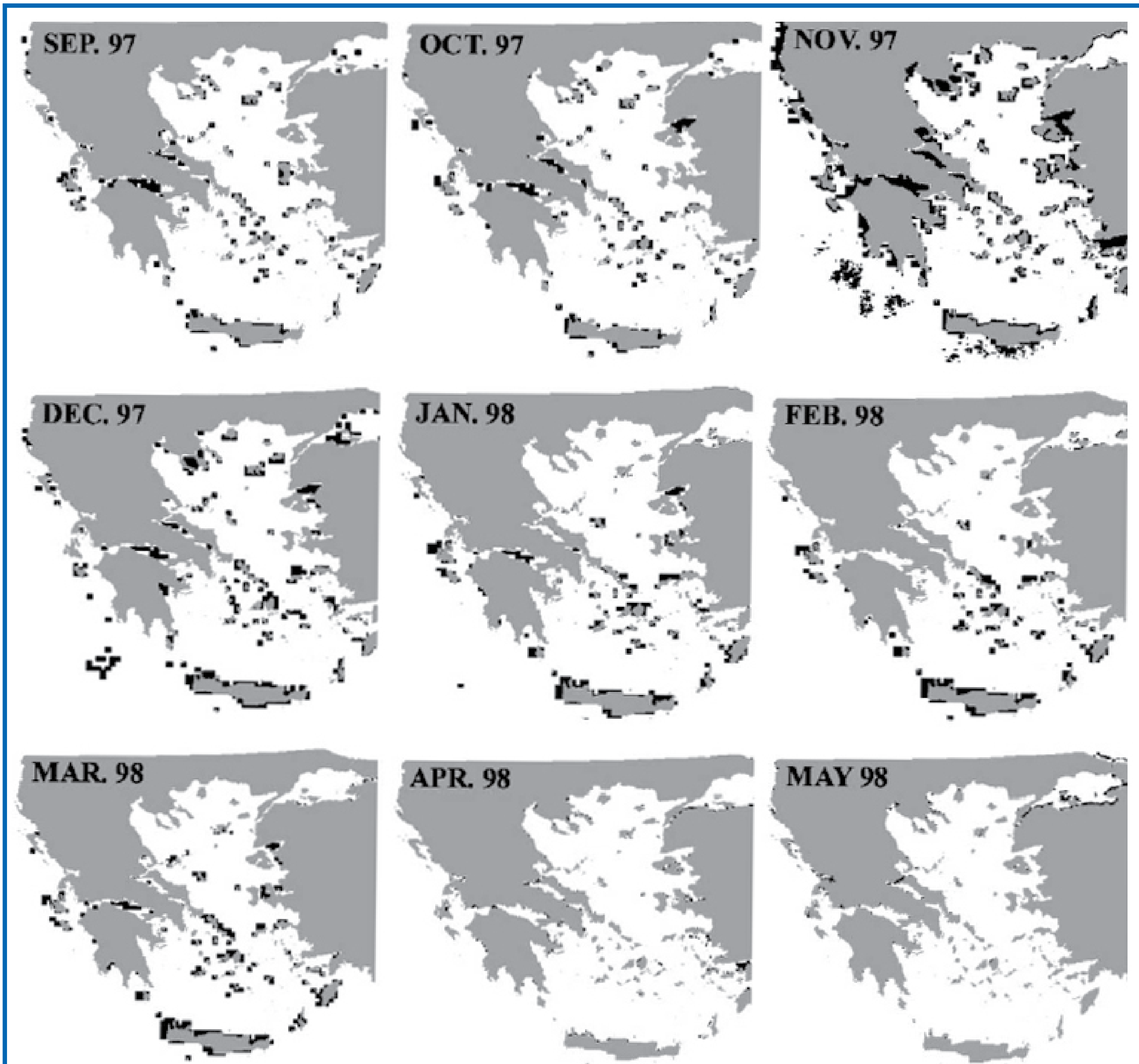

Figure 2: Essential Fish Habitat (EFH) mapping for short-finned squid in Hellenic Seas during 1997-98. Environmental habitat descriptors are derived from satellite images through extensive spatial integrations among georeferenced fishery data, catch distribution, bathymetry and fishing fleet major activity areas.

tors of their major concentration areas and are characterised by temperature 13-29°C, chlorophyll 0.30-15.60mg/m^3 and salinity 36.12-38.51‰ (VALAVANIS *et al.,* 2002, 2004) (Figure 2).

These EFH map products become invaluable in any fisheries' management plan because they are based on scientific and monitored information. They provide basic information for the design and designation of marine protected areas or seasonal fishing-closure areas (no take zones), a spatial measure that has been already used worldwide as part of fisheries' management policies. In addition, EFH products are used in combination with other GIS-based products, such as mapping of marine productivity hotspots (KAPANTAGAKIS *et al.,* 2002, KATARA *et al.,* 2005, VALAVANIS *et al.,* 2004) in order to identify alternative fishing activity grounds that are still unexploited (Figure 3). The

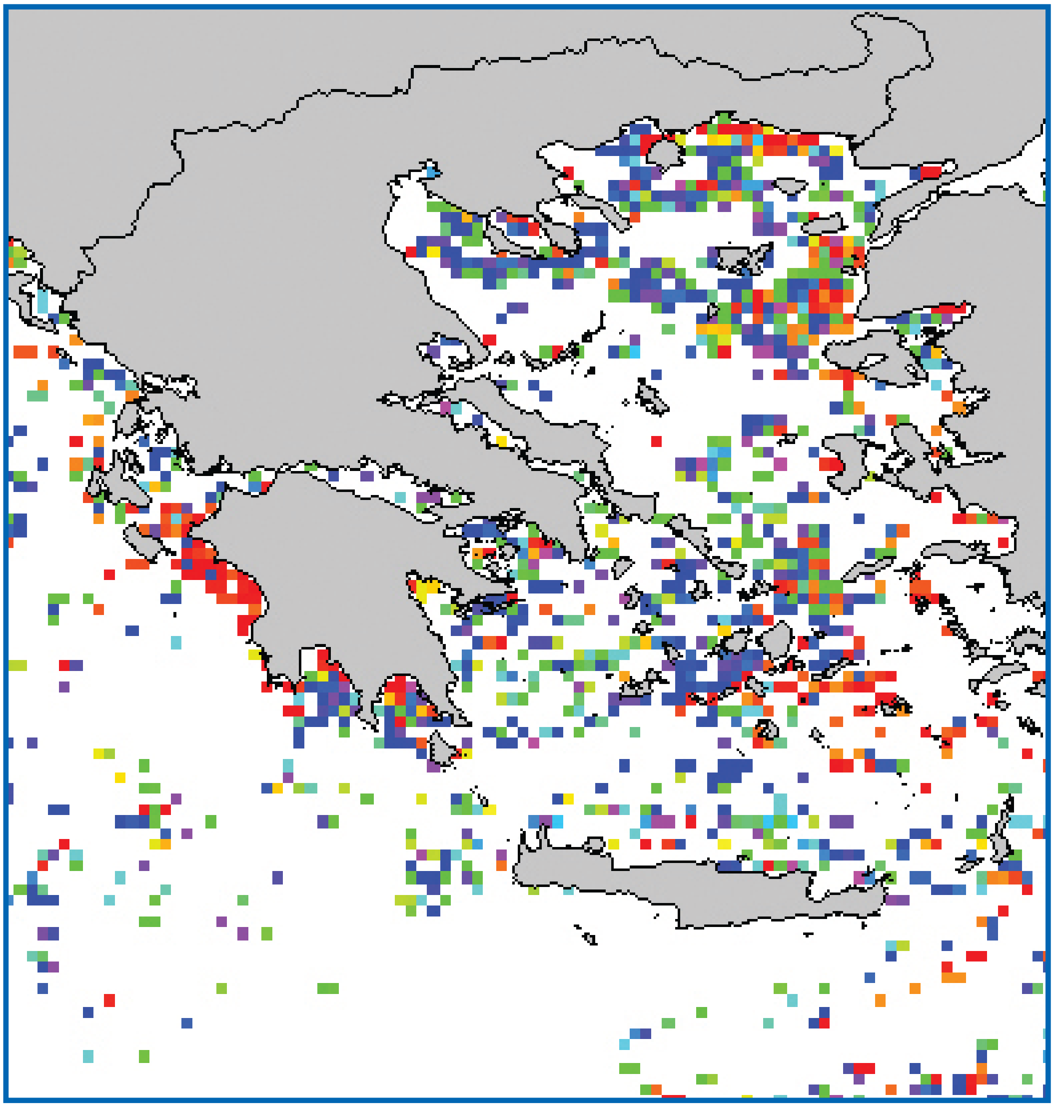

Figure 3: Spatial distribution of marine productivity hotspots (MPH) during December 2004. These areas are characterized by persistent and simultaneous high chlorophyll-a and low temperature pattern and may sustain several species populations. MPH areas reveal known fishing activity grounds (e.g. in the North Aegean and Kyklades Plateau) as well as unexploited regions that may be used as alternative fishing activity grounds.

ultimate goal of current multidisciplinary research on EFH mapping is to provide a clear picture of where species EFH are located and where fishing fleets may alternatively operate in order to allow the regeneration of traditional and over-exploited fishing grounds.

SENSITIVITY OF SEABED DOMINATED HABITATS

A variety of sea grounds are affected by routine anthropogenic activities, particularly in coastal areas. Activities may include engineering works, transport, recreational activities, fish farming, dumping, aggregate extraction and fishing. Knowledge of where EFHs are located is not enough to institute spatialized management plans. A very important piece of additional information concerns how sensitive/robust these habitats are. One of the best known biotopes in the Mediterranean are *Posidonia* meadows. These are found in coastal waters typically at depth ranges of 10-40 m. The system is complex with various habitats in the sediment, roots, between the leaf fronds and over the top of the meadows. For a large number of fish species meadows provide shelter, food resources and aggregating areas, and act as spawning, nursery and on-growing areas. A variety of research has been carried out on *Posidonia* meadows, but unfortunately little has been carried out on the associated fish communities. Meadows are extremely sensitive to physical disturbance and once plant cover has been removed, it may not return for a considerable time. Their sensitivity has been recognised and they have been protected across the Mediterranean with specific laws under the European Union, to ban trawling activities within the 50 m depth contour or the 3 mile limit whichever is nearest the coast. Specific sites (67 in total in Hellas) have been further designated and recorded under the Natura 2000 Programme (SIAKAVARA *et al.,* 2000).

Maerl reefs and maerl sands can be common at 50-100 m, are comprised of coralline algae that play a very similar role to *Posidonia* meadows, providing food, shelter and aggregation grounds. These habitats have a different type of fish community including commercial species such as red fish, groupers, sparids and lobsters. They are currently exploited both by active (trawls) and passive fishing gears (bottom nets and longlines). Like seagrasses, maerl habitats are also very sensitive because the corals are slow growing, long lived and very fragile. Trawlers have been damaging this habitat for some time, but with the recent adoption of northern European gears (rockhoppers and wheels on the ground ropes), reef areas that could not be fished before can now be accessed and are in more danger. As yet, there are no management/protection measures for maerl habitats, although this may change in the future because of their importance and sensitivity.

Excluding the two habitats mentioned above, sedimentary habitats in general provide spawning, nursery, feeding and on-growing areas for a large number of commercially important species. These areas are generally largely unmapped and there are no habitat specific regulations – although there are general spatio-temporal regulations aimed at stock protection and some specific closures on certain gulfs and bays. The majority of these areas are accepted as "fishing grounds" where fishing (fish removals and impacts with the seabed) is an acceptable practice. These areas are not uniformly affected by trawling, and effort tends to be concentrated in specific areas and tracks (known clear areas or areas previously fished that have given high returns). Trawling leaves persistent marks on the seabed that can be imaged over wide areas with side scan sonar. By using this technique over wider areas, the impacted areas can be initially identified and then monitored over time with repeat data collection (Figure 4) (SMITH *et al.*, 2000, 2003; SMITH & RUMOHR, 2005).

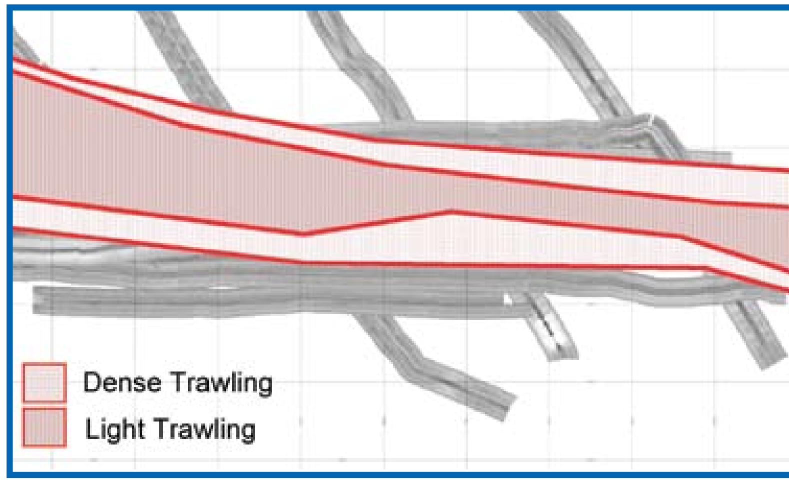

Figure 4: Trawling lane mapped out from side scan records in Irakleio Bay, Kriti (approximately 3 x 2 km).

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VII.4. GENETIC STRUCTURE OF FISH STOCKS IN THE HELLENIC SEAS AND THE MEDITERRANEAN

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INTRODUCTION

The recent advances in molecular genetic techniques and methodology in combination with the development of analytical tools in evolutionary and population genetics theory have revolutionized our knowledge on evolutionary history, population structure and biodiversity of living organisms. Fish have contributed significantly to our understanding of evolutionary change in wild populations, both because they display remarkable adaptive radiation and persistence across a wide range of environments, and they constitute the only major food resource harvested from natural populations (CARVALHO & HAUSER, 1998). It is estimated that of the more than 20 000 species of teleosts, at least 9 000 are exploited, and this represents a massive anthropogenic pressure on the natural dynamics and recruitment of many fish populations. It has been suggested that over 90% of the fish stocks of the world are overexploited, with likely negative effects on phenotypic traits affecting life cycle and production and with possible irreversible shifts in genetic structure and diversity (RYMAN *et al*., 1995). These risks on integrity and persistence of exploited fish population have fuelled the quest for describing and monitoring fish population structure.

Fisheries science is based on the notion of an "idealized unit stock", a discrete entity with its own origin, demographics and fate (WALDMAN, 2005). An understanding of stock structure is necessary for designing appropriate management regulations in fisheries where multiple stocks are differentially exploited (RICKER, 1981). Stock identification is an essential part of stock assessment - unit stocks cannot be assessed unless they are circumscribed, that is, their boundaries defined in relation to the other units of the same species.

Genetic methods can be extremely powerful tools in fisheries management, by enabling the identification of genetically differentiated populations, referred to as "*genetic stocks*" (JAMIESON, 1973; OVENDEN, 1990), i.e. units that are more or less reproductively isolated from each other, and thus they will react independently to exploitation. These populations may also differ in key parameters used in fishery models (e.g. growth, mortality, recruitment) (HAUSER & WARD, 1998). However, there may be fish populations that are not genetically differentiated, but will still react independently to exploitation. These independent units represent different "*harvest stocks*", defined as "locally accessible fish resources, in which fishing pressure on one resource has no effect on the abundance of fish in another contiguous resource" (GAULDIE, 1988). These later units are of interest to fisheries managers, but this concept does not imply any genetic or phenotypic differences between stocks.

Both stock definitions (*genetic* and *harvest*) are interpretations of the more general stock definition of IHSSEN *et al*. (1981), who defines stock as "an intraspecific group of randomly mating individuals with temporal and spatial integrity". This reflects the fact that there is lack of a universally applicable definition of the term "stock" and therefore the difficulty and practical problems faced when fish stocks have to be recognized.

The use of genetic methods to determine whether two samples collected from two different areas belong to a single panmictic population or to two separate sub-populations or stocks is not always straightforward. If there are statistically significant genetic differences between the samples, and these differences are assumed to have arisen from restricted gene flow rather than local selection, then two stocks can be inferred. If no genetic differences are detected, then the results are inconclusive: either there is a single stock or there are actually two stocks, but the molecular markers used are unable to resolve them. In other words, the null hypothesis, in this case *panmixia*, can be rejected if heterogeneity is detected, but a failure to reject the null hypothesis does not prove that it is true. A finding of sample heterogeneity allows more powerful conclusions concerning stock structure, than a finding of sample homogeneity (WARD, 2000).

A problem in identifying marine fish stocks using molecular markers is that marine fish in general show low genetic differentiation among stocks or populations (e.g. WARD *et al*., 1994). This is commonly attributed to the apparent lack of strong physical barriers in the marine environment and to the high level of current gene flow among populations as a result of the high dispersal capabilities of marine organisms, both in larval and adult stages (ABRNASON & PALSSON, 1996; VIS *et al*., 1997).

Very few migrants per generation are often sufficient to prevent detectable genetic differentiation between conspecific stocks (HARTL & CLARK, 1997) and they would appear to be panmictic. Yet for fisheries management an exchange of as high as 10% between populations may justify their treatment as separate stocks. Even by using the most sensitive molecular markers, the discrepancy in gene flow between harvest stock and genetic stocks still exists, and molecular markers alone may not suffice to identify stocks with small degree of isolation (HAUSER & WARD, 1998).

Moreover, marine fish populations are usually very large, resulting in low levels of genetic drift. *Genetic drift* (the stochastic change of allele frequencies from generation to generation due to finite population sizes), is the main force acting on neutral loci that leads to genetic differentiation between recently separated populations, and its strength is reversibly related to population size, thus the smaller the populations the stronger the effects of genetic drift (HARTL & CLARK, 1997). A lack of detectable genetic structure may reflect an appreciable level of current gene flow, but also gene flow in the near past, like in the cases of recently isolated populations or colonization events. Moreover, there are reasons of methodological nature that may be responsible for an apparent lack of genetic structure, such as inadequate sampling or limitations of the molecular marker employed (CARVALHO & HAUSER, 1998).

Because genetic differentiation among marine populations is usually low, it is difficult to discriminate signal from the genetic noise associated with limited sampling. Thus WAPLES (1998) recommended sample replication over time to discern signal from noise. However, in many studies no temporal sample replicates are used.

Another issue on fish stock structure is the *mixed stocks* where fish with discrete spawning grounds mix in the feeding grounds. In this case samples taken outside the spawning season may contain individuals from different stocks. Modern statistical approaches permit the recognition of genetically differentiated stocks, even when there is mixing.

MOLECULAR MARKERS USED IN ASSESSING THE STOCK STRUCTURE IN FISH

Different types of molecular markers have been used to assess the stock structure in fish. *Allozymes* was the first type of molecular marker widely used in population genetics and the study of stock structure. Allozymes are the electrophoretic expression of the different alleles of functionally similar enzymes produced by a gene (*locus*). Each diploid individual carries a combination of two alleles at a certain locus, which constitutes its genotype for that locus. By determining the genotypic composition of two or more populations for several loci, one can distinguish whether the populations differ significantly from each other. Allozymes have some advantages over other types of molecular markers. The cost of analysis is low and many samples can be analyzed in a relative short time for many different loci. On the other hand, their use has some disadvantages: genetic polymorphism in allozyme loci is low compared to that of DNA loci, thus they have low resolution power to detect genetic differences, and some loci may be under natural selection.

Mitochondrial DNA (mtDNA) was historically the next molecular marker, which was used and is currently extensively used to study the evolutionary history and the stock structure of fish populations. MtDNA of animals has characteristics (e.g. high evolutionary rate, lack of recombination, maternal inheritance) that make it an ideal marker for studying the evolutionary history of organisms. Traditionally, the most commonly used method for population-level analysis and stock identification was the *Restriction Fragment Length Polymorphism* (RFLPs), that is, analysis by means of cutting the DNA with restriction enzymes called restriction endonucleases, which recognize and cut DNA at certain, specific for each enzyme, sequence motifs. The invention of *Polymerase Chain Reaction* (PCR) in the late 1980s allowed the *in vitro* amplification of portions of the mtDNA molecule, even from minute amounts of genomic DNA. These amplified portions can be subsequently studied either by restriction analysis or by sequencing.

Another technique used in studying genetic stock structure is *Random Amplified Polymorphic DNA* (RAPD). The RAPD technique allows the detection of DNA polymorphisms by amplifying randomly chosen regions of DNA by PCR with single arbitrary primers. The comparative ease of the technique and the fact that it covers polymorphisms in a large part of the whole genome, is counterbalanced by technical problems i.e. the fragment patterns are sensitive to PCR and care is required to ensure reproducibility. This problem is overcome by a similar technique, *Amplified Fragment Length Polymorphism* (AFPL), which is a robust, multilocus PCR-based DNA fingerprinting technique that can provide efficient, reliable and economic analysis of population genetics. Nevertheless, both RAPD and AFLP markers behave as dominant (only the amplified allele is detected),

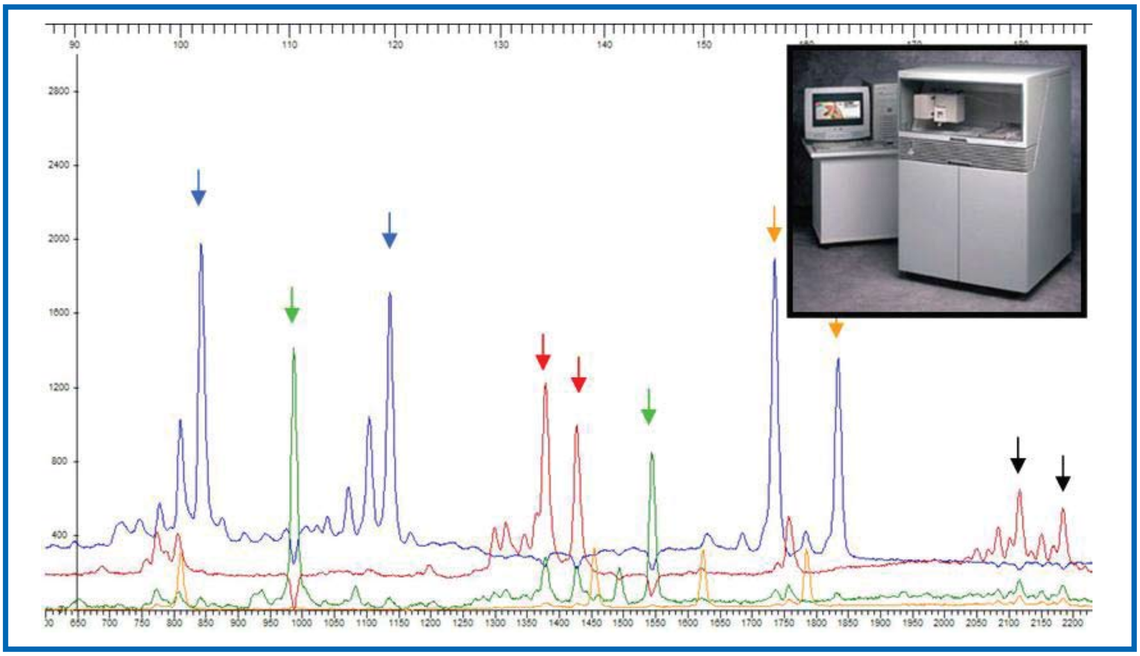

Figure 1: Chromatograph from the genotyping of a swordfish individual for five microsatellite loci in an ABI3700 automated sequencer. The alleles of each locus are denoted by arrows of different color.

which produces some statistical complications in the analysis of results.

Microsatellite DNA is another popular marker, which is currently considered the marker of choice in genetic stock identification studies. Microsatellite loci contain tandemly repeated motifs usually 2-6 base pairs long that are found scattered throughout the genome of all prokaryotes and eukaryotes investigated so far. Microsatellites used in stock identification studies typically contain di- tri-, or tetra- nucleotide repeats. They usually have higher resolution power to detect genetic differences among populations, due to their high mutation rate, which results in high levels of genetic variation in each locus. Different alleles at each locus usually differ in their number of repeats. Other advantages of microsatellites are the large number of loci that can be screened and the relative ease of analysis, particularly with automated DNA sequencers (Figure 1). A disadvantage may be the high cost and time for developing microsatellite markers *de novo*, for species that such markers have not already been developed.

The most recent addition in the ensemble of molecular markers used in population genetics is *Single Nucleotide Polymorphisms* (SNPs), which is emerging as a valuable new tool for stock identification and population history studies. SNPs are the most widespread type of sequence variation in the genomes. Although the use of SNPs as markers in population studies is still new, innovative methods for SNP identification, automated screening, haplotype inference and statistical analysis may quickly make SNPs the marker of choice (BRUMFIELD *et al*., 2003). So far SNPs have been used mainly in model organisms, for which SNP discovery can be done *in silico*, using the available sequence databases. In fisheries, at the moment, research using SNPs have been published only for the Atlantic salmo (*Salmo truta*) (RENGMARK *et al*., 2006).

GENETIC STOCK STRUCTURE OF FISH IN THE HELLENIC SEAS AND THE MEDITERRANEAN

In the present contribution we will present some case studies of genetic stock structure of commercially important marine species of the Hellenic Seas. Emphasis will be given to works that have been carried out by Hellenic scientists.

The majority of commercial fish species of Hellas present mainly an Atlanto-Mediterranean distribution (e.g. sardine, anchovy, gilthead sea bream), while others have a wider distribution, even worldwide (e.g. swordfish and blue-fin tuna). For several of these species genetic studies have been conducted in order to assess population structure. However, in the majority of the studies samples from only a part of the geographical distribution of the species were analyzed, so the emerging picture is not very conclusive in relation to their overall stock structure. In many cases genetic differentiation has been demonstrated between samples from different areas, but the sampling scheme was not usually dense enough to allow the clear delineation of stocks (discrimination of areas with sharp change in genetic composition). Furthermore, in many cases there are no temporal samples used, so when genetic differentiation is low, it is difficult to discern genetic signal from noise.

In a number of species genetic studies conducted so far were unable to reveal any genetic differentiation over a large geographical scale. A study on three mackerel species (Atlantic horse mackerel *Trachurus trachurus,* Mediterranean horse mackerel *T. mediterraneus* and Blue-Jack mackerel *T. picturatus*) using mtDNA RFLPs failed to reveal any intraspecific population structure in the Mediterranean and the NE Atlantic (KARAISKOU *et al*., 2004). For the Atlantic horse mackerel, a preliminary analysis of many samples throughout its distribution range using four microsatellite loci also failed to reveal any genetic structure (KASAPIDIS *et al*., in press). This work was carried out in the Institute of Marine Biology and Genetics of HCMR, within the framework of the EU project HOMSIR. In *Pagellus bogaraveo* both allozymes and mtDNA sequences did not reveal any genetic structure from Portugal to the Aegean (BARGELLONI *et al*., 2004), and the same pattern was revealed in *Scomber japonicus*, using mtDNA sequences (ZARDOYA *et al*., 2004). The lack of genetic structure in the aforementioned cases could be attributed to the high dispersal ability of those species. Nevertheless, the molecular markers used were mainly allozymes or mtDNA, which have a rather low power to resolve population structure.

A common pattern revealed in many other species is genetic differentiation between the Mediterranean and Atlantic populations. This pattern is associated with the broader area of the Straits of Gibraltar and especially the presence of a well defined hydrographic boundary area between Almeria (SE Spain) and Oran (Algeria), the Almeria - Oran front (TINTORE *et al*., 1988). In several cases it has been demonstrated that a barrier to gene flow exists at the Almeria-Oran front rather than in the Gibraltar Straits, with samples from the Alboran Sea, just east of Gibraltar, being genetically more similar to the Atlantic than to those from the rest of the Mediterranean Sea. Such a pattern has been found in many fish species (as well as in other taxonomic groups), like the flounder *Platichthys flesus* (BORSA *et al*., 1997), the common sole *Solea solea* (ROLLAND *et al*., 2007), different sparid species like *Lithognathus mormyrus, Dentex dentex, Spondyliosoma cantharus* (BARGELLONI *et al*., 2003), the hake *Merluccius merluccius* (ROLDAN *et al*., 1998; LUNDY *et al*., 1999 ; CASTILLO *et al*., 2004; LO BRUTTO *et al*., 2004; CIMMARUTA *et al*., 2005), the sea bass *Dicentrarchus labrax* (ALLEGRUCCI *et al*., 1997; ALLEGRUCCI *et al*., 1998) small pelagic like sardine *Sardina pilchardus* (RAMON & CASTRO, 1997), and big migratory pelagic like swordfish *Xiphias gladius* (MAGOULAS *et al.,* 1993; KOTOULAS *et al*. 1995; ALVARADO BREMER *et al*., 2005). For sardine, this pattern has been also demonstrated using microsatellites, within the framework of EU project SARDYN (KASAPIDIS *et al*., unpublished data)

For some species genetic differentiation has been also demonstrated within the Mediterranean, especially between the eastern and western basins. This differentiation is most probably caused by the Sicily - Tunisian Strait, which is known to be a biogeographical boundary between the two Mediterranean basins (QUIGNARD, 1978), although in very few cases this has been explicitly demonstrated.

Certain fish species have been extensively studied and shown patterns of prominent population structure within the Mediterranean. Anchovy, bonito, sea bass and red mullets are included in these. One of the strongest and most complex population structure for a marine species has been revealed in the European anchovy *Engraulis encrasicolus*. By studying RFLPs of mtDNA MAGOULAS *et al*. (1996) revealed the presence of two phylogenetic clades A and B (Figure 2). These two clades reflect an historical isolation of anchovy populations during the glacial cycles of the Pleistocene, possibly in the Atlantic and the Mediterranean (MAGOULAS *et al*., 2005). It is likely that the two clades have evolved in these isolated populations in the past and their coexistence in the greatest part of the present distribution range of anchovy is a result of secondary mixing after range expansion, most likely during the last deglaciation event. Currently these two phylogenetic clades are represented in different frequencies in the different basins of the Mediterranean and the Atlantic. In the Black Sea there is an almost exclusive presence of clade A, while in the north Aegean clade B has a frequency of ~15%, which increases to a frequency of ~65% in the southern Aegean and Ionian seas. The Adriatic is characterized by a high frequency of clade B (>82%), with a slight north to south cline in clade frequencies. Samples from the Ligurian Sea and the Gulf of Lions have clade B frequencies of ~56%. In the Atlantic, in samples from Dakar up to Aveiro in Portugal and to the Alboran Sea, clade A is again dominant ranging from 85 to 97%. In the Bay of Biscay, quite unexpectedly clade B is dominant (55%) (Figure 3).

European anchovy inhabits spatially complex coastal areas, and this complexity tends to isolate populations by reducing levels of gene flow between regions. Additionally, local upwelling and ocean gyres, further restrict gene flow within basins, and may explain this complex genetic structure.

Evidence for population structuring within the Mediterranean has been observed also for bonito *Sarda sarda*. An analysis of allozyme polymorphisms from samples from the Ligurian, Ionian and Aegean Seas provided preliminary evidence for two different groups of bonito, one in the Ligurian and the Ionian Seas and the other in the Aegean Sea (PUJOLAR *et al*., 2001). A more recent study using mtDNA sequences revealed a pattern of population structure very similar to that found in anchovy (VIÑAS *et al*., 2004): two phylogenetic clades A and B, represented in different frequencies in different basins.

The European sea bass (*Dicentrarchus labrax*) is one of the best studied European marine fish in terms of its population genetic structure. There are numerous genetic studies based on allozymes (ALLEGRUCCI *et al*., 1997; CASTILHO & MCANDREW, 1998), mitochondrial DNA (Patarnello *et al*., 1993) and microsatellites (GARCÍA DE LEÓN *et al*., 1997; BAHRI-SFAR *et al*., 2000; CASTILHO & CIFTCI, 2005) at different geographic scales. These studies have demonstrated genetic differentiation between the Mediterranean and Atlantic populations, with a transition zone located at the Almeria-Oran front (GARCÍA DE LEÓN *et al*., 1997), as well as between the east and west Mediterranean basins with a transition zone around the Sicily-Tunisian strait (BAHRI-SFAR *et al*., 2000). Within the eastern Mediterranean basin there are indications of further subdivision, as it has been demonstrated for example from the genetic differentiation between samples of the Ionian Sea and southern Turkey (CATSILHO *et al*, 2005). This genetic differentiation was surprising for this euryhaline and eurythermic demersal species, since adult migratory behaviour has been reported as reaching several hundred kilometers. Nevertheless, this might be related to climatic changes and sea water fluctuations during the Pleistocene that undoubtedly had a strong influence on the distribution of the species in the Atlantic Ocean and the Mediterranean Sea.

In red mullets, RFLP studies of mtDNA showed genetic differentiation between samples from the Aegean, Ionian and Mediterranean coast of France in *Mullus surmuletus*, while such a differentiation was not evident in *M. barbatus* (MAMURIS *et al*., 2001). The use of RAPDs markers in both species revealed a pattern of isolation by distance, while the use of allozymes was unable to reveal any differentiation (MAMURIS *et al.,* 1998a; MAMURIS *et al.,* 1998b; MAMURIS *et al.,* 1999).

