NEMED
CEC PROJECT

Nephrops norvegicus (L.): Comparative biology and fishery

MED92/008
Directorate General XIV

Final Report
November, 1996

Preamble

This study has been funded by the Commission of European Communities

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INDEX

Chapters

PREFACE

This report has been structured following the recommendations of the corresponding contract. However, given the large amount of data and the variety of subjects dealt with, the co-ordinator, with the agreement of the other partners, has made an effort to write this report concisely and with a clear and direct style.

All chapters represent a considerable effort of synthesis, specially introductory chapters and chapters dealing with standard and well-known methodologies. For convenience, reference is made to the relevant literature and results have been summarised in table format. Examples and results of data analyses are compiled in Annexes whenever they are repetitive.

This project does not intend to address new methodological questions. By using relatively simple methodologies, accepted and standardised in all study areas, we have stressed the comparative character of this project.

In order to avoid excessive text and repetition of information on methodology and results, reference will be made to Interim and previous Reports, keyed as follows:

S	Project Submittal
C	Contract
FIR	First Interim Report
SIR	Second Interim Report

We have aimed at pragmatic and committed Conclusions, in the light of the objectives proposed.

We have achieved all the objectives proposed in a correct and satisfactory way.

As co-ordinator I sign this Final Report of the Project MED92/008 in Barcelona, at 30 November of 1996

F. Sandá

SUMMARY

Title: "***Nephrops norvegicus***, Comparative Biology and Fisheries in the Mediterranean"

The project 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, covering representative zones scattered throughout the study area.

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.

The countries involved in the study, together with their target areas, were: Portugal (Algarve), Spain (Alboran and Catalan Seas), Italy (Ligurian, Tyrrhenian and Adriatic Seas) and Greece (Euboikos Gulf).

In order to make results perfectly comparable, each scientific subject has been developed by a specialised team using a unified and standardised methodology. The project is structured in Standard Actions, covering the general objectives of the project, and Special Actions, developed by some laboratories to enhance the general objectives of the project.

Concerning the biological aspects of 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 different 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 minimal effort reduction of at least 10% is highly 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.

TECHNICAL SUMMARY

Title: "***Nephrops norvegicus***, Comparative Biology and Fisheries in the Mediterranean"

The project 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, covering representative zones scattered throughout the study area.

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The study has focused on several aspects of Noway lobster biology and the fisheries of this species. The status of the various stocks has also been analysed in relation to the exploitation levels they support.

These two approaches of the project were necessary in order to understand whether the existing differences among areas are relevant. Also we examined whether those differences are due to biological adaptations of the species or they respond to environmental variation. On the other hand, the project intended to find out whether fishing pressure is variable among areas and to assess the risks and advantages of varying levels of fishing pressure.

Our results show that Mediterranean Norway lobster populations follow a common biological pattern. The differences observed can be attributed to environmental variations (temperature, geographical location, substrate features, etc.)

Fisheries aspects are considered to hold special significance. Fishing vessels and machinery are technically very similar in the Mediterranean. On the other hand, fishing gear is variable among areas in shape or size. The horizontal opening of the trawl is largest in the Algarve, Catalan, Alboran and Tyrrhenian seas. The western Mediterranean trawls have larger mouths and more hydrodynamic shapes, probably influenced in their design by North Atlantic countries. The implementation of technology is also more advanced in these areas, as fishing is conducted on deeper waters. Technological advances such as remote acoustic gear control (SCANMAR or the FURUNO plotter), precise positioning systems (GPS), double winch and high-powered engines are more common in these areas.

Considering all these factors the areas studied can be ranked according to exploitation status as follows: Catalan Sea, Tyrrhenian Sea, Adriatic Sea, Ligurian Sea, Euboikos Gulf, Algarve and Alboran Seas. The first three areas would be slightly overexploited, while the last two would be near the optimum exploitation level. Simulation studies of effort reduction show that a 20% effort reduction (number of fishing days, number of working hours, close seasons, etc.) would bring about a 10 to 15% recovery of the stocks in about 6 years after implementing the reduction measure. On the other hand, a 20% effort increase would contribute to about 10% losses over the same time interval.

Regulation measures regarding mesh size would not be very effective for the Norway lobster fisheries, although larger mesh sizes allow larger individuals to escape from the trawl. To make this process effective, it is recommended the use of meshes larger than 40 mm stretched mesh (or 20 mm side). However, regulation measures based on effort limitation are more effective as a conservation measure than mesh size limitations.

In conclusion, no signs of alarming overexploitation have been observed, but a progressive decrease of the fishing effort is recommended in order to maintain stocks at their current status and improve the situation in the future, avoiding large-scale negative impacts on the fishing sector.

INTRODUCTION

In this Introduction we present a structured summary on the objectives of the project, its principles and the general methodology employed.

Conceptual objective

A comparative study of the biology and fishery of the Norway lobster (*Nephrops norvegicus*) in E.U. Mediterranean countries has been carried. The underlying objective has been to assess whether a regulatory management strategy for Norway lobster in the Mediterranean should be established on a global basis or partially by differentiated stocks.

Work plan and partial objectives

The project comprises STANDARD ACTIONS, which were carried out by all the participant Institutions, and SPECIAL ACTIONS, developed by some partners only and being complementary to the objectives and general methodology of the project.

STANDARD ACTIONS comprise the following objectives:

- To obtain a size frequency structure characterising commercial catch in the different areas. To determine the parameters of von Bertalanffy's growth equation by modal progression analysis, and to establish whether growth parameters can be considered equal in all stocks.

- To establish the existence of possible lags in peak and length of the reproductive periods among the stocks studied. To specify the basic reproductive parameters relevant to fisheries management: size at first maturity, size at 50% maturity, sex-ratio and fecundity in females.

- To determine possible differences among the varied exploitation systems and fishing techniques that co-exist in the Mediterranean. State the difficulties encountered when attempting to obtain reliable catch and effort data, which are of primary importance in the application of sustainable models.

- To assess the exploitation status of fished stocks in relation to what has been established in the previous objectives. To set forth recommendations for a global and efficient management strategy of Norway lobster stocks in the Mediterranean.

SPECIAL ACTIONS comprise the following objectives:

-Instituto de Ciencias del Mar (Barcelona). Study the spatial distribution of shallow-water and deep-water populations off the Ebro delta (NE Spain). This is an exceptional study area in the Mediterranean where adjacent shallow and deep populations are found. In this objective are included, for the first time in the

Mediterranean, studies that relate environmental factors (substrate properties, water temperature, day-night cycles) to Norway lobster distribution.

- National Centre for Marine Research (Athens). Study of the behaviour of selectivity logistic curves for different mesh sizes. This Action is to be compared with a similar one carried out previously at the ICM (Barcelona).

- Departamento di Scienze Ambientale e del Territorio (Universitá di Pisa). Characterisation of the genetic structure of Norway lobster in order to assess the homogeneity of the species in the Mediterranean.

The subjects developed are outlined in the Contents.

Timing of the Work Plan

First Year:	Methodological basis Monthly sampling and collection of diverse information Special Action: Geostatistics 1st Workshop (Barcelona) 2nd Workshop (Tunis) First Interim Report (FIR)
Second Year:	Monthly sampling and collection of diverse information Special Action: Genetics Preliminary data analysis 3rd Workshop (Malta) Second Interim Report (SIR)
Third Year:	Data analysis, results and discussion Special Action: Selectivity 4th Workshop (Faro) 5th Workshop (Bari) Conclusions and Final Report

Project principles and methodology

* The project has been carried in a comparative way among the different study areas
* The project has been developed under a global perspective.
* Study areas and fishery characteristics have been established for each area (see FIR)
* A common sampling methodology has been followed in each subject, as specified in this Report.
* Fishery and technical information has been collected qualitatively (methodology in FIR and SIR)
* Monthly biological information has been compiled quantitatively (methodology in FIR and SIR)
* Data have been treated, analysed and presented by the corresponding specialised team for each subject (see FIR).
* All methodologies, results and conclusions have been discussed and agreed upon by all project partners at specific seminars and meetings.

