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NEPHROPS NORVEGICUS: COMPARATIVE BIOLOGY AND FISHERY IN THE MEDITERRANEAN SEA. *F. SARDÀ (ed.)*

Nephrops norvegicus (L.): Comparative biology and fishery in the Mediterranean Sea. Introduction, conclusions and recommendations.

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SUMMARY: The project, financed by the Directorate General XIV of the EC, has undertaken a comparative study on the biology and fisheries techniques of the Norway lobster in Mediterranean member states and adjoining Atlantic areas. The ultimate goal of the project has been to assess the conditions for a global regulation in the area and determine possible differences among exploited stocks. The areas selected are characterised by their importance in Norway lobster catch. The overall duration of the project has been three years. Sampling was concentrated in the first two years. Data analysis was conducted during the second and third years (1993-1995). The countries (areas) involved in the study, together with their target areas, were: Portugal (south coast of Algarve), Spain (Alboran and Catalan Seas), Italy (Ligurian, Tyrrhenian and Adriatic Seas) and Greece (Gulf of Euboikos). In order to make results perfectly comparable, each scientific subject has been developed by a specialised team using a unified and standardised methodology. From the biological standpoint, Norway lobster growth, reproduction, moult and feeding have been compared. Special studies on distribution and genetics have been also conducted. In the fisheries context, a comparison of fishing techniques has been undertaken. The fisheries studies have been complemented with reconstruction of virgin populations, comparison of yield per recruit, sensitivity analysis and transition analysis. Selectivity issues have been object of specific analyses. As a result of these studies, it is evident that Norway lobster populations in the Mediterranean follow a common life-cycle model. The differences among areas reported in this project respond to environmental variation and differential fishing pressure in each area. All populations are exploited near its carrying limit, although overexploitation is unlikely at this stage. However we identified varying levels of exploitation according to study areas: The Catalan, Tyrrhenian and Adriatic Seas populations are exploited at a high level; the Ligurian Sea and Euboikos Gulf populations at an intermediate level; and the Alboran Sea and Algarve populations are at a low level of exploitation. The regulation concepts could be applied globally to the Mediterranean, allowing for the differences observed. It is highly recommended that effort is not increased. It should rather be decreased as new technologies being implemented continuously are by themselves an effort increase. A effort reduction of 20% is desirable to ensure that stocks are maintained at their current levels. This measure should be foremost applied to those areas being subjected to the highest exploitation levels.

Key words: Norway lobster, *Nephrops norvegicus,* biology, fishery, Mediterranean Sea.

RESUMEN: *NEPHROPS NORVEGICUS* (L.): BIOLOGÍA COMPARADA Y PESCA EN EL MAR MEDITERRÁNEO. INTRODUCCIÓN, CONCLUSIONES Y RECOMENDACIONES. – El proyecto desarrolla un estudio comparativo de la biología y la pesca de la cigala en el Mediterráneo en los países miembros de la UE y en un área adjunta del Atlántico. Los países y áreas involucrados en el estudio fueron: Portugal (costa sur de Algarve), España (mar de Alborán y mar Catalán), Italia (mares Ligur, Tirreno y Adriático), y Grecia (Golfo de Euboikos). Ante las posibles diferencias que puedan existir entre poblaciones, el objetivo del proyecto es asesorar sobre las condiciones necesarias a tener en cuenta para llevar a cabo una regulación de la pesquería de esta especie en el Mediterráneo. La duración total del proyecto fue de tres años (1993-1995) concentrando los muestreos durante los dos primeros. El análisis de los resultados se realizó durante el segundo y tercer año. Los resultados procedentes de los distintos temas de estudio fueron tratados por un mismo científico especializado en el tema con el fin de que fueran completamente comparables. Se compararon aspectos de distribución, crecimiento, muda, reproducción, genética y alimentación respecto a la biología de la especie. En el contexto pesquero se compararon las técnicas de captura en cada zona y se hizo un estudio comparado de la dinámica poblacional. Estos estudios se complementaron con análisis de población virtual y comparaciones de producción por recluta. La selectividad de la especie fue también objeto de un estudio concreto. Como resultado principal se constata que la cigala presenta un modelo de ciclo vital común para todo el Mediterráneo y Atlántico adyacente. Las diferencias encontradas entre algunas poblaciones se atribuyen a las particulares

condiciones ambientales de las áreas correspondientes. Todas las poblaciones parecen explotadas en intensidades próximas a su límite o punto óptimo, a pesar de que existen distintos grados. En orden de más a menos explotadas podemos presentar las distintas áreas estudiadas: Las poblaciones del Mar Catalán, Tirreno y Adriático son las más explotadas y soportan una fuerte intensidad de captura. Las del Mar Ligur y el Golfo de Euboikos, son poblaciones medianamente explotadas y las de Alborán y la costa sur del Algarve, son las poblaciones menos explotadas. Así, los conceptos de regulación pueden ser aplicados globalmente a todo el Mediterráneo respecto a las características biológicas de la especie. Recomendamos fuertemente que no se aumente más el esfuerzo al mismo tiempo que se inicie una disminución del mismo, ya que las nuevas tecnologías implican un aumento sostenido de la capturabilidad de la especie. Se recomienda una reducción aproximada en un 20 % del esfuerzo si se quiere mantener las poblaciones en un estado de producción similar al actual. Esta medida debería ser aplicada rápidamente en las áreas de mayor explotación. También se hacen consideraciones sobre medidas cualitativas de regulación en base al ciclo vital y comportamiento de la cigala.