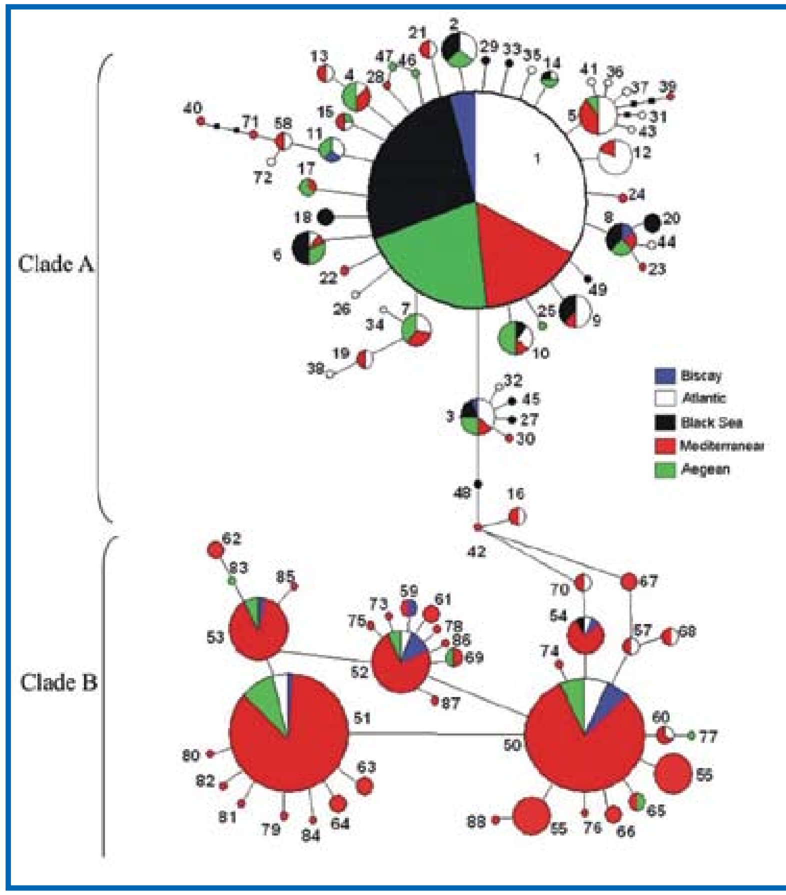

Figure 2: Median joining tree of the 88 haplotypes detected in *Engraulis encrasicolus*, which correspond to two evolutionary clades (A and B). The area of the circles is proportional to haplotype frequency. Shading refers to the region in which haplotypes were found (MAGOULAS *et al*. 2006).

CONCLUSIONS

Several phylogeographic studies conducted so far on marine fish of the Mediterranean and the Atlantic, using mitochondrial DNA sequences, have revealed traces of the historical background of species presently found in these basins. In several cases two main phylogenetic groups (clades) have been revealed, like in anchovy, bonito, swordfish etc. These two clades most likely correspond to the isolation of populations during the glacial pe-

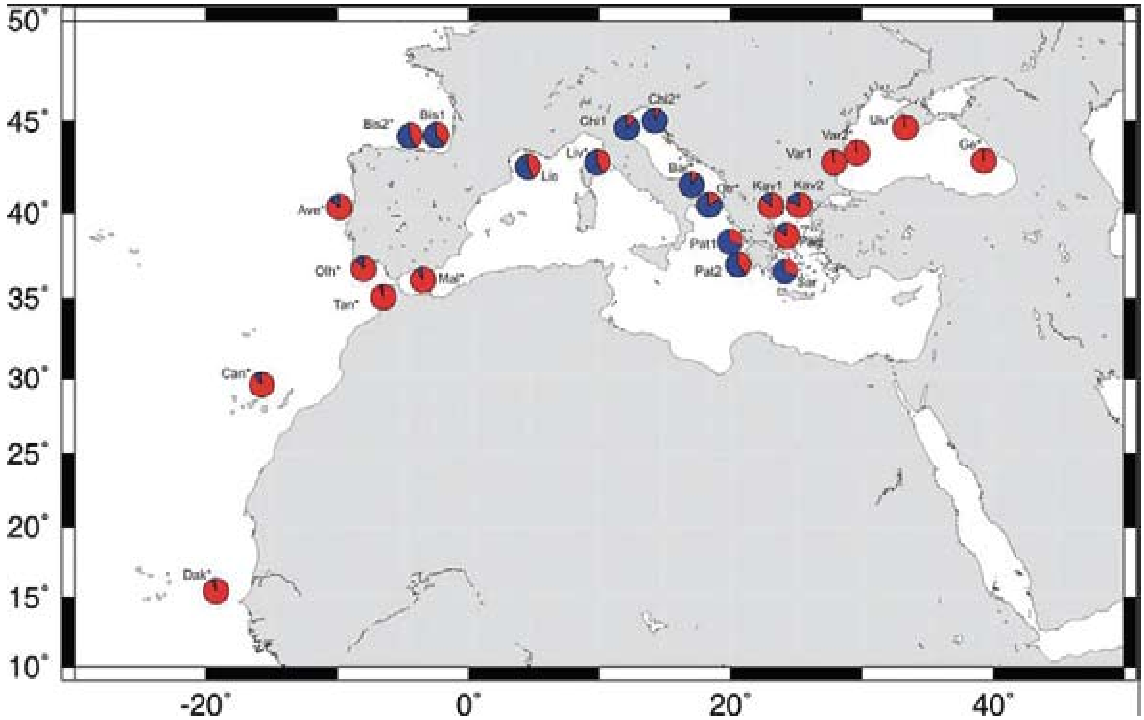

Figure 3: Frequencies of mtDNA clades A (red) and B (blue) in different anchovy samples from the Mediterranean and the Atlantic (from MAGOULAS *et al.* 2006).

riods of the Pleistocene. At least in some cases, these refugial populations seem to have been located in the Atlantic and the Mediterranean. After the end of the last glacial period these refugial populations expanded their distribution, and were mixed. In other species phylogeographic analyses have revealed only one clade, which point to a single refugial population surviving during glaciations. In all cases, a population expansion followed the end of the last glaciation, which was accompanied by extensive gene flow among different regions of the Mediterranean and the Atlantic. The current genetic structure is a result of these historical events combined with the current restrictions to gene flow (coastal configuration, hydrographic patterns, etc). Given the recent origination of most of marine fish stocks and the relatively high gene flow among some of them, it is obvious that genetic markers may be unable to detect genetic differentiation in some cases.

In the studies mentioned here, there were species with no detectable genetic structure over a large geographical scale, species that presented differentiation between the Atlantic and the Mediterranean but not within the Mediterranean, and species that had a finer genetic structure within the Mediterranean. In the Hellenic Seas, differentiation has been detected in a few cases between the Aegean and the Ionian. Furthermore, there are indications that the Bosporus Strait is a barrier to gene flow between the Black Sea and the Aegean, which at least in the case of anchovy appears as uni-directional.

Genetic markers alone can reveal genetic stock structure, but in the cases where no such structure is revealed, it is still possible that stock units exist reacting independently to exploitation, which is of great importance to fisheries managers. Thus BEGG & WALDMAN (1999) suggested a holistic approach, whereby available information on stock structure from different techniques is collated in a single review or multiple methods are applied to the same samples to infer stock structure. Incorporating different stock identification methods into a single study often allows apparent discrepancies implied by each method to be resolved, while additional information is gained by the interpretation of those discrepancies (WALDMAN, 1999). A wide range of methods are applied to identify fish stocks (tagging, life history characteristics, parasites, otolith microchemistry, morphology and genetics) (CADRIN *et al.*, 2005). This approach has been already applied in some EU-funded projects for stock identification, such as FAIR Hake (hake, *Merluccius merluccius*), SARDYN (sardine, *Sardina pilchardus*), and HOMSIR (horse mackerel, *Trachurus trachurus*). A special issue of *Fisheries Research* including a collection of papers produced by the last project (HOMSIR) is to be released soon. Despite the limitations of genetic markers in identifying fish stock, their use in fisheries management is very important. The advances in molecular technology currently allow the assessment of genetic differentiation of fish stocks with many markers (e.g. microsatellites), thus increasing the resolution power, at relatively low cost and short time. In the coming years, it is expected that a better characterization of commercial fish stocks will be achieved by using genetic markers, which will further allow the traceability of fish and fish products to their stock of origin, thus greatly improving stock management.

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VII.5. REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

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INTRODUCTION

During the last three decades, the advancing new technologies of Remote Sensing (RS) and Geographical Information Systems (GIS) allow us to use spatial data such as satellite imagery, aerial photographs, and geo-referenced data layers and the necessary tools to comprehend ecosystem functioning and environmental change and more effectively monitor and manage our marine natural resources.
The combined use of RS and GIS technologies form an invaluable tool for the identification and spatiotemporal mapping of environmental processes and changes, fish population dynamics and fisheries-environment interactions. RS and GIS facilitate the decision-making process and promote the scenarios for geographic information use, the ecosystem approach to fisheries' management and the sustainable use of marine resources by the year 2015, principles evolved and agreed during the Earth Summits organized for the environment in Rio de Janeiro (1992) and Johannesburg (2002) (Figure 1).
In this unit, the basic concepts of RS and GIS are explained and their combined application to Hellenic marine environment and fisheries are presented (VALAVANIS, 2002).

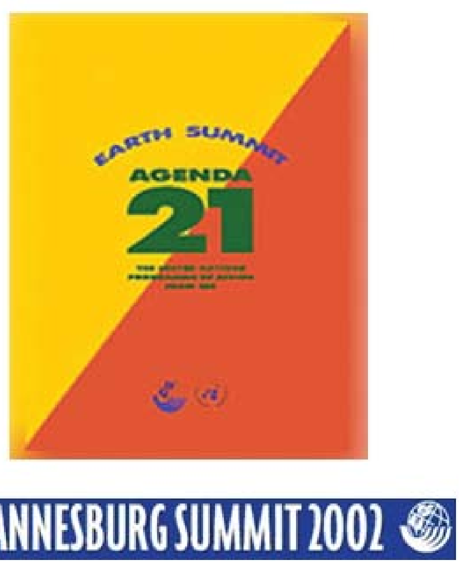

Figure 1: AGENDA 21 (Rio Declaration on Environment and Development 1992) as well as the Fisheries Agreement (Johannesburg Earth Summit 2002) describe the commitment of the world's governments to use geographic information from established and new monitoring systems in order to develop information-based management polices for decreasing over-fishing, restoring depleted fish stocks and using natural resources under sustainable and development schemes.

MARINE SATELLITE REMOTE SENSING

Remote Sensing (RS) aims to develop and use knowledge of the optic properties of the components of the earth's surface in order to obtain algorithms, which can be used to draw charts expressing important properties of the earth's surface on the basis of measurements taken from a variety of earth-orbiting satellites and other airborne systems and their sensors. In Marine Sciences, RS data obtained from visible or thermal infrared and microwave sensors include the charting of a variety of important water properties, including sea surface temperature, chlorophyll, photosynthesis levels and sea level altimetry measurements along wide ocean areas. Current basic RS research focuses on the development of new sensors for the measurement of additional sea properties, such as salinity.
The ways satellites and their sensors orbit around the earth and measure sea surface parameters are multifaceted. Environmental satellites are launched in geostationary or polar orbits. Geostationary satellites follow the earth's rotation and they monitor the same area of the earth and constantly send back information about that area. Polar-orbiting satellites go around the earth from pole to pole and they monitor different areas during their orbit (Figure 2).
A geostationary (GEO for geosynchronous) orbit is one in which the satellite is always in the same position with respect to the earth's rotation. The satellite orbits at an elevation of approximately 36 000 km because that produces an orbital period (time for one orbit) equal to the period of rotation of the earth (approximately 24 h). By orbiting at the same rate, in the same direction as the earth, the satellite appears stationary (synchronous with re-

spect to the rotation of the earth). Geostationary satellites provide a "big picture" view of the same part of the earth. Alternatively, polar-orbiting satellites provide a more global view of the earth, circling at near-polar inclination (the angle between the equatorial plane and the satellite orbital plane), orbiting at an altitude of approximately 900 km. A polar-orbiting satellite operates in a sun-synchronous orbit passing the equator and each latitude at the same local solar time each day, meaning the satellite passes overhead at essentially the same solar time throughout all seasons of the year. This feature enables regular data collection at consistent times as well as long-term comparisons. The orbital plane of a sun-synchronous polar-orbiting satellite rotates approximately one degree per day to keep pace with the earth's surface.

Satellites and their sensors monitor the earth's surface in two main ways (Figure 3). Sensors that provide their own source of energy are called active while sensors that rely on the sun's energy are called passive. Active sensors emit radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. Active sensors include radars, scatterometers, lidars, laser altimeters and sounders. On the other hand, passive sensors detect the sun's energy that is either reflected (visible wavelengths of the light spectrum) or absorbed and then re-emitted (thermal infrared wavelengths) by the earth's surface. Passive sensors include radiometers, spectrometers, spectroradiometers and hyperspectral radiometers. Both active and passive sensing provides a variety of measurements including both atmospheric and oceanic parameters (Table 1).

While satellite acquisitions are most often presented in the form of images, they are actually digital data. Acquired satellite data provide measurements of the sea surface temperature in °C, chlorophyll-a concentration in mg/m^3, ocean wind speed in m/sec, sea level altimetry in cm, etc. Examples of several satellite data are presented in Figure 4. Satellite measurements have three main characteristics that depend on the sensor's capacity to acquire data at a given detail. These characteristics are named spectral, spatial and temporal resolution and they depict the primary characteristics of each sensor. The spectral resolution of a sensor and its acquired data is a measure of its power to resolve features in a certain part of the electromagnetic spectrum (active sensors) or the spectrum of visible light (passive sensors). This is important because certain features are best monitored at certain parts of the spectrum. The spatial resolution of satellite data is a measure of the ability of a sensor to separate the images of closely adjacent objects, meaning the smallest area identified as a separate mapping unit is the picture element (pixel) of the satellite image. Objects that are smaller than the spatial resolution of an image are not monitored. Finally, temporal resolution is the frequency at which satellite data are recorded in a specific place on earth. The more frequently an

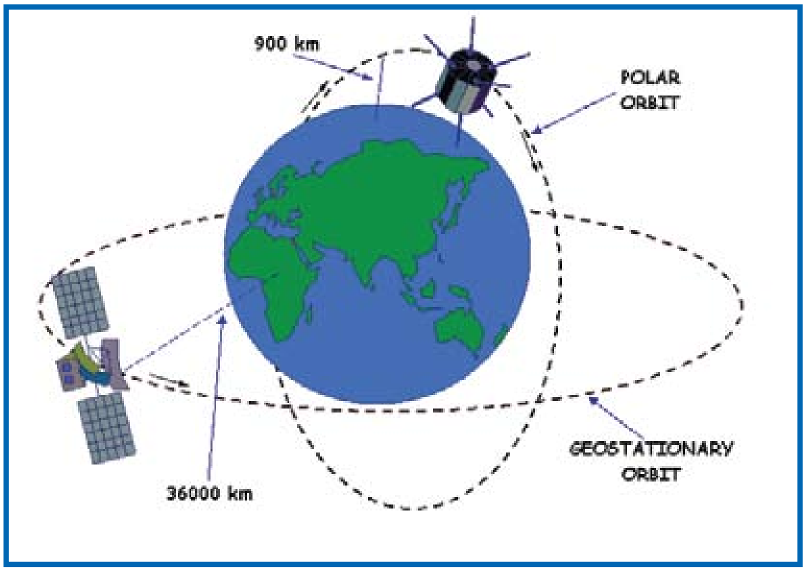

Figure 2: The geostationary and polar orbits of environmental satellites. Sensors in geostationary orbit constantly monitor the same area of the earth while sensors in polar orbit provide data for essentially all the earth's surface.

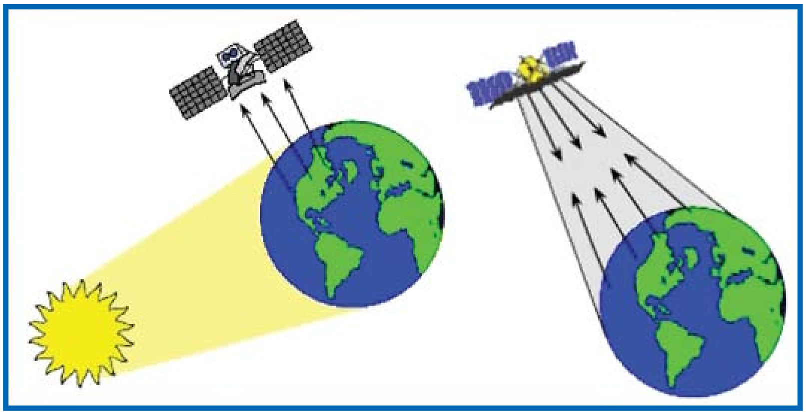

Figure 3: The passive and active Remote Sensing sensor systems. Sensors absorb either the sun's light reflectance to the earth (passive) or they transmit and absorb their own signal (active). Different environmental parameters are measured by each sensor system.

Table 1. Main environmental satellites, their sensors and measured environmental parameters applied in oceanographic and fisheries research.

SATELLITE	SENSOR	TYPE	PARAMETER
NOAA-POES Polar Operational Environmental Satellites	AVHRR Advanced Very High Resolution Radiometer	Passive, multispectral radiometer	Sea Surface Temperature
AQUA	MODIS Moderate Resolution Imaging Spectroradiometer	Passive, imaging spectrometer	Sea Surface Temperature and Chlorophyll
SeaStar ORBVIEW	SeaWiFS Sea viewing Wide Field-of-view Sensor	Passive, ocean colour sensor	Sea Surface Chlorophyll, Photosynthetically Active Radiation
QuikSCAT	SeaWinds	Active, radar scatterometer	Ocean Wind Speed and Direction
ERS-2 European Remote Sensing	WD Wind Scatterometer	Active, radar scatterometer	Ocean Wind Speed and Direction
ERS-2 European Remote Sensing	RA Radar Altimeter	Active, radar altimeter	Significant Wave Height, Surface Wind Speed
TOPEX-Poseidon	Doris Doppler Orbitography and Radiopositioning	Active, radar altimeter	Wind Speed, Wave Height

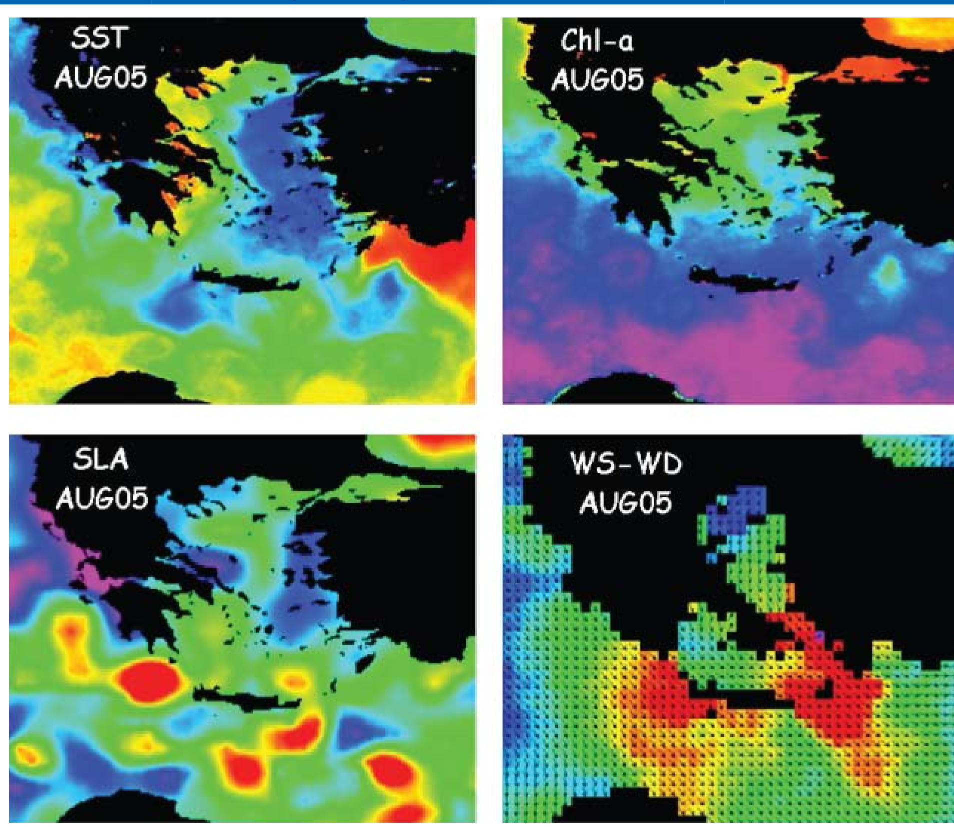

Figure 4: Examples of monthly-averaged satellite data for August 2005 in the SE Mediterranean. Main oceanic processes (e.g. gyres, eddies, fronts and upwelling) are visible in SST (sea surface temperature), Chl-α (chlorophyll), SLA (sea level altimetry) and WS-WD (wind speed and direction) satellite images. Colours depict real parameter values (purple/blue: low, green/yellow: medium, red: high).

area is monitored, the better or finer the temporal resolution is for that area.
Today, the combination of fine spectral, spatial and temporal resolutions characterizes most satellite sensors and acquired multi-parameter data that provide an enormous amount of information for the state of the sea surface. These data are widely processed through GIS to identify several ocean processes and marine species-environment interactions.

MARINE GEOGRAPHICAL INFORMATION SYSTEMS

Geographic Information Science (GI Science), the scientific context to Geographic Information Systems (GIS), which is the technical content of GI Science, are both emerging and coherent science and technology fields with two important research streams: research in basic GI Science (e.g. software integration, data scale and resolution, process models) and research using GIS (e.g. data modelling and integration, decision support). In Marine Sciences, GIS are widely applied to data modelling and integration producing analytical results in the form of charts that depict the condition of the marine environment and its living resources in spatiotemporal scales and effectively support information-based natural resource management schemes (Figure 5).
GIS is considered the main framework for geospatial data handling. The main two components of a GIS are its database and its analytical capacity. GIS has the ability to relate different data in a spatial context and to reach a conclusion about their relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. In GIS databases, two main data models are stored. These data models, raster (e.g. satellite data) and vector (Figure 6) represent the whole variety of marine data used in various analytical procedures. Because data in GIS are stored under a common geo-reference system, different types of data can be viewed through a map overlay (Figure 7). This technique allows the combined analysis of raster and vector data in order to identify any possible relations among different datasets.
The common geo-reference of different data types is the first step in GIS development. Given this uniform storage of various data, GIS analyses include a variety of data integration and statistical procedures that are applied to data according to specific questions to be answered. Such questions include six basic concepts that are inherently spatial and are used by geoscientists in studying spatial phenomena. These spatial concepts are location, distribution, region, association, movement and diffusion.
The most basic spatial concept is that of location. For example, the location of a meteorological station will give a spatial meaning to the associated dataset. Also, the first question, for example, that an oceanographer studying an upwelling event will typically ask is "where does it occur"? Distributions may be thought of as sets of individual locations of one or more datasets describing a part or the whole of an area. A region is an area that is distinguished from other areas by one or more characteristics. By creating a region a scientist is able to generalize and simplify. A region, for example, is an area where sea surface temperature (SST) is generally lower than in the surrounding area. If we have two different spatial distributions that appear to be similar, we have a spatial asso-

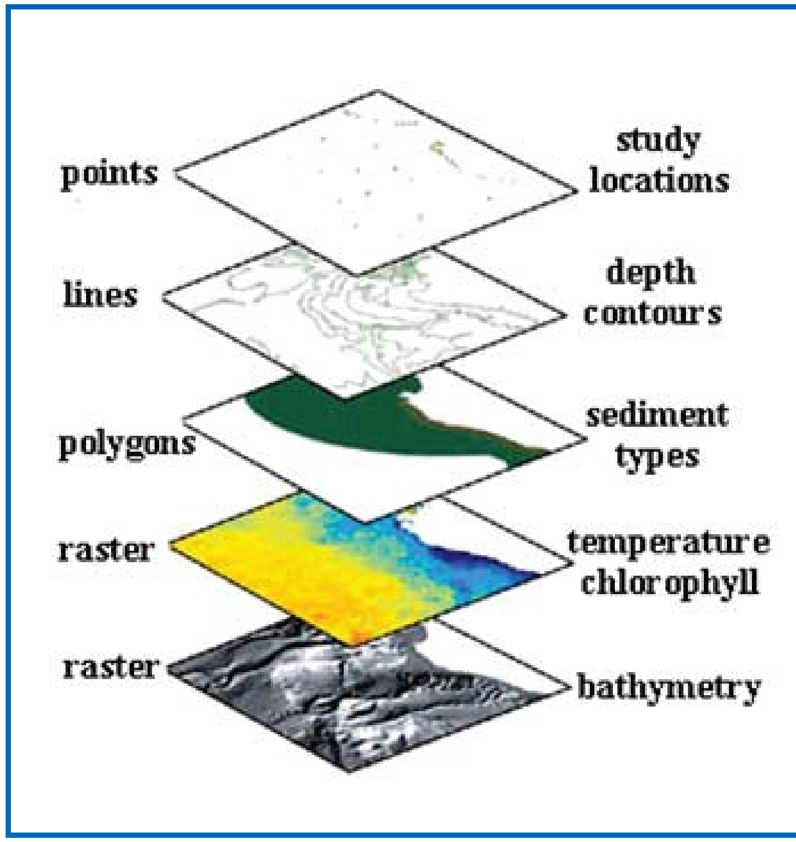

Figure 5: Examples of the variety of data types handled by Marine GIS. Points, lines and polygons are vector data type while satellite imagery and model output are raster data type. Under GIS databases, different data formats are uniformly stored and referenced through a common geo-reference system. Then, spatial integration and GIS analysis of different data formats is applied.

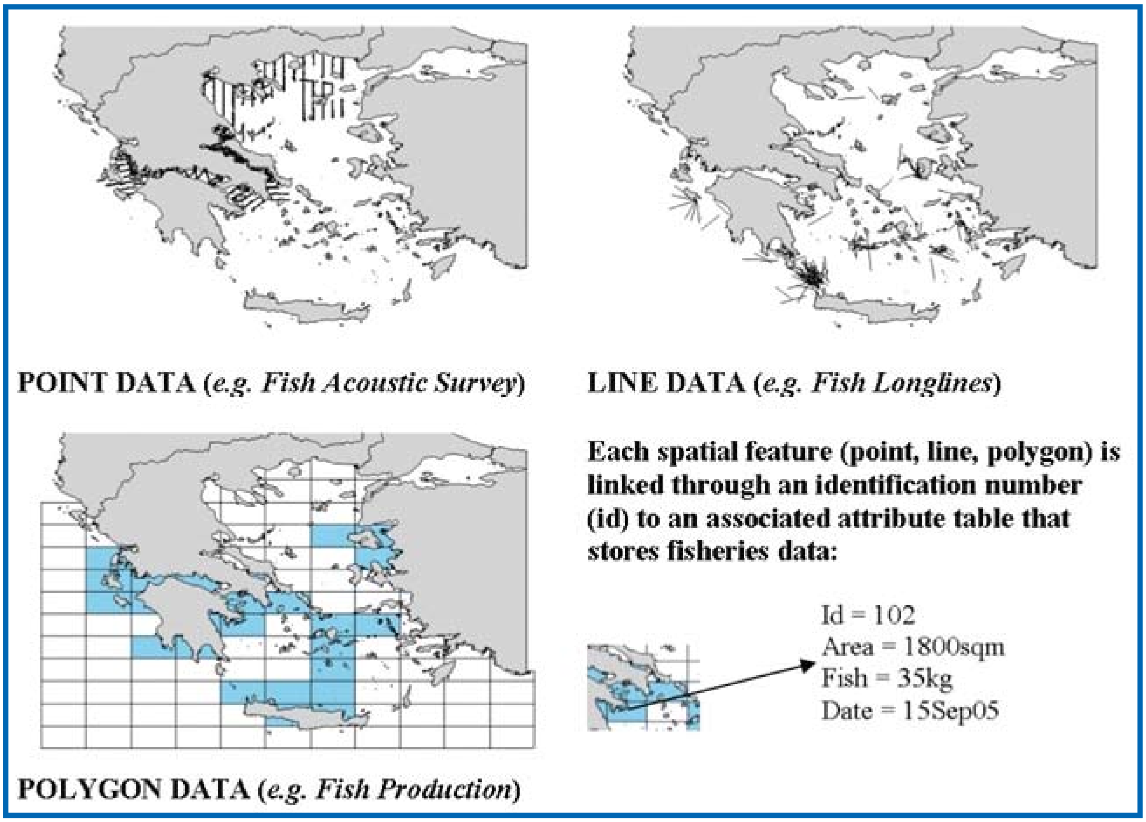

Figure 6: Examples of a vector GIS database including fisheries attribute data represented by points, lines and polygons. Here, research vessel acoustic surveys are represented by points and longline fishing activity is represented by lines. Polygons represent the official sampling units for the monitoring of Hellenic fisheries' resources (size: 1° x 0.5°).

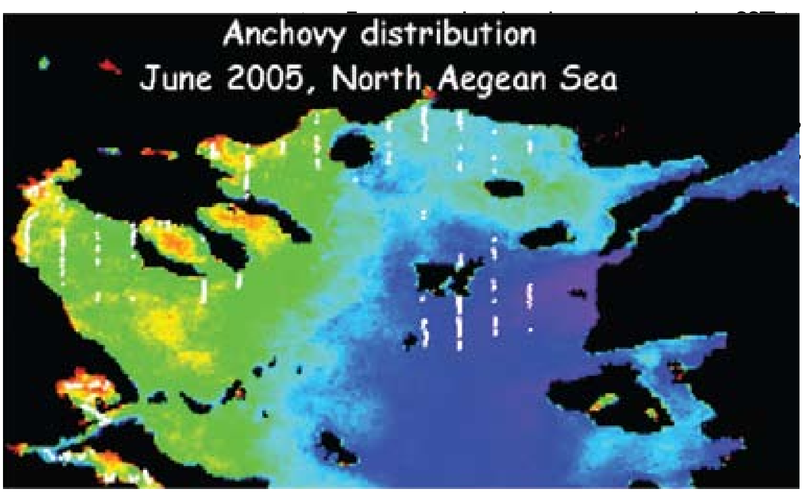

Figure 7: Overlay example of vector and raster GIS datasets including anchovy attribute data (vector-points) and sea surface temperature (raster-colours). The common geo-reference storage of different data models in GIS databases prepares data for further statistical and GIS analyses.

geoscientist may integrate the associated datasets and explain, for example, how the distribution of wind data from several locations of meteorological stations affects a region where a spatial association between SST and Chl-a does exist and how movements of fish populations correspond to this process, and finally, how this process is diffused in space and time.

Spatial analysis in GIS refers to a large number of modelling data operations including a variety of techniques, such as classification and aggregation, proximity analysis, adjacency analysis, connectivity analysis, optimum path analysis, statistical analysis, interpolation and outlining as well as other data integrations.

Classification involves reassigning a data value to a descriptive attribute of a polygon according to the values taken by other attributes. Classification can be followed by aggregation, which involves grouping two or more adjacent reclassified units by dissolving boundaries between polygons and then reconstructing new data topology. For example, an SST image can be classified based on certain data ranges and then aggregated to areas of low, medium and high temperature values (e.g. identification of upwelling areas). Proximity analysis involves the determination of several spatial features (points, lines, polygons) located within a maximum distance from a given spatial feature. Proximity analysis introduces the concept of a 'buffer zone', which can be of a fixed or variable size. For example, proximity analysis may be used to locate fishing ports that are within 100 miles from a given fishing area (e.g. spatial relation between catches and landings). Adjacency analysis involves reassigning to a given data value a new value, which depends on that of neighbouring data values. In raster data, such as satellite images and aerial photographs, adjacency analysis might employ a filter, such as a summation, mean or gradient filter. For example, adjacency analysis may be used for the computation of slope (e.g. the rate of change in data values) in a Chl-a image (e.g. identification of Chl-a fronts). Connectivity analysis consists of determining the boundaries of an area by starting from a certain data value and moving in every direction in order to locate the points verifying a given data value (e.g. threshold value). For example, connectivity analysis may be used for the identification of areas where SST is between 20 and 23 °C.

Optimum path analysis consists of determining the optimum path between two points or areas considering distance, cost, time and other factors. For example, when combining fish migration habits and environmental data, this type of analysis applies well to seasonal fish migrations. Impedance, which is defined by characteristics such as certain data values, is assigned to each data value revealing, e.g. the difficulty of a species to pass through certain data values of SST (according to species-preferred living environmental conditions). Statistical analysis supplies basic statistics on the descriptive data such as mean, standard deviation, minimum, maximum and median values and histograms of data distribution. More sophisticated analyses such as regression, classification and Principal Component Analysis (PCA) provide valuable information, for example in relations between fisheries' populations and oceanography. These calculations are common in image processing software packages and are widely used in GIS. However, current GIS packages often do not include extensive statistical tools but do provide data exchange with such tools. Interpolation techniques provide an estimate of a value at a point where the value is unknown, within a region covered by a number of known values of sampled points. The choice among the many interpolation methods depends on the spatial model, which is best fitted to the sampled values. Two commonly used interpolation methods are local interpolation (spline, weighted mobile mean), and kriging. These methods are based on the hypothesis whereby two points, which are close to each other are more likely to have similar values for a given property than two distant points are. They take into account the fact that space is not necessarily isotropic (e.g. the bottom sediment values from a point sonar survey are more likely to vary through the whole of a study area than between two close together and parallel transect lines).

During the process of marine GIS development, often multiple inputs are required. For example, the explanation of why a mobile cephalopod species (e.g *Loligo vulgaris*) is found 200 km offshore at certain times of their life cycles, requires the input of species life history data into their migration habits (fisheries' biologists), wind and current patterns, and the identification of food supply upwelling events in the region at that specific time (physical and biological oceanographers) as well as expert GIS developers for the integration of this knowledge. From the GIS point of view, the ultimate aim is to join all required knowledge and develop a model of the marine environment in order to understand what and where things are and how and why they are where they are.

MARINE GEOGRAPHIC INFORMATION SYSTEMS IN HELLENIC SEAS

Over the last two decades, there has been increasing recognition that problems in fisheries and related marine areas are nearly all manifest in the spatial and temporal domain. The combination of oceanographic and fisheries' GIS applications and tools provides the opportunity to identify the dynamic relations between species populations and ocean processes in spatial and temporal scales. The need for the identification of interactions between environment and fisheries becomes crucial in the fisheries management process.