Summary of the objectives and methodologies

Objective	Methodology (see FIR and SIR for details)
STANDARD	
Size-frequency distribution by sexes	Monthly sampling aboard commercial boats operating over the exploited stock fishing grounds. CL to the nearest mm.
	Modal progression analysis by fitting von Bertalanffy's model. Software used: MIX, FISHPAR, FISAT
Reproduction: sex-ratio, reproductive period, fecundity and size at first maturity	Monthly biological batch. Gonad dissection, egg count, % mature females and % berried females by size.
Fishery characteristics	Qualitative information on gears, manoeuvres and markets. Accompanying species (by-catch).
Exploitation status	VPA, Y/R under equilibrium. Transition analysis
SPECIAL	
Distribution and density	Kriging. Intensive sampling aboard research vessel
Selectivity	Cod-end liner of ... mm mesh size
Genetics	Electrophoretical enzyme analyses

Total month sampling: size frequency and biological samples in number of individuals are shown in tables 1 and 2.

1993-1994		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Ago	Set	Oct	Nov	Dec
Atlantic	M	0	586	37	262	73	131	161	290	229	795	136	377	0	844	55
	F	0	256	24	83	44	74	153	328	227	985	64	164	0	401	41
Alborán	M	736	198	399	107	414	549	389	333	233	420	202	198	134	110	250
	F	710	186	202	56	289	650	644	923	601	798	205	191	106	99	153
Catalan	M	106	880	681	365	563	194	850	544	919	381	307	503	559	563	472
	F	91	655	526	302	554	281	1196	630	1100	355	237	356	504	409	478
Ligurian	M	0	251	0	0	553	503	0	97	337	0	0	193	126	490	0
	F	0	240	0	0	437	389	0	87	460	0	0	173	103	370	0
Tyrrehenian	M	480	881	737	579	826	595	761	333	327	407	403	306	1090	574	799
	F	447	712	547	474	761	622	824	241	340	398	439	250	692	540	774
Adriatic	M	1606	835	630	565	487	202	879	653	788	491	350	853	370	659	0
	F	1574	925	561	496	385	182	1017	777	883	514	362	915	451	542	0
Euboikos	M	2254	2535	1825	1200	806	764	375	347	405	344	726	689	1505	644	402
	F	1841	2632	1630	1357	867	1099	485	435	452	464	749	570	1354	590	416
1995																
Atlantic	M				86	0	107	99	103	300	321	0	0	318		
	F				84	0	107	94	135	362	578	0	0	235		
Alborán	M				315	388	185	284	125	123	0	539	372	312		
	F				210	283	142	301	172	159	0	619	339	251		
Catalan	M				405	348	361	290	335	471	1897	587	382	730		
	F				430	309	490	393	373	587	949	486	310	615		
Ligurian	M				435	208	0	171	159	477	1158	561	479	373		
	F				345	107	0	180	332	435	1176	490	534	340		
Tyrrehenian	M				788	384	268	574	631	637	618	1057	572	642		
	F				619	393	317	480	647	586	740	939	500	530		
Adriatic	M				0	275	0	786	662	497	535	668	780	0		
	F				0	200	0	916	841	598	708	624	699	0		
Euboikos	M				535	669	297	288	1102	490	406	286	590	0		
	F				456	838	448	526	1937	772	434	271	635	0		

Table 1.- Number of individuals sampled for size frequenc..y analyses

Months		**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Ago.**	**Set.**	**Oct.**	**Nov.**
Zones		**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
Alborán	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
Tyrrhenian	M	125	490	0	435	208	0	171	159	477	1158	0	0	0	0
	F	103	369	0	345	107	0	180	166	435	1176	0	0	0	0
Atlantic	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

Table 2.- Number of individuals sampled for biological condition

Previous projects and bibliography

Introductory aspects of the fishery, local and previous knowledge of the biology of the species, a global description of the study areas and biogeography can be found in the reference lists of this chapter and in Sardà, (1995), as well as in the two Interim Reports and in the following projects funded by the European Commission for each area:

- "*Nephrops norvegicus* biology", including a revision and updated references for the Mediterranean:

SARDA, F. (1995). A Review (1967-1990) of some aspects of the life history of *Nephrops noevegicus* (L.). ICES mar. Sci. Symp., 199: 78-88.

ANONIMOUS. Working Group on *Nephrops* stocks. CM 1994 and previous assessments. Copenhagen.

Final Report Layout

This Final Report is organised in different chapters, following approximately the same order of the S, C, FIR and SIR. Standard and Special Actions have been logically connected in order to facilitate the comprehension of their scientific fundamentals throughout this Report.

Each chapter contains:

Introduction: Specific techniques
Material and methods: Detailed description
Results: Whenever possible, summarised in table format.
Discussion: Specific and directly related to the results
Conclusions: Clear, concise as possible.
Literature: only main literature directly cited in the text

Annexes only contain examples of data analysis and methodologies employed.

In order to reduce report volume the text has been type in single space and double face

Short description of the study areas and general literature(Fig. 1)

Atlantic (Faro, fig.2)

The grounds where *Nephrops* is caught off the Algarve coast are located at depths from 200 to 600 m. The species can be found at even greater depths but those grounds are not exploited in a systematic way (Figueiredo, 1989). However *N. norvegicus* is presented in discrete areas, with two major concentrations off the southwest and south coasts. These two large patches cover the edge of the continental platform and the slope, with highest concentrations between 200 and 400 m. some fishing grounds extend down to 700 m (Viriato