Palabras clave: Cigala, *Nephrops norvegicus,* biología, pesquería, Mediterráneo.

INTRODUCTION

Nephrops norvegicus L. is extremely popular throughout the Mediterranean region (lagostim in Portugal, cigala in Spain, escampo in Italy, karavida in Greece) and is a target species in fisheries operating at depths of around 400 m within the framework of a more general, multispecies fisheries carried out in the Mediterranean Sea. The species' culinary quality, relatively low abundance, and high price in the marketplace make it highly attractive and popular, along with hake, monkfish, and shrimps, which are also taken conjointly in the same demersal habitat. Despite the heavy fishing pressure borne by this species, it appears to be withstanding overexploitation. This may, however, be a false impression relatively unrepresentative of the true situation, since the Norway lobster fishing grounds are currently threatened. We will briefly describe the present state of knowledge on this species, its exploitation, and action needed to achieve more sustainable yields in the future in an endeavour to recapitulate the current status.

More has probably been written about the Norway lobster, *Nephrops norvegicus* (L.), than about any other decapod crustacean in Europe. Stocks have always been present at relatively high abundance levels on muddy bottoms on the slope at depths between 400 and 600 m, and it is one of the study priorities of the International Council for the Exploration of the Sea (Anon., 1997). Although the first studies on Norway lobsters date from the beginning of this century, the first review of the biology and fisheries for this species, by Figueiredo and Thomas, was not published until 1967. Later, Farmer (1975) updated recent advances in knowledge, and Sardà (1995) reviewed the main thrust of research in modern times. All these reviews have helped to delimit the biology and main behavioural patterns of the species.

While most available information on the species has come from the Atlantic waters of Europe, various researchers have undertaken studies in the Mediterranean Sea. Some years ago Karlovac (1953) described the biology of this species in the Mediterranean. More recently, Orsi Relini and Relini (1989) reported on the reproductive pattern for this species in the Ligurian Sea; Froglia and Gramitto (1979, 1981) published the main biological parameters in the Adriatic Sea; Abelló and Sardà (1982), Sardà (1983a and b, 1985, 1991), Sardà and Cros (1984), Froglia and Gramitto (1988), Sardà and Valladares (1990), Sardà *et al*. (1993), and Sardà and Lleonart (1993) have presented various studies on moulting, regeneration, metabolism, feeding, selectivity, and stock assessments, respectively, off the coast of Catalonia in Spain.

The life cycle of this species varies according to latitude and habitat type (Sardà, 1995). This characteristic makes overall management of this resource difficult, because different regulations are required according to the population structure at each locality (Chapman and Howard, 1988).

A number of experts in decapod crustacean biology and fisheries undertook the "*Nephrops norvegicus*: comparative biology and fisheries in the Mediterranean" (NEMED) project from October 1993 to December 1995 under the auspices of the EU, with a view to formulating a global management programme for this resource and improving the state of knowledge of this species in the Mediterranean Sea. This project involved six cooperating Institutes and led to publication of a comparative study of the biology and fishery for seven populations of this species in different areas of the Mediterranean (Fig. 1): the Atlantic Ocean off the Algarve, the Alboran Sea, Catalan Sea, the Ligurian Sea, the Tyrrhenian Sea, the Adriatic Sea, and the Gulf of Euboikos. A brief description of each individual area follows.

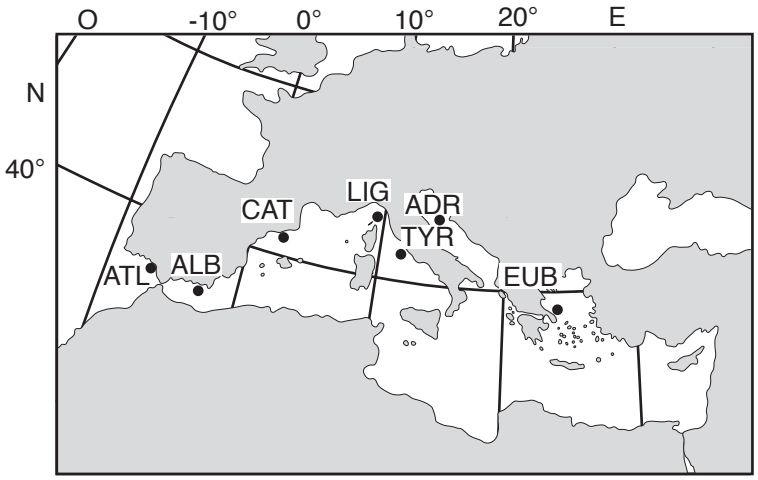

FIG. 1. – General view of the Mediterranean studied areas.