For these reasons, an integrated approach to the management of Hellenic fisheries' resources includes the development of a multi-component management system by the Institute of Marine Biological Resources (IMBR) of the Hellenic Centre for Marine Research (HCMR). IMAS-Fish (Development of an Integrated Management System to support the sustainability of Hellenic Fisheries' resources: IMAS-Fish) delivers data and analytical information to fisheries' policy makers and supports the decision process towards new and effective management schemes. The system includes all the components of past and current monitoring systems of the Hellenic fisheries' resources and in-

tegrates latest developments in statistical, GIS and RS applications in fisheries' management promoting the ecosystem and precautionary approaches.
The components of IMAS-Fish are multifaceted. The system operates on a 3-fold technological setting, including an Oracle database, a GIS database and an Internet server. Databases include a variety of fisheries and oceanographic datasets (e.g. fisheries' effort and production, survey data, satellite imagery and other environmental data) while its analytical functions are accessible through the Internet. RS and GIS developments for the Hellenic Seas over the last decade are incorporated into this system. The IMAS-Fish tool is accessible at: http://efterpi.ncmr.gr/imasfish (ZERVAS *et al.,* 2004; DAMALAS, 2005; DAMALAS *et al.,* 2006).
A variety of marine and fisheries' GIS research applications aim to identify the spatial component of ocean processes, fisheries' resources and their relations. From the oceanographic perspective, several studies deal with the classification of sea surface waters (DRAKOPOULOS, *et al*., 1999, 2000, 2002) and the mapping of ocean processes, namely fronts, gyres, marine productivity hotspots and upwelling (VALAVANIS *et al.,* 1999, 2004, 2005; KATARA *et al.,* 2005). From the fisheries' perspective, several studies deal with the mapping of fish population distributions (VALAVANIS *et al.,* 2002, 2004), mapping of essential fish habitats (VALAVANIS *et al.,* 2004; GIANNOULAKI *et al.,* 2006) and species-environment relationships (VALAVANIS *et al.,* 2002; KAPANTAGAKIS *et al.,* 2002). These GIS-based research applications use satellite environmental data and surveyed fisheries' data combined with various GIS, statistical and geostatistical techniques.
The classification of surface waters based on their temperature, chlorophyll and salinity characteristics provides an insight into the state of the sea surface environment and explains why fish population distributions are concentrated in more productive areas in the north and central Aegean Sea while gradually diminishing in numbers in less productive waters in the south Aegean and the Cretan Sea. In fact, 60-70% of total fisheries' production comes from the north/central Aegean Sea that is characterized by productive waters, river run-off and Black Sea water input. Four classes of water are identified through Principal Component Analysis (PCA) and unsupervised classification of combined satellite and model data. Classified water bodies in the Hellenic Seas have the following characteristics (Figure 8): 16-24°C, 0.20-3.80 mg/m^3 and 37.9-38.3 psu (red), 18-23°C, 0.10-0.27 mg/

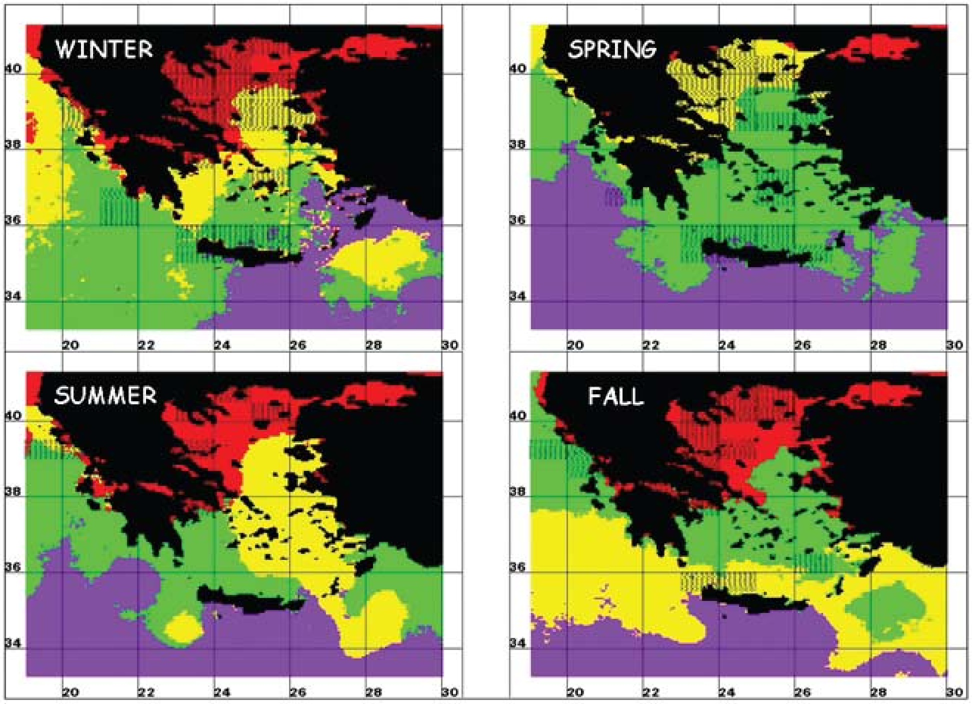

Figure 8: Seasonal classification of surface waters based on their temperature, chlorophyll and salinity content for the period 2000-2005. General distribution of *Loligo vulgaris* (short-finned squid) is also shown for the same period. Four classes of water are identified (see text for colour-scale description). Monitored squid production is mostly associated to colder, less saline and more productive water bodies, a pattern that is observed in most commercial fish species in Hellenic Seas.

m³, 38.2-38.6 psu (green), 18-25°C, 0.08-0.14 mg/m³, 38.3-39.7 psu (yellow) and 19-25°C, 0.05-0.08 mg/m³, 38.6-38.8 psu (purple).

The mapping of major ocean processes provides invaluable knowledge on the identification of certain marine areas that affect fish population distributions, either passively or actively (Figure 9). For example, a productive thermal front (an area where different water masses converge) is an area where many fish species actively aggregate for their feeding. Marine productivity hotspots and upwelling have similar fish aggregation effects while productive gyres and their surrounding currents often function as natural barriers where fish are passively trapped inside these productive areas. Depending on species' life stage (egg/larvae, juvenile, adult), these ocean processes create favourable environmental conditions and habitats that are used by various fish species for spawning/nursery, feeding and mating purposes.

For example, the spatial distributions of *Engraulis encrasicolus* (European anchovy) acoustic survey data and mesoscale thermal fronts in the north Aegean Sea during June 2004 present strong associations. Accompanied GIS and Generalized Additive Model (GAM) analysis reveals the distribution of fronts and trends in anchovy presence and its distributional abundance. In the Thracian Sea (permanent anticyclones and fronts) results indicate that anchovy is distributed within the continental shelf (depths <200m), an area dominated by chlorophyll-a concentrations around 0.45 mg/m³. Anchovy abundance is higher in areas of less than 300m, around 22.75°C and 0.58 mg/m³. In the Thermaikos Gulf (extended continental shelf), anchovy is present in areas less than 60m. In both areas, anchovy abundance is within 5.55 nautical miles minimum distance from fronts (total study area 160x105 nautical miles). Alternatively, ocean gyres function as natural barriers between different life stages of the same species. A typical example of this pattern is the distribution of European anchovy larvae inside a gyre while adults are distributed around the gyre boundary.

Such multi-parameter GIS spatial associations are very important for the management of marine fisheries' resources. The over exploitation of fisheries' resources is a worldwide spatial problem. Previously rich areas in marine resources and favourable habitats have been either over fished or destroyed by certain fishing gears. The need to design and protect over exploited regions and identify alternative fishing grounds is growing rapidly. Thus, GIS applications dealing with this important subject produce integrated map products that aim to facilitate this important issue. For example, the mapping of marine productivity hotspots reveals both known fishing grounds and potential alternative fishing activity areas (Figure 10). This trend may be used for the design of seasonal and spatially-variable marine protected areas that will help the natural conditioning of traditional fishing grounds in regenerating themselves. On the other

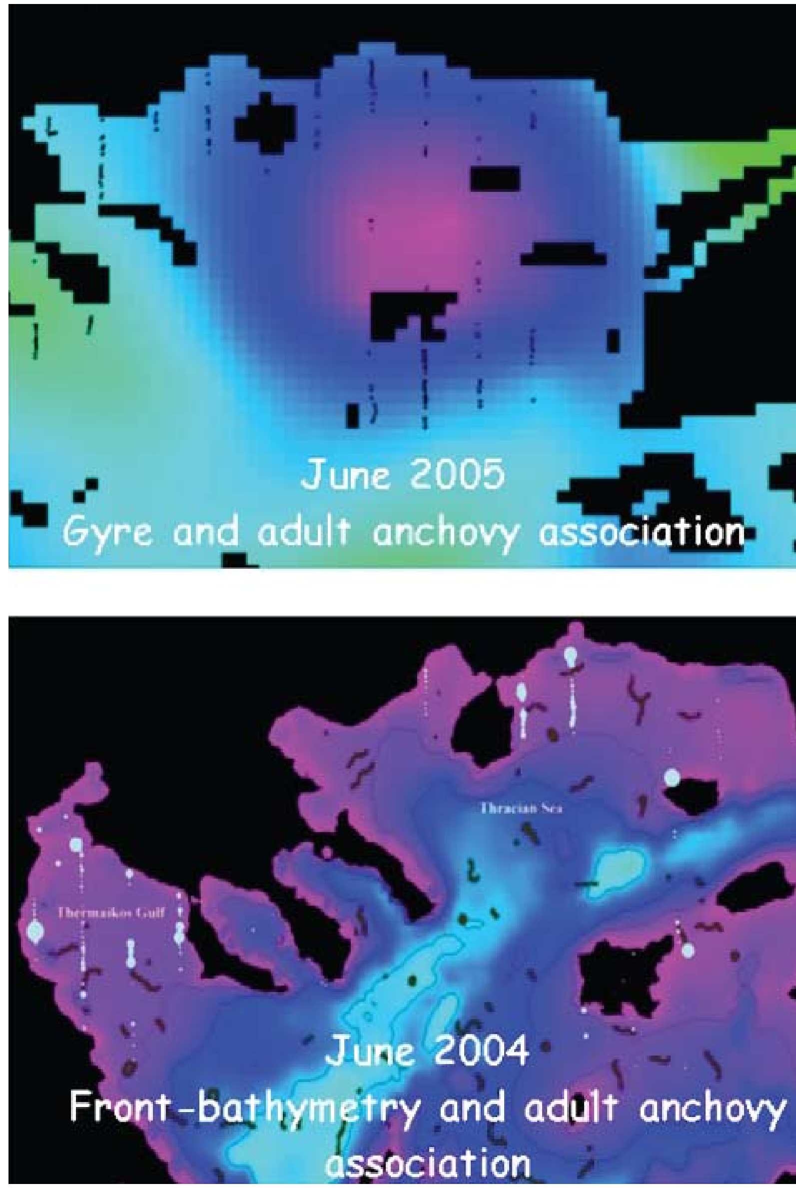

Figure 9: Spatial associations of adult *Engraulis encrasicolus* (European anchovy) acoustic survey data in the north Aegean Sea to gyre formation (June 2005) and mesoscale thermal fronts (June 2004). Shaded bathymetry (purple to light blue for shallow to deeper waters) and isobaths of -100m, -300m and -1 000m are also shown.

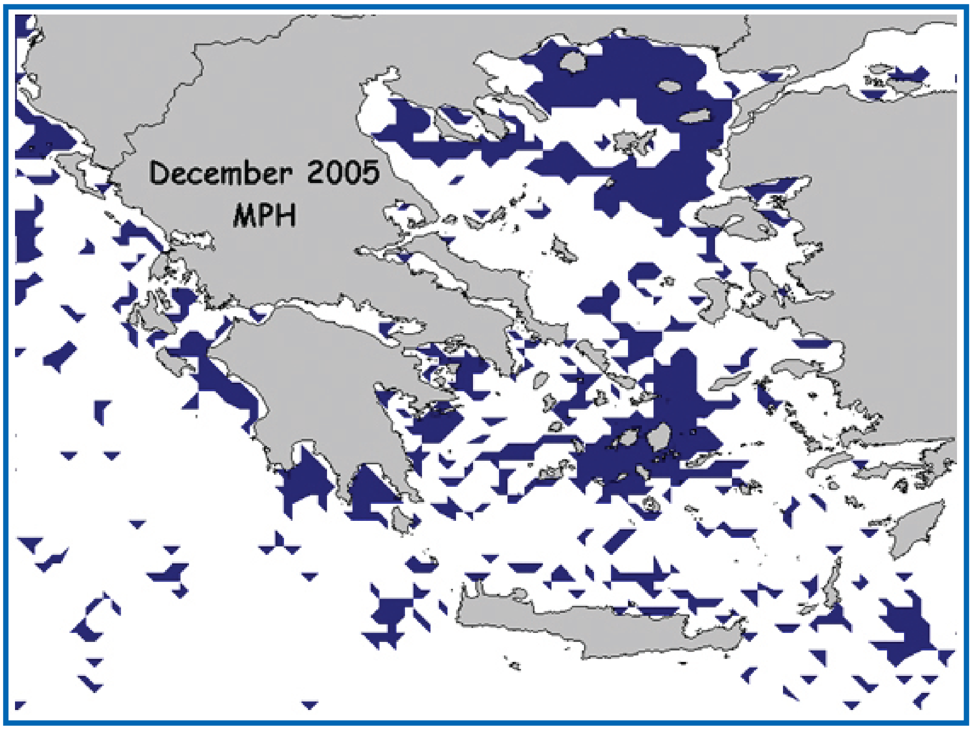

Figure 10: Marine Productivity Hotspots (MPH) in Hellenic Seas in December 2005. MPH are characterised by negative SST and positive Chl-α anomalies and reveal known fishing grounds as well as potential alternative fishing activity areas. Such GIS products may facilitate the spatial component of the fisheries' management process.

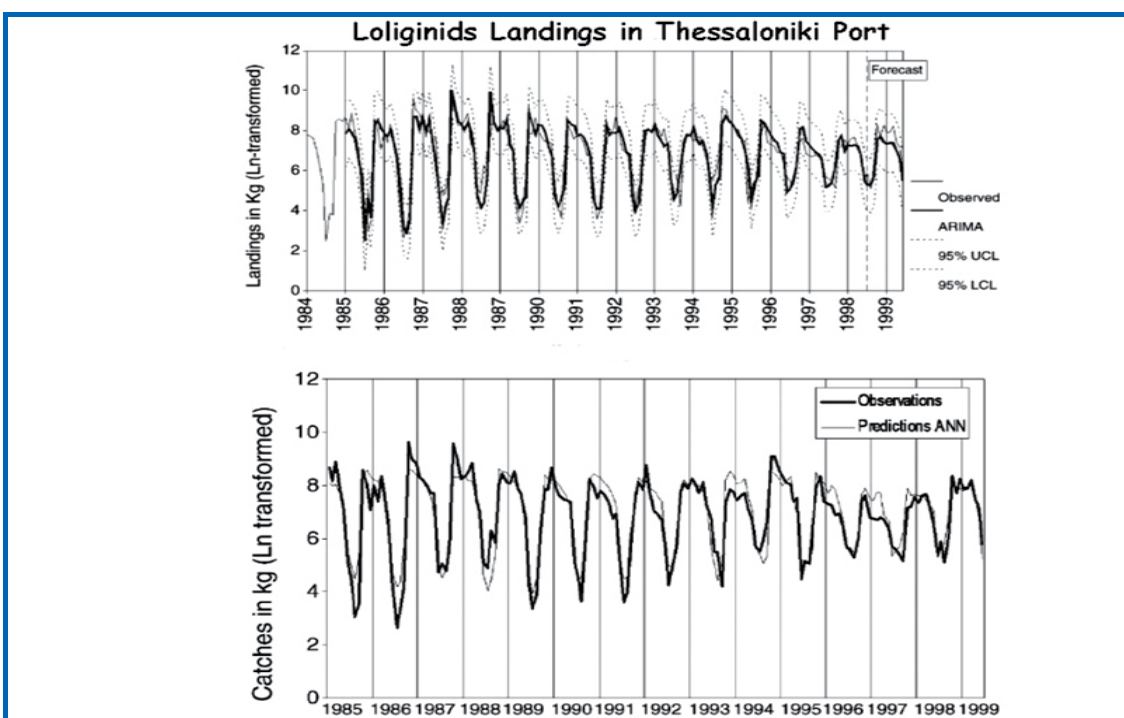

Figure 11: The use of environmental parameters for fisheries' forecasting and prediction using Auto-Regressive Integrated Moving Average (ARIMA) model and Artificial Neural Networks (ANN) for Loliginids landings in Thessaloniki port (1985-1999). Sea Surface Temperature (SST) may be used as environmental descriptor for the prediction of landings at high confidence limits.

hand, fishing activities could be led to new unexploited areas.

In association with this, fisheries' forecasting becomes important (Figure 11). Modelling fish production and distribution in short and medium terms greatly facilitates the management process. GIS and statistical applications on this subject provide important outputs on the identification of those environmental factors that may be used as indicators of fish production and distribution (GEORGAKARAKOS *et al.,* 2002, 2006).

In a spatial context, combined RS/GIS/statistical applications aim to facilitate the complex fisheries' management process by providing products that are based on scientific knowledge and analysis in order new management schemes could be based on analyzed monitored information and eventually become more effective than current policies.

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VII.6. DEEP-WATER FISHERIES RESEARCH IN THE HELLENIC SEAS

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INTRODUCTION

The deep sea is the most vast and unexplored environment on the planet. In addition to its large volume, the deep sea comprises a variety of different habitats, from plains of mud, to rocky seamounts, hot spots, chemosynthetic environments and cold deep-water coral reefs. Most of our knowledge up to now of the inhabitants of the ocean is derived from the top 100 m. Of the six million species records currently in the Ocean Biogeographic Information System (OBIS), only 1% is from below a depth of about 1 000 m. Scientists began studying life in the deep sea in the 19th century; the first record presented by RISSO in 1816. The Challenger expedition (1872-1876) in the Atlantic and the Pacific Oceans was the first systematic oceanographic expedition, followed by the Pola (1890-1893), Dana (1908-1910) and Thor (1921-1922) expeditions in the Mediterranean (CARTES *et al.*, 2004 and references therein). Nevertheless, most scientific study on deep-sea ecosystems has occurred only in the last one or two decades, after the development of the deep-water fishery. Deep-water fisheries resources started to be exploited in the early decades of the 20th century, and commercial fisheries increased in importance since 1950s in the western Mediterranean (SARDÀ *et al.*, 2004) and late 1960s and 1970s in the ICES Area (BERGSTAD *et al.*, 2005).

Beds deeper than 1 000 m can be considered generally unexploited in the Mediterranean Sea. This is more or less the case for the Hellenic Seas below 500 m up to now, since bottom trawling is rare and only specific net and long-line fishing activities occur in these depths nowadays. Deep-waters (>500 m) cover a large proportion of the Hellenic Seas. The maximum depth is 5 121 m off the south-western Peloponnisos, which is the greatest depth for the whole Mediterranean Sea. The biology and ecology of the Hellenic deep-water resources constitute a relatively recent research field for the Hellenic scientists and particularly fisheries biologists. The Institute of Marine Biological Resources (IMBR) of HCMR initiated this activity in 1996. However, information on deep-water species has also been provided from 1994, in the framework of the general scope project MEDITS-GREECE. Nevertheless, the real kick-off point for deep-water research was in 1996 with a research project, focusing on the deep-water fishery and resources in the southern Ionian Sea. Eight research projects were carried out afterwards, all directed towards objectives related with deep-water fishery and resources: the study of the reproduction and feeding strategies of deep-water fish, the exploration and assessment of the deep-water resources, the abundance and distribution of the blue and red shrimp *Aristeus antennatus,* the study of the gill net selectivity, assessment and biology of the blackspot red seabream (*Pagellus bogaraveo*), the state of the wreckfish (*Polyprion americanus*) stocks, the exploration of the pristine red shrimp stocks in the southern Hellenic Ionian Sea and the comparison with the exploited ones in the northern Italian Ionian and finally the elaboration of the Mediterranean red shrimps data collected up to now in the framework of the MEDITS programme. It is also worth noting here that information concerning deep species is provided in some cases in the framework of the National Programme for the Collection of Fisheries' data although it does not include deep-water fishery as a particular task among its objectives.

In the present work, a brief description of the above mentioned projects and a summary of their results would be attempted.

International bottom trawl survey in the Mediterranean - MEDITS

The surveys of the MEDITS Programme (1994-2006) are described in Chapter VI (POLITOU *et al.*).

Deep-water species or species whose distribution extends to deep waters, included among the MEDITS target species, are the following: *Aristaeomorpha foliacea, Aristeus antennatus, Helicolenus dactylopterus, Lepidorhombus boscii, Lophius budegassa, Lophius piscatorius, Merluccius merluccius, Nephrops norvegicus, Pagellus bogaraveo, Parapenaeus longirostris* and *Phycis blennoides*,. Data concerning these species are mainly presented in BERTRAND & RELINI (2000) and ABELLÓ *et al.* (2002).

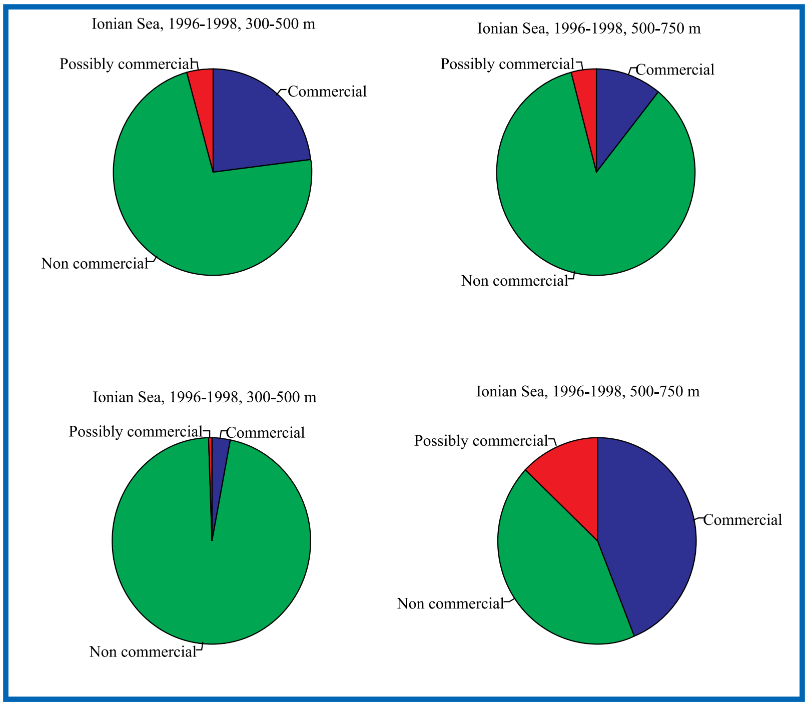

Figure 1: Pies of the commercial, non-commercial and possibly commercial catch (by numbers-above and by weight-below) in the 300-500 and 500-750 m depth zones in the Ionian Sea.
Source data: MYTILINEOU *et al.,* 1999.

Developing Deep-water Fisheries: data for their assessment and for understanding their interaction with and impact on a fragile environment

This research project was in fact the first project of IMBR targeted to study the deep-water resources and their fishery in Hellenic waters. It was carried out in a restricted area of the southern part of the Ionian Sea from 1996 to 1998. The objectives of the project were (1) to describe the deep-water fisheries of Hellas, (2) to analyse the deep-water species data and collate them with those from previous surveys of IMBR, (3) to study the discards from deep-water bottom trawl experimental fishery, (4) to sample the landings of the red sea bream (*P. bogaraveo*) and (5) to study the biological parameters of the most important deep-water resources in the area. The main results of this project are cited below:
Significant quantities of fish and crustaceans were found during trawl surveys in waters deeper than 300 m. The catch of crustaceans consisted mainly of commercial species and the quantity was enough to support a commercial fishery (PETRAKIS & PAPACONSTANTINOU, 1997; PETRAKIS *et al.*, 1999b). The most important commercial crustaceans were the red shrimp *A. foliacea* and the blue and red shrimp, *A. antennatus;* the latter less abundant than the first one.
The study of discards, based on three categories of the catch, the commercial, non-commercial and possibly commercial species, showed that the commercial part of the catch (by weight) was higher in the 500-750 m than the 300-500 m depth zone (MYTILINEOU *et al*., 1999) (Figure 1).
The study of *P. bogaraveo* gill net fishery showed that the commercial catch by number consisted almost exclusively (90%) of that species. More information concerning this species is included in PETRAKIS *et al*. (1999c).
The results from the study of the length composition, monthly catch per unit effort variation, mean length relationship with depth, number and weight of individuals with depth, length-weight relationship, maturity, sex ratio, age, growth and mortality of the target species are presented in PETRAKIS *et al*. (1999b), KAPIRIS *et al*. (1999), KAPIRIS & THESSALOU-LEGAKI (2001; 2002), PAPACONSTANTINOU & KAPIRIS (2001; 2003), KAPIRIS (2004a), ANASTASOPOULOU (2005), ANASTASOPOULOU & PAPACONSTANTINOU (2006).

Evaluation of the reproductive strategy of deep-water fish species on the west coast of Hellas (Ionian Sea)

This research project, carried out between 1998-2003, was targeting the study of the spawning biology and fecundity of *H. dactylopterus, H. mediterraneus*, *Peristedion cataphractum*, *L. boscii*, *Etmopterus spinax* and *G. melastomus*, the most abundant by-catch species in the deep-water experimental bottom trawling in the southern Ionian Sea (Hellas). The aim of the project was to acquire basic information on the reproductive strategies of the studied species, an important contributor in understanding stock dynamics and obtaining basic biological information for use in stock assessments.
Among the results of this study are the differences in the spawning period and fecundity and the estimation of the length at first maturity of the target species (TERRATS & PETRAKIS, 1999; TERRATS, 2003).

Feeding strategies and energy requirements of deep-sea demersal fish in the eastern Mediterranean

This research project, carried out between 1998-2003, aimed to describe the structure and functioning of the deep fish community in the southern Ionian Sea. The study area was the same with the previous project. The studied species were *G. melastomus, E. spinax, Coelorhynchus coelorhynchus, Hymenocephalus italicus, Nezumia sclerorhynchus, H. mediterraneus, H. dactylopterus* and *L. boscii*.

Three major groups were identified in the examined demersal assemblage (benthic feeders, pelagic feeders and mixed diet species). The dominant species were pelagic feeders. Season was the main identified factor influencing both fish assemblage composition and biomass, while no differences were found with depth. Food availability was the main factor affecting the studied demersal assemblage. Diel patterns involved mesopelagic and suprabenthic prey via circadian migratory movements of these organisms. Food resources were well partitioned among the co-existing demersal fish species of the bathyal-eastern Ionian Sea. This partitioning was mainly determined by fluctuations in prey availability and by prey size. Overall results underline the importance of mesopelagic decapods in the dynamics of food webs of the studied fish community (MADURELL, 2003).

The state of the European wreckfish (*Polyprion americanus*) stocks

This research project was carried out in the Cretan and Ionian waters between 1999-2001 (MACHIAS *et al.,* 2001). The objectives of this project were the following: (1) The collection of data concerning wreckfish fishery and landings in the eastern Mediterranean (Cretan waters-Hellas and Ionian Sea-Italy); (2) The collection of population dynamics data from this fishery and the study of the age, growth and maturity; (3) The analysis of stock structure by means of mitochondrial DNA, specifically by the comparison of the Atlantic and Mediterranean populations; (4) The acquisition of biological data by monitoring juveniles and adults in captivity, originated from Atlantic and Mediterranean stocks.

The main results of this project, reported in MACHIAS *et al*. (2001; 2003), were as follows:

The wreckfish fishery in the Cretan and Ionian waters was found to be highly site-specific, exercised at depths between 500 and 850m. For more information see Chapter IV (MYTILINEOU & MACHIAS). The length composition of the wreckfish catches in the Cretan Sea, during the years when the project was carried out, is presented in Figure 2.

Histological analysis showed that wreckfish reaches sexual maturity at a length of approximately 70-80 cm and reproduces during the winter months (December-March), when the fishing effort declines notably; thus, wreckfish spawning aggregations are somehow protected. The pattern of oocyte development in wreckfish is characteristic of group-synchronous species. Females spawn, on average, 80 000-150 000 eggs/Kg. Post-larvae of the species were collected for the first time in the Mediterranean, during February and March. MACHIAS *et al*. (2003) found that the estimated upper range of the settlement size was 65 cm, which is close to the length at first maturity and lower than the minimum size caught in wreckfish long-line fishery (70 cm). The estimated growth parameters for Hellenic and Italian waters did not presented a statistically significant difference, but total mortality was higher in Cretan waters.

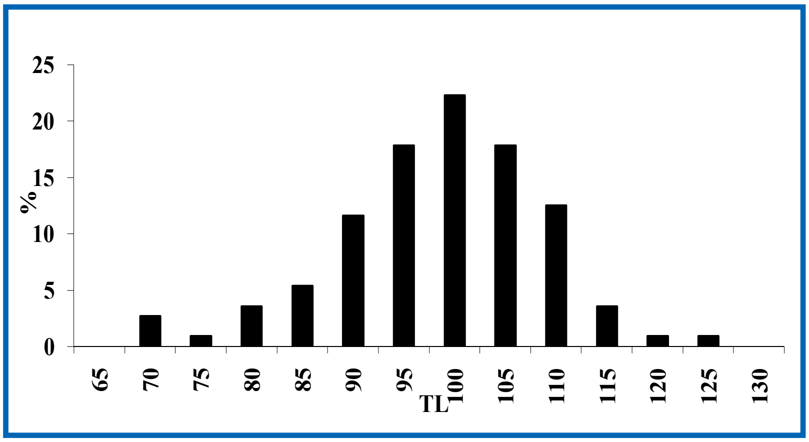

Figure 2: Length composition (TL) of *Polyprion americanus* in the Cretan Sea caught by long-lines Source data: MACHIAS *et al.,* 2001.

The analysis of mitochondrial DNA showed a remarkable similarity between populations from Hellas, Italy and the Atlantic coasts of France. Although the examined stocks were genetically homogeneous, they differed significantly with regard to morphometry and seemed to consist of different "phenotypic stocks".

***Pagellus bogaraveo* gill net métier in the Ionian Sea: gill net selectivity, assessment and biology**

The aim of this research project (PETRAKIS *et al*., 2001) was to assess the red seabream gill net fishery in Hellenic waters and study the biology of the species in order to recommend measurements for this fishery. Data were collected interviewing fishermen and by experimental and commercial fishing in depths from 200-550 m in the Hellenic Ionian Sea. Among the main results, the following should be mentioned:

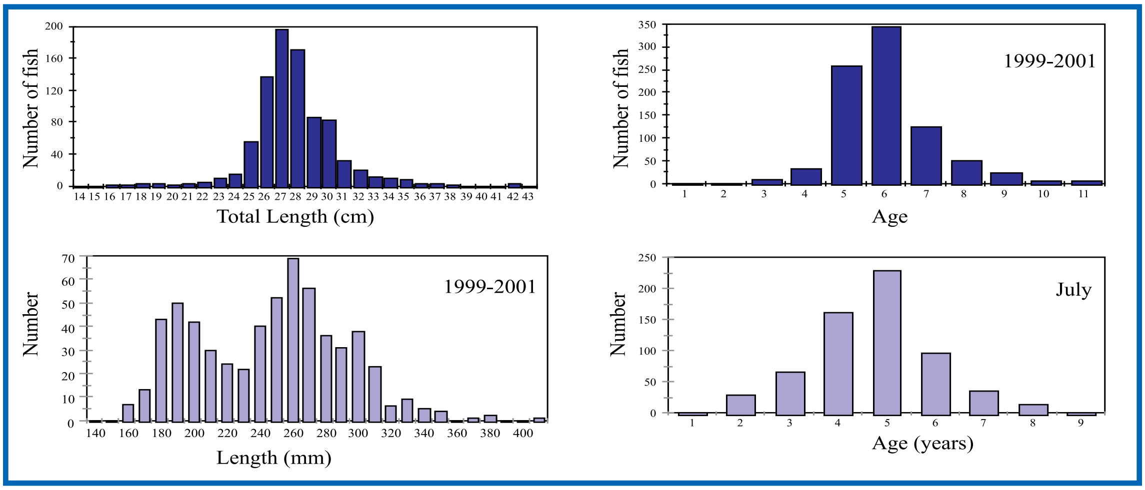

Figure 3: Catch composition of the *P. bogaraveo* gill net fishery by number and by weight in the Ionian Sea in 2001.
Source data: PETRAKIS *et al.,* 2001.

Nine and eleven age groups were determined by means of otolith and scale reading, respectively. The estimated growth parameters are mentioned in PETRAKIS *et al*. (2001), whereas in CHILARI *et al*. (2006) they are presented by sex. Spawning of red seabream was assumed to take place during winter. Males were more abundant than females in the small sizes; the opposite occurred in large individuals, a fact coinciding with the protandric nature of the species.

The commercial catch in this fishery consisted mainly of *P. bogaraveo* (Figure 3). The length composition of the species in the catch ranged from 16 to 40 cm, consisting mainly of fish 3 to 6 years' old. The number of vessels working in this métier reduced during the last years due to the decline of the catches; of them, 50% used long-lines, 45% gill nets and 5% both. According to the fishermen, the main reason that the catch has declined drastically the last years is over-fishing, gill nets, sport- and ghost-fishing. The gill net selectivity was studied for six mesh sizes. Various models have been applied to estimate the most appropriate among them.

According to the results of the project, it was suggested that the stock of the blackspot red seabream and consequently the fishery had been reduced due to the lack of any management plan and any regulation. The gill net métier was considered one of the most species and size selective in Hellenic waters (with very few by-catch species) and for this reason it would be easily regulated. The recommendations of the project are mentioned in Chapter IV (MYTILINEOU & MACHIAS).