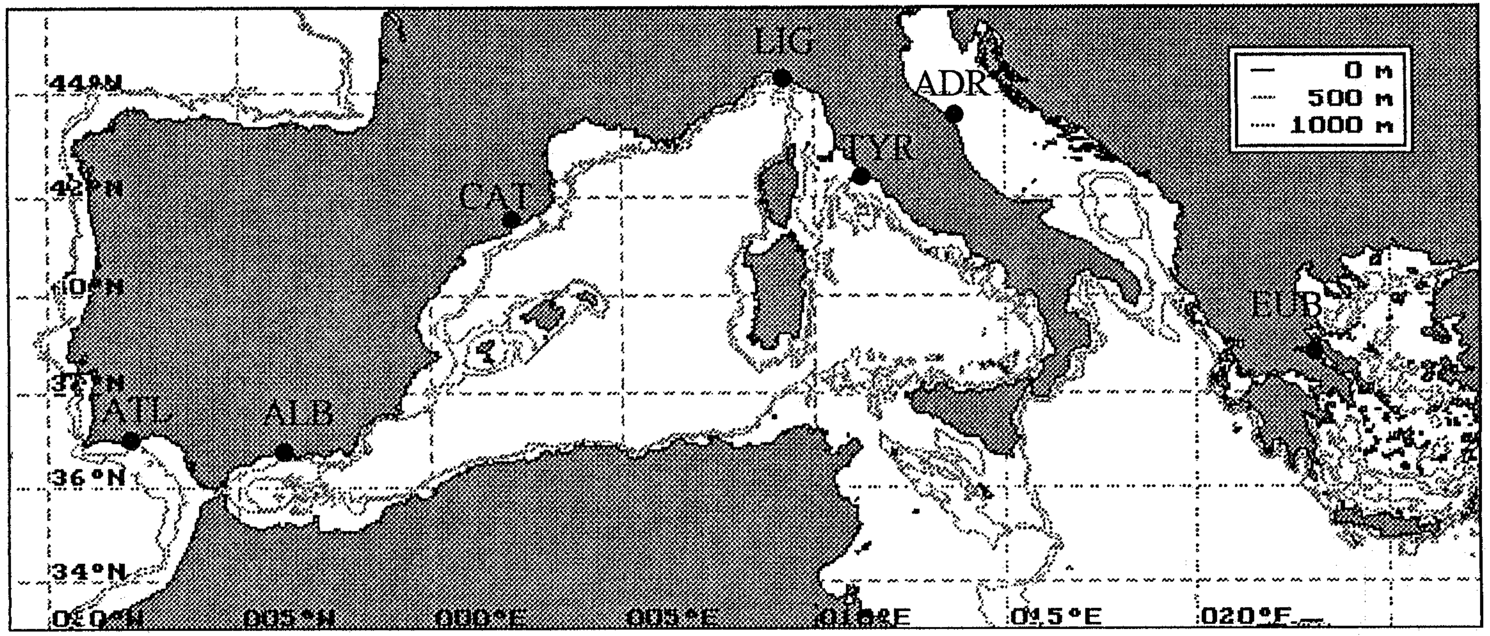

LIG
ADR
TYR
CAT
EUB
ATL
ALB
0 m
500 m
1000 m
44°N
42°N
36°N
34°N
000°E
005°E
020°E

FIG. 1

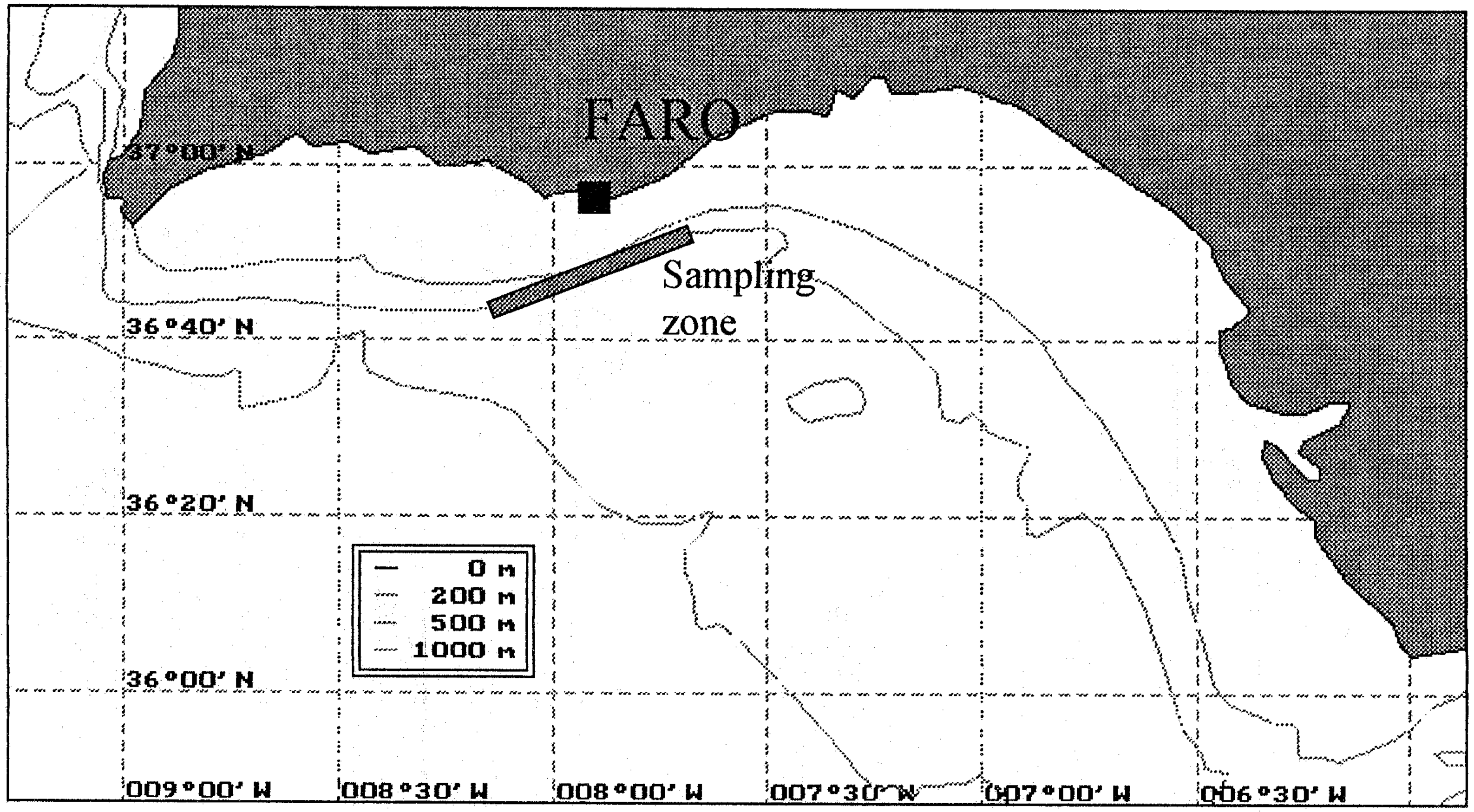

FARO
37°00' N
Sampling
zone
36°40' N
36°20' N
36°00' N
0 m
200 m
500 m
1000 m
009°00' W
008°30' W
008°00' W
007°30' W
007°00' W
006°30' W

FIG. 2

and Figueiredo, 1991). The study area chosen for sampling is designed by "Regato de Aberta", "Regato de Faval" or "Monte de Cabeida". It consists in a canyon ranging from 500 to 600 m depth, bounded by depths of around 300 m. (Fig. 2).

The coastal upper layers show a strong variability along the year, linked to upwelling phenomena which is more dominant in late spring and summer. The coastal flow along the southern Algarve is towards the east. At the surface the oceanic waters lying offshore flow westward. In the southern, during winter, both bottom and surface currents flow northward (Frouin, 1990; Haynes and Barton, 1990). The surface circulation changes during upwelling phenomena which occur mainly during spring and summer, creating surface coastal currents that flow south

Haynes, R and E.D. Barton (1990). A poleward flow the Atlantic coast of the Iberian peninsula. J. Geoph. Res. 95, 11 425-11 441.

Figueiredo, M.J. (1989). Distribuçao batimétrica do Lagostim e espécies associadas de interessa comercial, ao longo da costa continental portuguesa. Relatorios Técnicos e Científicos do Instituto Nacional de Investigaçao das Pescas. Lisboa. 12, 53 pp.

Frouin, R (1990). Observations of a poleward surface Current off coasts of Portugal and Spain during winter. J. Geoph. Res. 95: 679-691

Viriato, A and M.J. Figuiredo (1991). Topografia submarina dos fundos de Crustáceos da vertente Algarvia. Relatorios Técnicos e Científicos do Instituto das Pescas. Lisboa. 43, 31 pp.

Alboran (Málaga, fig. 3)

Norway lobster is exploited by 20 boats based in the ports of Estepona, Marbella, Málaga, and Motril which fish frequently by night. Norway lobster landings are variable. Mean size of individuals is larger than in other areas, and juvenil forms are scarce. Fisheries description was made by Gil de Sola (1993, 1994).

The Alboran Sea is characterised hydrographically by the exchange of Mediterranean and Atlantic waters. Atlantic water enters the Straits and mixes at the surface and at medium depths. Its salinity is 36 ppt, lower than Mediterranean water. This area features a complex hydrography, with gyres and currents that generally produce mixing in layers of variable depth (Cano and García Lafuente, 1991) and upwelling of Mediterranean waters. Seasonal variations in this model may result in upwellings of differing intensity (Gil, 1985).