The Algarve coast - Atlantic Ocean (Faro, Portugal, Fig. 2)

The grounds where *Nephrops* are fished off the Algarve in Portugal range from 200 to 600 m in depth. The species can be found at even greater depths, but those areas are not systematically exploited (Figueiredo, 1989). However, *N. norvegicus* is present in discrete areas, with two major concentrations off the southwestern and southern coasts. These two large patches span the edge of the continental shelf and slope, with the highest concentrations at depths between 200 and 400 m. Some fishing grounds extend down to a depth of 700 m (Viriato and Figueiredo, 1991). The study area chosen for sampling is known by the names "Regato de Aberta", "Regato de Faval", or "Monte de Cabeida". It consists of a canyon ranging from 500 to 600 m in depth bounded by rises to a depth of around 300 m (Fig. 2).

The upper layers inshore display high variability over the year linked to upwelling, which is stronger in late spring and summer. Coastal flow along the southern Algarve is in an easterly direction. The oceanic waters at the surface offshore flow in a westerly direction. In southern Portugal in winter, both bottom and surface currents flow in a northerly direction (Frouin, 1990; Haynes and Barton, 1990). The surface circulation changes during active upwelling, mainly during spring and summer as stated above, creating surface coastal currents flowing in a southerly direction.

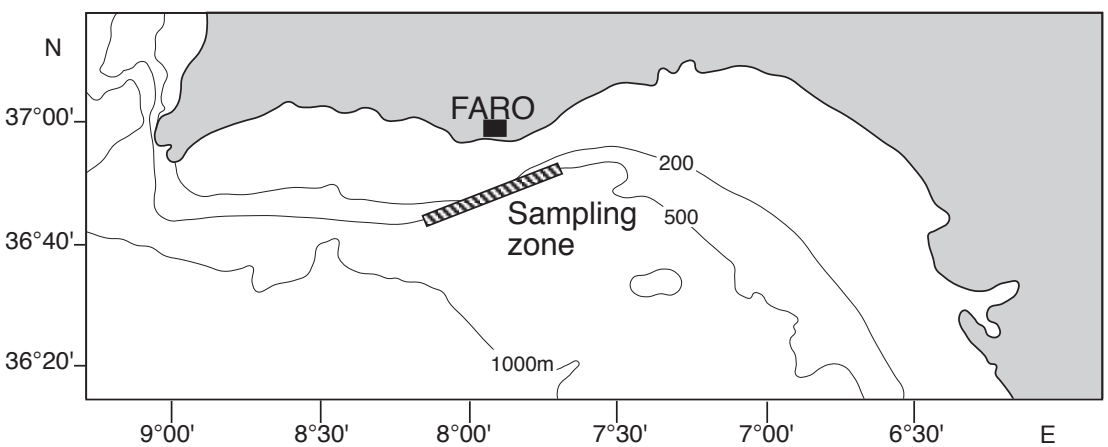

FIG. 2. – Algarve sampling zone.

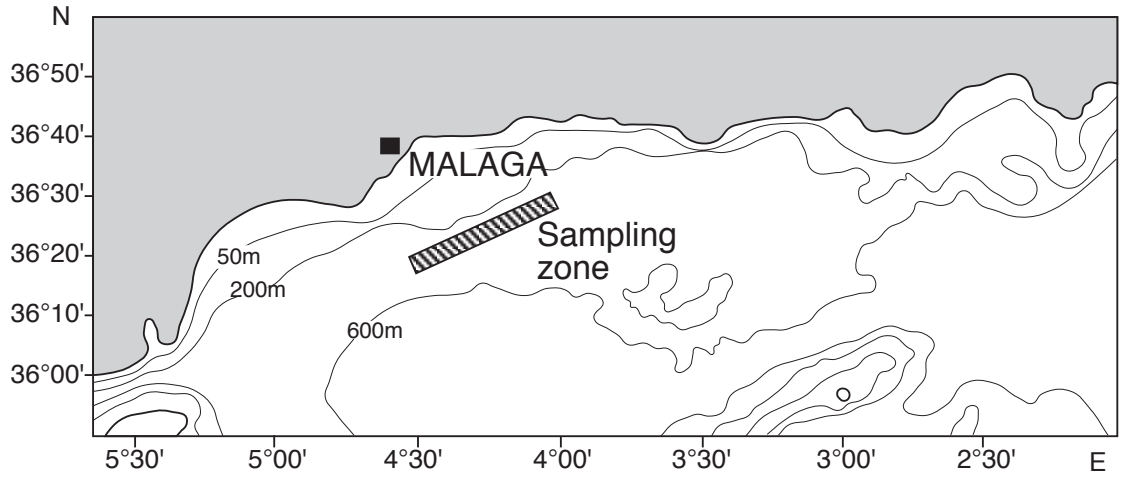

FIG. 3. – Alboran sampling zone.

The Alboran Sea (Malaga, Spain, Fig. 3)

The Norway lobster stock is exploited by 20 boats based in the harbours at Estepona, Marbella, Malaga, and Motril, frequently operating at night. Norway lobster landings are variable. Mean individual size is larger than in other areas, and juveniles are scarce. The fishery has been described by Gil de Sola (1993, 1994).