Exploration of the renewable marine biological resources in the deep waters -INTERREG II Hellas-Italy

The main objectives of this project were (a) to investigate the spatial distribution and abundance of important deep-water resources in the Ionian Sea, focusing on the red shrimps, *A. foliacea* & *A.antennatus*, (b) to collect useful information for the management of deep-water resources and particularly for the development of a sustainable Hellenic Deep-water Fishery, (c) to compare the results of the Hellenic to those of the Italian Ionian, and (d) to transfer information and technologies to the local Authorities and fishermen's associations. Sampling was carried out in the northern Hellenic Ionian Sea (60 stations), from Othoni island to Zakynthos island, and the north-western Italian Ionian (29 stations), between 300-1 200 m of depth, from 1999 to 2000, using two commercial vessels, equipped with a bottom trawl of 40 mm cod-end mesh size.

The most important results of this project (ANON, 2001a) are summarized as follows:

44 crustaceans, 101 fish and 25 cephalopods were identified in the deep waters of the Hellenic Ionian Sea; some of them mentioned as first records for Hellenic waters or the Hellenic Ionian Sea (LEFKADITOU *et al*., 2003; MYTILINEOU *et al*., 2005; POLITOU *et al*., 2005). Two distinct faunal assemblages were identified, determined by depth at around 500 m. The first one, in the upper slope, was characterized by the high abundance of many species and particularly of *C. agassizi*, whereas, the second one in the middle slope, was characterized by the high abundance of the red shrimps (D'ONGHIA *et al*., 2003).

Table 1. Growth parameters of the studied species in the northern Hellenic Ionian Sea.

Species	L_∞ (mm)	K	Mortality
***A. antennatus* Male**	60	0.4	
***A. antennatus* Female**	72.5	0.43	Z=0.4-0.5 M=0.4-0.5
***A. foliacea* Male**	46	0.35	
***A. foliacea* Female**	71	0.39	Z=0.4-0.5 M=0.4-0.5

The total and commercial catch was higher in the depth zone 300-500 m than in deeper waters. Commercial fish catch was highest in the depth zone 300-500 m, whereas commercial crustaceans presented highest value in the depth zone 500-700m (POLITOU *et al.*, 2003). The red shrimps, *A. foliacea* and *A.antennatus*, were found in significant quantities in the whole Hellenic study area. Catch of *A. foliacea* was higher in the depth zone 500-700 m, ranging between 4-6 Kg/h; that of *A. antennatus* was higher in the depth zone 700-900m, ranging between 0.5-1.1 Kg/h (POLITOU *et al.,* 2003). *A. foliacea* was more abundant in the Hellenic Ionian; *A. antennatus* in the Italian Ionian (ANON., 2001a, D'ONGHIA *et al.*, 2003).
Larger lengths were observed for some species (e.g. *A. foliacea*) in the Hellenic Ionian compared with those from Italian waters (Figure 4); higher number of species and specimens of Chondrichthyans and presence of some species; all indicating the pristine condition of the Hellenic deep waters and the impact of fisheries exploitation in the Italian ones (MYTILINEOU *et al.,* 2001, D'ONGHIA *et al.*, 2003). The examination of the bathymetrical distribution showed the bigger-deeper phenomenon for many species (MYTILINEOU *et al.*, 2003a). Demographic (length composition, abundance), and biological information (maturity, spawning, sex ratio, feeding, age, growth, mortality) was studied for various species (KAPIRIS *et al.*, 2001; 2002; 2005; KAPIRIS, 2004b; KAPIRIS & MYTILINEOU, 2004; MYTILINEOU *et al.*, 2004; 2006b, c; D'ONGHIA *et al.*, 2005; 2006). The estimated mortality rates for red shrimps in Hellenic waters (Table 1) indicated the unexploited condition of the red shrimp stocks with similar values for total and natural mortality (D'ONGHIA *et al.*, 2005; KAPIRIS *et al.*, 2005). This unbiased estimation of natural mortality M is very important for the population dynamic studies of these species in all Mediterranean waters. In addition, the estimated L∞ for the red shrimps (Table 1) were very close to their larger observed sizes (Figure 4).
One colony of the deep black coral *Leiopathes glaberrima* and many colonies of the bamboo coral *Isidella elongata* were identified in Hellenic waters (VAFIDIS *et al.,* 2006), species whose presence decreased in the Italian Ionian due to the trawl activity.
Recommendations according to the results of the

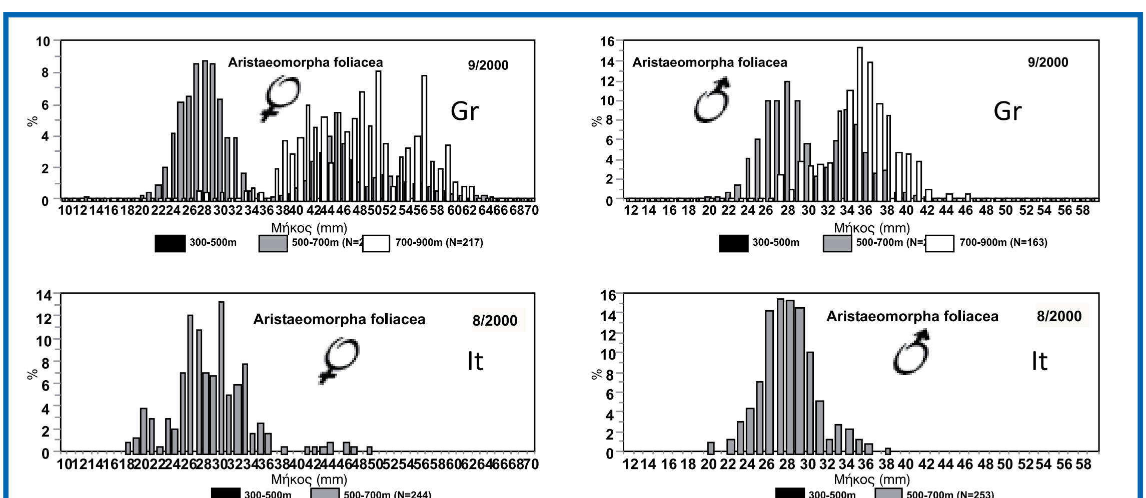

Figure 4: Length compositions of female (left) and male (right) *A. foliacea* in the Greek (top) and Italian (bottom) Ionian Sea.
Source data: ANON., 2001a.

project included the increase of the cod-end mesh size and the closure of trawling during the reproductive period and recruitment of the red shrimps. More studies should be carried out to protect areas of particular interest (e.g. corals, nursery and spawning grounds). Since a Hellenic deep-water trawl fishery could be developed in the future, more detailed studies should be promoted to investigate the pristine Hellenic deep-water stocks (ANON., 2001a).

Exploratory survey to collect data of the exploited and virgin stocks of deep-sea shrimp *Aristeus antennatus,* of interest to the CFP – DESEAS

The main objective of this research project (ANON., 2001b) was to collect data regarding the maximum depth distribution of the blue and red shrimp *A. antennatus* in the Mediterranean Sea. A single research vessel was used to explore various locations of the Mediterranean Sea including depths down to 4 000 m during a single survey.

The abundance and biomass of *A. antennatus* decreased with increasing depth. Maximum values were found near 800 m at rates of around 1 000 ind/km^2. At around 1 000 m depth the density decreased down to 200 ind/ km^2 and to 10 ind/ km^2 down to 3 300 m depth. This last depth was the maximum where the species was detected. Recruitment was suggested to take place at depths around 1 500 m, an extraordinary finding for a commercial species (SARDÀ *et al.*, 2004a). *A. foliacea* biology was also studied (POLITOU *et al.*, 2004) as well as various other topics (SARDA *et al.*, 2004b). The differences between areas and depths were greater than those between exploited and non-exploited stocks. This was attributed to the physical characteristics of the water masses, which were different between the western and eastern Mediterranean; temperature in waters deeper than 800 m was colder westwards and salinity increased eastwards.

Based on the results of the study, it was recommended that (1) the fishery of *A. antennatus* should be restricted to above 900 m depth for a sustainable management, (2) studies relating environmental conditions with deep-sea shrimp spatio-temporal movements and behaviour should be encouraged, (3) deep Mediterranean waters should be maintained unexploited in order to conserve the weak ecological equilibrium and biodiversity of this environment taking also into account the sensitivity of Selachians and other invertebrates, and (4) stricter laws and punishments should be established because of the dumping of waste (ANON., 2001b)

Exploration of pristine red shrimp resources and comparison with exploited ones in the Ionian Sea – RESHIO

The objectives of this project, (MYTILINEOU *et al.*, 2003b), were (1) the investigation of the distribution and abundance of *A. foliacea* and *A. antennatus* in the South-Eastern side of the Ionian Sea (Hellenic waters) and the study of their biological characteristics (2) the identification of differences in abundance, population structure and biological characteristics for both species, between an exploited area (Italian Ionian) and an unexploited one (Hellenic Ionian) and (3) the determination of the composition and abundance of the by-catch species, particularly between the exploited and the unexploited area. Sampling was carried out off the coast of the south-eastern Hellenic Ionian Sea (83 stations) and in the Italian Ionian Sea (25 stations) from 2000 to 2001.

Thirty-one crustacean, 72 fish and 21 cephalopod species were identified in the Hellenic study area. Depth was found to play an important role in the deep-water community structure of both areas, distinguishing two main faunal assemblages; one in the depth stratum 300-500 and another in depths between 500-900 m (POLITOU *et al.*, 2006).

The commercial (total, crustacean & fish) catch was highest in the 500-700 m depth zone. Discards (non-commercial species) constituted only 29% of the total catch. The highest catch of *A. foliacea* was found in this zone (14 Kg/h), whereas that of *A. antennatus* in the zone 700-900m (2 Kg/h) (MYTILINEOU *et al.*, 2006a). The commercial catch and particularly that of the red shrimps was higher in the southern than the northern Hellenic Ionian Sea (MYTILINEOU *et al.*, 2006b). Generally, abundance values were lower and smaller sizes appeared in the stocks of the Italian area comparing to the Hellenic, indicating the impact of intensive fishing activities in the first area (MYTILINEOU *et al.*, 2003b).

The spatial distribution and abundance study of the red shrimps revealed a patchy distribution of these stocks (KAVADAS *et al.*, 2002) (Figure 5). Abundance was found to be statistically significant related with temperature, latitude and depth in order of importance for both shrimp species; it showed an increasing trend with temperature, decreasing with depth and it was lower in the northern than the southern Ionian Sea (MYTILINEOU *et al.*, 2006b). Age, growth and mortality parameters of red shrimps were similar to those found for the red shrimps in the northern Ionian Sea (MYTILINEOU *et al.*, 2003b).

Many colonies of the bamboo coral *Isidella elon-*

gata and parts of the coral *Desmophyllum crystagalli* were identified in the study area (MYTILINEOU, unpublished data).

A greater mesh size and closure of trawling during the recruitment period were recommended as measures protecting juvenile *A. foliacea*. The high vulnerability of this species should be taken into consideration in the case of development of a Hellenic deep-water fishery, particularly because this would be the main species in the commercial catch (MYTILINEOU *et al*., 2003b; 2006a).

National Programme for the Collection of Fisheries' Data (2002-2006)

The objectives of this general scope project, designated by the EC Regulation 1543/2000, do not concern deep-water fishery in the Hellenic waters. However, data collected for hake (*M. merluccius*) long-line fishery in the Aegean and Ionian Sea provide useful information on the length and age composition of the species in deep waters (ANON., 2006).

DISCUSSION-CONCLUSION

The research activity on deep-water fisheries' resources biology, their relation with deep environment and their management, including protection or exploitation, increased considerably during the last decade in Hellas (MYTILINEOU, 2006 and references therein).

Considering the results of the above mentioned research projects, the following could be summarized:

A large number of species has been identified during various surveys up to now, some of them reported for the first time for the Hellenic Seas. The large number of species in high abundances and the large range of body size indicate the virgin situation of the deep-water resources.

There are important commercial biological resources in Hellenic waters in the depth zone 500-800 m; the majority of them consisted of commercial fish and crustaceans. The main commercial crustacean species is *A. foliacea* (5-14 Kg/h). The commercial red shrimp *A. antennatus*, more abundant in the western and central Mediterranean, is present in quite lower quantities in Hellenic waters (0.5-2 Kg/h). Other species of commercial importance are the shrimps *Plesionika martia, Plesionika edwardsii*, the fishes *H. dactylopterus, M. merluccius, Lophius spp., P. bogaraveo* and always in negligible quantities the cephalopods *Todarodes sagittatus, Todarodes eblanae* and *Loligo forbesi*.

Deep-water fishery does not exist as a special sector in the Hellenic Industry. The main activities in the Hellenic deep-waters are up to now the wreckfish, red seabream and hake fisheries with long lines or nets. These fisheries show a declining trend in their catches during the last years that should be taken into account for urgent management measures. Deep-water bottom trawl fishing is rare and occasional, mainly occurring at the end of the trawl fishing period (April-May), when shallow-water catches decrease. The identified quantities of commercial catch in the deep waters of the Hellenic Ionian showed the possibility of development of a Hellenic deep-water trawl fishery. However, the sensitivity of the deep-water environment and of the main commercial deep-water resources, such as *A. foliacea*, demand more detailed studies on this topic to plan a sustainable management.

The deep-water ecosystem is a sensitive environment, for which there are still many aspects to study for its better understanding. Particular biotopes (hot spots, seamounts, coral reefs) exist in the deep seas that are not explored or discovered

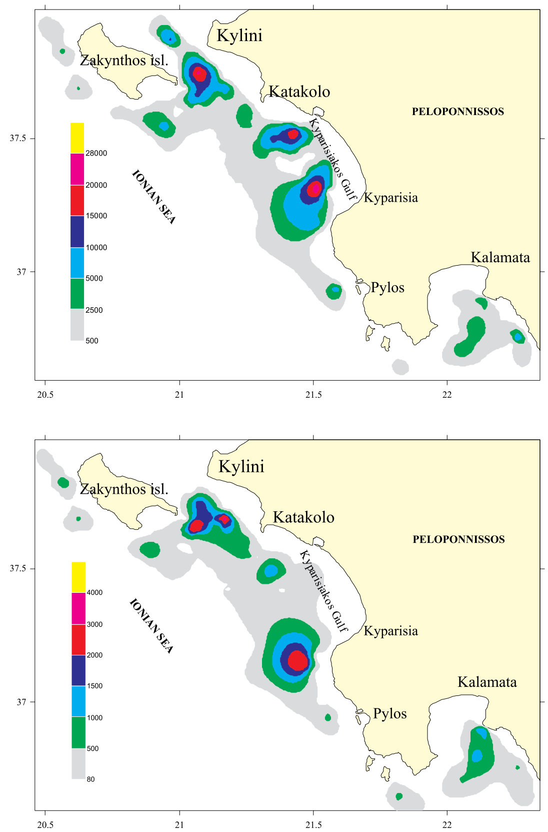

Figure 5: Spatial distribution and abundance (N/km2) of *A. foliacea* (top) and *A. antennatus* (bottom) in the southern Hellenic Ionian Sea in September 2000.
Source data: KAVADAS *et al*., 2001.

yet. Many species (fish, corals) in deep waters are long living and characterized by low growth rates. This makes them vulnerable to fishery or any kind of exploitation. This is the case of Elasmobrachians (sharks, rays) and deep-water corals, whose biodiversity, abundance and body size is considerably lower in intensively exploited waters. Other species, like *H. dactylopteus*, are also sensitive because of their low fecundity or the presence of their juveniles in the shallow intensively fished waters, leading to the over exploitation of their stock. Summarizing, in the framework of a sustainable management of the Hellenic deep-water resources and environment, some general remarks could be noted: the sensitive deep-water ecosystem should be investigated as a whole; deep-water assemblages and biodiversity should be maintained and particular biotopes should be protected; "Essential" and "Sensitive habitats" should be determined and their role should be understood; an integrated management plan is needed. As a consequence, more studies focusing on deep-water resources and environment should be encouraged.

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VII.7. RESEARCH ON SHRIMPS' RESOURCES AND FISHERY IN HELLENIC WATERS

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INTRODUCTION

In 2003, the world crustacean catches in marine fishing areas were 5 574.137 t, while in inland areas they reached 490 506 t representing 6.8% and 5.4% of the total catches of marine and inland areas, respectively (FAO data). Shrimps (Decapoda Crustacea) constitute 3.9% of the world captures production in fisheries (FAO data), while less important are other groups of crustaceans, such as crabs, lobsters, sea-spiders, krill, etc. It is worth noting that during 2003 the world shrimps' aquaculture production was 1 804 932 t with a total value of 9 322 859 $.

The crustacean fishery in Hellenic waters does not constitute a particular branch of the multispecies Hellenic fishery. The main target crustacean species in Hellenic waters are *Nephrops norvegicus, Melicertus kerathurus*, *Palinurus elephas*, *Homarus gammarus* and *Parapenaeus longirostris (*Chapter II: Decapod crustaceans.). Apart from these, some other species could be characterized as by-catch such as *Liocarcinus depurator, Maja* spp.*, Calappa granulata, Squilla mantis* and *Munida* spp. Concerning shrimps, the commercial species in Hellenic waters are *Perapenaeus longirostris* and *Melicertus kerathurus,* which are the most important in terms of landing and economic value (MYTILINEOU *et al*., 2001). Furthermore, some other shrimps are potentially marketable species, such as the deep-water shrimps (*Pandalidae, Aristeidae*) or are locally important species, such as the plain shrimp (*Palaemon adspersus)*.

According to the last available statistical data of ETANAL (Fisheries' Development Company S.A.) (2002), the crustacean landings from Hellenic waters were 2 660 t, representing 4.09% of the total landings; being about 8% of the value of the total landings (ETANAL data). The total catch of shrimps was 3 249 t (85% of the crustaceans' catch), while the rest of the catch consisted of lobsters, spiny-rock lobsters, crabs, sea-spiders and freshwater crustaceans (FAO data). According to the NSSG data (National Statistical Service of Hellas) the mean annual crustacean catches in Hellenic waters showed a continuous increase from 175 t (1928-1934) to 1 260 t (1964-1981) and from 3 181 t (1990-2002) to 3 330.71 t (2003) and 4 210.40 t (2004) (STERGIOU, 1986; NSSG data). Their economic value has also increased initially: the mean value in the period 1991-1995 was 4 043 666 euros, reaching 9 173 252 euros (1996-2000) and then it remained stable in 8 872 906 euros (2000-2002) (ETANAL data, 2002).

Despite their fishing importance in Hellenic waters, only a few studies have been carried out on the distribution and biology of shrimps in Hellenic waters, and very few refer to their fisheries, including studies concerning the total crustaceans in Hellas (e.g. STERGIOU, 1986; MYTILINEOU *et al.*, 2001). Similarly, few studies have been carried out on their distribution in the Hellenic area. The first study was made by KOUKOURAS & KATTOULAS (1974) who have collected 24 natantians from the Evvoikos Gulf; five of them were recorded for the first time in the Hellenic fauna. Later, KOUKOURAS *et al.,* (1997a) recorded eight pelagic shrimps in the N. Aegean and discussed their vertical distribution. In the Ionian Sea and the Argosaronikos Gulf, fourteen and nineteen Natantia were found, respectively, and their depth distribution has also been studied, in the framework of MEDITS 96 and 97 projects (POLITOU *et al.*, 1998). Among the species found in the Argosaronikos, *Pandalina profunda*, and *Plesionika gigliolii* were reported for the first time in Hellenic waters. In the framework of several scientific projects of the various research centres of Hellas the fishery and biology of crustaceans - shrimps included - have been studied.

The main objective of the present paper is to describe the current state of the research directed on the biology, distribution and fishery of the most important shrimps (*Parapenaeus longirostris* (Figure 1)*, Melicertus kerathurus* (Figure 2) in Hellenic waters, as well as shrimps with some biological and ecological importance (such as the deep-water species of *Aristeidae, Pandalidae*) or local value (*Palaemon adspersus*) in the same areas.

COMMERCIAL SHRIMPS

Parapenaeus longirostris **(Lucas, 1846) (Decapoda, Penaeidae)**

The deep-water rose shrimp, *Parapenaeus longirostris*, is one of the most important species of the crustacean landings in Hellas, fished mainly in depths ranging between 150 and 400 m and being very widespread both in the Aegean and the Ionian Sea

Figure 1: *Parapenaeus longirostris* (source: http://www.univ-lehavre.fr/cybernat/pages/paralong.htm)

Figure 2: *Melicertus kerathurus* (Source: http://www.imv.uit.no/crustikon/Decapoda/Decapoda2/Species_index/Melicertus_kerathurus.htm

(KOUKOURAS & KATTOULAS, 1974; KOUKOURAS *et al.*, 1997b; POLITOU *et al.*, 1998; TSERPES *et al.*, 1999; MYTILINEOU *et al.*, 2001). The highest abundances of this species in Hellas have been found in the N. Ionian Sea, the Argosaronikos Gulf and the Aegean Sea (ABELLÓ *et al.*, 2002). In the southern Ionian Sea this species was also found in lower abundance (KAPIRIS *et al.*, 2002).
FAO catches and landings' statistics from 1972 to 1991 indicated that this shrimp is the fifth species among crustaceans in order of importance in terms of biomass landed in the whole Mediterranean area (STAMATOPOULOS, 1993). This decapod is the most important trawlable crustacean along the coasts of Spain, France and Italy (SOBRINO *et al.*, 2005) and plays an important ecological role in many demersal communities of the continental shelf and of the upper part of the continental slope.

LIFE HISTORY

In Hellenic waters, there is a great lack of knowledge on the exploitation state and biology of this important species. The main source of knowledge is coming from the results of the experimental surveys in the framework of European projects carried out by the Hellenic Centre for Marine Research (MEDITS- ABELLÓ *et al.*, 2002; ANON., 1999; 2001; 2003; KAPIRIS *et al.*, 2002).
The deep-water rose shrimp is a short-lived epibenthic species, very mobile, and with relatively high growth and mortality rates (RIBEIRO-CASCALHO & ARROBAS, 1987). The Von Bertalanffy growth parameters have been estimated in Hellenic waters giving lower growth rates (females: CL_{∞}=37.2 mm, s, K= 0.52, t_0=-0.30, males: CL_{∞}=33.7, mm, K= 0.62, t_0=–0.16) (ANON., 1999). In the Hellenic Ionian Sea, the sex ratio remained close to 1:1 and the younger individuals (CL 15-20 mm) were present in almost all seasons, reinforcing the view of continuous reproductive activity (ANON., 1999). The feeding habits of *P. longirostris* in Hellas have been studied (LABROPOULOU & KOSTIKAS, 1999; KAPIRIS, 2004) and characterized by a large variety of preys, mainly small fishes, cephalopods and crustaceans. It is worth noting that no clear differentiation in the feeding behaviour, in terms of either diet composition or feeding activity between sexes, was observed.

FISHERY

P. longirostris, fished in all the Hellenic Seas, constitutes the most important species (in catch weight, landings, and value) among the commercial crustaceans in Hellas (MYTILINEOU *et al.*, 2001). The fishing gears used for *P. longirostris* in the Hellenic fishery are trawls (66.79% of the total catch of this shrimp is fishing by trawls), seine nets (3.61%), ring nets (0.98%) and other (28.63%) (NSSA data). The mean annual landings of *P. longirostris* during the period 1990-2004 were 1 226.87 t (28.31% of the total crustaceans' landings (NSSG data). The mean annual landings passing through auctions were 1 118.19 t (62.91%) according to ETANAL, in the same period (1991-2002). Many of those data have already been published in MYTILINEOU *et al.* (2001).
The annual catches of *P. longirostris* in Hellas

(1990-2002) showed a great variability, with two maxima in 1992 and 1997, three minima in 1991, 1995 and 2001 (NSSG data) and a weak negative trend with time at significance level 90% (Figure 3). Although, in the last two years (2003, 2004) a slight increase of landings was shown (Figure 3). In contrast, the annual landings passing through the landing ports (ETANAL data) increased during 1991-2002 (77% of the total crustaceans landings in 2002), indicating a positive trend with time at a significant level of 90% with an increasing trend, particularly from 1996 (MYTILINEOU *et al.*, 2001) (Figure 3).

In Figure 4 the mean annual landings (t) of *P. longirostris* and *Melicertus kerathurus* by landing port (ETANAL, 1991-2002) are given.

In Table 1, the mean annual landings per fishing area (NSSG data, 1990-2002) and the mean annual price per kg of the landings of *P. longirostris* (ETANAL data) are given. Many of those data have already been published in MYTILINEOU *et al.*, 2001.

The higher mean annual landings of *P. longirostris* were landed in the ports of Peiraias and Thessaloniki, followed by the ports of Kavala, Alexandroupolis and Patra (ETANAL data, Figure 4), while, according to NSSG data the most important fishing areas in Hellas for *P. longirostris* are: 13 (Thermaikos Gulf), 14 (N. Aegean Sea) and 18 (Kriti) (MYTILIN-

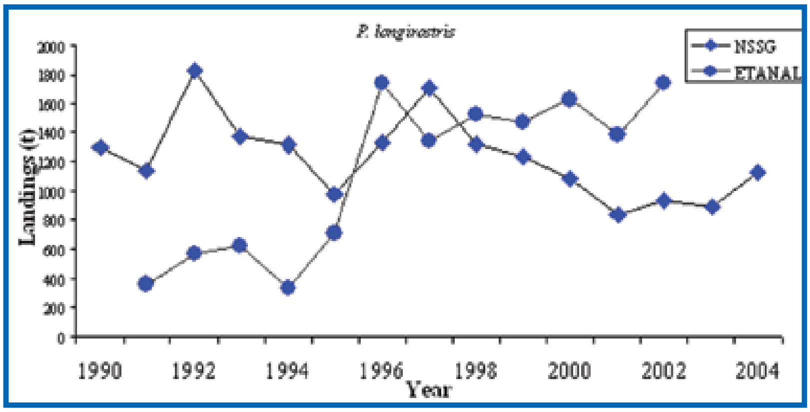

Figure 3: Annual landings of *Parapenaeus longirostris* in Hellas from NSSG (NSSG data, 1990-2004) and ETANAL (ETANAL data, 1991-2002)

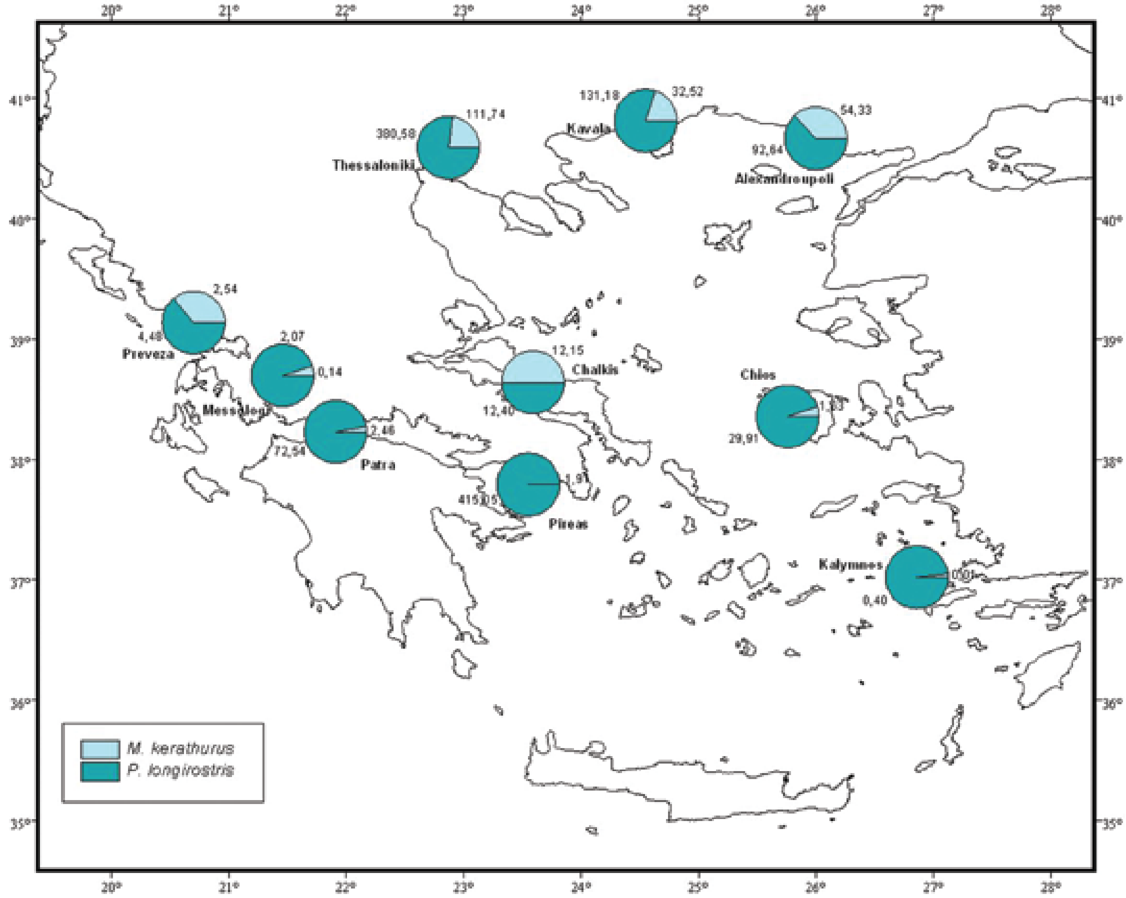

Figure 4: Mean annual landings (t) of *Parapenaeus longirostris* and *Melicertus kerathurus* by landing port (ETANAL, 1991-2002).

Table 1. Mean annual landings (t) of *P. longirostris* by fishing area (NSSG, 1991-2004). The annual price (euro/kg) of the same species (ETANAL data, 1991-2002) is also presented.

NSSG			ETANAL	
Fishing area		Mean annual landings	Year	Mean annual price (euro/kg)
03	Coasts of Ipeiros and Kerkyra	8.6	1991	3.20
04	Amvrakikos Gulf and coasts of Lefkada island	7.4	1992	3.15
05	Coasts of Kefalonia, Zakyntos and Gulf of Patra	56.6	1993	2.35
06	Gulf of Kyparissia and Gulf of Messinia	7.6	1994	3.31
07	Gulf of Lakonia	2.6	1995	2.64
08	Gulf of Argolida and Saronikos Gulf	177.8	1996	2.11
09	Gulf of Korinthia	15.15	1997	2.02
10	Gulf of S. and N. Evvoia-Gulf of Lamia	5.22	1998	2.72
11	Pagasitikos Gulf	8.77	1999	2.91
12	Eastern coasts of Evvoia and Sporades islands	42.6	2000	2.60
13	Thermaikos Gulf and Gulf of Chalkidiki	374.8	2001	2.74
14	Strymonikos, Gulf of Kavala, Thassos, Thracian Sea	259.5	2002	3.52
15	Islands of Lesvos, Chios, Samos and Ikaria	64.5	**Mean**: 2.77 €	
16	Dodekanisos	1.47		
17	Kyklades	24.9		
18	Kriti	182		

EOU *et al.*, 2001) (Table 1). The annual economic value increased during the studied period (ETANAL data, 1991-2002), ranging from 22%-50% of the total crustacean value, indicating a similar trend with time and landings. On the other hand, the annual price of this species showed a great variability during the studied period (Table 1) without displaying any significant trend. According to MYTILINEOU *et al.* (2001) the large amount of catches and the relatively low value/kg of this species may be the reasons that led fishermen to pass most of their catches through the official landing ports, since no better price would be obtained by the direct market, and such a volume of catches is difficult to sell directly to the small merchants. However, it seems that the value/kg is affected by the volume of landings, reaching a maximum with minimum landings, and inversely so. (Figure 4, Table 1).

An evaluation of the exploitation state of this resource indicates a general over- or full- exploitation in Hellenic waters. The total mortality estimated (Z) for the period 1994-1999 in some Hellenic areas, was: 2.06 (E. Ionian), 2.72 (Argosaronikos Gulf), 2.41 (N. Aegean) and 3.22 (S. Aegean Sea) (ABELLÓ *et al.*, 2002). Global and analytical models applied to local populations of the Mediterranean showed in general the need for a reduction in fishing effort (10-15%) and an increase of the cod end mesh size in order to reduce fishing mortality of juveniles (SOBRINO *et al.*, 2005).

P. longirostris seems to be the most important shrimp in terms of landings and economic value and could be considered as over or fully exploited. For this reason, it is recommended to improve the monitoring of landing and fishing effort and to increase the knowledge on some poorly known aspects of the biology and population dynamics of this economically important species.

Melicertus kerathurus (Forskål, 1775) (Decapoda, Penaeidae)

Melicertus kerathurus supports a valuable, yet relatively small and dispersed, shrimp fishery along the northern Mediterranean coast (FAO, 1987) (Figure 2). The most important grounds in Hellenic waters are along Western Hellas (from the island of Kerkyra to the North western Peloponnisos and especially in the Amvrakikos Gulf) and in the North Aegean Sea (from the Thermaikos Gulf to Alexandroupolis) (CONIDES *et al.*, 1990;

CONIDES, 2001). Due to its commercial importance, *M. kerathurus* has been a target species for a number of studies in Hellenic waters (e.g. KLAOUDATOS *et al.*, 1992), which were mainly focused on its growth, reproduction, migration and physiology. Recently, the feeding habits of this species in the Aegean Sea have been studied (KARANI *et al.*, 2005).

LIFE HISTORY

The available knowledge about the life history of this species comes from systematic studies carried out in the Amvrakikos Gulf. In this area, the population of *M. kerathurus* is mainly composed of 1-year-old individuals and a broad size overlap between males and females exists, suggesting that the population is young (CONIDES *et al.*, 2006). The oldest specimens were around 24-26 months old, based on the carapace length frequency distribution. The estimated Von Bertalanffy parameters were: females: $CL\infty$ = 69.704 mm, $TL\infty$ =309.14 mm, $W\infty$ = 123.01 g, K = 1.062 year^{-1}, t_o=0.238 years, males: $CL\infty$=62.658 mm, $TL\infty$=274.18 mm, $W\infty$=115.979 g, K=1.253 year^{-1}, t_o=0 years. The reproductive period extends from May to September and the small individuals appear after September in the catches. Mortality estimates for *M. kerathurus* in Amvrakikos gulf were similar for both sexes.