The continental shelf is relatively narrow (fig. 3), 2 to 10 km wide, with rocky bottoms near shore and small submarine canyons around 10 km long, reaching down to 2000 m. Sediment cover comprises sands and muds, the grain size becoming progressively finer offshore.

Cano, N and J. García Lafuente. (1991). Corrientes en el litoral malagueño. Baja frecuencia. Bol. Inst. Esp. Oceanogr. 7(2): 415-459

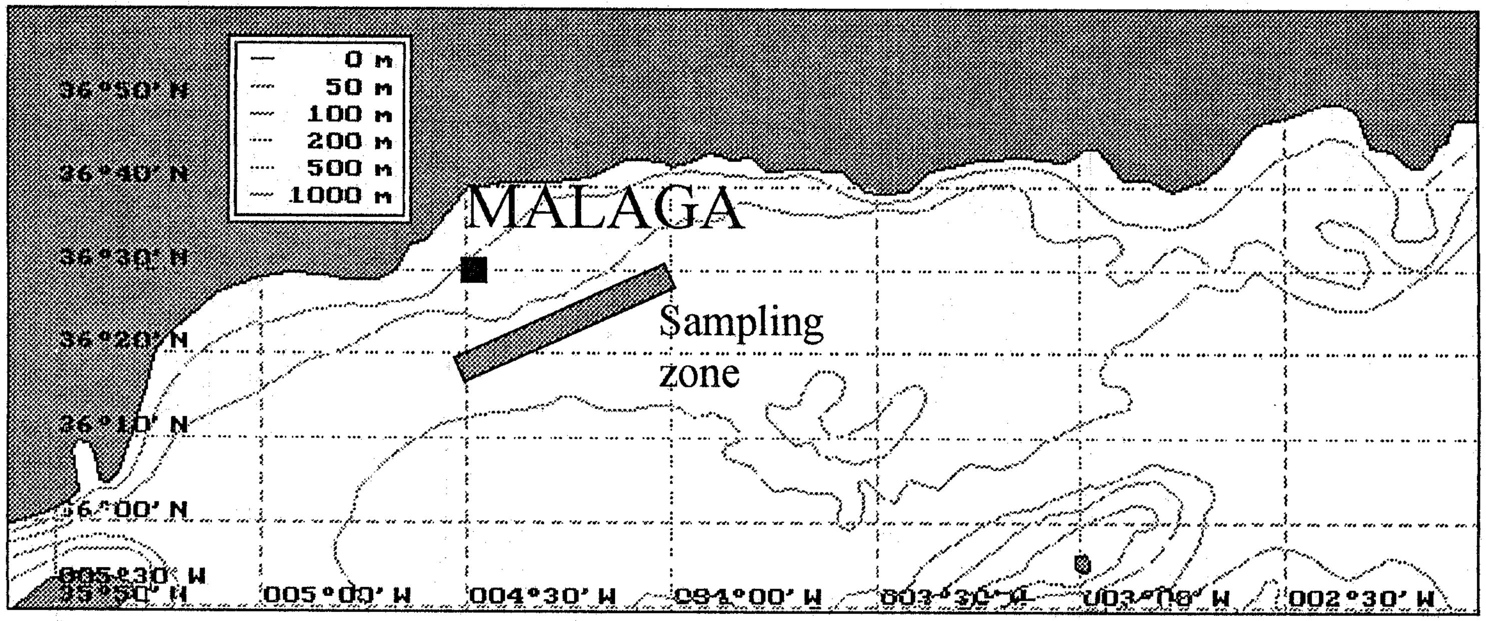

0 m
50 m
100 m
200 m
500 m
1000 m
36°50' N
36°40' N
36°30' N
36°20' N
36°10' N
36°00' N
35°50' N
005°30' W
005°00' W
004°30' W
004°00' W
003°30' W
003°00' W
002°30' W
MALAGA
Sampling
zone

FIG. 3

Gil de Sola, L. (1993). Las pesquerías demersales del Mar de Alborán (sur Mediterráneo ibérico). Evolución en los últimos decenios. Inf. Téc. Inst. Esp. de Oceanogr., 142

Gil de Sola, L. (1994). Ictiofauna demersal de la plataforma continental del mar de Alborá (Mediterráneo suroccidental ibérico). Bol. Inst. Esp. Oceanogr. 10(1): 17 pp.

Catalan (Barcelona. fig. 4)

The study area comprises the fishing grounds named "Serola" located off Barcelona (fig. 4). Its surface is 300 square miles approximately and comprises depths of 300 to 600 m. The local Nephrops population is traditionally exploited by the fleet based in Barcelona (Sardà and Lleonart, 1993). A general description of the fishery can be found in (Martín, 1989).

The continental slope is gentle, extending to 11 miles offshore. The study area is bounded by submarine canyons, which disrupt the stability of the Nephrops population and its community. Sediment comprises fine and compact mud suitable for burrow digging.

Water temperature is very stable, at around 13 °C, and salinity is around 38.4 ppt, which are features of the so-called 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. Its effects become progressively weaker as it nears the protruding continental shelf off the Ebro river. In general, the study area shows the 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 study area is in poor environmental condition, due to fishing pressure (fleets based in Barcelona, Vilanova and Arenys) which has caused extensive damage to benthic organisms, and due to pollution (industrial, chemical, organic and from maritime traffic)

Project: Bio-ecological and fishery considerations on the Norway lobster *Nephrops norvegicus* (L.) in the Western Mediterranean. DG. XIV/B/1 (1991)

Project: Evaluación del recurso de cigala *N. norvegicus* en el mar Catalán. DG. XIV/C/1 (1991/14)

Project: La pesquería en Catalunya y Valencia: descripción global y planteamiento de bases para su seguimiento. DG XIV 1989/3 (1990).

Hopkins, T. S (1984). La fisica del Mar En: El Mediterráneo Occidental. De por R. Margalef. Omega. Barcelona:102-127.

Martín, P. (1989). Dinámica de la pesquería de arrastre. Tesis Doctoral. Universidad de Barcelona. 358 pp.