Hydrographically, the Alboran Sea is characterized by the exchange of Mediterranean and Atlantic waters, giving rise to a complex regime, with gyres and currents causing mixing in layers of variable depth (Cano and García Lafuente, 1991) and upwelling of Mediterranean water. Thus, Atlantic waters enter the Straits and mix at the surface and at medium depths. Salinity is 36 ppt, lower than the value for Mediterranean water. Seasonal variations in this pattern may produce upwelling of varying intensity. The continental shelf is relatively narrow (Fig. 3), 2 to 10 km in width, with rocky bottoms inshore and small submarine canyons around 10 km long reaching down to 2 000 m. Sediment cover is sand and mud, grain size becoming progressively finer offshore.

The Catalan Sea (Barcelona, Spain, Fig. 4)

The study area comprised the "Serola" fishing grounds off Barcelona (Fig. 4), with an area of approximately 300 square miles and ranging from 300 to 600 m in depth. The local *Nephrops* population has traditionally been exploited by the fleet based in Barcelona (Sardà and Lleonart, 1993). Martín (1989) provided a general description of the fishery. The continental shelf/slope descends gently out to 11 miles offshore. The study area is bounded by submarine canyons that disrupt the continuity of the *Nephrops* population. The sediment is fine, compact mud highly suitable for the excavation of burrows (Maynou *et al*. 1997).

Water temperature is quite stable at around 13 °C, salinity is around 38.4, both features of what is known as the Mediterranean Deep-Water mass (Salat and Font, 1985). Water circulation is dominated by the N-S surface current originating in the Gulf of Lions gyre, though its effects grow

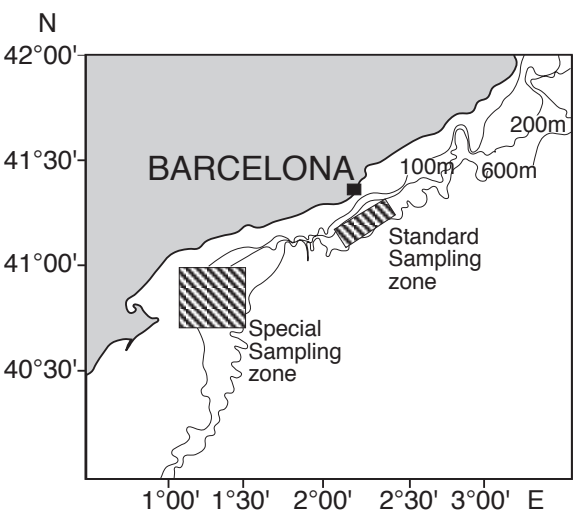

FIG. 4. – Catalonian sampling zones.

progressively weaker as it nears the protruding continental shelf off the Ebro River mouth. On the whole, the study area displays the general hydrographic, climatological, and ecological features of the Western Mediterranean Basin (Hopkins, 1984): summer stratification, surface currents originating in the Gulf of Lions, and benthic oligotrophy, mainly influenced by weak north-westerly winds.

The Ligurian Sea (Genoa, Italy, Fig. 5)

The depth of the trawl fishing grounds in the Ligurian Sea ranges from 50 to 700 m. The continental shelf grows progressively wider from west (Genoa) to east (La Spezia) (Fig. 5). Off Genoa the shelf area covers 175 square miles, the slope 220 square miles. To the east, the shelf covers 350 square miles, the slope 610 square miles. Fleets trawling over this area are based at the harbours at Genoa, Camogli, Sta. Margherita Ligure, Chiavri, Lavagna, Sestri Levante, and La Spezia. In the Ligurian Sea Norway lobsters inhabit the bathyal mud biocenosis at depths between 200 and 700 m (Relini Orsi and Relini, 1989).

The hydrology of the Ligurian Sea is characterised by three stratified water masses (Stocchino and Testoni, 1979) and presents the general features of the Western Mediterranean (Hopkins, 1984). The *Nephrops* population attains its maximal densities in the Intermediate Water mass on the slope (Relini Orsi and Relini, 1989).

The Tyrrhenian Sea (Porto St. Stefano, Italy, Fig. 6)

The study area comprises the southern Tuscany Archipelago between the islands of Elba and Giannutri (Fig. 6). Bottom morphology is characterized by a wide depression in the central part of the area known as the "Central Basin", gradually becoming deeper southward and reaching a depth of 600 m between the islands of Montecristo and Giannutri. This huge, amphitheatre-like depression is bounded by a broad continental shelf to the east, by the Elba island shelf and the Piombino channel to the north, and by the Elba ridge to the west.