FISHERY

The fishing gears used for the *M. kerathurus* fishery in Hellenic waters are trawls (77.53%), beach seine nets (5.03%), ring nets (1.73%) and other (15.71%). Concerning this species, the fishing operation in the Amvrakikos Gulf, the most valuable commercial product of the region, is conducted with trammel nets: 22 mm inner mesh and 11 mm outer mesh, with an average length of 800-1000m and height between 1.5 and 4 m. Fishing procedure is carried out by 350 professional fishermen, organised in 5 cooperatives using small boats (5-6 m), not more than 25 HP; usually 5-10 HP. In the other areas of Hellas, fishing is carried out by trawling but the species is considered as a by-catch fished together with other species of high commercial value such as *Nephrops norvegicus*, *Homarus* etc.

In Figure 5 the annual landings per fishing gear (NSSG data, 1990-2004) and the annual total landings in all the auctions (ETANAL data, 1991-2002) of *Melicertus kerathurus* in Hellas are given. Many of those data have already been published in MYTILINEOU *et al.* (2001).

The mean annual landings of *M. kerathurus* in the period 1990-2004 were 1 110.38 t (25.62 % of the total crustaceans' landings NSSG data) or 215.51 t (12.12%) according ETANAL data, respectively (1991-2002). The annual catches of *M. kerathurus* presented an increasing trend, at a significant level of 90%, in Hellas taking into account both NSSG and ETANAL data (MYTILINEOU *et al.*, 2001 and present data) (Figures 5, 7).

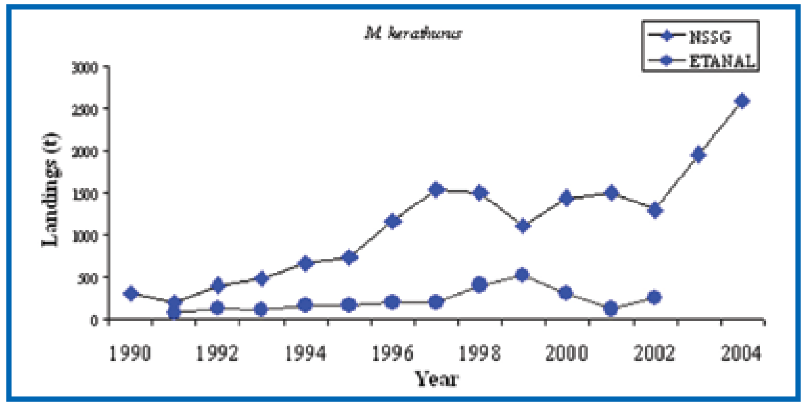

Figure 5: Annual landings of *M. kerathurus* in Hellas from NSSG (NSSG data, 1990-2004) and ETANAL Source data: ETANAL, 1991-2002.

The landings passing through the official ports (ETANAL data) were considerably lower than the total landings (NSSG data) (Figures 5a, 7) showing that an important quantity is distributed directly to the market (MYTILINEOU *et al.*, 2001). A slight decrease of the landings was observed during the last years, with a minimum in 2002, although an abrupt increase was shown in the last two years (2003-2004, NSSG data) (Figure 5).

In Table 2 the annual landings of *M. kerathurus* (NSSG data) and the annual price (euro/kg) of the landings (ETANAL data) are given.

The higher mean annual landings were measured in the auction of Thessaloniki and Alexandroupolis (ETANAL data), while, according to NSSG data, the most important fishing areas in Hellas for *M. kerathurus* are the N. Aegean Sea (fishing areas: 13. 14 in Table 2) and the Patraikos-Ionian Sea (fishing area: 5 in Table 2). The annual economic value (17-45% of the total crustacean value) increased during the studied period (ETANAL data, 1991-2002), being in accordance with the landings. Its price in Hellas is 1.5-2 times the price of other important products such sea bass and sea breams. In the Amvrakikos Gulf, the monetary value of the landing is approximately 3 200 000 euros/year (2002), while in the other Hellenic areas it is approximately 1 500 000 euros (CONIDES, 2001).

There is no processing industry associated with the fishery of this important crustacean. The prod-

Table 2. Mean annual landings (t) of *M. kerathurus* by fishing area (NSSG, 1990-2004). The annual price (euro/kg) of the species over the same period (ETANAL data) is also presented.

NSSG			ETANAL	
Fishing area		**Mean annual landings**	**Year**	**Mean annual price (euro/kg)**
03	Coasts of Ipeiros and Kerkyra	4.7	1991	6.48
04	Amvrakikos Gulf and coasts of Lefkada island	1.5	1992	6.63
05	Coasts of Kefalonia, Zakynthos and Gulf of Patra	42	1993	5.10
06	Gulf of Kyparissia and Gulf of Messinia	4.26	1994	5.59
07	Gulf of Lakonia	0.6	1995	6.03
08	Gulf of Argolida and Saronikos Gulf	8.9	1996	7.25
09	Gulf of Korinthia	4.7	1997	6.29
10	Gulf of S. and N. Evvoia-Gulf of Lamia	10.2	1998	8.14
11	Pagasitikos Gulf	3.6	1999	7.96
12	Eastern coasts of Evvoia and Sporades islands	24.5	2000	9.11
13	Thermaikos Gulf and Gulf of Chalkidiki	221.1	2001	12.74
14	Strimonikos, Gulf of Kavala, Thassos, Thracian Sea	736.3	2002	11.20
15	Islands of Lesvos, Chios, Samos and Ikaria	21.6	**Mean**: 7.60 €	
16	Dodekanisos	1.7		
17	Kyclades	15.7		
18	Kriti	24.7		

uct is consumed locally and sold as whole, fresh on ice. In general, there is no particular interest from the central administration in this fishery.

Overfishing and pollution have resulted in the decline of the population in the Amvrakikos Gulf, suggesting that it is very sensitive. The population of *M. kerathurus* has received important ecological pressure during the last 20 years due to the degradation of the environmental quality in the gulf and because of the effects of the intensive coastal fishery (CONIDES *et al.*, 2006). An improved management scheme must be applied to *M. kerathurus* fishery in Hellas taking into account the detailed study of the environment, the research of the economic sector, the infrastructure (fleet, distribution of fleet, age, fishing distances), the monitoring system of the environment and fisheries, the legislation and environmental protection schemes (CONIDES, 2001).

DEEP-WATER SHRIMPS WITH POTENTIAL ECONOMIC VALUE IN HELLENIC WATERS

The overexploitation of the existing marine biological resources could be overcome by the identification of new biological resources and new fishing grounds. These may contribute to the distribution of the fishing effort to more extended grounds. The biology and ecology of the Hellenic deep-water resources represent a new research field for Hellenic scientists and especially for biologists. In the deep waters of the Hellenic Ionian Sea, thirty decapod species were found in the depth zone 300-500 m. (POLITOU *et al.*, 2005). Among them, the most common were *P. longirostris, Plesionika heterocarpus* and *Plesionika antigai*. From the 27 species caught in the depth zone 500-700 m, *Aristaeomorpha foliacea* and *Plesionika martia* were the most abundant, while in the deepest depth zone (700-900 m) 19 species were found of which

A. foliacea and *Aristeus antennatus* were the most numerous. Two families of the deep-water shrimps have some economical and ecological importance in Hellenic deep waters. These are the families *Aristeidae (A. foliacea* and *A. antennatus*) and *Pandalidae*.

Aristeidae

***Aristaeomorpha foliacea* (Risso, 1827), *Aristeus antennatus* (Risso, 1816) (Decapoda, Aristeidae)**

The red shrimps, *A. foliacea and A. antennatus* (Figure 6), are the main target species of the Mediterranean deep-water trawling. Both species were prevalently caught in the depth zone 500-800 m in the Mediterranean basin, though *A. foliacea* is often found in shallower waters (200-500 m) and *A. antennatus* can be also found much deeper (> 800 m). Recently, the latter species was found until the depth of 3300 m in the Mediterranean (SARDÀ *et al.,* 2004). In the Mediterranean, red shrimps are mainly exploited over large portions of the continental slope by the Spanish (almost completely *A. antennatus*) and Italian fleets (both species).

In Hellenic waters, there are sporadic references on the red shrimps' presence in the Aegean Sea (e.g. the North Aegean, Argosaronikos area, Kyklades Islands, Kriti, Dodekanisos Islands: MYTILINEOU & POLITOU, 1997). The last decade, based on their abundance, biology and population dynamics, it was shown that both red shrimps' populations have the potential to support a viable fishery in the Eastern Ionian Sea (ANON., 1999, 2001, 2003; PAPACONSTANTINOU & KAPIRIS, 2001, 2003; POLITOU *et al.*, 2005; MYTILINEOU *et al.*, 2006). Since no fishery exists, according to the results of the experimental surveys, in the Hellenic Ionian Sea, *A. foliacea* is the most abundant species in the depth zone 500-700 m (CPUE: 4.3-8.5 kg/h), while in the same depth zone *A. antennantus* was found in lower quantities (CPUE: 0.4-0.65 kg/h). In deeper waters (700-900 m), the CPUE for both species was 1.2-2.8 kg/h and 1.1 kg/h for *A. foliacea* and *A. antennatus*, respectively (POLITOU *et al.*, 2003). In the central E. Ionian Sea the abundance of *A. foliacea* and *A. antennatus* was 9.1-20 kg/h and 0.5-7.7 kg/h, respectively (ANON, 1999).

Several studies have been carried out on their biology and ecology in the Hellenic Ionian Sea (e.g. PAPACONSTANTINOU & KAPIRIS, 2001, 2003; KAPIRIS *et al.*, 2002; KAPIRIS & THESSALOU-LEGAKI, 2001; KAPIRIS, 2004). These species are not very popular yet with the Hellenic consumer because (a) fishery is not carried out in these depths, because it is considered to yield a relatively low economic return; and (b) knowledge of

Figure 6: *Aristeus antennatus* and *Aristaeomorpha foliacea* (Source: www.vincenzolfd.co.uk, www.unica.it).

fishing practice in these depths and gear technology is still limited. The absence of fishing pressure in depths beyond 500 m in the Hellenic Ionian Sea makes their populations an unexploited resource. Thus, the presence of a stock of potentially high commercial value in such a pristine condition is scientifically valuable because of the possibilities offered to understand their population. The general view is that these resources seem to be relatively resistant to the fishing pressure because the fishing gears used do not heavily exploit their young-of-the-year recruits.

The two species present a sex dimorphism in the carapace length and the body weight. In both species, females are larger and heavier than males, thus, they present more age groups, higher growth performance index values (φ'), higher asymptotic length (CL_∞) and asymptotic weight (W_∞), lower value of K and higher longevity than males. The estimated life span in the present study (7.5 years for females and 5.3 for males of *A. foliacea*, 7.7 years for females and 6.7 for males of *A. antennatus*) does not differ significantly from other areas in the Mediterranean reported in the literature. The sex ratio in *A. foliacea* slightly differs from the 1:1 in almost all the study period, in favour of males. On the contrary, the sex ratio in *A. antennatus* is always in favour of females. Considering that in the Hellenic Ionian Sea, the stock of both species is in pristine condition, their mortality would be due to natural causes. Indeed, the mortality estimates (natural and total) were found to be similar, confirming the

Figure 7: Several species of the family *Pandalidae* (source: www.afsc.noaa.gov).

fact that (a) the study area is unexploited, since the fishing mortality is null, and (b) the methods of mortality estimation used, are suitable. The values of mortality were smaller than those estimated for the same species in other Mediterranean areas, where the populations are exploited. Females exhibit smaller values of mortality - consequently a larger fraction survive. In the study area, the two species exhibited an intense reproductive capacity and showed a remarkable synchronization regarding gonad maturation, coupling and deposition of ova. In comparison to *A. foliacea*, *A. antennatus* presents (a) more extensive reproductive activity [lower CL of smaller mature male and female and CL_{50}, smaller female with spermatophores] and (b) higher absolute and relative fecundity. On the other hand, *A. foliacea* presents higher wet weight and gonad volume, double diameter and volume of ova, smaller gonad water content than *A. antennatus*. Both species present increased feeding activity (small values of vacuity index, increased stomach fullness index) (KAPIRIS, 2004).

Plesionika* sp and *Pandalidae

The species of the genus *Plesionika,* small and intermediate sized shrimps, have a subtropical and tropical geographical distribution, with a benthic or nektobenthic occurrence over the shelf and the slope (VAFIDIS *et al.*, 2005) (Figure 7).

In the Mediterranean Sea, the ten known pandalid species belong to the genera *Chlorotocus, Pandalina* and *Plesionika.* In the Mediterranean, *Plesionika* shrimps are mostly caught as a by-catch and are usually found at the local markets (MAIORANO *et al.*, 2002). Their spatial distribution and biology in Hellenic waters have been recently studied (KOUKOURAS *et al.*, 1997a, b, 1998; POLITOU *et al.*, 1998, 2003, 2004; THESSALOU-LEGAKI, 1989; THESSALOU-LEGAKI *et al.*, 1989; THESSALOU-LEGAKI, 1992; CHILARI, 2002; VAFIDIS *et al.*, 2005).

In the Ionian and the Aegean Seas the most common species are: *Plesionika heterocarpus, Plesionika gigliolii, Plesionika martia, Plesionika acanthonotus, Plesionika edwardsii, Plesionika antigai* and *Plesionika narval,* which occur in the upper and middle slope zone, depending on environmental factors. These species play an important ecological role within the various megabenthic assemblages, due to their abundance and trophic relationships.

In the Eastern Mediterranean (Hellenic waters included) the species of this genus have no commercial importance with the exception of *Plesionika edwardsii* and *Plesionika narval*, and they are almost all discarded (MACHIAS *et al.*, 2001). In both the Ionian Sea and Argosaronikos area, during the period 1996-1999, eight species were caught: *Chlorotocus crassicornis, Pandalina profunda, Plesionika acanthonotus, P. antigai, P. edwardsii, P. gigliolii, P. heterocarpus, P. martia,* and *P. narval. P. martia* was occasionally found in the 200-500 m depth zone, while it was the most abundant species in the depth zone 500-800 m, presenting a CPUE 99 ind/hour in the Ionian Sea and 147 ind/hour in Argosaronikos area (POLITOU *et al.*, 1998). On the other hand, *P. narval* was the less abundant species (found only in the Argosaronikos area: 7 ind /h, in the 200-500 m depth zone). *P. heterocarpus* was also very common in 200-500 m in both areas representing 27% of the total decapods' catch in the Ionian Sea and 8% of the total catch in the Argosaronikos (POLITOU *et al.*, 1998). A trap fishery has been developed for the species *P. edwardsii* and *P. narval,* in the western and eastern Mediterranean Sea, respectively (THESSALOU-LEGAKI *et al.*, 1989).

Only little scientific information exists for these species concerning their biology in Hellenic waters. In the Hellenic Ionian Sea, the mean size of females of the species of genus *Plesionika* is greater than males and the mean carapace length is positively related to depth. The sex ratio is in favor of females in *P. martia* and *P. edwardsii*. The reproductive period for *P. martia* in the Ionian Sea lasts from April to October, with two reproductive peaks in May and September and its fecundity is positively related to carapace length and body weight (CHILARI, 2002).

The *Plesionika* stocks are not managed *per se* in the European waters (Mediterranean and Atlantic waters), and only general regulations of the trawl fishery and regional or local regulations are directly applied to these fisheries. In a more general understanding of the exploited marine ecosystem, they should be considered in the management policy of marine resources (VAFIDIS *et al.*, 2005).

LOCAL ECONOMICALLY IMPORTANT SPECIES

Palaemon adspersus

The geographic distribution of the species is limited between the Black Sea, the Mediterranean Asian coasts, the Atlantic coasts of Europe down to Morocco, the 54^{th} parallel (Southern England and Denmark) and the north African coasts. The species is endemic within this geographic region and inhabits brackish waters as well as hyper-saline waters in lagoons and river deltas/estuaries. It prefers mud bottoms in which it can burrow (Figure 8).

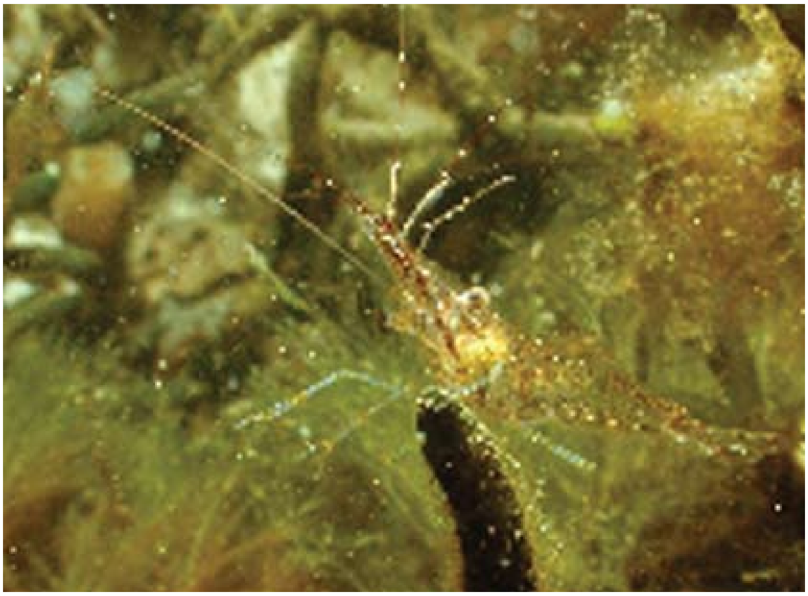

Figure 8: *Palaemon adspersus* (source:: *http://www.imv.uit.no/crustikon/Decapoda/Decapoda2/Species_index/Palaemon_adspersus/Palaemon_adspersus_Netherlands_fig1.jpg*

P. adspersus is not a target one for most fishing areas due to its low commercial value. The species is used mainly as bait for artisanal fisheries of high valued commercial species such as *Lithognathus mormyrus, Sparus aurata* and *Dicentrarchus labrax* as well as for long-line fishing. It cannot also be considered as a by-catch or discard since the gear used for the capture of the *Palaemonidae* shrimps is unique and selective only for this species. The amounts of the species landed have never been reported separately, since the statistical bulletins from the regional fishmonger markets report all shrimp species together. The only known data coming from the Messologhi-Aitolikon lagoons (West Hellas). The recent statistical bulletins from representative fishmonger markets show that the contribution of the *Palaemonidae* fishery to the local economy of the above area is very low. The amounts landed and their values are very low in relation to other fishery products in order to sustain fishermen and therefore, it could not become a primary fishery product or a target species for a certain group of fishermen.

The species can be found almost anywhere along the Hellenic coast. Adults of the species were found in extremely shallow waters, in lagoons and river estuaries/deltas as well as in saltpans (KLAOUDATOS & TSEVIS, 1987). The population of *P. adspersus* compresses a commercially valuable stock that is constantly exploited in the Messologhi-Aitolikon lagoons (West Hellas). The growth (KLAOUDATOS & TSEVIS, 1987; CONIDES *et al.*, 1992; CONIDES *et al.,* 1989) and the migratory movements (TSEVIS *et al.*, 1989) of this local population have already been studied.

There is no fleet associated with the fishery of Palaemonidae species. Fishing is carried out in areas with soft muddy or sand-mud sediment during the night from the coast using traps, artificial substrates and scoop-nets. The species is burrowing and during the day remains in the sediment. The species can be caught during its night movements for feeding. In addition, it can be caught using scoop-nets and other gear intended to scratch the upper layers of the sediment in which they burrow during the day time (CONIDES *et al.*, 1992).

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VII.8. SHARKS AND RAYS

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INTRODUCTION

Sharks and rays belong to the taxonomic class Chondrichthyes, or cartilaginous fishes, as their internal skeleton is formed from flexible cartilage. The chondrichthyan fishes are divided in two main groups: the subclass Elasmobranchii, which is the larger and includes sharks and rays and the subclass Holocephali, which includes the chimaeras and many extinct species (fossil records). There are over 500 shark and 600 ray living species all over the world. Sharks and their relatives were much more abundant and diverse in the fossil record, which include over 3 000 fossil species. Some fossil species that lived 150 million years ago are almost identical to some modern sharks, rays and chimaeras (COMPAGNO *et. al.,* 1984).

During the last decades, primarily in response to the rapidly increasing demand for shark fins, meat and cartilage, the commercial exploitation of sharks has been rapidly increasing all over the world, making information about their life history essential for understanding and managing their populations. Today many shark species are directly targeted in some commercial and recreational fisheries and are caught incidentally as by-catch in many other fisheries. Mortality of incidentally caught sharks is believed to be significant, especially from trawl nets, gill nets, purse seines and long lines, and may exceed mortality from directed fisheries. STEVENS *et al.,* (2000) have noted that some 50% of the estimated global catch of Chondrichthyans is taken as by-catch, does not appear in official fishery statistics and is almost totally unmanaged. Shark fisheries are inadequately controlled, due in part to a lack of understanding of the limitations of traditional teleost fisheries' assessment models when applied to elasmobranchs. The major difficulties faced by researchers and managers attempting to evaluate and manage shark and ray populations are the lack of available quality data, management tools, and political will. Elasmobranch biology is generally poorly understood and little fishery – independent or taxonomic research is under way (CAMHI *et al.,* 1998).

ELASMOBRANCHII IN THE MEDITERRANEAN

Seventy nine elasmobranchii species, belonging to seventeen families exist in the Mediterranean Sea. From them 70 species are native, i.e. known to live for a very long time in the Mediterranean, but also exist in other oceans; 4 are endemic, (i.e. species living only in the Mediterranean) and 4 are introduced recently in the Mediterranean through the Gibraltar Straits or the Suez Canal. The endemic species are: *Leucoraja melitensis, Dasyatis tortonesei, Raja polystigma* and *Raja rondeleti*. The introduced species in the Mediterranean are: *Himantura uarnak* through the Suez Canal and *Carcharhinus falciformis, Carcharhinus altimus* and *Galeocerdo cuvier* through the Gibraltar Straits (GOLANI *et al.,* 2002).

Concerning their habitat, 15 species are living in deep waters, characterized as bathydemersal, 7 are benthopelagic species, 29 demersal, 6 pelagic and 21 reef-associated. The average trophic level is around 4, classifying them on a high level in the food web. Species of the Carcharirhinidae, Alopiidae, Lamnidae, Odontaspididae and Sphyrnidae families appear on a higher trophic level (www.fishbase.org). Their maximum lengths range from 160 to 980 cm. The smaller animals belong to the families Scyliorhinidae and Squalidae and the bigger to Cetorhinidae, Alopiidae, Carcharinidae and Lamnidae.

Several shark stocks, especially the pelagic, are shared stocks and are fished by different countries bordering the Mediterranean. Three elasmobranch species occurring in the Mediterranean are the most endangered: the basking shark (*Cetorhinus maximus*), the giant devil ray (*Mobula mobular*) and the great white shark (*Carcharodon carcharias*), and have been included under international conventions (Specially Protected Areas and Biological Diversity in the Mediterranean, Convention on International Trade in Endangered Species, a.o.). A monitoring programme for these species (Mediterranean Large Elasmobranchs Monitoring) has been recently created under the auspices of General Fisheries Commission for the Mediterranean (GFCM).

RESEARCH ON ELASMOBRANCH SPECIES IN HELLAS

In Hellas there is not any specific fishery targeting the elasmobranch species but they are caught as side (by-catch) or incidental catch in various fisheries. Demersal shark and ray species are caught by various trawl-net, gill net and benthic long line fisheries, while pelagic species are caught in the drifting surface long line fisheries targeting swordfish and tunas.

According to the official fisheries' statistics, the contribution of elasmobranchs to the total commercial landings is low, ranging from 1.1 to 1.4% and the annual elasmobranch landings in the last decade do not exceed the amount of 1 700 MT. However, data available in the national administrations are generally quite incomplete and in most cases elasmobranch catches are not reported on a species basis but by broader groups, which include several species. A large part of shark by-catches, especially from the small-scale fishery, is also discarded at sea and in most cases this is poorly monitored.

The main objective of the present work is to provide information on the current state of the research and the main findings concerning the biology, distribution and fishery of the most common demersal and pelagic elasmobranch species in Hellenic waters.

Demersal species

A scientific bottom-trawl survey is conducted annually in the Hellenic Seas since 1994 aiming to monitor biological and population trends for a series of demersal species. The survey is realized in the frame of an international bottom trawl survey (MEDITS) covering the northern part of the Mediterranean basin and it includes sampling in 180 pre-defined stations distributed all over the Hellenic Seas. Sampling follows a common standardized protocol (BERTRAND *et al.,* 2000). Among the monitored species, are included the elasmobranchs *Scyliorhinus canicula, Galeus melastomus, Raja clavata, Raja asterias, Mustelus mustelus, Centrophorus granulosus, Squalus acanthias*. Based on the estimated abundance indices, the distribution patterns of the most common species are illustrated in Figures 1 to 4. Apart from the monitored species, data on the occurrence of other demersal elasmobranch species are also recorded. These include information on the bathydemersal species *Etmopterus spinax, Heptranchias perlo, Dalatias licha, Oxynotus centrina*, *Chimaera monstrosa*, and several species of the Triakidae, Dasyatidae, Rajidae and Squatinidae families.

Based on the MEDITS data for the 1994-2000 period biomass trends in the south Aegean Sea, were examined for a list of 14 demersal species, including the elasmobranchs *Squalus acanthias* and *Scyliorhinus canicula* (TSERPES & PERISTERAKI, 2002).

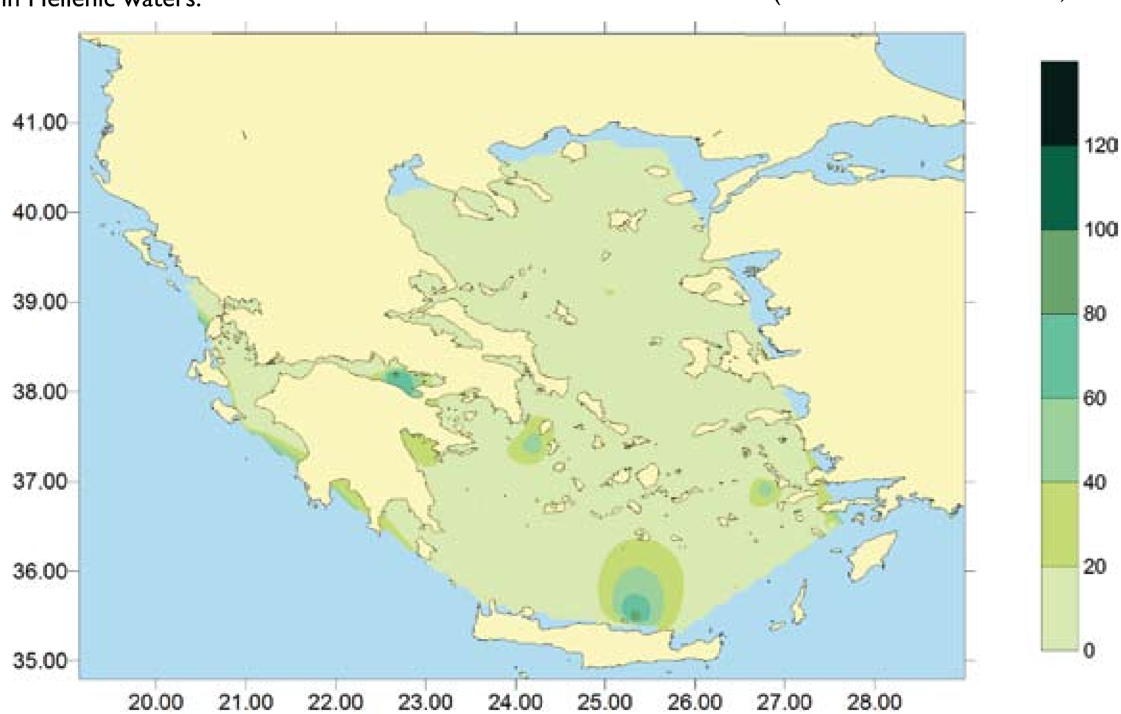

Figure 1: Distribution pattern of *Galeus melastomus* in the Aegean Sea, based on the extrapolation of estimated abundance indices (kg/Km^2) from the MEDITS surveys in 2004-2005 (PERISTERAKI *et al.,* 2007b).

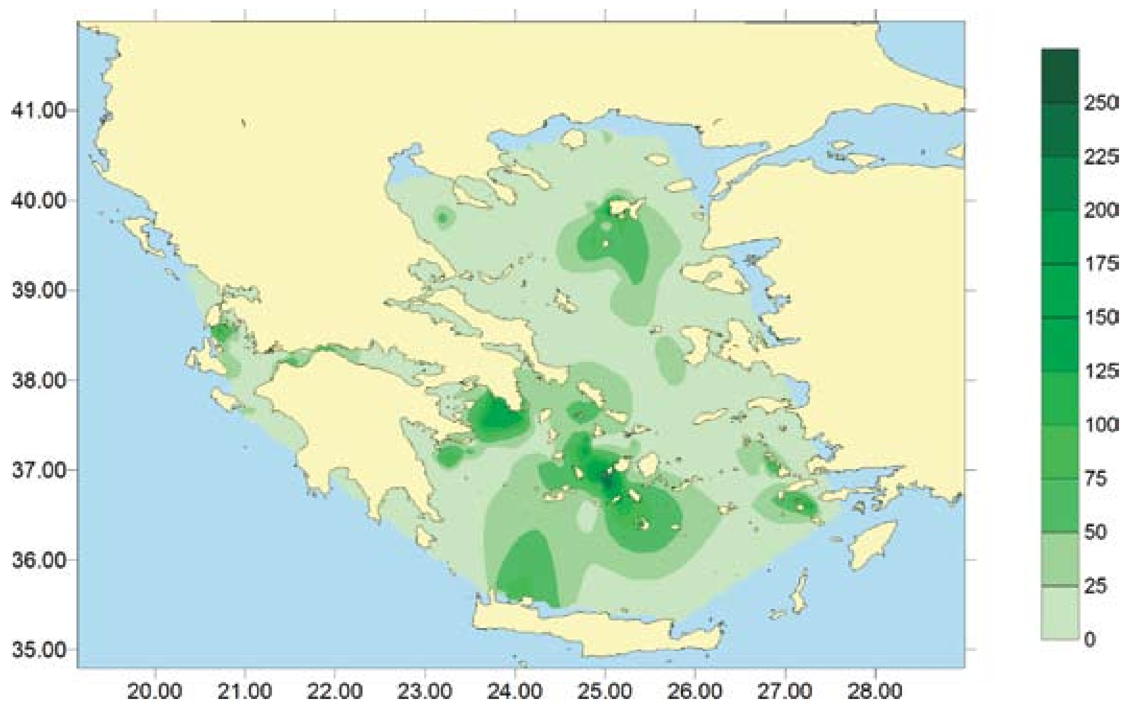

Figure 2: Distribution pattern of *Raja clavata* in the Aegean Sea, based on the extrapolation of estimated abundance indices (kg/Km^2) from the MEDITS surveys in 2004-2005 (PERISTERAKI *et al.,* 2007b).

The results suggested the existence of a generally increasing trend for *Squalus acanthias*, while no significant trend was observed for *Scyliorhinus canicula*.

In the frame of a national project (Pythagoras II, University of Athens), aiming to study the impact of certain fisheries on demersal sharks, the most commonly caught shark species have been recorded and various aspects of their biology and fisheries have been examined. The list of the most common species includes: *Scualus acanthias, Squalus blainvillei, Scyliorhinus canicula, Galeus melastomus, Etmopterous spinax, Dalatias licha, Heptranchias perlo, Mustelus mustelus, Oxynotus centrina* and *Centrophorus granulosus* (MEGALOFONOU, 2005).

In the frame of the aforementioned project, the reproductive biology of *Squalus acanthias, Centrophorus granulosus* and *Galeus melastomus* were studied and findings indicated that Mediterranean individuals reach maturity at a smaller length than the Atlantic ones (CHATZISPYROU & MEGALOFONOU, 2005; COUSTENI *et al.*, 2006a; MEGALOFONOU & CHATZISPYROU, 2006). Fecundity rates were also lower than those reported in the Atlantic. Study of the egg case of a dogfish revealed that it forms a complex composite with extraordinary mechanical and functional properties and it is largely made of an analogue of the mammalian collagen (ICONOMIDOU *et al.*, 2007).

Examination of the mercury concentrations in edible tissues of certain commercial shark species by means of Cold Vapor Atomic Absorption Spectrometry revealed that concentration levels in dogfish specimens coming from certain areas, were higher than those established by the EU Decision 93/351 (MEGALOFONOU, 2005; COUSTENI *et al.*, 2006b; KOUSTENI *et al.*, 2006).

Pelagic species

Pelagic elasmobranch species are incidentally caught in surface drifting long lines targeting swordfish and tunas. Until, 2001, information on pelagic elasmobranchs has originated from six EU projects aiming at the monitoring of large pelagic fisheries and one by-catch study. Since 2002 pelagic shark catches are regularly monitored in the frame of the National Fisheries Data Collection Programme.