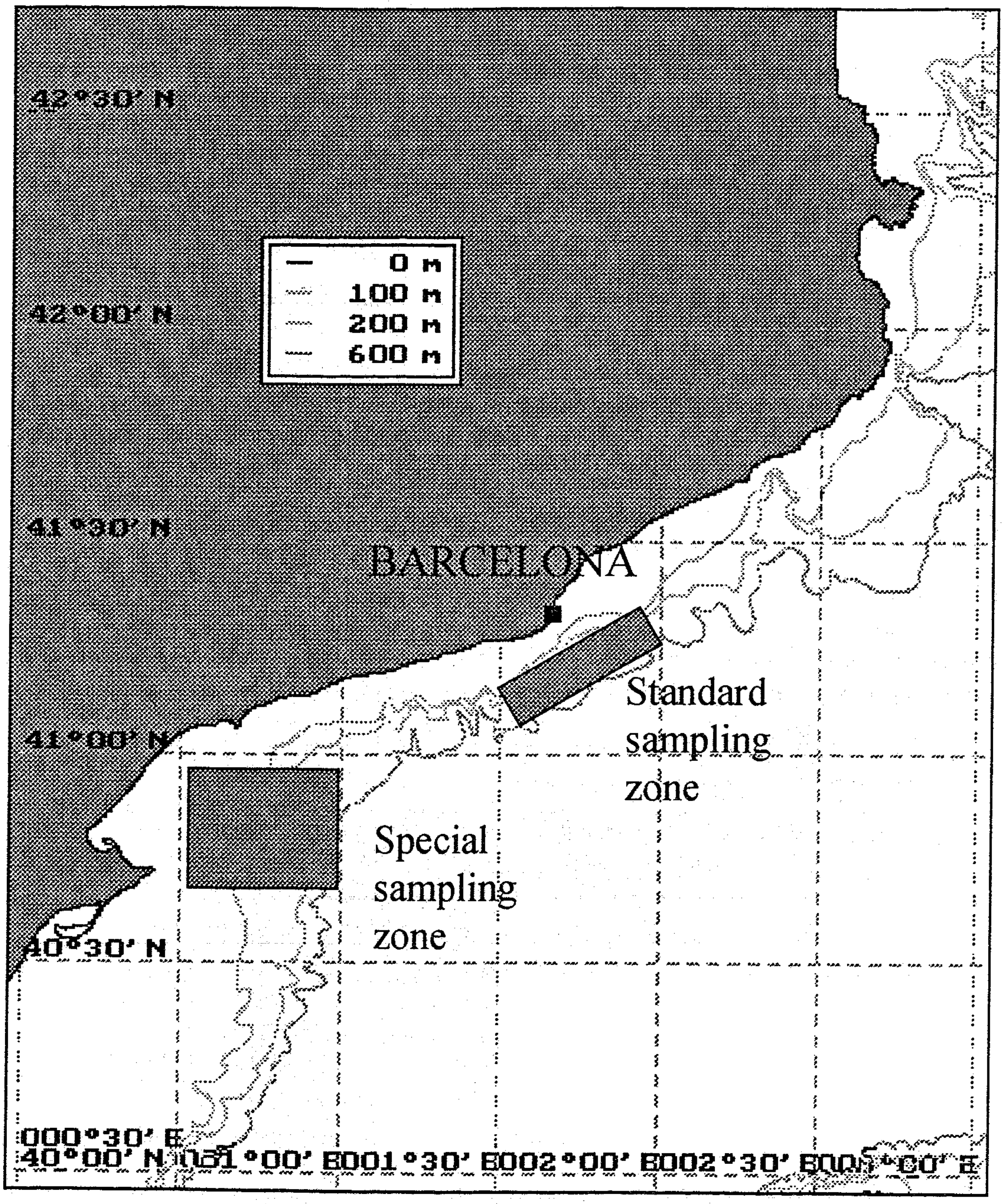

42°30' N
42°00' N
41°30' N
41°00' N
40°30' N
40°00' N
000°30' E
001°00' E
001°30' E
002°00' E
002°30' E
003°00' E
0 m
100 m
200 m
600 m
BARCELONA
Standard sampling zone
Special sampling zone

FIG. 4

Salat, J and J. Font (1985). Masses d'aigua y circulació a la Mediterrània. Quaderns d'Ecologia Aplicada. diputació de Barcelona. nº 8: 61-98.

Sardà, F. and J. Lleonart (1993). Evaluation of the Norway lobster (*Nephrops norvegicus*, L.) resource off the "Serola" bank off Barcelona (western Mediterranean). Sci. Mar. 57(2-3): 191-197

Ligurian (Genova, fig. 5)

Depth of fishing grounds for trawlers in the Ligurian Sea varies from 50 to 700 m. The continental shelf becomes progressively wider from west (Genoa) to east (La Spezia). Off Genoa, the shelf area covers 175 square miles and the slope 220 square miles. Eastwards, shelf area is 350 square miles and slope area 610 square miles.

Fleets trawling over this area belong to the ports of Genoa, Camogli, Sta. Margherita Ligure, Chiavari, Lavagna, Sestri Levante and La Spezia. Norway lobster in the Ligurian Sea is found on the bathyal mud biocoenosis, between 200 and 700 m depth (Orsi Relini and Relini, 1989).

The hydrology of the Ligurian Sea is characterised by three stratified water masses (Stocchino and Testoni, 1979), coinciding with the general features of the Western Mediterranean (Hopkins, 1984). *Nephrops* is found at its maximum density over the slope in the Intermediate Water mass (Relini Orsi and Relini, 1989).

Project: Evaluation of demersal resources in the Ligurian Sea (1990-93). ref. 1990/5 and MED/92/016

Project: International bottom trwl survey in Mediterranean (1995-1998) ref 94/055; 93/006; 94/057; 95/65; 65/66

Orsi Relini, L. and G. Relini. (1989). Reproduction of *Nephrops norvegicus* L. in isothermal Mediterranean waters. In Ryland J.S. and P.A. Tyler (Eds.): Reproduction, Genetics and distributions of Marine Organisms. 23rd European Marine Biology Symposium. Olsen and Olsen Publ., Fredensborg, Denmark: 153-160.

Stocchino, C. and A. Testoni. (1979). Trasporto costiero del Mar Ligure tratto da Ventimiglia al Promontorio di Piombino. Parte Prima: Caratteristiche betimetriche, morfologiche, meteorogiche, idrologiche e correntometriche del Bacino. Istituto Idrografico della Marina. Genova. I.I. 3066: 30 pp.

Tyrrhenian (Pisa, fig. 6)

The study area extends over the Southern Tuscany Archipelago, between the islands of Elba and Giannutri. A wide depression in the central part of the area named "Central Basin" characterises the bottom morphology. It becomes gradually deeper southward down to 600 m depth between the islands of Montecristo and Giannutri. This huge amphitheatre-