The general hydrology and water mass circulation in the southern Tuscany Archipelago are poorly known. The main currents flow in a northerly direction, though there is high seasonal variation. Surface currents originate from a branch of Atlantic surface water flowing northward along the coast of southern Italy. The Levantine current, originating from warm, highly saline water masses in the Eastern Mediterranean Basin, is located at depths between 200 and 700 m in the southern

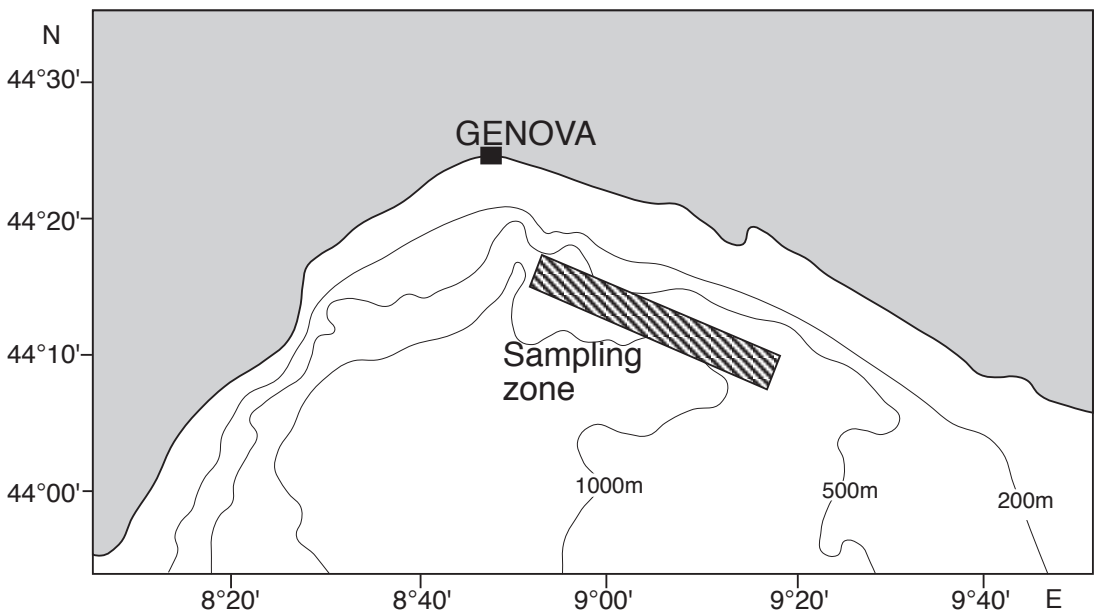

FIG. 5. – Ligurian sampling zone.

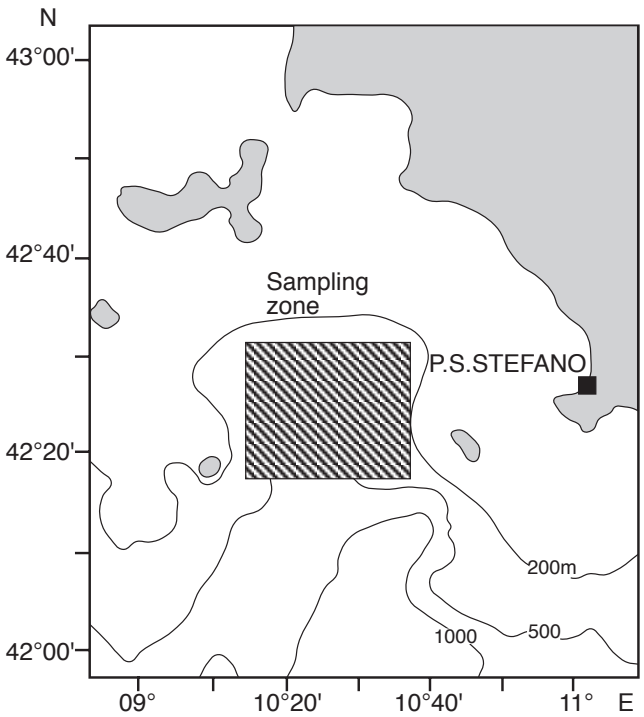

FIG. 6. – Tyrrhenian sampling zone.

Tuscany Archipelago.

The Adriatic Sea (Ancona, Italy, Fig. 7)

Whereas in the Western Mediterranean *Nephrops* are confined to bathyal depths (usually below 200 m), in the Central Adriatic Sea the species distribution range also extends to soft circalittoral bottoms deeper than 50 m (Froglia and Gramitto, 1988). The *Nephrops* grounds located off Ancona (Fig. 7) are under the influence of dense cold water masses originating in the northern part of the basin, mainly as a consequence of evaporation processes caused by the Bora wind (NNE) blowing in winter. These water masses, with salinities of around 38.3 PSU and a temperature of around 10 °C, flow near the bottom of the western Adriatic shelf and sink in the Pomo pit and in the southern Adriatic Basin (Zore-Armanda, 1963; Artegiani *et al*., 1993). A narrow area located about 25 miles off Ancona was selected for research into the biological parameters of the "shallow-water" *Nephrops* stocklets. In that area depth ranges between 70 and 75 m. The sampling area comprised trawl fishery grounds exploited by a fleet of about 200 boats based in the harbours of Ancona and Civitanova. Silt-clay fractions dominate the sediment colonized by *Nephrops* (Artegiani *et al*., 1979), and the annual temperature range is between 10 and 14 °C. The annual temperature excursion near the bottom on these grounds located NW of Ancona is 2 °C.