The main species caught in the large pelagic fisheries are the blue shark (*Prionacea glauca*) and the pelagic sting ray (*Dasyatis violacea*) (MEGALOFONOU *et al.*, 2000; DAMALAS & MEGALOFONOU, 2003; TSERPES *et al.,* 2006; TATAMANIDES *et al.,* 2006). The devil fish (*Mobula mobular*), great white shark (*Carcharodon carcharias*), smooth hammerhead (*Sphyrna zygaena*), thintail thresher *(Alopias vulpi-*

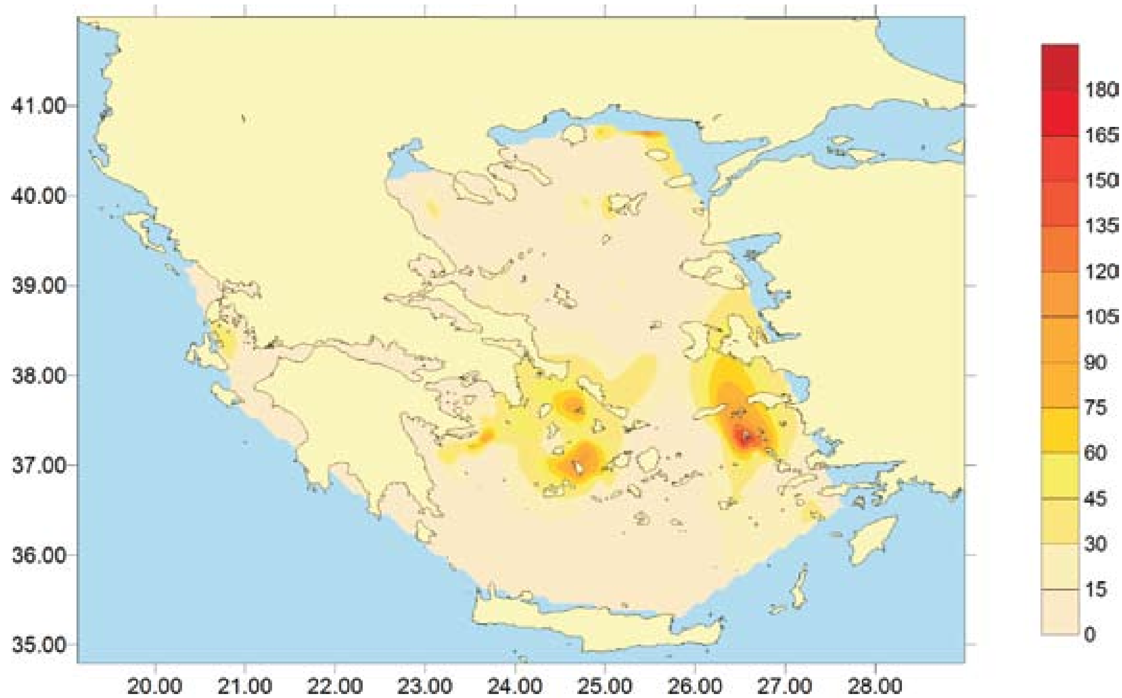

Figure 3: Distribution pattern of *Scyliorhinus canicula* in the Aegean Sea, based on the extrapolation of estimated abundance indices (kg/Km^2) from the MEDITS surveys in 2004-2005 (PERISTERAKI *et al.,* 2007b).

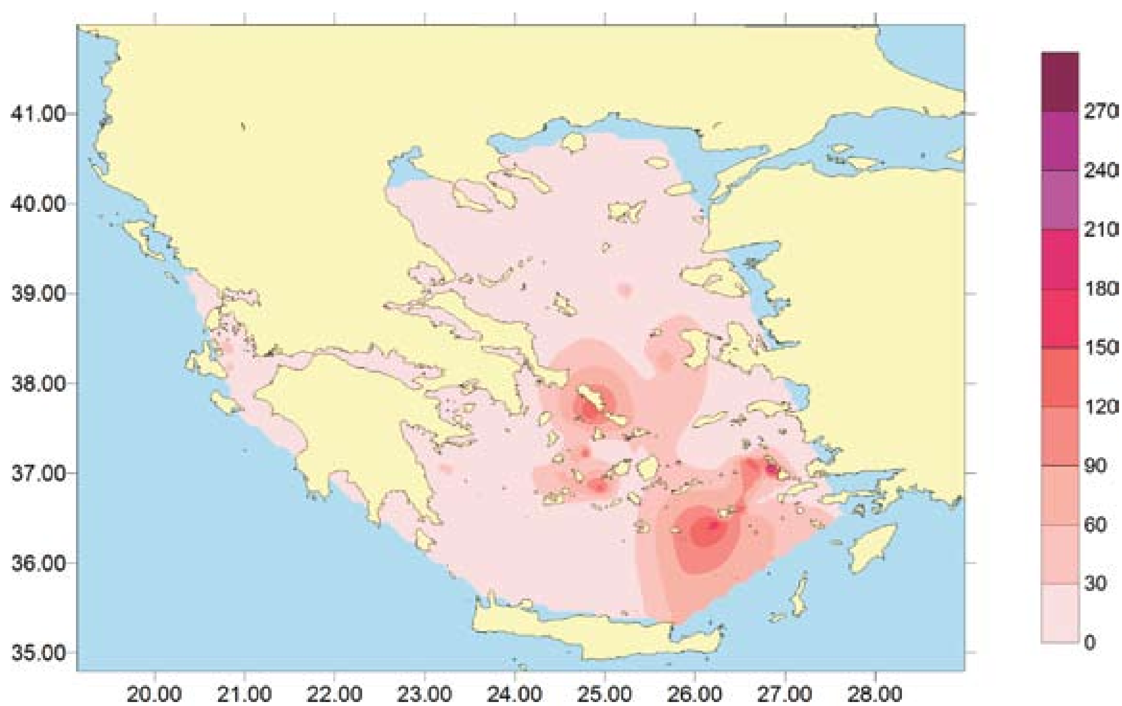

Figure 4: Distribution pattern of *Squalus acanthias* in the Aegean Sea, based on the extrapolation of estimated abundance indices (kg/Km^2) from the MEDITS surveys in 2004-2005 (PERISTERAKI *et al.,* 2007b).

nus), short-finned mako (*Isurus oxyrhinchus*) and tope shark (*Galeorhinus galeus*), have been also recorded as incidental catches. Rare records of the big-eyed thresher shark, *Alopias superciliosus,* the sharpnose sevengill shark, *Heptranchias perlo,* the big-eyed sixgill shark, *Hexanchus nakamurai* and the sixgill shark (*Hexanchus vitulus*) have been also reported (MEGALOFONOU *et al.,* 2002; 2005a,b; PERISTERAKI *et al.,* 2007a).

In the frame of the project "By-catches and discards of sharks in the large pelagic fisheries in the Mediterranean Sea" (No 97/50), annual catches of large pelagic sharks have been estimated to range from 48 to 123 tons, for the period 1998-2000. Catch comparison among the examined fisheries revealed higher shark catches in the swordfish fishery reaching a 3.8% in terms of total number of fish and 3.6% in terms of total biomass. In the albacore fishery shark catches were lower (2.2% in number and 0.9% in kg). Analysis of catch composition of the swordfish fishery by area showed higher percentages of shark catches in the Ionian Sea (5.6%), followed by the Levantine Basin (4.3%) and the Aegean Sea (3.8%) (MEGALOFONOU *et al.,* 2000).

Analysis of the data collected in the frame of the National Fisheries Data Collection Programme has shown that the annual production of pelagic sharks in the 2004-2006 period ranged from 13 to 17 tones of fillet weight (ANONYMOUS, 2005; 2006; 2007).

Spatiotemporal variations in shark by-catches of the Hellenic swordfish long line fishery operating in the eastern Mediterranean were examined by means of Generalised Linear Modelling techniques applied to presence-absence and catch per unit effort data, collected from 2000 to 2003 through onboard sampling. Results revealed significant, monthly and area variations, while the yearly pattern was stable. Higher abundance indices were observed in the Levantine basin and in the waters around Kriti; concerning season, the higher values were observed in February, March and August (Figure 5). It is likely that these variations are related to the reproductive and feeding behaviour of the species (TATAMANIDES *et al.,* 2006). Results, also, demonstrated that the higher incidence of sharks in the catches is expected in February and July (Figure 6), (TSERPES *et al.,* 2006).

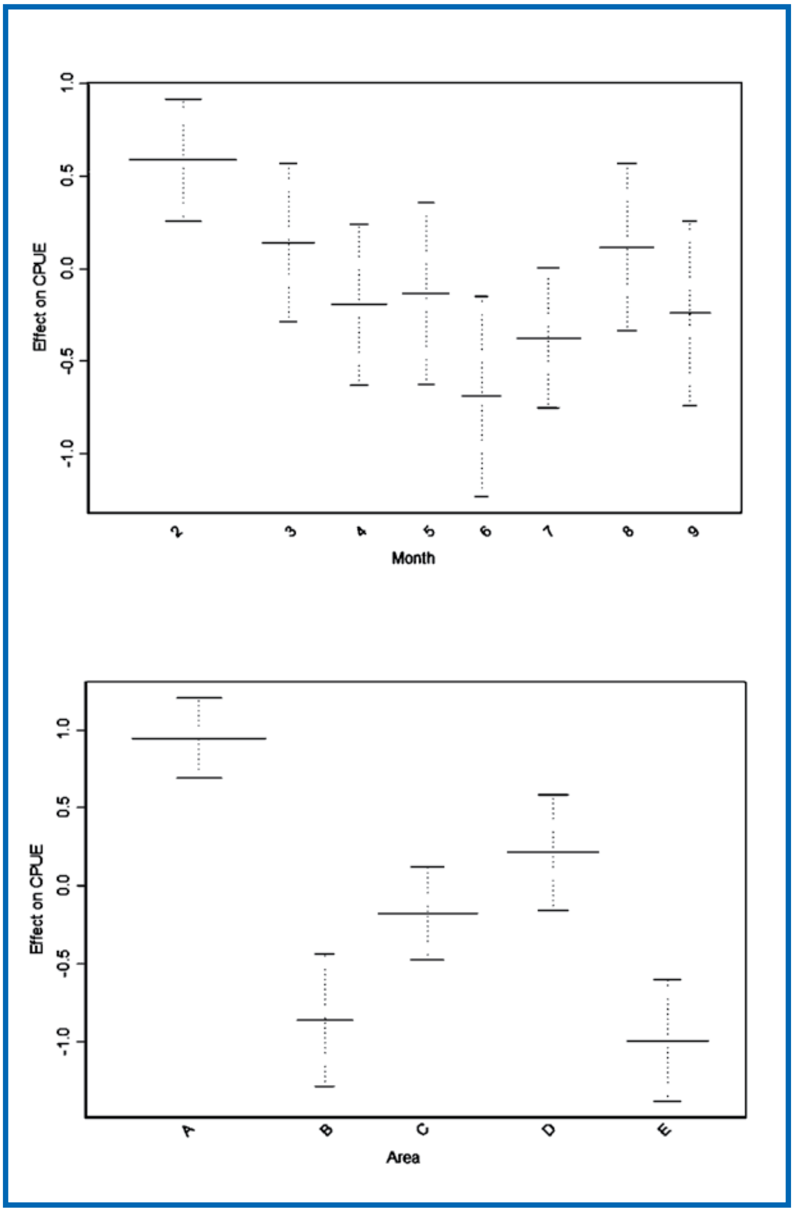

Figure 5: Generalized linear model derived significant effects of month and area on CPUE index of elasmobranch species. Each plot represents the contribution of the corresponding variable to the fitted predictor. The fitted values are adjusted to average zero and the broken lines indicate two standard errors. Bar widths correspond to the observation frequency at each variable level. Months: 2-9 February-September, A=Cretan Sea, B=Kyklades, C=Dodekanisos, D=Levantine. (Source data: TATAMANIDES *et al.,* 2006).

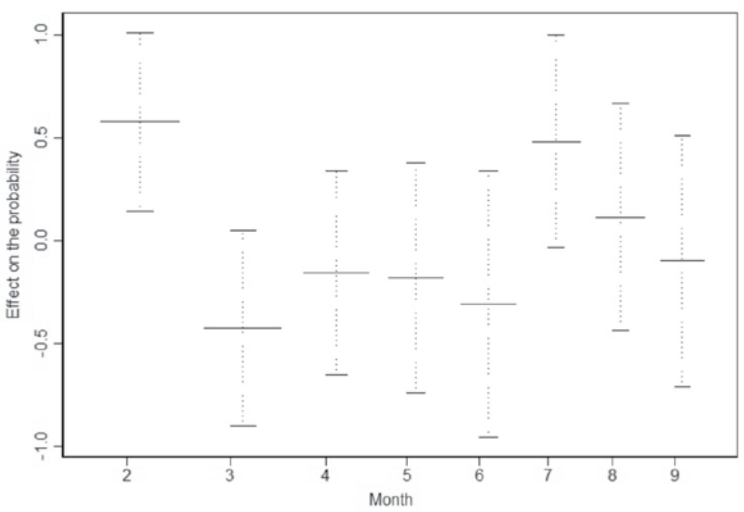

Figure 6: GLM derived effect of month on the probability to catch sharks. The fitted values are adjusted to average zero and the broken lines indicate two standard errors. Bar widths correspond to the observation frequency at each variable level. Months 2-9: February-September. (Source: TSERPES *et al.,* 2006).

FUTURE RESEARCH NEEDS-KNOWLEDGE GAPS

Extended monitoring of commercial fisheries capturing sharks is necessary for stock assessment studies. It should be noted, that as most pelagic elasmobranches are landed decapitated, finned and usually skinned, it is difficult to identify the species from landings and onboard sampling is needed.

Time series of data collected through experimental surveys such as the "MEDITS" can be used to establish population indicators for the monitored elasmobranch species and can provide valuable information for management purposes. Most shark species are highly migratory; hence stock boundaries extend beyond national borders. Consequently, international cooperation is needed to optimize research on those species. Since there are serious uncertainties regarding migration patterns and stock structure of pelagic sharks, research on these aspects (e.g. tagging operations, genetic studies, etc.) is necessary to achieve rational management of those resources. In addition, there is need for further research on the biology of the species mainly focusing on growth and maturity studies.

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VII.9. RESEARCH ON CEPHALOPOD RESOURCES IN HELLAS

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INTRODUCTION

Several cephalopod species are considered commercially important in Hellas (Chapter II.4) and, as coastal finfish stocks undergo depletion in heavily exploited fishing grounds, the interest in the exploitation of cephalopod resources is steadily increasing.

Fisheries research conducted during the last seventeen years includes the study of the biology, ecology, fisheries and rearing conditions of Cephalopods, aiming at the conservation of wild Cephalopod populations and the development of aquaculture.

Available information on Cephalopods' resources, resulting from the analyses of fisheries' statistical data and the investigation based on experimental surveys, visual census, cephalopod fisheries' monitoring and laboratory rearing is compiled in this document. Among our aims is (a) to summarize research conclusions related to management measures, and (b) to identify in this context gaps in knowledge and priorities for future research.

STUDIES ON SPECIES' LIFE HISTORY

Demographic analysis and estimation of the basic biological parameters of selected Cephalopod species has been included in national and international research projects concerning the assessment of commercially important stocks in various areas of the Hellenic Seas and based on trawl surveys, since 1990.

Analyses of seasonal size and maturity stages' composition, performed for *Illex coindetii, Eledone cirrhosa, Eledone moschata, Sepia elegans, Sepia orbignyana Sepietta oweniana* and *Alloteuthis media* sampled with trawl nets in the Aegean Sea, have shown prolonged spawning and recruitment periods for all species, with one or more seasonal peaks (Table 1). Considerable variation has been observed in species' abundance between seasons or different years, related to their short life-span, rapid population turnover, reproductive behaviour and recruitment seasonality (PAPACONSTANTINOU *et al.*, 1993, 1994, 1998).

The data collected during trawl surveys were insufficient for life cycle studies of neritic commercially important species such as *Sepia officinalis, Loligo vulgaris* and *Octopus vulgaris*. Biological studies of the latter two species have been carried out, however, in the framework of two PhD studies based on respectively, a) *Octopus vulgaris* on monthly visual census at several coastal sites (0-30 m depth) of the southern Aegean and Ionian Seas (KATSANEVAKIS, 2004), and b) *Loligo vulgaris* on monthly sampling of commercial catches by beach-seiners and trawlers in the Thracian Sea (LEFKADITOU, 2006). Moreover, monthly progress of maturation and length-weight relationships were studied for *Illex coindetii, Loligo vulgaris* and *Sepia officinalis* in different areas of the Hellenic seas, based on monthly sampling of commercial catches carried out in the framework of the European research projects CEPHVAR (Environmental, Genetic and Biological Variation of Cephalopods in European Waters. 1997-2000) and CEPHASSES (ARVANITIDIS *et al.,* 2001, 2002; MORENO *et al.*, 2002).

Two main benthic settlement (recruitment) peaks were found for *Octopus vulgaris,* indicating respective spawning peaks (Table 1), which were more pronounced and shorter in duration when seasonal temperature increased (KATSANEVAKIS & VERRIOPOULOS, 2006a). A similar effect of temperature has been observed during the spawning period of *Loligo vulgaris* which was found to last from late winter to early autumn in the Thracian Sea, reaching a peak in spring (LEFKADITOU, 2006).

Density of both species in the coastal zone was also found to be associated with temperature. Adult octopuses (>200 g) tended to dwell deeper during the period of intense thermocline than during the no-thermocline period (KATSANEVAKIS & VERRIOPOULOS, 2004), whereas, *Loligo vulgaris,* as supposed by beach-seine CPUE variations, migrated extensively to inshore fishing grounds after a considerable decrease of temperature in late November (LEFKADITOU *et al.*, 1998).

Octopus life-span and growth rate (Table 1) were estimated by a time-variant, stage-classified, matrix population model based on monthly density measurements of 4 size stages (1:<50g, 2: 50-200g, 3: 200-500g, 4: >500g) (Figure 1) which were recorded during scuba diving (KATSANEVAKIS & VERRIOPOULOS, 2006b).

Table I. Life cycle features and parameters of commercially important and most abundant cephalopod species in Hellenic Seas (compiled from LEFKADITOU & PAPACONSTANTINOU, 1995; ANONYMOUS, 2000; ARVANITIDIS *et al.*, 2001; 2002; MORENO *et al.*, 2002; ANONYMOUS, 2005; KATSANEVAKIS & VERRIOPOULOS, 2006; LEFKADITOU, 2006)

Species	ML_{max} (cm)	ML_{50} (cm)	Spawning period (peak season)	Recruitment period (peak season)	Length-weight relationship	Life span (months)	DGR range (g/day)	Relative Fecundity (No oocytes/ g BW)	Food items (rank order)
Alloteuthis media	♀ 10.4 ♂ 8.1		All year	All year (autumn-winter)	$BW=0.0012ML^{2.06}$ $BW=0.0022ML^{1.89}$				
Eledone cirrhosa	♀ 15.5 ♂ 12.0		early summer-mid autumn	All year (autumn-winter)	$BW=0.0026ML^{2.51}$ $BW=0.0034ML^{2.43}$				
Eledone moschata	♀ 18.4 ♂ 18.2		March –September (early summer)	All year (autumn)	$BW=0.0004ML^{2.87}$				
Illex coindetii	♀ 24.0 ♂ 18.0	14.6-18.1 11.3-13.8	All year (summer)	All year (autumn-winter)	$BW=7x10^{-5}ML^{2.83}$ $BW=1x10^{-5}ML^{3.25}$	13.5 14.5	0.06-1.17 0.06-1.09	506 (±101)	Fish Cephalopod Crustacean
Loligo vulgaris	♀ 29.5 ♂ 46.5	13.9-18.9 13.5-15.5	November-June (mid spring)	All year (summer)	$BW=0.0001ML^{2.81}$ $BW=0.0002ML^{2.59}$	12 13.5	0,13-10,39 0,12-8,93	44(±11)	Fish Cephalopod
Octopus vulgaris	♀ 21.5 ♂ 20.0		(late winter-spring & late summer-early autumn)	All year (late spring-summer & late autumn)	$BW=0.0034ML^{2.60}$	12-15	1.74-3.89*		
Sepia elegans	♀ 7.6 ♂ 5.7		All year (spring)	summer-winter (autumn)	$BW=0.0007ML^{2.51}$ $BW=0.0009ML^{2.44}$				
Sepia officinalis	♀ 26.4 ♂ 32.0			All year (summer)	$BW=0.0064ML^{2.18}$ $BW=0.0025ML^{2.37}$				
Sepia orbignyana	♀ 9.1 ♂ 8.4		All year	All year (autumn)	$BW=0.0017ML^{2.36}$ $BW=0.0019ML^{2.3}$				
Sepietta oweniana	♀ 3.6 ♂ 3.4	1.8 - 2.4 1.4 - 1.8	All year (spring)	All year (autumn)	$BW=0.0069ML^{2.12}$ $BW=0.0107ML^{1.97}$			16 (±4)	Crustacean Fish Cephalopod

* estimation for octopods 50-500g based on analysis of monthly population density of 4 size classes, which was measured through visual census.

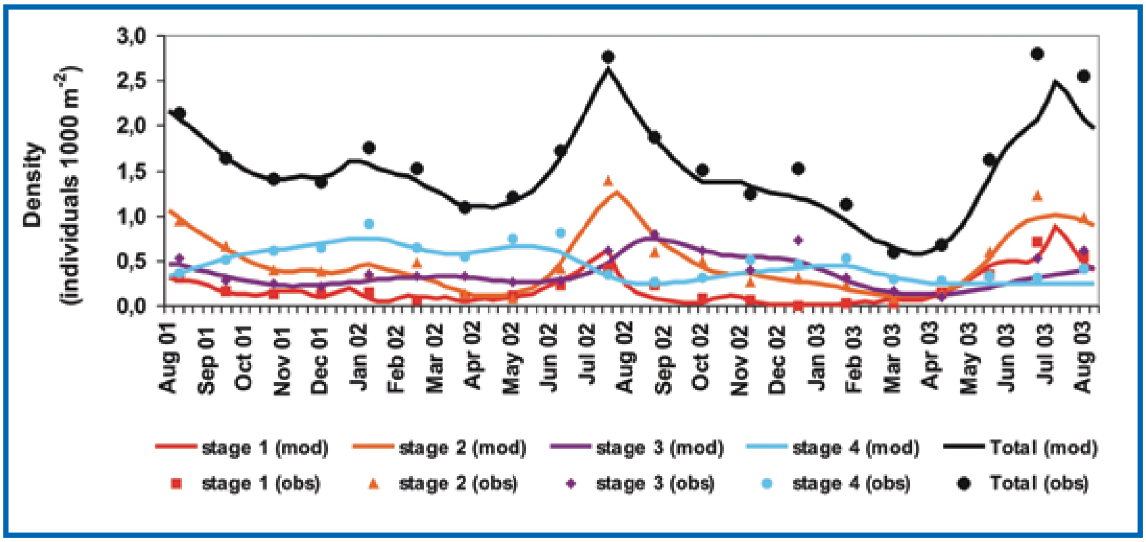

Figure 1: Model predictions, starting from an initial density vector n_1 equal to the observed vector at that time, vs. observed densities. Lines represent model a estimations and markers represent observed data. Source: KATSANEVAKIS & VERRIOPOULOS, 2006.

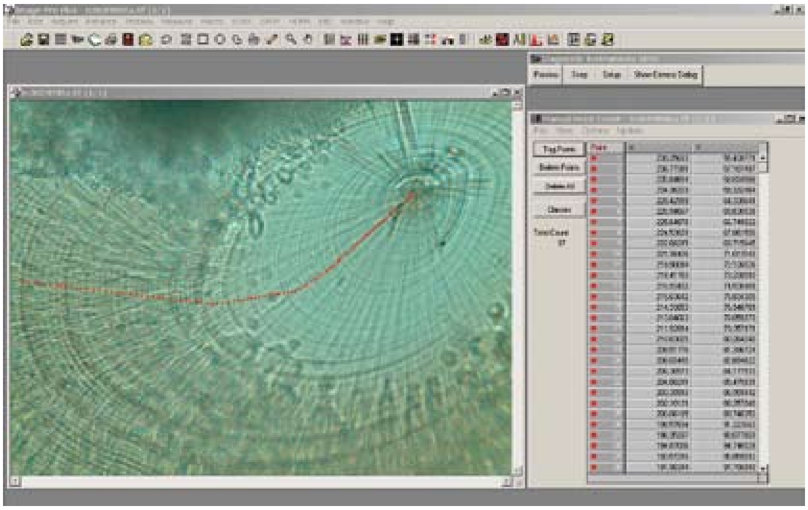

Figure 2: Manual tagging of growth increments on a digital image from *Illex coindetii* statoliths and recording of tag coordinates through the routines of IMAGE-PRO-PLUS programme.

Estimates of *Illex coindetii* life-span by modal analyses of seasonal length frequency through indirect methods calculating the Von Bertalanfy growth equation parameters, were considered overestimates when compared to direct age estimates from statoliths (PAPACONSTANTINOU *et al.*, 1993, 1994). The daily nature of growth increments exposed on ground squid statoliths has been verified by chemical marking for several squid species since the mid 1980s, whereas direct ageing resulting from increment counts in cuttlefish statoliths and octopus beaks has not been validated yet. In Hellas the reading of statoliths started in 1992 in the framework of a PhD thesis (LEFKADITOU, 2006) including, among other issues, the ageing of *Illex coindetii* and *Loligo vulgaris*. The development of the ageing methodology using squid statoliths was greatly facilitated by the use of an Image Analysis System obtained by HCMR in 1996, as well as, by its further updates concerning the routines of the IMAGE-PRO-PLUS programme (Figure 2), the frame grabber and the rest of the hardware used.

In respect to the diet composition of cephalopod species, the existing information originating from examination of material collected in various areas of the Aegean Sea, indicates that Fish, Crustacean and Cephalopods compose the preferential prey categories, their dominance order depending on the species and the fishing ground, while other groups such as Polychaeta Annelida, Tunicata and Cnidaria Hydrozoa participate with very low percentages (KOUKOURAS *et al.*, 2001; LEFKADITOU, 2006).

MONITORING OF CEPHALOPOD FISHERIES IN THE THRACIAN SEA

According to analyses of National Staticis data on cephalopod catches by fishing region and fishing gear for the period 1998-2002, small-scale fishery (beach seine and other gears) contributes half or more of the cephalopod catches in most fishing areas (Figure 3), whereas the major part of the

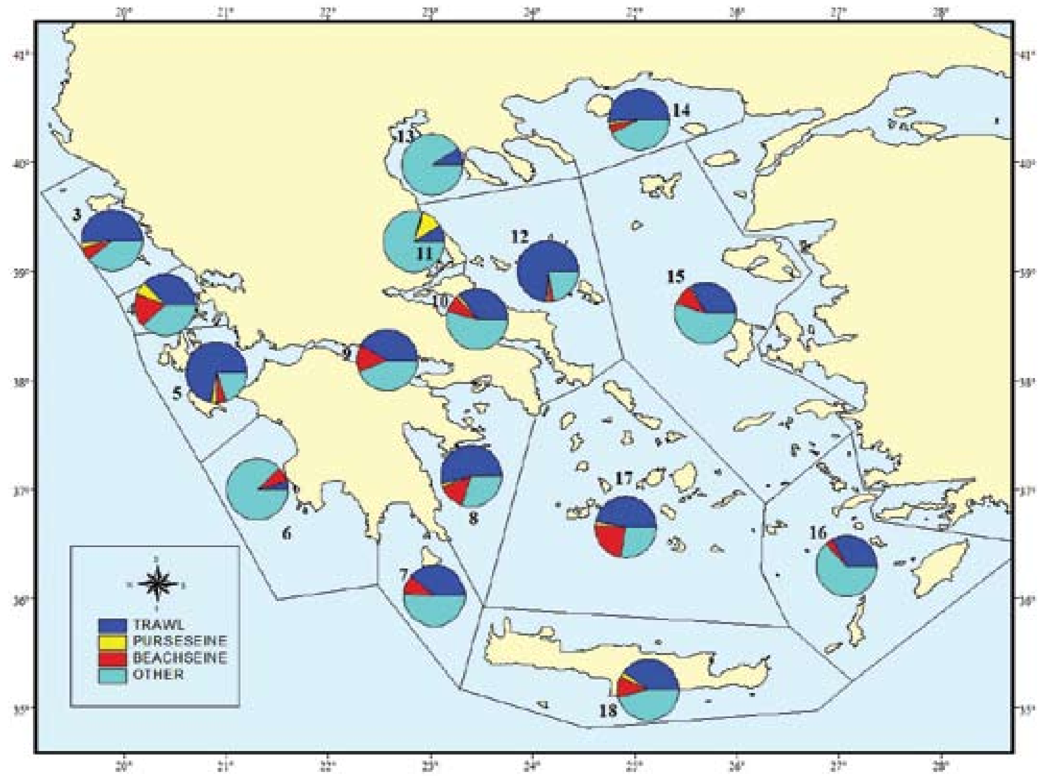

Figure 3: Percentage contribution of different fishing gear categories in cephalopod catches by fishing area, during the period 1998-2002.

cephalopod catches is exploited in the Thermaikos Gulf (Region 13) and Thracian Sea (Region 14), where *Sepia officinalis* and *Octopus vulgaris* dominate the continuously increasing catches (LEFKADITOU *et al*., 2002).

Since 1994 four research projects that have been undertaken by FRI and HCMR (Table 2), aimed at the investigation of exploitation patterns for *Loligo vulgaris, Sepia officinalis, Octopus vulgaris, Eledone moschata* and *Eledone cirrhosa* in the Thracian Sea, where apart from the traditional gears fishing Cephalopods, new profitable fishing techniques (fyke-nets, plastic pots) for common octopus have been developed since the early 1990s.

Multi-species gears, such as trawl and beach-seine, were observed to undertake in some cases specific hauls targeting commercially important species like *Octopus vulgaris, Sepia officinalis* and *Loligo vulgaris*. During the fishing period October 1998-May 1999, Cephalopods constituted 27% of the trawler landings at the port of Kavala and 19% of their total sales. *O. vulgaris* was the most important species among Cephalopods in terms of landings and sales (49%), followed by *S. officinalis* (23%). The average contribution of *Loligo vulgaris* in Cephalopod sales (17%) was quite higher than in landings (6%), due to its higher price in the market. Eledonids had the lowest prices among Cephalopods and contributed the lowest proportion (*E. moschata*: 6%, *E. cirrhosa*: 2%) in cephalopod sales (LEFKADITOU *et al.,* 2001). The contribution of Cephalopods to the total sales of beach-seiners (36%) was higher than for their landings (17%). This was due to the dominance of low-price species such as *Sardina pilchardus* in their landings (LEFKADITOU & ADAMIDOU, 1997), particularly in winter, whereas, the highly priced *Loligo vulgaris* represented 49% of the cephalopod landings accounting for 74% of the total cephalopod sales. Average annual catches of common squid per vessel for beach seiners has been shown to be threefold that of trawlers operating in the Thracian Sea (LEFKADITOU & PAPACONSTANTINOU, 1999), thus proving the importance of beach seine gear for the exploitation of this coastal resource. Considering the likely implications of Fisheries Regulations which might stop beach seine operation in Hellenic waters, an experimental hand operated jigging machine with light attraction was tested as potentially alternative fishing gear for the coastal exploitation of *L. vulgaris*, which however, has been proved

Table 2. Research projects undertaken by FRI and HCMR, concerning cephalopod fisheries' monitoring in the Thracian Sea. List of studied species, fishing gears (BS: Beach-seine, PS: Purse-seine, TR: Trawl, FN: Fyke-nets, TN: Trammel-nets, STN: Sepia-trammel-nets, P: Pots) and LPUE data collection period.

Title of Study	Fishing gears	Species	Data collection period
Experimental squid jigging with light attraction (Studies/ EU DG XIV, Contract No: MED93/19).	Beach-seine Purse-seine Trawl	*Loligo vulgaris*	Oct. 1994 – May 1995 (daily)
Stock assessment of some coastal species (COASTAL) (Studies/ EU DG XIV, Contract No: 96/054).	Fyke-nets Trammel-nets	*Octopus vulgaris* *Sepia officinalis*	Sep. 97- Sep 99 (fortnightly)
Analysis and evaluation of the fisheries of the most commercially important cephalopod species in the Mediterranean Sea. (Studies/ EU DG XIV, Contract No: 97/054)	Beach-seine	*Eledone moschata* *Loligo vulgaris* *Octopus vulgaris* *Sepia officinalis*	Oct. 99 – May 99 (fortnightly)
	Fyke-nets	*Octopus vulgaris*	Oct. 99– June 99 (fortnightly)
	Sepia-trammel-nets	*Sepia officinalis*	Feb. 99 – May 99 (fortnightly)
	Trawl	*Eledone moschata* *Eledone cirrhosa* *Loligo vulgaris* *Octopus vulgaris* *Sepia officinalis*	Oct. 99 – May 99 (fortnightly)
Cephalopod Stocks in European Waters: Review, Analysis, Assessment and Sustainable Management (CEPHSTOCK) (Concerted Action/ EU DG XII, Contract No: Q5CA-2002-00962)	Trammel nets Pots	*Sepia officinalis* *Octopus vulgaris* *Octopus vulgaris*	April 1998 - Dec. 2003 (daily)*
	Pots	*Octopus vulgaris*	Oct. 2003 – June 2005 (daily)*

* Data provided by the Fishermens' Cooperative "EVROS" of artisanal vessels operating in the eastern Thracian Sea.

inefficient (LEFKADITOU *et al.,* 1997).

Fyke nets, used for fishing octopus since 1982 on bottoms covered by sea grass, composed 6% of small-scale fishing gears recorded in the whole area but 56% of gears used around Thassos island (KALLIANIOTIS & KOUTRAKIS, 1999). PVC/plastic pots (Chapter III.4) targeting octopus on sandy or muddy bottoms since 1992 and traditional Sepia-trammel nets, contributed 90-98% of annual cephalopod quantities landed in the years 1998-2003 by the small-scale fishing vessels of the Fishermens' Cooperative "EVROS" operating in the eastern Thracian Sea (LEFKADITOU *et al*., 2004). Various types of hand jigs targeting *O. vulgaris* and *L. vulgaris* were considered of minor importance since they are mainly used by sport-fishermen.