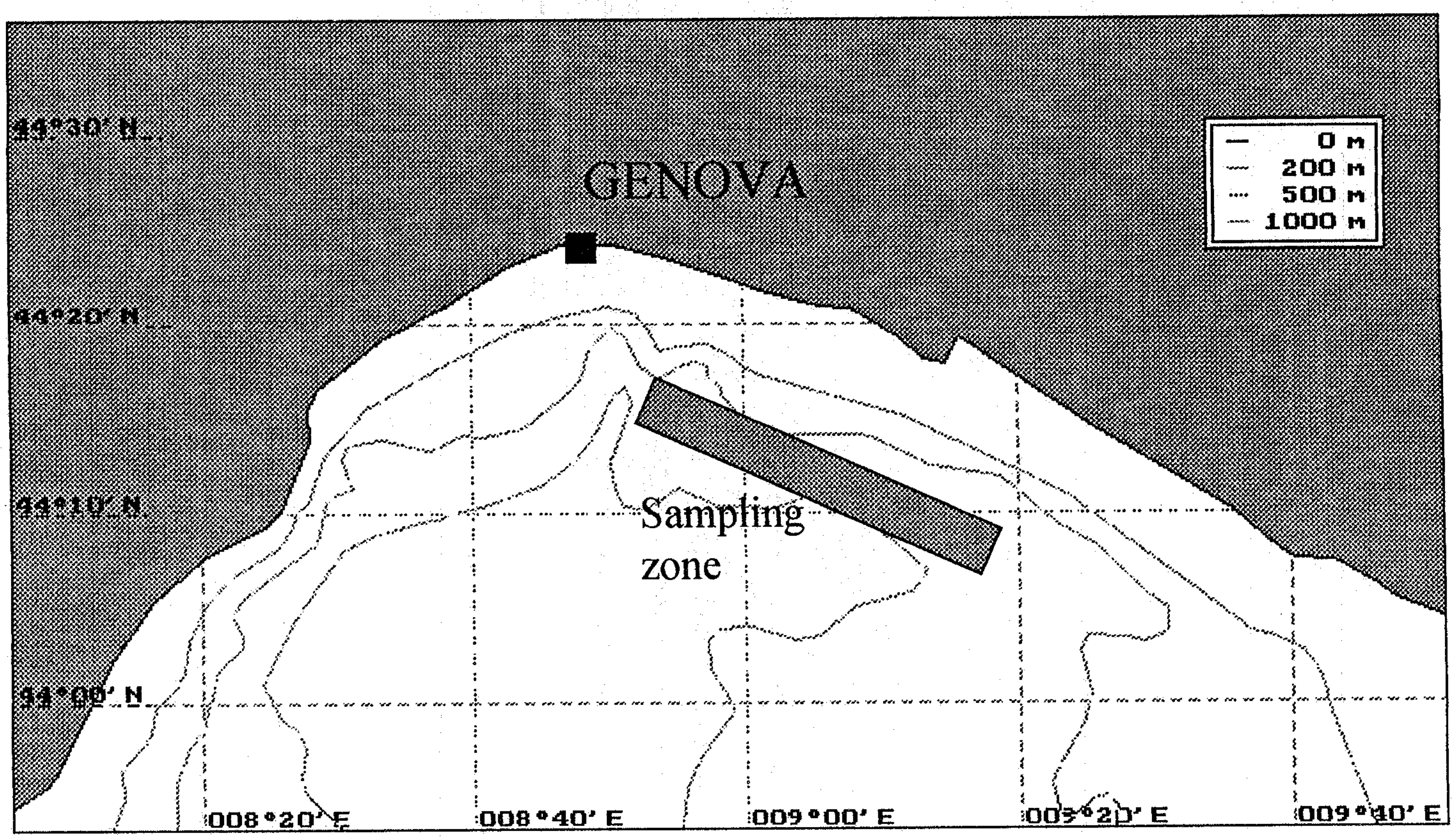
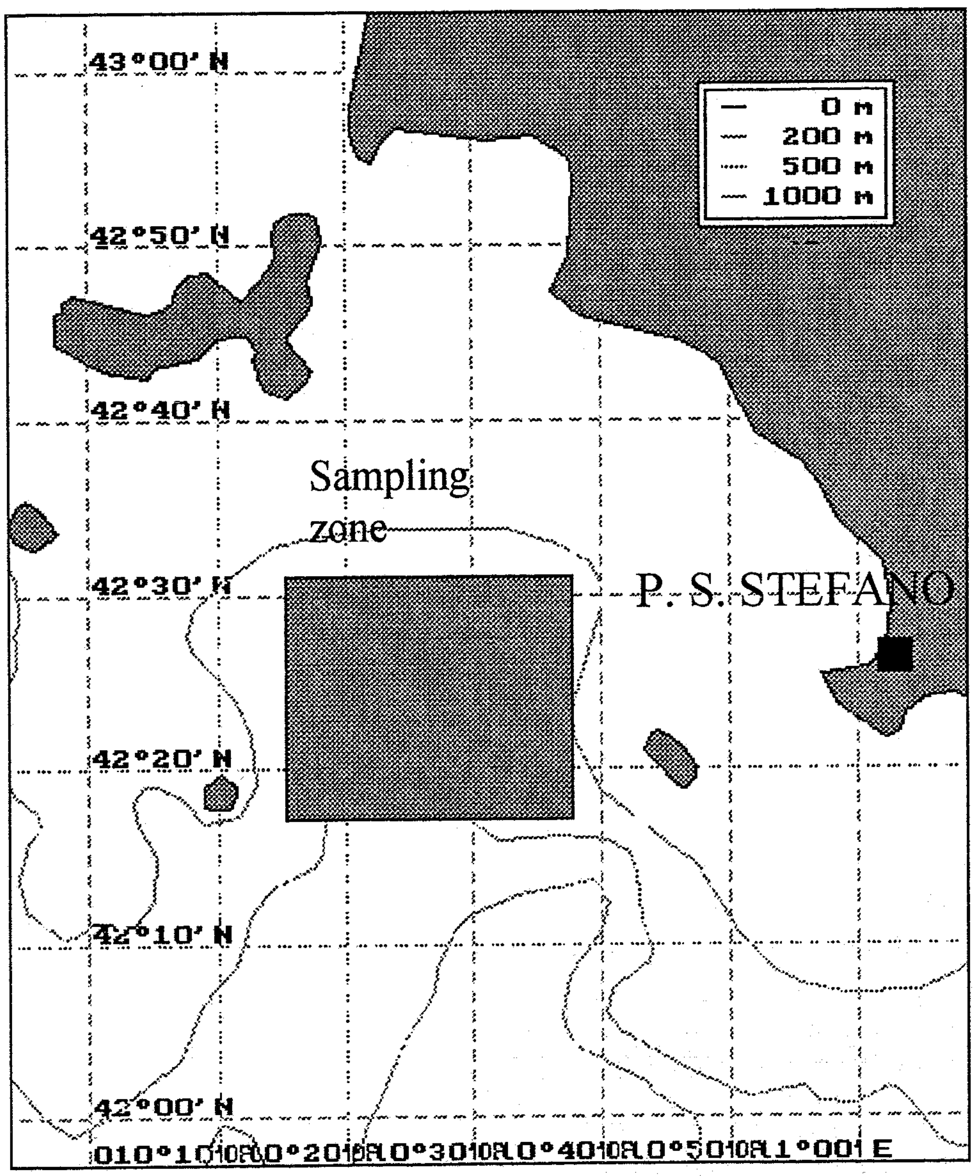

44°30' N
GENOVA
0 m
200 m
500 m
1000 m
44°20' N
44°10' N
Sampling zone
44°00' N
008°20' E
008°40' E
009°00' E
009°20' E
009°40' E

FIG. 5



43°00' N
42°50' N
42°40' N
42°30' N
42°20' N
42°10' N
42°00' N
0 m
200 m
500 m
1000 m
Sampling zone
P. S. STEFANO

FIG. 6

like depression is limited eastward, by a wide continental shelf, northward by the shelf of the Elba island and Piombino channel, and westward by the Elba ridge

The general hydrology and the circulation of water masses in the southern part of the Tuscany Archipelago are poorly known. The main currents show a northwards flow, although high seasonal variability is present. Surface currents originate from a branch of Atlantic surface water flowing northward along the southern Italian coastline. The Levantine current, originating in the Eastern Mediterranean Basin from warm and very salty water masses is found between 200 and 700 m depth in the southern islands area.

Project: Programme pilote de gestion/conservation halieutique. DG XIV-1/MED/91/015C

Project: Study for the assessment and management of fisheries in the western Mediterranean - part 1 and 2. FAR MA 1-232 and FAR MA 3-621

Project: Evaluation and analysis of the interaction of fishing gears in the demersal fisheries of the western Mediterranean. DG XIV MED/92/009