The Gulf of Euboikos (Chalkis, Greece, Fig. 8)

The northern part of the Gulf of Euboikos is a long arm of the Aegean Sea covering 1 163 km^2 (Fig. 8). It is located between central Greece and the northern part of the island of Euboikos. It is open to the Aegean Sea through the Oreos channel to the north and to the southern part of the Gulf of Euboikos through the Strait of Euripus to the south. The northern Gulf of Euboikos is an enclosed area characterized by relatively shallow waters (to a depth of 100 m) and a small, deep central basin (<440 m). In the north, the Sperkhios River flows into the Maliakos Gulf, and the freshwater inputs affect the salinity of the gulf waters. Surface temperatures fluctuate between 11 and 12.5 °C (Balopoulos and Papageoriou, 1991), while deep-water temperatures range from 11.7 to 12.5 °C (Papathanassiou *et al*., 1992). Surface salinities range between 11.7 and 12.7, deep-water

salinities between 37.2 and 37.5.

Coastal sediments are sand and mud-clay, mostly of biogenic origin, with clays dominating on the deeper bottoms in the gulf (Chronis *et al*., 1984). The area surrounding the northern Gulf of Euboikos, particularly on the western side, is characterized by intense human activity (household, touristic, agricultural, industrial). A fleet of 15 trawlers works the study area, but not all the catch is necessarily auctioned at the Chalkis

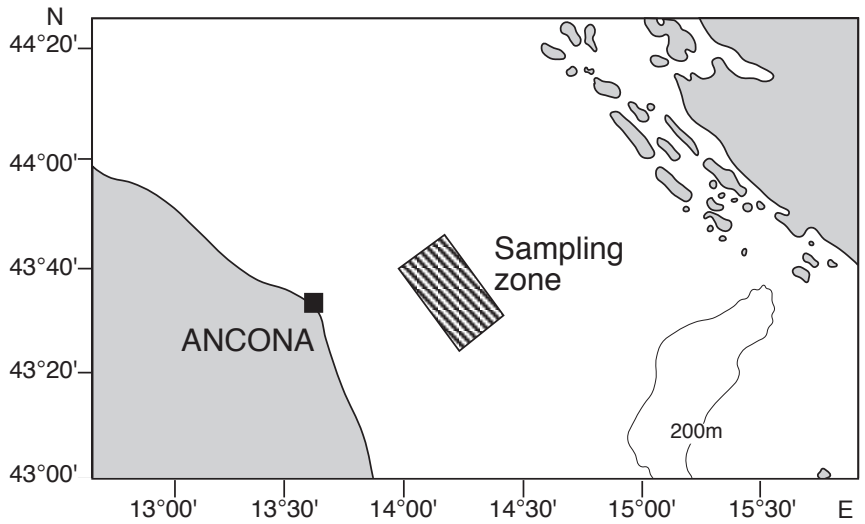

FIG. 7. – Adriatic sampling zone.

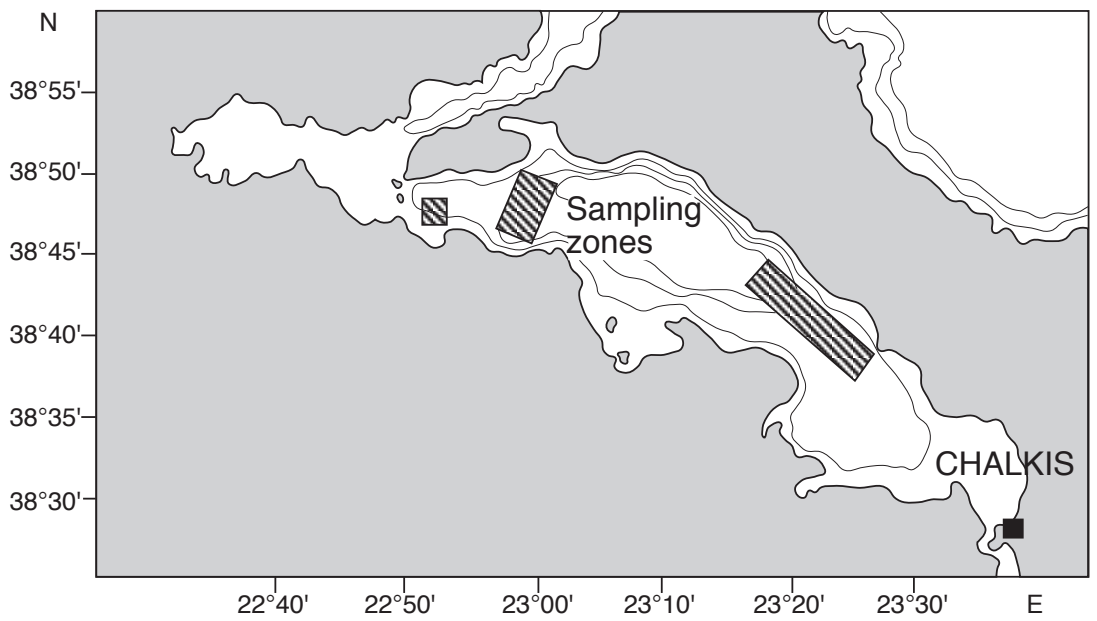

FIG. 8. – Gulf of Euboikos sampling zones.