Analyses of LPUE monthly variation (Figure 4) have shown seasonal peaks related to pre-spawning and spawning aggregation of neritic species on trawl and inshore fishing grounds respectively, as it is observed for *L. vulgaris* during early autumn-winter, for *S. officinalis* during late winter – spring and for *O. vulgaris* during late spring-early summer. On the other hand, Landings per Unit Effort (LPUE) variation may also reflect local fishery legislation and the strategy of the fishing fleet, as indicated, for example, by the inverse trend of the two eledonid species LPUE in autumn 1998, which is decreasing for *E. cirrhosa* and increasing for the neritic *E. moschata* in November, when fishing grounds closer to the coast were opening for trawling activity. The evident decline of *L. vulgaris* LPUE from winter to early spring, for both trawl and beach-seine fisher-

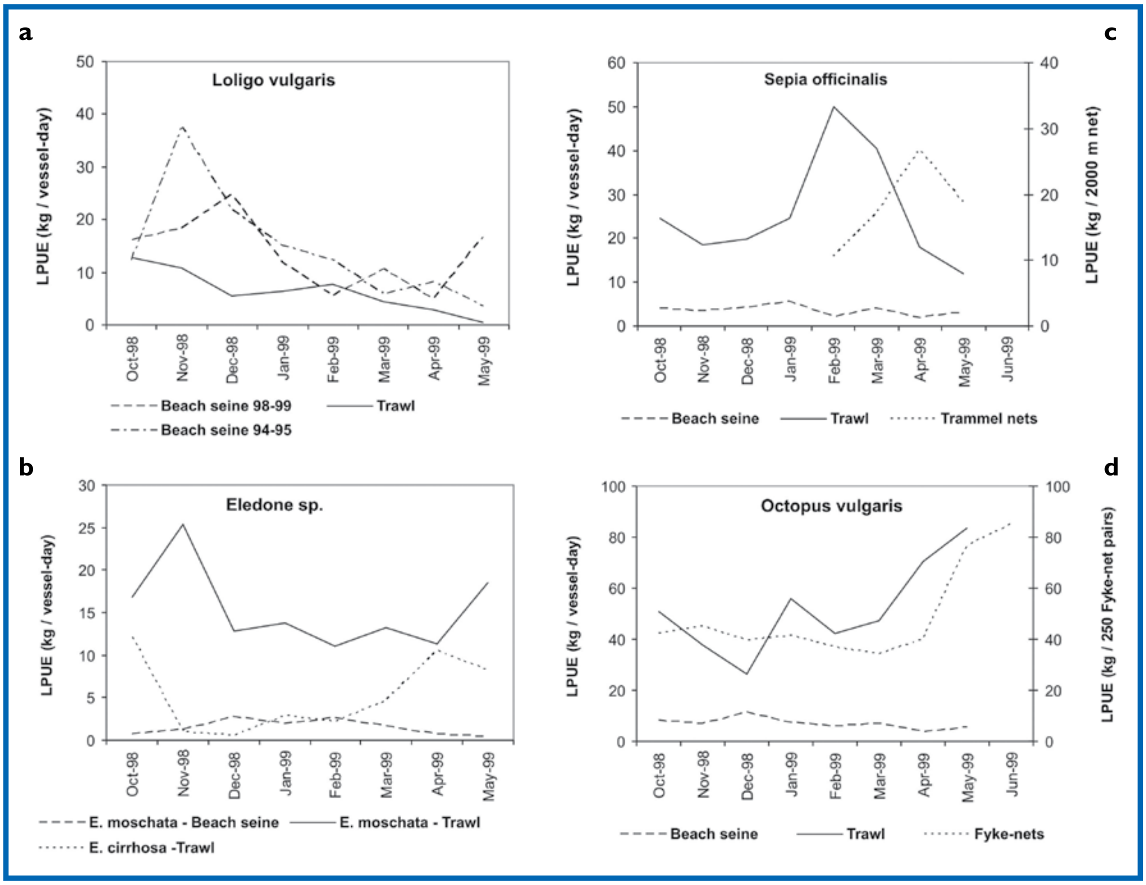

Figure 4: Monthly evolution of *L. vulgaris* (a), *E. moschata* & *E. cirrhosa* (b), *S. officinalis* (c) and *O. vulgaris* (d) LPUE by different fishing gears in the Thracian Sea.

ies, provided some scope for the use of depletion models to estimate population size (TSANGRIDIS *et al,* 1998). However, the fact that the period of decreasing LPUE coincides with the spawning period of *L. vulgaris* (Table I) has to be taken into account, which means that the effects of fishing are not easy to distinguish from the consequences of high post-spawning mortality.

Length composition analyses for the monthly catches of *O. vulgaris* and *S. officinalis* by the various types of fishing gears have shown that, in general, trawlers exploit smaller specimens which have not reached maturity, whereas, selective artisanal gears operating in the coastal zone of the Thracian Sea (fyke-nets, pots, Sepia-trammel-nets) affect spawners mainly (KALLIANIOTIS *et al*, 2001; BELCARI *et al*, 2002; TSANGRIDIS *et al*, 2002; ADAMIDOU & KALLIANIOTIS, 2005).

MODELLING TEMPORAL AND SPATIAL VARIATION OF CEPHALOPOD CATCHES

A few attempts were made to model temporal variation of cephalopod landings in relation to temperature variations (STERGIOU, 1987; GEORGAKARAKOS *et al.*, 2002, 2006) or to simplistic estimations of fishing effort in number of vessels or vessel's total horsepower (STERGIOU, 1989). During the pre-war period (1928-1939) of low fishing pressure, significant positive correlations of total cephalopod, squid, cuttlefish and octopod catches with the mean annual, February and March air temperature have been encountered, whereas squid and octopod catches were shown to be significantly correlated also with the 3-year running means of the mean December air temperature (STERGIOU 1987). GEORGAKARAKOS *et al.* (2002) have also found positive correlations of common squid landings with SST during February and March of 1988, 1993 and 1995 in the Thermaikos Gulf (NW Aegean Sea). The second period (September-October) with high cross-correlations between SST and landings of both common squid and flying squid, noted by GEORGAKARAKOS *et al.* (2002), should however, be reconsidered by taking into account the opening of trawl and beach-seine fisheries in October, since these fishing gears exploit the above-mentioned species

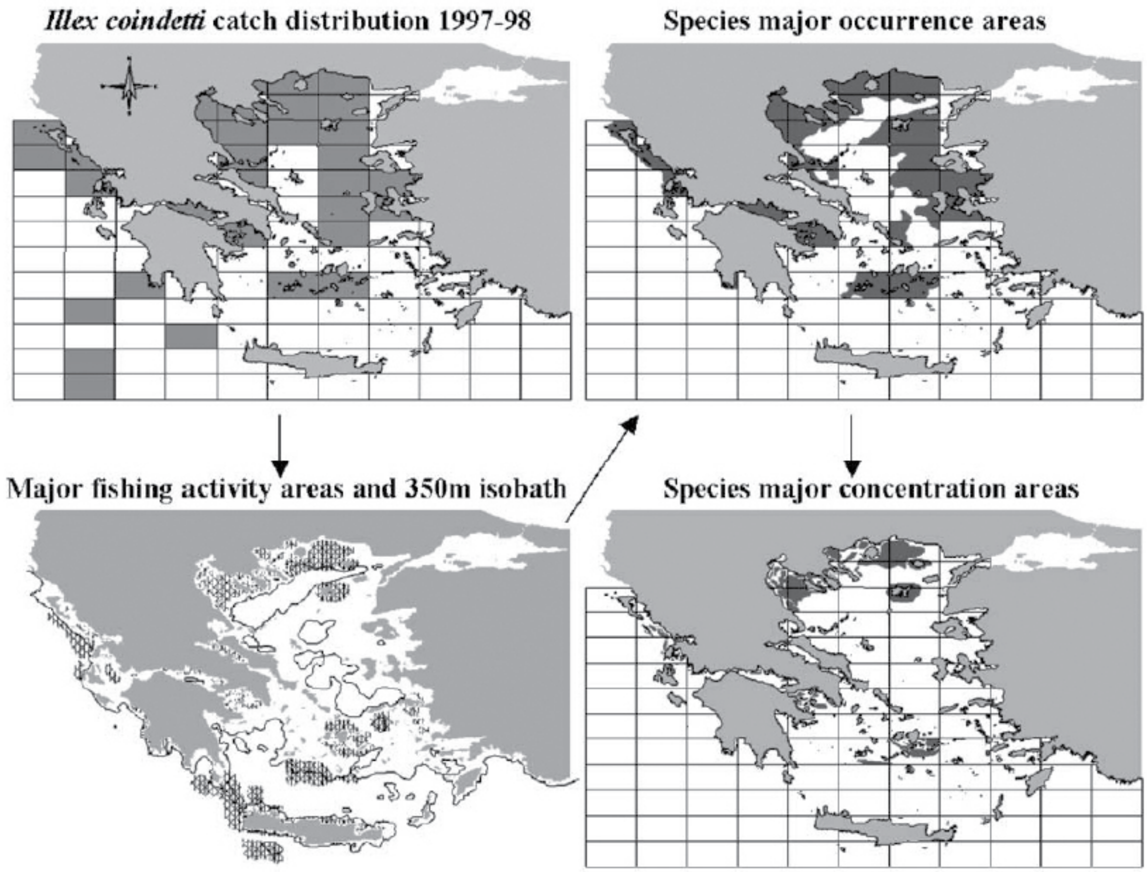

Figure 5: Spatial integrations among georeferenced fishery data for *Illex coindetii*, by the GIS tool: 'Marine Information System for Cephalopod Fisheries in the Greek Seas'. Catch distribution (top left) is integrated with bathymetry (bottom left) to reveal species major occurrence areas (top right), which in turn, is integrated with fishing fleet major activity areas (bottom left) to reveal species major concentration areas (bottom right). (Compiled from VALAVANIS *et al.,* 2004).

almost exclusively. STERGIOU (1989) analysing cephalopod catches during 1964-1981 suggested that fishing played rather the most important role in the decreasing trend of Catch per Unit Effort (CPUE), noting however, that the simplistic models used might overlook other important natural or economic reasons.

The use of more sophisticated models (Artificial Neural Networks and Bayesian Dynamic System Analysis) seemed to enable prediction of annual landings of the neritic common squid in the north Aegean Sea based on Sea Surface Temperature (SST) descriptors but not of those of the flying squids, which inhabit deeper waters where SST could not express adequately the environmental conditions (GEORGAKARAKOS *et al.*, 2006).

A GIS tool for mapping seasonal distribution patterns of commercially important cephalopod species (VALAVANIS *et al.*, 2002) has been developed by ex Institute of Marine Biology of Crete (IMBC), in the framework of the EU research projects CEPHVAR and CEPHSTOCK. The tool features a menu-driven user-interface and a comprehensive database of commonly geo-referenced biological and environmental datasets. The innovative aspect of this marine geographic system is the integration of species' life history data in GIS analysis (Figure 5). Species' preferences for certain spawning conditions, migration habits, and depth ranges are used as constraints in GIS analysis and integration. VALAVANIS *et al.* (2004) using catch and effort data collected per statistical rectangle of NPFDC along with SST and chlorophyll concentration (CHL) and Sea Surface Salinity distribution (SSS) in the Hellenic Seas, has found a significant overlap of monitored distribution of *Loligo vulgaris* and *Illex coindetii* CPUE with the spatial extent of marine productivity hotspots in the north Aegean, the Kyklades Plateau and the Ionian Sea fishing grounds.

Table 3. Relationships between common octopus body weight (W, g) and specific growth rate (SGR, %day^{-1}), absolute growth rate (AGR, g day^{-1}), absolute feeding rate (AFR, g day^{-1}), feed efficiency (FE, %), protein retention efficiency (PRE, %), energy retention efficiency (ERE, %), oxygen consumption rate (R, mg h^{-1}) or ammonia excretion rate (U, µmol h^{-1}) at different temperatures (T) (compiled from KATSANEVAKIS *et al.*, 2005; MILIOU *et al.*, 2005)

T (°C)	Regression equation	n	R^2
15	LnSGR=-2.0342+0.3936lnW	16	0.89
20	LnSGR=1.5091-0.3106lnW	17	0.92
25	LnSGR=2.9832-0.5842lnW	17	0.98
15	LnAGR=-6.6206+1.3880lnW	16	0.99
20	LnAGR=-3.1116+0.6912lnW	17	0.98
25	LnAGR=-1.6626+0.4219lnW	17	0.95
15	LnAFR=-3.5493+0.9662lnW	16	0.97
20	LnAFR=-3.0741+0.8955lnW	17	0.97
25	LnAFR=-3.2478+0.9229lnW	17	0.98
15	LnFE=1.3911+0.4618lnW	16	0.90
20	LnFE=4.6212-0.2020lnW	17	0.58
25	LnFE=6.1824-0.4897lnW	17	0.94
15	LnPRE=1.4248+0.4622lnW	16	0.89
20	LnPRE=4.6789-0.2051lnW	17	0.58
25	LnPRE=6.1936-0.4837lnW	17	0.93
15	LnERE=1.2986+0.4638lnW	16	0.89
20	LnERE=4.5462-0.2028lnW	17	0.57
25	LnERE=5.9837-0.4673lnW	17	0.93
13	LnR=-2.66+0.893lnW	9	0.97
15.5	LnR=-2.33+0.907lnW	20	0.91
20	LnR=-1.99+0.951lnW	22	0.96
25	LnR=-1.53+0.886lnW	27	0.97
26	LnR=-1.18+0.858lnW	18	0.95
28	LnR=-0.92+0.829lnW	12	0.96
15.5	LnU=-1.87+1.177lnW	9	0.95
20	LnU=-0.16+0.937lnW	19	0.92
25	LnU=0.27+0.877lnW	26	0.91
26	LnU=1.16+0.768lnW	14	0.88

LABORATORY STUDIES ON SPECIES PRESENTING AQUACULTURE POTENTIAL

Octopus vulgaris, a commercial cephalopod species that is easy to rear under captivity conditions, at least from the benthic juvenile stage to the adult stage, has been identified as an important potential candidate for mariculture, due to its rapid growth and high food conversion. Experiments with common octopus rearing have been conducted at the Department of Zoology-Marine Biology of the University of Athens since 2000. Combined effects of temperature (T) and body mass (M) on octopus growth, feed efficiency, metabolic rates, biochemical composition and protein retention efficiency were studied (Table 3), whereas, experiments related to the reproduction, hatching and paralarvae rearing of octopus have been also carried out (TZITZINAKIS *et al.,* 2001).

Specific growth rates (SGR) estimated for *O. vulgaris* (114 - 662 g) feeding on anchovy at a constant temperature of 20 °C ranged from 0.43 to 0.95 %day^{-1} and were similar to those reported for other high-lipid diets (bogue, sardine) and lower than SGR values found for low-lipid, high-protein diets (squid, crab) (PETZA *et al.*, 2006) The estimated assimilation efficiency (AE) values (80.9-90.7%) were lower than the AE values estimated for other cephalopod species with different diets of lower lipid content such as crabs or mussels. The atomic oxygen-to nitrogen (O/N) ratio values found were low (5.5 – 15.6), indicating a protein-dominated metabolism for *O. vulgaris*, with no significant dependence on body mass or temperature in the range of 15.5-26 °C (KATSANEVAKIS *et al.* 2005a, PETZA *et al.* 2006). However, O/N value depends on the type of food and different O/N ratios might arise under different feeding conditions (KATSANEVAKIS *et al*., 2005a).

The energetic cost of octopus feeding was not found to differ for temperatures examined (20-28°C) and the SDA (Specific Dynamic Action, reflecting the energy requirements of the behavioural, physiological and biochemical processes that constitute feeding) response was proved to be relatively fast in relation to the response in other temperate species, indicating the ability of the species to digest and assimilate food rapidly and efficiently (KATSANEVAKIS *et al*., 2005b).

The temperature for maximum growth rate and feed efficiency decreased with increasing octopus size. Furthermore, proximate composition and the protein/energy ratio were not affected by temperature or body weight, whereas, protein utilization was more efficient at maximum growth rate temperature; in smaller (50-150 g) individuals protein retention was better at 25 °C, while in larger ones (200-600g) at 15 °C (MILIOU *et al*., 2005). Fatty acid composition of *O. vulgaris* was influenced by temperature and body weight, but with an n-3/n-6 ratio of more than 3 and a docosahexaenoic/eicosapentaenoic (DHA/EPA) ratio of more than 1.5. Thus to optimise the economic viability of rearing, temperature should be adjusted according to the body weight of octopus, being higher for small individuals and gradually reduced for larger animals (MILIOU *et al*., 2005; 2006). *O. vulgaris* has been also shown as an excellent potential source of arachidonic acid, containing sufficient n-3 Highly Unsaturated Fatty Acids (HUFA) levels in warm temperatures for small individuals and in low temperatures for large ones, i.e. at temperatures that promote growth in relation to the body weight of octopuses (MILIOU *et al*., 2006).

GAPS IN KNOWLEDGE-PRIORITIES FOR FUTURE RESEARCH

Despite the importance of Cephalopods for Hellenic fisheries, there are still major gaps in the biological knowledge of even the commonest and most widespread species (Table I). Moreover, due to the general characteristics of their life cycle, i.e. the short life-span, the plastic growth of neritic species in particular, the extended periods of spawning and recruitment, the rapid generation turnover and the weak stock-recruitment relationships, Cephalopods dynamics is inherently difficult to model.

Growth parameters and their spatio-temporal variation in the Hellenic Seas, should be estimated for all commercially important cephalopod species, presupposing the development of direct ageing techniques for cuttlefishes and octopods. The use of indirect methods not based on the Von-Bertalanfy equation for the estimation of growth parameters could be an alternative for some cephalopod species, provided that monthly or even better fortnightly sampling of size composition of the population including early life stages could be ensured. Tagging experiments, as well as, targeted sampling of cephalopod paralarvae should be attempted also, as a complementary approach to understand cephalopod species dynamics.

Regarding the use of recorded cephalopod landings for monitoring cephalopod fisheries and resource assessment, species recorded under the same common name should be distinguished in fisheries' statistics, at least in case where the component species are exploited in important quantities and can be easily identified, as in the case of the 2 eledonid species. A further distinction is also necessary in the category of the artisanal fishing gears and particularly the consideration of the specified fishing methods targeting cuttlefish and common octopus as separate "métiers" during routine fisheries' data collection, in order to quantify their contribution, given that they have been shown to contribute the major part of the targeting species catches in the NE Aegean Sea and they are expected to expand more due to the increasing market demand for these species and the heavy exploitation of coastal fish resources. In order to produce a framework for implementation of management measures for cephalopod resources, a long-term monitoring of the traditional and the newly developed small-scale fisheries targeting Cephalopods, as well as, of trawl fisheries is required. Pilot monitoring of Cephalopod fisheries is proposed to be established according to priority in the Thracian Sea and the Thermaikos Gulf (North Aegean Sea), where more intensive exploitation of Cephalopods does occur.

The GIS tools and the advanced modelling methodology seem to be promising for the study of the spatio-temporal variations in the catches of cephalopod species that are sensitive under certain environmental conditions demonstrating, however, the need for integrated monitoring of fishing effort directed to Cephalopods and of marine environment changes, as well as for a thorough knowledge of target species' life history. Further development of GIS tools enabling the mapping of meso-scale thermal fronts and fine-scale environmental variability in particular, will greatly enhance the spatial component of cephalopod fisheries' assessment and management.

Concerning the potential of octopus aquaculture, although considerable progress has been made recently, in order to be considered self-sustainable further investigation on the development of suitable artificial feeds, as well as on eco-physiological and nutritional requirements of paralarvae, which are still impossible to rear at successful survival rates, is needed.

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VII.10. NEPHROPS FISHERIES IN HELLAS

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INTRODUCTION

Nephrops norvegicus (Scampi, Langoustine, Norwegian lobster, Dublin Bay prawn, Karavida) is a decapod crustacean (Figure 1) with a wide geographic range that extends from Iceland and Norway in the north to Morocco and Hellas to the south (FARMER, 1975). It is found on muddy bottoms in marine waters to approximately 600 m depth. Its upper distribution is more dependent on temperature, requiring waters that do not exceed 16 degrees C. Adult *Nephrops* live within the sediment, in complex burrow structures, foraging out on to the sediment surface to feed, generally in the hours of darkness. Females spend longer amounts of time in the burrow and do not venture out to feed when they are carrying eggs (late autumn/ winter). The species is restricted to certain types of sediment with a specific percentage of silt-clay fraction. Although *Nephrops* density is related to sediment grain size this relationship is not linear (BELL *et al*., 2006). *Nephrops* fishing grounds are found throughout the Aegean in deeper offshore waters and more rarely in shallower depths (less than 100 m) with suitable muddy sediments and low temperatures (SMITH *et al*., 2001; SMITH *et al*., 2003a). In the southern Aegean it is only found in depths of over 350 m. Because it lives in the sediment, it is partially protected from intensive trawling. The juveniles/adults are non-migratory and remain within a localised area.

Figure 1: *Nephrops norvegicus*.

OVERVIEW OF NEPHROPS FISHERIES IN THE EU AND THE MEDITERRANEAN

The European fishery for *Nephrops norvegicus* is highly valuable for a significant proportion of the European demersal trawl fleet. In 2001, the total EU landings were 56 000 tonnes, valued at 208 million Euros. The importance of *Nephrops* varies considerably between fisheries. The UK accounts for 50% of EU *Nephrops* landings and Italy for over 60% of Mediterranean *Nephrops* landings. In some areas *Nephrops* is the main component, with other species considered as by-catch, the opposite being true elsewhere. The current EU regulation framework in Nephrops' fisheries differs between regions and especially so between the Mediterranean and the rest of the EU fishing areas. Differences include variations in minimum landing sizes (e.g. 20 mm carapace length (CL) in the Mediterranean, 25 mm in the North Sea), minimum mesh sizes (e.g. 40 mm in the Mediterranean, 70-95 mm in the North Sea), by-catch limitations and the compulsory use of selectivity devices (square mesh codends, grids, etc.) in certain areas. In the Mediterranean, Nephrops is one of the most important commercial crustacean species of the slope mixed demersal fishery for shrimp (*Parapenaeus longirostris*) and hake (*Merluccius merluccius*). It is primarily fished through trawling, although there are some localised fisheries using traps and nets. Highest *Nephrops* abundance and highest levels of exploitation are seen in the Catalan Sea (W Med) and the Adriatic Sea (E Med). Rich fishing grounds are also found in the Gulf of Lions and off Corsica. In the Mediterranean in the mid-1990s, *Nephrops* represented 1.4 and 2.5% of the total landings' value in the western and eastern Mediterranean, respectively (FIORENTINI *et* *al.,* 1997) and *Nephrops* catches were in the region of 6 000 tons. In the eastern Mediterranean the trawl fishery is characterized by a wide variety of species, both marketable and discarded and the small mesh size used, with *Nephrops* being only part of an assemblage of target species. Countries principally involved are Italy (Adriatic), Hellas and Turkey (Aegean). In Hellas *Nephrops* is caught along with blue whiting, hake, flatfish, and three species of shrimp. There are other less important species landed as well. Total catches of *Nephrops* in Hellas have fallen from 1 607 tonnes in 1990 to 215 tonnes in 2002 and in terms of percentage contribution in the Mediterranean from 22% in 1980 to 6% in 1997 (FAO data, www.fao.org/figis) (Figure 2).

OVERVIEW OF NEPHROPS FISHERIES IN HELLAS

The *Nephrops* fishery in Hellas is primarily part of the mixed multi-species demersal trawl fishery on the continental shelf and upper slope. In addition, in some areas (e.g. Pagasitikos), there is a variation of the gillnet multi-species fishery using slightly different riggings depending on whether the principal target species is hake or *Nephrops*. The gear is more or less the same for both, but if targetting *Nephrops* less floats are used on the net and bait is attached; the rigging allows the net to lie «heavy» on the seabed and the bait attracts the *Nephrops*. Fishermen will re-rig the nets on a non-seasonal basis depending on where the fishing is best. With a recent law (in 2004) allowing the use of traps under a new regulation framework, a targetted *Nephrops* fishery using baited traps is developing in the Evvoikos and Pagasitikos Gulfs. The regulation framework for these types of fisheries differs with major differences seen in minimum mesh size (MMS) and closed seasons. MMS is 20 mm diamond mesh for the trawl codend, 26-28 mm diamond for the nets and 28 mm square mesh for the traps. The closed fishing season for the trawls is 1st June to end of September and for the traps 1st May to end July (no closed season for the net fishery). The richest fishing grounds in Hellas are in the north Aegean (mostly on the continental slope) areas and in the more eutrophic mainland gulfs (e.g. Argosaronikos).

A 20-year time-series (1982 to 2002, source NSSG) of low resolution data, is available on *Nephrops* total landings per month for all vessels except less than 10 m length, all gears and all areas in Hellas (Figure 3). Total monthly *Nephrops* landings show a similar trend with total annual landings (Figure 2). *Nephrops* production per month was around 100 t in the early 1980s, increased to about 300 t in 1990, followed by a decrease and a second peak in the mid 1990s (around 150 t), dropping again to around 50 t in 2000.

Although these data are valuable in terms of long-term trends, they are, however, inadequate when considering each fishery separately. Detailed data on the trawl fleet and coastal/artisanal fleets of Hellas are collected through the National Centre for Data Collection for which HCMR is responsible. Data collection includes effort and landings by gear; vessel size and geographical area and outputs maybe given as graphs, tables or maps. Figure 4

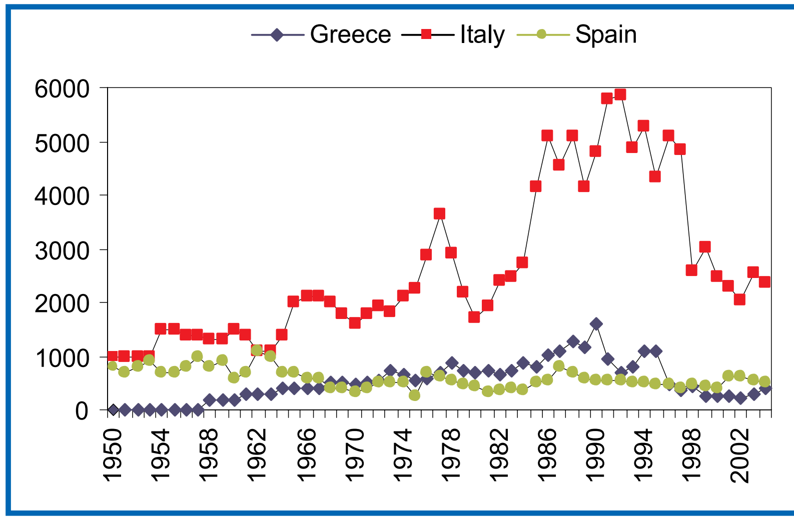

Figure 2: *Nephrops* annual landings (t) in the Mediterranean. Source: FAO.

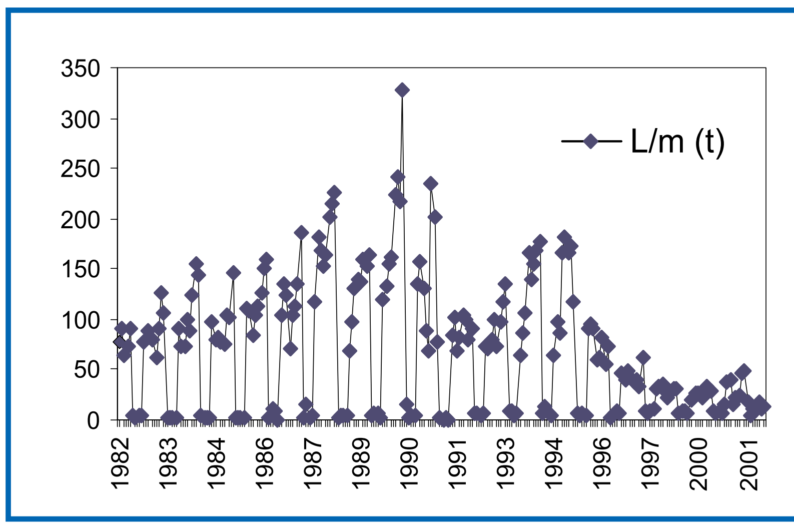

Figure 3: *Nephrops* total landings per month (t) in Hellas: all vessels except less than 10 m length, all gears, all areas. Source data: NSSG.

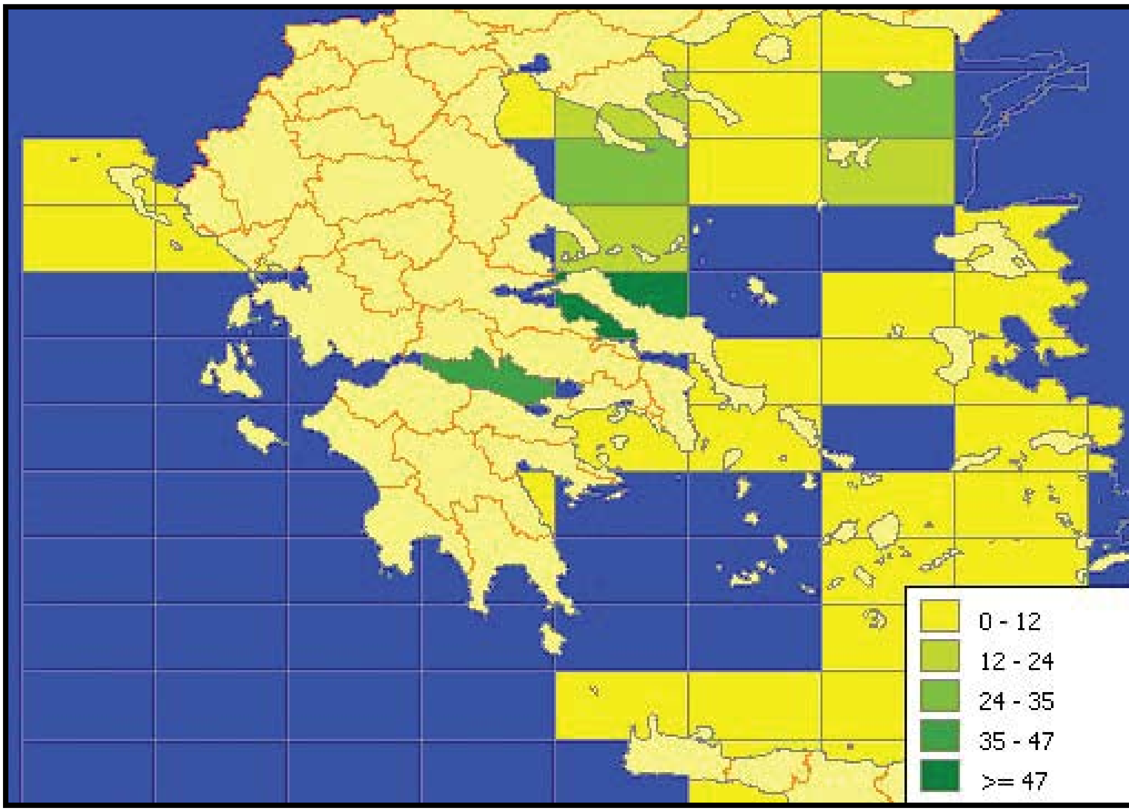

Figure 4: *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel in autumn 2005.

shows a map of *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel in autumn 2005.

A short time-series (1998 to 2005) of detailed data on *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel (12-24 m, 24-40 m, all vessel segments) and total landings per day per month (Total L/d/m in tonnes) for all trawl vessels engaged in otter trawling in the Aegean (12-24 m, 24-40 m, all vessel segments) is shown in Figures 5-7. No trend is evident for either the 12-24 m fleet segment or the total trawl fleet. A significant trend is seen in the 24-40m fleet segment indicating increasing L/d/m (p 0.0021) and Total L/d/m (p 0.0001) in the last years for *Nephrops*. This is also true for total demersal landings for the 24-40m fleet segment (p 0.0003 & p 0.0001).

A short time-series (1998 to 2005) of detailed data on *Nephrops* landings (L/d/m in kg) per day per month per vessel (<12 m) and total landings per day per month (Total L/d/m in tonnes) for all coastal vessels engaged in fishing in the Aegean (<12 m) is shown in Figure 8. Significant trends are seen indicating decreasing L/d/m (p 0.0001) and Total L/d/m (p 0.0001) in the last years for *Nephrops*.

FRAMEWORK OF RESEARCH

The framework of work includes two major lines: multi-annual monitoring and research. Monitoring programmes included a series of EU funded MEDITS (Mediterranean International Trawl Survey) projects, a series of EU funded DISCARDS (Analysis of trawls' discards operation in the central and eastern Mediterranean) projects and more recently multi-annual monitoring through the ERANET project.

Annual surveys are conducted through the MEDITS (BERTRAND *et al.,* 2002) project (1994-2001 and from 2002 as part of the NATIONAL project), following standardized sampling procedures and random sampling stratified by depth, taking place along the European coasts of the Mediterranean Sea from the Straits of Gibraltar to the Aegean Sea. The only available information on Hellenic *Nephrops* comes from ABELLO *et al.,* (2002) who looked at geographical patterns in abundance and population structure of *Nephrops norvegicus* and *Parapenaeus longirostris* along the European Mediterranean coasts. Published data for the period 1994-1999, by ABELLO *et al.* (2002) include data on CPUE (expressed as abundance (individuals/square km) and biomass (kg/square km) and total mortality rate Z per year for both species for

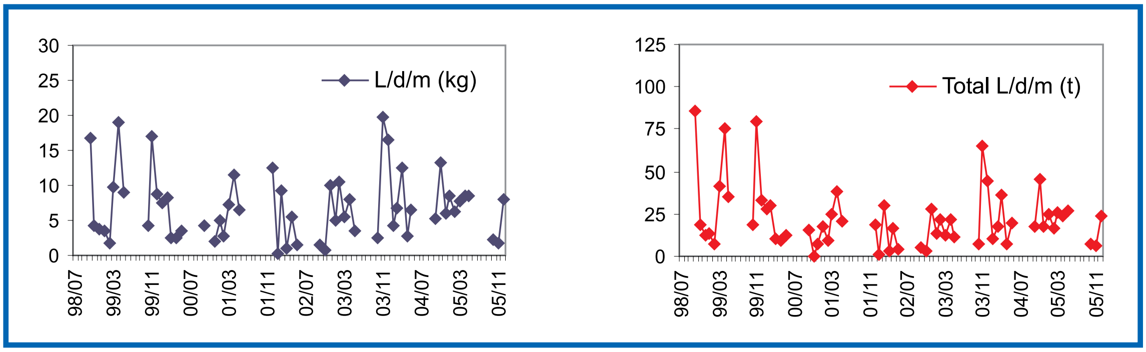

Figure 5: *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel and total landings per day per month (Total L/d/m in t) for the 12-24 m trawl fleet segment.