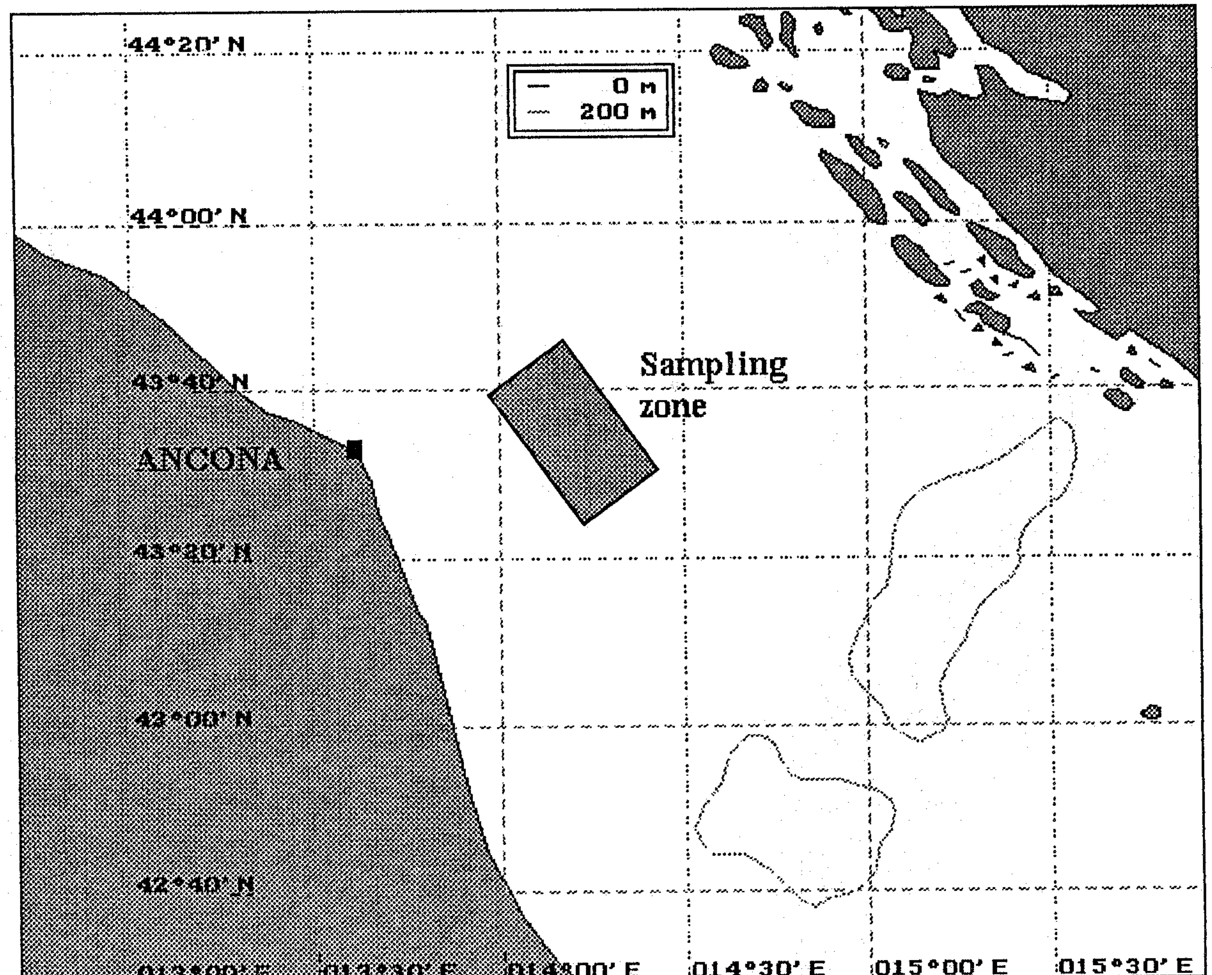
Project: Discards of the western Mediterranean trawl fleets. DG XIV/94/027.

Adriatic (Ancona, fig. 7)

Whereas in the Western Mediterranean *Nephrops* is restricted to the bathyal depths (usualy below 200 m), in the Central Adriatic Sea its distribution range encompasses also the circalitoral soft bottom deeper than 50 m. (FROGLIA AND GRAMITO, 1988). The *Nephrops*, grounds located off Ancona are under the influence of dense cold water masses originated in the northern part of the basin, mainly in consequence of evaporation processes caused by the Bora wind (NNE) blowing in winter. These water masses with salinity around 38.3 PSU and 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 ARMANDE, 1963; ARTEGIANI ET AL, 1993). Within the NEMED project, we selected a narrow area located about 25 miles off Ancona to investigate the biological parameters of the "shallow water" *Nephrops* stocklets. In this area depth ranges between 70 and 75 m.. The sampling area comprises trawling grounds exploited by a fleet of about 200 boats based in the harbours of Ancona and Civitanova. The silt-clay fractions dominate the sediment occuped by *Nephrops*, (Artegiani, et al., 1979) and annual temperature ranges between 10 and 14 °C. On these grounds located NW of Ancona, annual excursion of temperature near the bottom is 2 ° C.

Artegiani, A., P. curzi, C. Froglia, R. Lenaz and L. Tomadin. (1979). Primi resultati delle indagini sui fattori biologici, oceanografici e sedimentologici che condicionano la distribizione degli scampi (*Nephrops norvegicus*) in Adriatico. Atti Convengno Scientifico Nazionale P.F. Oceanografia e fondi marini, 1: 229-241

Artegiani, A., M. Gacic, A. Michelato, V. Kovacevic, A. Russo, E. Paschini, P. Scarazzato and A. Smircic. (1993). The Adriatic hydrography and circulation in spring and autumn (1985-1987). Deep Sea Res. 40(6):1143-1180.



44°20' N
0 m
200 m
44°00' N
Sampling
zone
43°40' N
ANCONA
43°20' N
43°00' N
42°40' N
013°00' E
013°30' E
014°00' E
014°30' E
015°00' E
015°30' E