TABLE 1. – Number of individuals studied during the sampling period for biological conditions. M, males. F, females.

Months		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Ago.	Sep.	Oct.	Nov.
Year	Sex	94	94	94	95	95	95	95	95	95	95	95	95	95	95
Atlantic	M	0	96	55	38	0	51	59	64	75	69	0	0	0	0
	F	0	83	33	38	0	37	59	81	81	59	0	0	0	0
Alboran	M	81	106	150	163	201	156	167	78	120	0	179	135	136	157
	F	98	98	113	168	191	111	160	125	149	0	203	164	105	218
Catalan	M	198	249	236	375	279	361	290	335	471	453	295	382	464	319
	F	219	174	239	395	252	491	393	373	587	371	216	310	349	277
Ligurian	M	125	490	0	435	208	0	171	159	477	1158	561	310	615	0
	F	103	369	0	345	107	0	180	166	435	1176	490	479	373	0
Tyrrhenian	M	200	200	200	200	200	150	200	200	200	200	200	200	190	0
	F	200	200	200	200	205	150	199	200	200	200	200	200	200	0
Adriatic	M	119	166	0	0	157	0	207	175	145	148	257	155	0	0
	F	102	115	0	0	90	0	145	150	128	113	214	103	0	0
Euboikos	M	180	202	183	179	188	146	226	150	123	115	122	239	0	0
	F	175	149	125	112	163	163	299	140	137	111	126	216	0	0

wharf.

GENERAL METHODOLOGY

Because the NEMED project involves a comparative study, special attention has been paid to data collection and processing. Tables 1 and 2 set out the sampling frequency and sample size in number of individuals per area. Sampling was carried out at the same time using uniform methodology in each study area, though responsibility for data processing was assigned to a specialist for each subject area. The scientist in charge of a given subject area was responsible for supervising the information collected in each area, pooling together all the data from all the areas for processing, and drawing general conclusions. M. Castro (UCTRA, University of Algarve, Faro) and Ch. Mytilineou (National Centre Marine Research, Athens) were responsible for growth data; E. Gramitto (Consiglio Nazionale delle Ricerche, Ancona) was responsible for data on moult cycles; L. Relini (Istituto di Zoologia, University of Genova) was in charge of data on reproduction; F. Sardà (Instituto de Ciencias del Mar-CSIC, Barcelona) coordinated the fisheries data; Ch. Mytilineou (NCMR, Athens) was in charge of selectivity data; F. Maltagliati and F. Biagi (Dip. Scienze dell'Uomo e dell'Ambiente, University of Pisa) were responsible for electrophoretic differentiation of populations; M. Cristo (UCTRA, Faro) and J.E. Cartes (ICM-CSIC, Barcelona) analysed the stomach contents; and F. Maynou (ICM-CSIC, Barcelona) applied geostatistical methods to establish distribution patterns.

This structured methodology was applied to each subject area considered and has resulted in separate chapters in this volume dealing with a comparison of growth as evidenced by moult cycles, estimation of growth parameters, and a discussion of methodological aspects of application of the von Bertalanffy equation. The section dealing with reproduction considers the duration of the different spawning periods, sizes at first maturity and berry, and fecundity in the different populations. The data compiled in the respective sections were used to prepare an overview of the state of exploitation of the main populations in the Mediterranean. These main chapters are accompanied by comparative considerations of more specific aspects such as genetics, fisheries structure, selectivity, distribution, and feeding, adding to the scientific value of this work. This volume places special emphasis on presenting an overview of the *Nephrops* situation in the Mediterranean ecosystem as a whole, the first time this scientific approach has been employed.

Finally, by way of recommendations for responsible management to achieve sustainable yields for this resource in the Mediterranean, there follows a summary of the conclusions contained in the project report, which was the basis for this monograph on

TABLE 2. – Number of individuals sampled for size frequencies distributions.