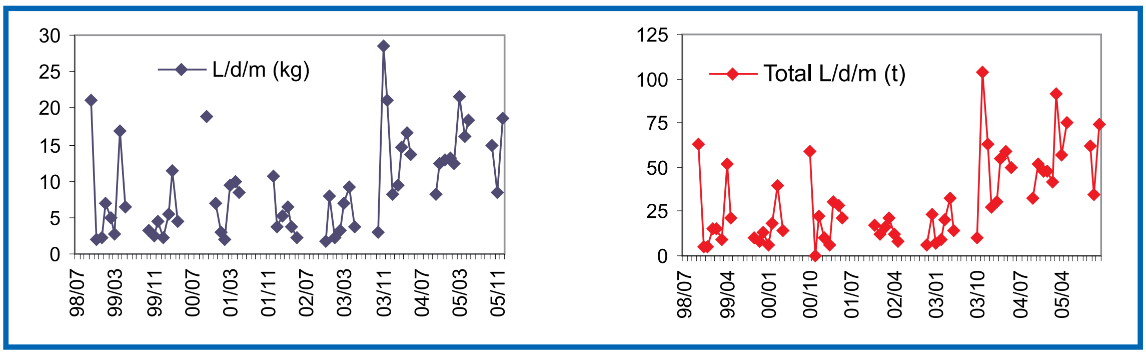

Figure 6: *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel and total landings per day per month (Total L/d/m in t) for the 24-40 m trawl fleet segment.

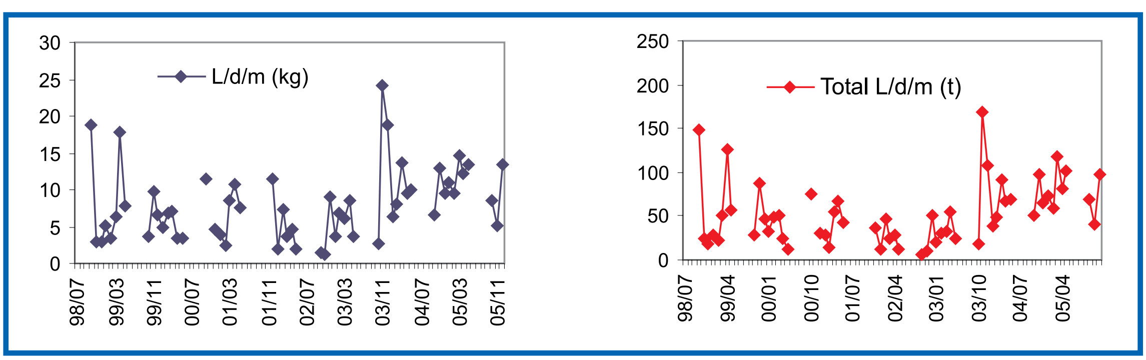

Figure 7: *Nephrops* landings (L/d/m in kg) per day per month per trawl vessel and total landings per day per month (Total L/d/m in t) for all trawl fleet segments.

each sector. A summary of their findings is given below.

Distribution: The highest proportions of *Nephrops* on the Hellenic continental shelf were found in the Ionian Sea and Argosaronikos Gulf. The highest abundance and biomass were found in the 200-500 m depth stratum, especially in the Ionian and N. Aegean Sea. In the S. Aegean *Nephrops* is found at both the 200-500 and 500-800 m depth strata (TSERPES *et al.*, 1999).

Population size structure: A number of increasing-decreasing trends were observed between different geographically adjacent areas. In Hellenic waters, an increasing trend in mean size was found from the E. Ionian Sea to the S. Aegean Sea through the Argosaronikos and the N. Aegean Sea.

Mortality estimates: Total mortality was found significantly and negatively correlated with the mean size obtained in each of the sectors. High mortality related to small mean sizes was particularly

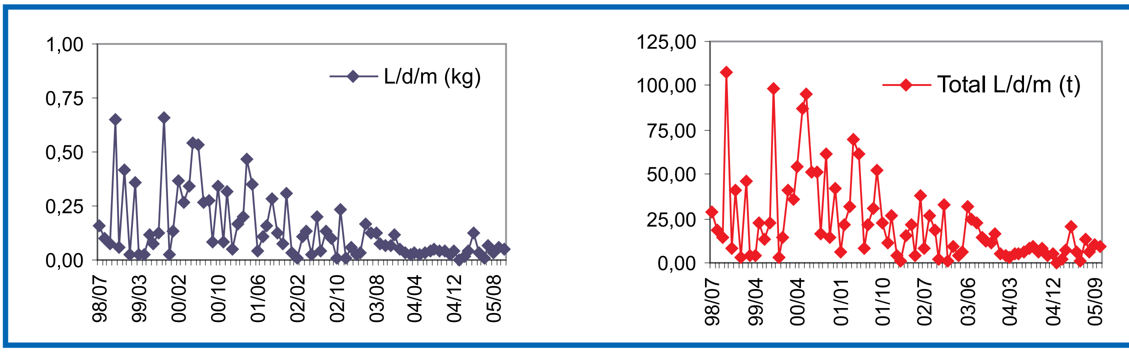

Figure 8: *Nephrops* landings (L/d/m in kg) per day per month per vessel and total landings per day per month (Total L/d/m in t) for all coastal vessels (<12 m) fishing in the Aegean.

evident in the Catalan Sea, whereas the inverse relationship was found in the Alboran Sea and Corsica. Sectors such as the Alboran Sea, Corsica, Argosaronikos and N. Aegean showed lower values of total mortality and these findings look consistent with the relatively modest fishing pressure exerted on *Nephrops* in these areas.

The DISCARDS project conducted annual surveys (1994-2001 and from 2002 as part of the NATIONAL project) following standardized sampling procedures and random sampling, taking place along the European coasts of the Mediterranean Sea including the Ionian and Aegean Seas. The only available information on Hellenic trawl discards comes from MACHIAS *et al.* (2001 & 2004) who looked at the description of discards (i.e. species, sizes, quantities) and the root causes for discarding. Very little information is available on *Nephrops* however. Although, *Nephrops* is noted to have consistently exhibited both marketable and discard fractions (MACHIAS *et al.,* 2001), no published information exists on discarded quantities or size.

The NATIONAL ERANET project "National Fisheries Data Collection Programme" (1st phase: 2002-2006, 2nd: from 2007) conducts multi-annual surveys following on from the MEDITS and DISCARDS projects as well as Biological sampling. Biological sampling includes port sampling of a number of species with the aim to collect data on species' composition of landings, as well as size, age, growth, maturity and fecundity per species. Although not yet published, *Nephrops* data are collected on an annual basis from trawl landings from two sites in the Aegean and one in the Ionian Sea and from coastal boat landings in the Pagasitikos Gulf.

A large number of research projects have been carried out in Hellas either dedicated to *Nephrops* fisheries research or including *Nephrops*. In the latter category the projects SAMED (Stock Assessment in the Mediterranean, 2000-2002), Patterns and Propensities in the Hellenic fishing effort and catches (ANON., 2001a) and ELME (European Lifestyles and Marine Environments, 2004-2007, PAPADOPOULOU *et al.,* 2006a) looked at, among others, stock assessment issues and trends in *Nephrops* catches and fishing effort.

A large amount of work has been devoted to the study of various aspects of gear selectivity. STERGIOU *et al.* (1997a) and STERGIOU (1999) looked at trawl codend selectivity comparing 14 mm and 20 mm square and diamond mesh sizes noting that the retained proportions of *Nephrops* did not differ considerably for the three mesh sizes studied. From dedicated studies on selectivity and *Nephrops*, STERGIOU *et al.,* 1997b found that both 14 and 20 mm meshes (the latter being the legal mesh size now) are inappropriate for this species as L50 values are below the length of *Nephrops* at 50% maturity, suggesting as appropriate a square mesh codend size around 30 mm. MYTILINEOU *et al.* (1998a), as part of the EU NEMED project "*Nephrops norvegicus*: comparative biology and fishery in the Mediterranean Sea (1993-1996, SARDA (ed.) 1998)", studied among others, the selectivity of 32.0, 40.8, 47.0 and 51.8 mm stretched mesh sizes concluding that none of these mesh sizes gave results adequate for *Nephrops*, with estimated L50s being again lower than the length at first maturity of this species. They also noted that the species' biology (burrowing life style) and morphology (presence of spines and pincer claws) make the problem more complex. The EU NETRASEL project (1999-2001) (ANON., 2001b) experimented with the use of sorting grids developed in the northern European trawl fisheries, with the aim to separate *Nephrops* and shrimps from hake. Aegean trials were, however, partially successful (ANON., 2003). The EU NECESSITY project "*Nephrops* and Cetacean Species Selection Information and Technology (2004-2007)" studied the catch composition, by-catch and discards of the *Nephrops* trap fishery as well as the selectivity of 17, 22 and 28 mm (the latter being the legal mesh size) plastic fixed square mesh used in this fishery. The poorer selectivity of the 17 and 22 mm mesh sizes was noted, justifying its recent ban (PAPADOPOULOU *et al.,* 2006 b&c). The NECESSITY project looked also at comparisons of trap selectivity, in terms of both species and size, with that of experimental gillnets (48-60 mm stretched mesh) and the current legal trawl mesh (40 mm stretched mesh) with results highlighting the low trawl selectivity for *Nephrops*, retaining a significant proportion of immature individuals below the MLS and the length at first maturity (PETRAKIS *et al.,* 2007; SMITH, *et al.,* 2007a; SMITH & PAPADOPOULOU, 2007).

During the last 15 years, two lines of *Nephrops* research have also received some attention and EU funding: work on the species biology and fisheries independent stock assessment methods (ANON., 1994; MARSS *et al.,* 1996 & 1998; SMITH *et al.,* 2001 & 2003; SMITH & PAPADOPOULOU, 2003). The latter is fully reported in Chapter VII, Smith 2007 in this book. Work on the biology of *Nephrops* has included studies on growth, moulting, female reproduction, size at sexual maturity (SOM), mortality as well as population dynamics (morphometrics, sex ratio, etc.) and genetic structure.

The NEPHROPS (ANON., 1994), NEMED (SARDA (ed.) 1998) and NEP-GM ("Growth and natural mortality of Nephrops norvegicus, with an introduction and evaluation of creeling in Mediterranean waters", SMITH *et al.*, 2001) EU Projects studied various biological parameters of *Nephrops* working in Limnos, Skyros, the Evvoikos and Pagasitikos Gulfs and various Mediterranean and Atlantic areas. In crustaceans, growth is a non-continuous process with moults separated by intermoult periods. Moulting is known to be more frequent in juveniles and decreases with increasing size particularly in the females (BAILEY & CHAPMAN, 1983). GRAMITTO (1998, Evvoikos Gulf, NEMED, data 1993-1995) and SMITH *et al.* (2001, Pagasitikos Gulf, NEP-GM, data 1997-1998) are the only sources of information on moulting frequency and periodicity in male and female *Nephrops* in Hellas. Adult females moult once per year in spring after hatching their eggs. Adult males may moult throughout the year, or at the end of spring with some having a second moulting period coinciding with that of females. The estimation of growth in *Nephrops* is especially difficult due to the lack of hard parts (such as otoliths in fish) where age can be registered. Existing techniques are based on the analysis of length frequency distributions (from port sampling or sampling at sea), mark-recapture data from tagging as well as from direct observations on animals kept in captivity in aquaria. Published growth studies (ANON., 1994 (trawling); MYTILINEOU *et al.,* 1998b (trawling), SMITH *et al.,* 2001 (trawling & mark-recapture), data 1992-1993, 1994-1995 and 1997-1998, respectively) recorded a number of similarities and differences in growth parameters within and between Aegean and Mediterranean sites with, for example, the Alboran sea male *Nephrops* population having a higher growth rate than that of the Catalan Sea and the Evvoikos population having a lower growth rate than that of the Pagasitikos Gulf. However, differences seen have important site specific attributes related to environmental (such as sediment type, water circulation and temperature) and biological factors (such as density and food availability) as well as fishing effort. The on-going multi-annual NATIONAL project is expected to report on age and growth parameters of four Hellenic *Nephrops* populations. The ongoing Archimedes (MENTE *et al.*, 2007) project is looking at the Pagasitikos Gulf *Nephrops* population, studying growth at captivity (keeping *Nephrops* in aquaria) and aspects of feeding behaviour as well as experimenting with different food items. So far, MYTILINEOU *et al.* (1992) (N. Aegean) and CRISTO & CARTES (1998) (Evvoikos) are the only sources of information on feeding ecology of *Nephrops* in Hellas. The basis of the diet of *Nephrops* consists of decapod crustaceans, euphausiids, peracarids and fish (CRISTO & CARTES, 1998). The feeding activity (based on % of empty stomachs) is lower in the summer and autumn for the females, these periods corresponding to the peak of female gonad maturation (where the enlargement of the gonad compresses the stomach in the females) and egg bearing season (MYTILINEOU *et al.,* 1992; CRISTO & CARTES, 1998).

The seasonality of the female reproduction of *Nephrops* in the Mediterranean is well documented. The timing of basic processes of ovarian maturation and laying of embryos on the pleopods is very similar with only minor differences recorded related to depth (shelf-slope) and latitude (north-south) (ORSI-RELINI *et al.*, 1998). In Hellas, the peak of females with mature green ovaries is in the summer (June-July), followed by egg bearing in the autumn (usually November) and hatching of embryos in winter (ORSI-RELINI *et al.*, 1998; SMITH *et al.*, 2001 & 2007b). Large differences are, however, seen both between and within Mediterranean and Hellenic *Nephrops* populations in fecundity (embryos hatched) and sexual maturity (size of first maturity - SOM). Geographic variation in fecundity is thought to be linked with growth, SOM, density-dependant processes and environmental characteristics (TUCK *et al*., 2000; FARINA *et al.,* 1999). Significant spatial differences are also seen in the biochemical composition of ovary and hepatopancreas which may be also related to whole body growth (TUCK *et al*., 1997b).

Female maturity is usually studied by measurement of the smallest ovigerous female and by estimation of 50% maturity from ovary examination, while male maturity can be investigated from claw morphometric data (for example claw propodal length) or length of appendix masculina (ORSI-RELINI *et al*., 1998; SMITH *et al*., 2001; TUCK *et al*., 2000; MCQUAID *et al*., 2006). Female *Nephrops* SOM has been estimated at 33, 30 and 26 mm CL in the Evvoikos Gulf, off Skiathos and in the Pagasitikos Gulf, respectively. Male *Nephrops* SOM for Skiathos and Pagasitikos populations has been estimated at 46mm CL, similar to that for a fast growing male population in the Firth of Clyde (SMITH *et al*., 2007; TUCK *et al.,* 1997a & 2000). Variations in SOM over small geographic scales could have important implications for fisheries' management, particularly if mesh sizes are set to avoid the capture of immature individuals (TUCK *et al.,* 2000). Thus, different regulations may be required according to the population structure at each locality so that acquisition of area specific values is essential.

Finally, the NEPHROPS and NEMED projects and STAMATIS *et al.* (2004 & 2006) looked at the genetic variation among *Nephrops'* populations. Allozyme studies comparing Mediterranean with Atlantic *Nephrops* populations (including three from the Aegean) detected no clear geographical pattern of genetic differentiation, with genetic variability arranged according to the island model (ANON., 1994; MALTAGLIATI *et al.,* 1998; STAMATIS *et al.*, 2004 & 2006). However, morphometric differences do exist at various spatial scales which are mostly attributed to environmental parameters and differing degrees of exploitation (ANON., 1994; CASTRO *et al*., 1998; SARDA *et al*., 1998; SMITH *et al*., 2001 & 2003; SMITH & PAPADOPOULOU, 2003).

In conclusion, a significant and increasing amount of research has been and is being carried out in Hellenic waters for *Nephrops*. However, large knowledge gaps still exist, emphatically highlighting future research needs. Gaps not dealt with in the NATIONAL project include information on recruitment and on spawning stock biomass for *Nephrops* in Hellas. Gaps dealt with partially in the NATIONAL project include lack of spatially extensive information on size structure, mortality, growth, fecundity and sexual maturity of *Nephrops*, as well as lack of regular stock assessments.

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VII.11. PELAGIC FISH ASSEMBLAGES ASSOCIATED WITH FISH AGGREGATION DEVICES (FADS) IN HELLENIC WATERS

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INTRODUCTION

Observed trends of many exploited stocks suggest a grim picture, yet the pressure on fishery resources continues to intensify. Analysis of trends in the average trophic levels of FAO capture fisheries' production statistics revealed declining trends in most regions of the world, especially in the Northwest Atlantic (FAO, 2004). As indicated in *The State of World Fisheries and Aquaculture 2002* (FAO, 2002) the global situation of the main marine fish stocks for which assessment information is available suggested that overall, as fishing pressure continues to increase, the number of fully exploited stocks remains relatively stable, the number of over exploited, depleted and recovering stocks is increasing slightly, and the number of under exploited and moderately exploited fisheries' resources continues to decline slightly. In fact, the latter group was estimated to reach 25 percent of the major marine fish stocks or species' groups representing the main source for the potential expansion of total marine catches (FAO, 2002). In such fish stocks/species' groups certain middle pelagic ones (e.g. the dolphinfish *Coryphaena hippurus* and the greater amber jack *Seriola dumerili*) are comprised, which are known to be associated with floating structures, particularly during their juvenile stages.

Many factors acting on the individuals and several mechanisms have been suggested to explain the association of fishes with floating objects and in fact, thigmotropism in fish (the attraction to a solid object) is a well-documented phenomenon. Three of the more accepted mechanisms are: shelter from predators, food supply, schooling companions (GOODING & MAGNUSON, 1967; HUNTER & MITCHELL, 1967; WICKHAM *et al*., 1973; WICKHAM & RUSSEL, 1974; MATSUMOTO *et al*., 1981; ROUNTREE, 1989; FONTENEAU, 1993). Worldwide, more than 300 species belonging to 96 families of fishes have been observed in association with floating structures (CASTRO *et al*., 2002). Natural and artificial structures deployed specifically to concentrate fishes are often called fish aggregation devices (FADs), and are used extensively for recreational (HOLLAND *et al*., 2000), small scale artisanal (MORALES-NIN *et al*., 2000) and large scale commercial fisheries (FONTENEAU *et al*., 2000). FADs have been considered one of the significant developments in recent years for enhancing recreational and commercial fisheries, and in the last decade they have been introduced also into industrial fisheries for tropical tuna (CADDY & MAJKOSKI, 1996).

In the Mediterranean, building and using FADs for fishing purposes dates back to 200 years B.C. FAD fishing has remained active over the centuries and similar structures to those used in antiquity and described by the Roman author Oppian in Halieutica are still in use in the western and central Mediterranean Sea (MORALES-NIN *et al*., 2000). In particular, FADs are deployed off Morocco, Tunisia, Malta, Sicily and Majorca, from August to November, to exploit young-of-the-year *C. hippurus* spawned in June-July from adult migratory fish, which arrive in spring possibly from Atlantic warm areas. Mediterranean dolphinfish (<8 months of age) yearly catches reach more than 1 000 tonnes and this fishery is an important activity for the artisanal fleet of the central-western Mediterranean. In the eastern part of the Mediterranean no data exist on the application of this technique, while recently in Hellenic waters there has been an effort to study the effectiveness of FADs for expanding the fishing activities of the small-scale fishery sector. Those studies were conducted in the framework of two research projects coordinated by the HCMR to evaluate results from the application of this "new" for Hellenic waters fishing technique in pursuit of a possible diversification of the fishing effort from over exploited stocks to under-moderately exploited ones.

FISH COMMUNITIES ASSOCIATED WITH FADS

a. Species composition and abundance

FAD associated fish communities in waters of the south Peloponnisos and around Dodekanisos were studied to gather data on spatial and temporal colonization of FADs in the Hellenic seas. In the former area the study took place from May 2000 till April 2001 and in Dodekanisos waters (off Kalymnos Island) in August - November 2003 and July - November 2005. FADs were constructed by tying 4-5 palm leaves together and they were moored in depths from 40 to 250 meters. During the study period they were visited every 10-15 days and aggregations were recorded with direct visual methods and experimental fishing.

A total of 13 species, six of which belonged to the family Carangidae, were recorded beneath/around FADs in Hellenic waters (Figure 1). This is in accordance with observations from previous studies in different areas of the world mentioning that carangid species were by far the most frequently observed in the vicinity of FADs.

Well pronounced differences in species composition and abundance, however, appeared between the two areas. In particular, in Peloponnisos waters, *C. hippurus* was one of the most important species of the FAD community in terms of percentage relative abundance (number of individuals per FAD), followed by *Naucrates ductor*. In the Dodekanisos *C. hippurus* exhibited significantly lower abundance and *N. ductor* was absent from the FAD vicinity, while small juveniles of *Caranx crysos, Balistes carolinensis* and *Seriola dumerili* dominated. Overall, our results showed an eastward decline of FAD aggregations; south Peloponnisos FADs seemed to attract a greater number of species and specimens in relation to those off Kalymnos Island. However, the limited aggregations in the latter area could arise from the small life duration of the FADs there, which in most cases did not exceed a fortnight. It is known that floats undergo a maturation process (ARENAS *et al.*, 1992) and since older FADs are more completely colonised by a fouling community (algae, hydrozoans and crustaceans, hence available food resources)

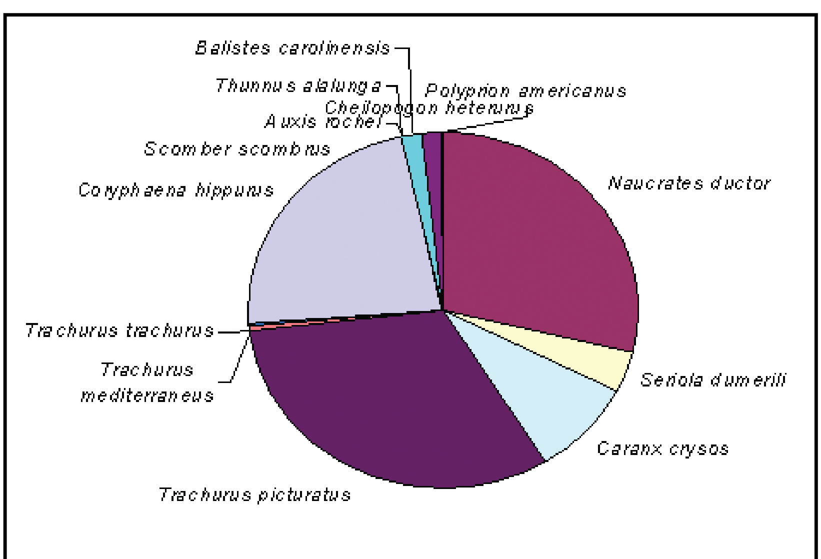

Figure 1: Percent relative abundance of the fish species associated to FADs in Hellenic seas.

they could possibly support a higher aggregated biomass. Thus, although losses of natural FADs are a common phenomenon particularly in Mediterranean waters (ANONYMOUS, 1998), in Kalymnos waters constant damages due to strong currents and/or sailing vessels possibly masked observations and made it difficult to draw firm conclusions on species aggregations in the latter area. Another point that should be underlined also is that both studies were based on observations conducted in the immediate vicinity of FADs, hence it could be possible that certain species/individuals occurring further from FADs or deeper in the water column might have been missed. Finally our studies were carried out during the day, while other species may occur during the night.

b. Seasonal patterns and processes linked to association of fishes with FADs

The seasonal character of the FAD associated fauna was corroborated by our findings in south Peloponnisos waters, where FAD aggregations have been studied for a twelve month's period, which allowed thorough observations on the colonization of the structures by the various species. Total fish abundance, number of speciments and length range of the species that formed the FAD community were significantly related to season (recruitment period), resulting in a sequential colonization of the FADs during the study period.

Results suggested that *N. ductor* exhibited the most extended presence as compared to the rest of the species included in the FAD fauna (Table 1); the first individuals (<200 mm TL) were observed in mid-summer, their abundance peaked in mid-autumn, reaching more than 150 specimens under certain FADs, while a few specimens were also observed in early winter (December). In all, *N. ductor* appearing beneath FADs had sizes of 190-300 mm TL and they were 2-5 month's old. During their association with Peloponnisos FADs, specimens were planktivorous, the most important prey items in terms of abundance and weight in the stomachs being decapod larvae, hyperiid amphipods and pelagic polychetes. Similar findings were reported for the species in the central-western Mediterranean (RELINI *et al.*, 1994; RENONES *et al.*, 1998, PIPITONE *et al.*, 2000) and in particular RELINI *et al.* (2000) monitoring the behaviour of fishes associated with a buoy in the Ligurian Sea mentioned that *N. ductor* preferred to stay within surface waters close to the buoy, where it actively caught plankton organisms. On the other hand, it should be noted that the species was absent from FADs in Kalymnos waters, as well as from

Table 1. Sequential evolution of the species beneath FADs in southwestern Peloponnisos waters in a 12 month's period.

Family	Species	Months											
		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Serranidae	*Polyprion americanus*		■	■									
Carangidae	*Naucrates ductor*			■	■	■	■	■	■	■			
	Caranx crysos					■	■	■					
	Trachurus picturatus	■	■	■									
	Trachurus mediterraneus			■	■	■							
	Trachurus trachurus						■	■					
Coryphaenidae	*Coryphaena hippurus*				■	■	■	■					
Scombridae	*Scomber scombrus*								■				
	Auxis rochei						■						
	Thunnus alalunga						■						
Balistidae	*Balistes carolinensis*						■	■					
Exocoetidae	*Cheilopogon heterurus*					■							

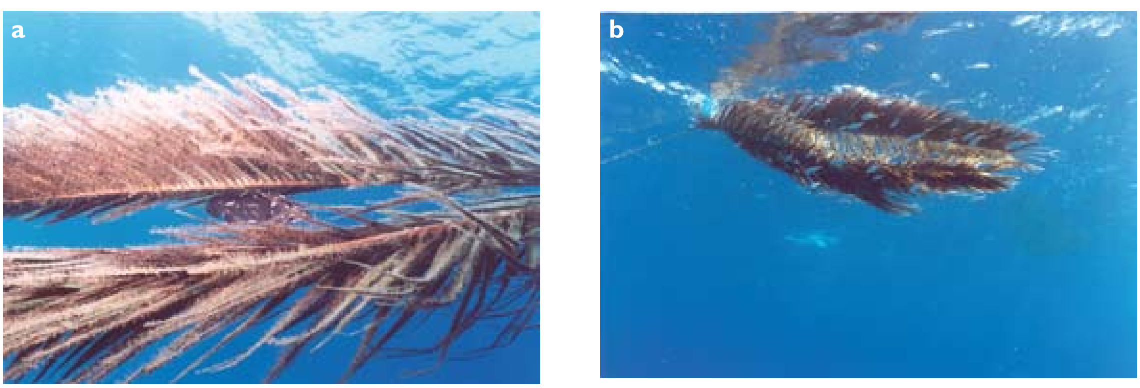

Figure 2: (a) A specimen of the species *P. americanus* appearing to take refuge between the fragments of submerged palm branches constituting the floating structure of a FAD unit, and (b) a shoal of *S. dumerili* closely associated to a floating unit.

structures deployed in the Thracian Sea (ANONYMOUS, 2002) suggesting possibly a limited presence in the Aegean and/or differences in certain biological-physical processes possibly influencing its association with FADs in the area.

Trachurus picturatus juveniles appeared under floating structures in late spring – early summer (Table 1). Their sizes were 60-120 mm TL and in some cases they formed schools of more than 200 specimens. Off the Spanish coast DEUDERO *et al.* (1999) cited schools of *T. picturatus* comprising up to 500 specimens per FAD during the summer period. *Caranx crysos* juveniles (65-110 mm FL) appeared in September and remained under FADs till November, when the largest specimens reached 150 mm FL. This species also formed schools under FADs, which, however, did not exceed 50 specimens. The other two Carangidae *T. trachurus and T. mediterraneus* were rarely present in the summer and autumn with specimens of 35-70 mm FL. *Balistes carolinensis* (100-130 mm TL) and *Polyprion americanus* (220-270 mm TL) were present with few solitary juveniles under FADs. Juveniles of the two species appeared during different time periods of the year reflecting possible differences in recruitment time. According to DEUDERO & MORALES-NIN (2000) FADs act as food suppliers for *P. americanus,* since their study showed that the species took advantage of fish aggregations, predating on shoals of juvenile pelagic fishes, essentially *Trachurus sp*. However, FADs also seem to provide refuge for juvenile *P. americanus*, that take shelter between the fragments of the submerged palm branches of the floating structure, as appearing in Figure 2a.

The species *Seriola dumerili* which is also among those considered typical of the FAD community in the Mediterranean was absent from FADs in Peloponnisos waters, but it appeared in Dodekanisos FADs in July-September, where it formed groups of 5-25 fish. These fish were 100-130 mm TL and were yellow in colour. For Juvenile *S. dumerili*, being closely associated with FADs (Figure 2b), the structures appeared to provide protection from predators and could also play the role of a reference point for the formation of schools. SINOPOLI *et al*. (2007) stated that in central Mediterranean waters, *S. dumerili* specimens <150 mm TL showed a strong affiliation with floating structures, while larger specimens moved to considerable distances.

Coryphaena hippurus were associated to FADs between August and November in both study areas and they were found to be between 2 and 5.5 month's old. Our findings suggest a more limited presence of the species' juveniles in Hellenic waters in relation to central-western Mediterranean ones, where it appears from August to January. The presence of the species around FADs seemed to be rather related to the concentration of certain food items under flotsam. In a single case when *Cheilopogon heterurus* were observed around FADs in September 2000 off southern Peloponnisos coasts, they were pursued by a shoal of *C. hippurus*. After catching some speciments of the latter species, almost all comprised speciments of the former species in their stomachs. In fact, diet analysis of *C. hippurus* showed that the species devoured mainly fish, some of which were comprised in the FAD catches. According to DEMPSTER (2005) large schools of *Trachurus* sp., a major prey for *C. hippurus,* were only seen around FADs deployed off the Australian coast, in the absence of the latter species, suggesting that the absence of predators might have an effect on the presence of prey. Finally, our data showed a pronounced impact of temperature, on the appearance of *C. hippurus* around FADs. In particular, the species appeared when temperatures were >20° C, in November, as temperatures dropped below that threshold, the species disappeared from FADs. The latter is in absolute agreement with findings of NORTON (1999), BENNETT (2001) and DEMPSTER (2005), who stated that on a worldwide basis *C. hippurus* presence is restricted to waters warmer than 20° C.

Hence, the specific composition of the FAD community appears to be influenced by a number of factors such as protection, recruitment, predation, while oceanographic features have an impact on the spatial distribution of fish and hence may cause changes in the composition of fish assemblages.

FAD FISHERIES PERSPECTIVE IN HELLENIC WATERS

Our data showed an eastward decline of FAD fish aggregations. In particular, in Peloponnisos waters the increased abundance of *C. hippurus*, as well as the presence of *N. ductor* could constitute an alternative practice that could contribute both to diversification of fishing effort and enhancement of the income of local fishers. In Sicily, for example, the decreasing effort in swordfish fishery which is diverted to dolphinfish fishery is very important (CANNIZZARO *et al.,* 1999). In Hellas at present, however, both species present either low (*C. hippurus*) or no (*N. ductor*) commercial value, mainly due to the fact that they are more or less unknown to the fish market. Thus, in case fishermen would be interested in developing such a fishery, there should be a parallel effort to develop consumer habits accordingly.

Another point that should be considered while evaluating the potential development of such a fishery is that it targets juvenile specimens, which could raise a matter regarding the sustainability of the particular stocks. These stocks consist of highly migratory, fast-growing and early maturing animals, which according to theoretical population dynamics should be less susceptible to fishing disturbance, in relation at least to slow growing animals, which mature at a late age. Moreover, according to preliminary population dynamics analysis conducted for *C. hippurus* in the central-western Mediterranean, the stock exhibits a moderate exploitation rate and could be considered as an under exploited resource (MASSUTI *et al*., 1999). In any case, if such a fishery would be introduced into Hellenic waters, appropriate measures would be required to manage various species appearing around the devices, as well as to ensure that the E.U. regulation is applied (e.g. regulation 1626/94 concerning size limitation of landings).

Finally, in the Dodekanisos the limited abundance of dolphinfish and the relatively small aggregations represent a rather feeble option for the development of this technique for fishery purposes. Nevertheless, in the latter area, where a number of aquaculture enterprises are developed, the use of FADs as tools to attract juvenile *S. dumerili,* exhibiting a relative abundance in the area, for rearing purposes could constitute an alternative.

CONCLUSIONS

Summing up, FADs in eastern Mediterranean waters seem to be partially effective in attracting certain fishes, and can be regarded as temporary habitats shared between those fishes. Many factors are probably involved in the establishment of the FAD fish community (shelter, food, predation, competition), making it difficult to discern whether FADs can be regarded as nursery areas providing spatial refuge rather than increasing the food resources for the juvenile fish assemblages. The need to conduct manipulative experiments to separate the effects of different confounding factors would contribute to better understanding the role of FADs in the settlement and distribution patterns of the associated fish fauna.

Both studies also underline the gap in knowledge concerning the size of the various fish stocks not attracted by FADs (i.e. adults) in the two areas, particularly the spawning stock biomass, as well as the rate of arrival of juveniles to FADs. The latter information is crucial, and would further contribute to the clarification of the FAD fishery perspective in Hellenic waters on an ecosystem-based approach.

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