Months		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Ago.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Ago.	Sep.	Oct.	Nov.
Years		93	93	93	94	94	94	94	94	94	94	94	94	94	94	94	95	95	95	95	95	95	95	95	95	95	95
Atlantic	M	0	586	37	262	73	131	161	290	229	795	136	377	0	844	55	86	0	107	99	103	300	321	0	0	318	0
	F	0	256	24	83	44	74	153	328	227	985	64	164	0	401	41	84	0	107	94	135	362	578	0	0	235	0
Alboran	M	736	198	399	107	414	549	389	333	233	420	202	198	134	110	250	315	388	185	284	125	123	0	539	372	312	430
	F	710	186	202	56	289	650	644	923	601	798	205	191	106	99	153	210	283	142	301	172	159	0	619	339	251	356
Catalan	M	106	880	681	365	563	194	850	544	919	381	307	503	559	563	472	405	348	361	290	335	471	1897	587	382	730	319
	F	91	655	526	302	554	281	1196	630	1100	355	237	356	504	409	478	430	309	490	393	373	587	949	486	310	615	277
Ligurian	M	0	251	0	0	553	503	0	97	337	0	0	193	126	490	0	435	208	0	171	159	477	1158	561	479	373	0
	F	0	240	0	0	437	389	0	87	460	0	0	173	103	370	0	345	107	0	180	332	435	1176	490	534	340	0
Tyrrhenian	M	480	881	737	579	826	595	761	333	327	407	403	306	1090	574	799	788	384	268	574	631	637	618	1057	572	642	678
	F	447	712	547	474	761	622	824	241	340	398	439	250	692	540	774	619	393	317	480	647	586	740	939	500	530	592
Adriatic	M	1606	835	630	565	487	202	879	653	788	491	350	853	370	659	0	0	275	0	786	662	497	535	668	780	0	0
	F	1574	925	561	496	385	182	1017	777	883	514	362	915	451	542	0	0	200	0	916	841	598	708	624	699	0	0
Euboikos	M	2254	2535	1825	1200	806	764	375	347	405	344	726	689	1505	644	402	535	669	297	288	1102	490	406	286	590	0	0
	F	1841	2632	1630	1357	867	1099	485	435	452	464	749	570	1354	590	416	456	838	448	526	1937	772	434	271	635	0	0

Nephrops.

CONCLUSIONS

The general conclusions drawn by the NEMED project were:

- There is no evidence of significant differences in the life-cycle patterns of Norway lobsters in the different populations of the Mediterranean and adjacent Atlantic areas (Portugal). The litle differences observed have been attributed to environmental variations among the study areas and the fishing pressure exerted on each of the stocks.

- Natural mortality is the most important factor affecting stock production levels. If M = 0.2, all the stocks would be slightly overexploited, in the following order from more to less: Catalonia Sea, Adriatic Sea, Tyrrhenian Sea, Ligurian Sea, Gulf of Euboikos, Atlantic, and Alboran Sea. If M = 0.1, all the stocks would be overexploited yet not near collapse. If M = 0.3, most stocks would be near the optimum level of exploitation.

- Gear shape, structure, and technology differ substantially among the areas

- A 20% reduction in fishing effort would increase Y/R by 10 to 15 %, and stocks would reach an optimum state of exploitation about six years after implementation of effort reduction measures. Conversely, an increase in fishing effort would result in heavier exploitation, with overexploitation and a decrease in Y/R.

- All the foregoing indicates that current exploitation levels are near maximum exploitation but not excessive, depending on the area concerned. The response of stocks to a gradual increase in effort would be slow, but an increase is not recommended for stocks such as the one in the Catalan Sea, which could rapidly fall prey to overexploitation.

- The ability of populations to recover and defend themselves against fishing pressure is good. The burrowing behaviour of this species represents an added protection against fishing. Preservation of the substratum and lower levels of disturbance would be concomitant benefits from a strategy of effort reduction.

- There are indications of higher exploitation rates on females than on males, and this should be borne in mind when attempting to reduce effort by means of closed seasons.

RECOMMENDATIONS

Pursuant to the results obtained and the conclusions reached, the following recommendations can be put forward with a view to responsible management to achieve sustainable yields from this resource.

1) Each State should have a centralized administration capable of collecting and pooling real catch and effort data from different markets.

2) General measures for moderate effort reduction are recommended for the Mediterranean as a whole, except where they are already in effect (e.g., the Gulf of Euboikos). Management measures are clearly needed in the Catalan, Adriatic, and Tyrrhenian seas. An effort reduction of around 20 % would be recommendable.

3) All management measures should be appropriate to the multispecies nature of the fisheries. Any reduction measure beneficial to other species (*Merluccius*, *Lophius*, *Phycis*, *Lepidorhombus*, etc.) should be equally beneficial to *Nephrops*, and vice-versa.

4) A substantial increase in catchability has been recorded in the study areas and is attributable to a series of factors that are difficult to quantify: technological advances in navigational positioning, mechanical improvements, better manoeuvring, and remote control of fishing gears. These difficulties should be addressed as a matter of priority.

5) Fisheries regulations relating to mesh trawl selectivity for *Nephrops* are not very efficient and should be abandoned.

6) Specifically, the management measures adopted should adhere to one or more of the following criteria:

a) For stocks presenting clear size segregations, the depths at which the smallest individuals are located should be protected from exploitation, to safeguard inputs to the population from recruitment (e.g., in the Catalan and Adriatic seas).

b) For stocks in which females are heavily exploited, effort reductions should concentrate on the maturity stage preceding berry, because females are naturally protected during berry by their burrowing habits.

c) When considering effort reductions based on shortening the working day, fishing should be avoided during the daily peak period of activity for this species. Specifically, the peak periods of activity for Norway lobsters are noon in deep-water stocks and dusk and dawn in shallow-water stocks (e.g., the Adriatic Sea and Gulf of Euboikos).

d) If effort reduction is to consist of closing the fishery for an extra working day per week, closure should follow weekends to help lessen continuous disturbance to the habitat.

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