FIG. 7

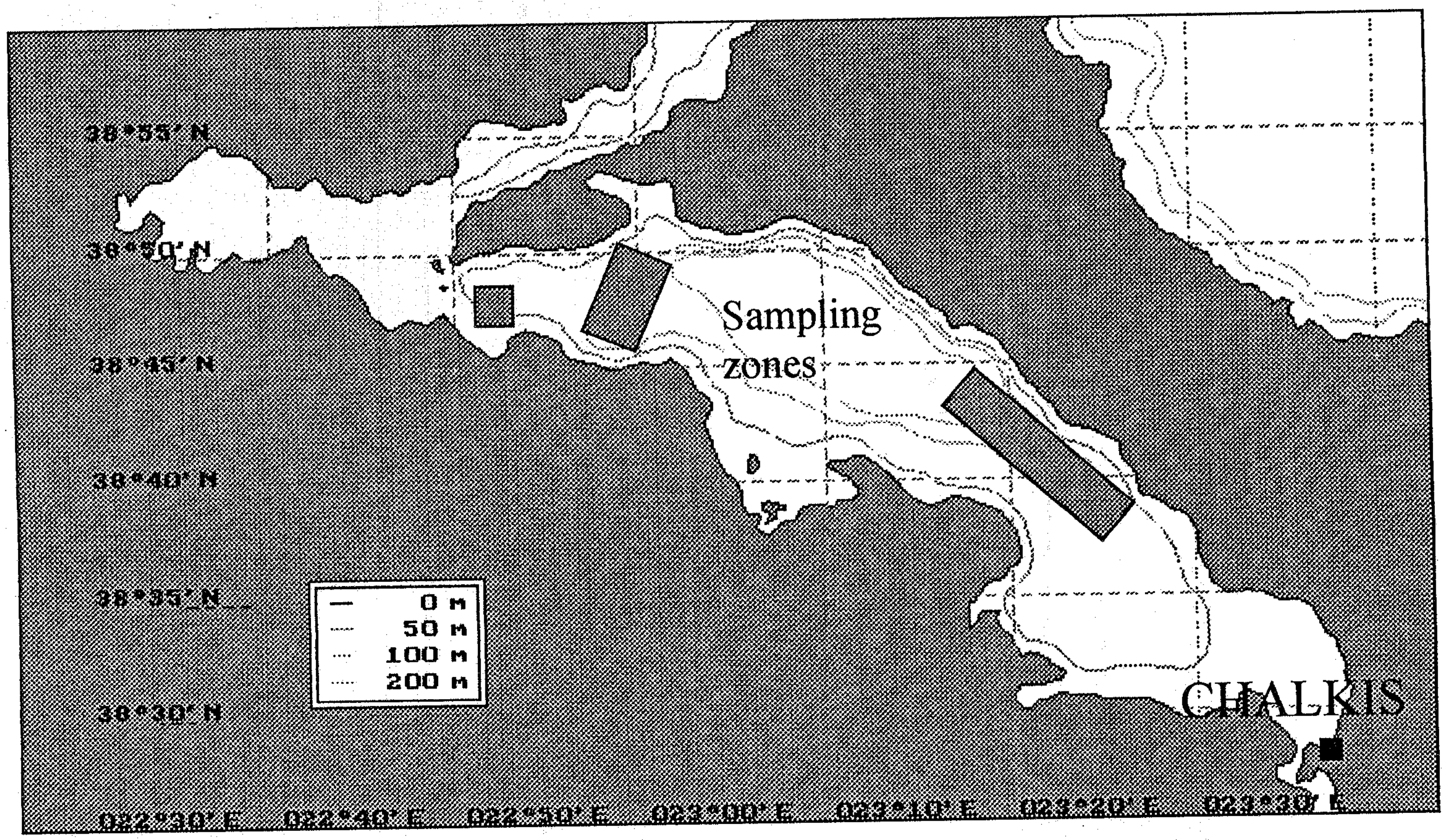

38°55' N
38°50' N
38°45' N
38°40' N
38°35' N
38°30' N
022°30' E
022°40' E
022°50' E
023°00' E
023°10' E
023°20' E
023°30' E
0 m
50 m
100 m
200 m
Sampling zones
CHALKIS

FIG. 8

Froglia , C., and E. Gramito. (1988). An estimate of growth and mortality parameters for Norway lobster (*Nephrops norvegcus)* in the central Adriatic Sea. FAO Fish. Rep., 394: 189-203.

Zore-Armanda, M. (1963). Les masses d'eau de la mer Adriatique. Acta Adriatica, 10(3): 38p.

Project: Sampling system for the collection of fishery statistics (1995). CEE 94/036

Project: Intercalibration des campagnes internationales de chalutage démersal en Mediterránée centrale.(1994) MED/93/015

Project: *Nephrops norvegicus*. stock variability and assessment in relation to fishing pressure and environmental factors (1992). DG XIV-1MED/91-003

Euboikos (Athens, fig. 8)

The North Euboikos Gulf is a long sea area arm shaped, extending 1163 Km^2 (Fig. 8). It is located between Central Greece and the northern part of Euboea Island. It is open to the north to the Aegean Sea by the Oreos Channel and to the south to the South Euboikos Gulf by the Euripus Channel. The North Euboikos Gulf is an enclosed area, which is characterised by relatively shallow waters (down to 100 m) and a restricted deep basin (< 440 m depth) in the central area. In the northern part the Sperchios river, flowing into Maliakos Gulf, enriches the area with fresh waters affecting the salinity of the gulf waters. The surface temperature fluctuates between 11 and 12.5 °C (Balopoulos and Papageorgiou, 1991), whereas the temperature in deep waters ranges from 11.7 to 12.5 °C (Papathanassiou *et al.*, 1992). The surface salinity ranges between 11.7 and 12.7 ppt, whereas in deep waters ranges from 37.2 to 37.5.

The coastal sediments are classified as sand and mud-clay, mostly of biogenic origin, whereas clays dominate at deeper bottoms of the Gulf (Chronis *et al.*, 1984). The area around the N. Euboikos, especially the western part, is characterised by intense human activities (domestic, touristic, agricultural and industrial), especially the western part.

A total of 15 trawlers work over the study area, but all the catch does not necessarily pass through the auction of Chalkis port.

Project: Investigation of the abundance and distribution of demersal stocks of primery importance to the Greek fishery in the N. Aegean Sea. MA 1/80/1 GR,I/90

Project: International bottom trawl survey in the Mediterranean MEDITS 95. Biology Studies 94/C/051

Project: The development of the Greek fishery. 1994. Support Framework Operational Program for Research and Technology

Project: Analysis of trawl's discard operation in the Central and Eastern Mediterranean Sea Biological Studies

BALOPOULOS, E., AND E.J. PAPAGEORGIOU. (1991). Water masses and flow features in the North Euboikos Gulf (Eastern Mediterranean) an initial assessment. Vie et Milieu, 41: 169-176

CHRONIS, E., S. STAVCAKAKI, C. CGIONOS; C. ANAGNOSTOU; E. BARBETSEE AND A. KARAGIORGIS. (1984). New and recent sedimentation in the southern part of N. Euboikos Gulf. Proc. of the A'Pouhel Symp. Ocean. Fish. Athens: 468.476.

PAPATHANOSSIOU, E., ANAGNOSTOU, C., VOUTSINOU-TALIADOURI, F el al. (1992). Environmental study of the North euboikos Gulf. Final Techn. Report., NCMR. 243 pp.

MOULT

INTRODUCTION

In Crustaceans, growth is a discontinuous process with a succession of molts separated by intermolts. At each molt the old exoskeleton is shed and the animal grows very quickly, before the new exoskeleton hardens. Two components can be recognised in growth (Hartnoll, 1982): the growth factor (increase in size at each molt) and the intermolt period (time between two successive molts). To identify molting periods and periodicity is of great importance in growth studies, and this can be easier in Decapods because of the presence of gastroliths. These are transitory structures present in species with a very hard exoskeleton and to which Calcium is not readily available in the environment, so that they store it under this solid form. Gastroliths are situated in the wall of the cardiac chamber of the stomach, between the epithelium and the cuticularized layer. Here, during pre-molt phases, Calcium mobilized from the old exoskeleton to blood under molting hormone control, is stored as Calcium carbonate and phosphate crystals (Skinner,1985). After ecdysis, gastroliths are quickly dissolved and Calcium is used to harden the new exoskeleton.

The duration of molt cycle (from proecdysis to anecdysis) differs among species, and is highly influenced by environmental factors (particularly temperature and light), interacting with secretion of molt hormone (Skinner, 1985). As a consequence, also the period of presence of gastroliths is variable.

To define the duration of molt phases, identified in accordance with Drach scale (1939), Aiken (1973) studied the structural changes in pleopods of *Homarus americanus*. The same method was used by Sardà (1983) on *Nephrops norvegicus*.

Subsequently, experiments on variation of Calcium concentration in different body structures (Sardà and Cros, 1984) evidenced that in *N. norvegicus* the maximum increment in gastroliths volume takes place during last phases of premolt (D2..D4), that means about 15 days before molt. After ecdysis, gastroliths are reabsorbed very quickly (less than 24 hours after molt).

Therefore in this species, the presence of well-developed gastroliths indicates that the animal is ready to molt within a few days, and it can be used as an index of molting periods.

In the NEMED project it was decided to use gastroliths presence or absence with the aim of clarifying molting periodicity and of verifying if a common pattern of molt exists between the investigated areas.

MATERIAL AND METHODS

From October '93 to September '95 (October '95 in some areas) each operational team involved in NEMED programme collected monthly samples to obtain biological data. Sampling technique was not the same in all the areas. Some team collected data on the whole catch or on a random sample, if *Nephrops* catch was too large (Tyrrhenian and Ligurian Sea, Spain). The others (Portugal, Greece and Adriatic Sea) had systematic sampling on *Nephrops* catches, trying to obtain at least 10 specimens per sex and length class (each length class had a range of 5 mm Carapace Length). In any case, the total size of each monthly sample had to be at least 150 males and 150 females. Unfortunately this amount was not always reached for *Nephrops* paucity in some areas or in some year periods. Sometime it was impossible to have regular samples all around the year for rough sea, trawler unavaliability, etc.

All the specimens in the sample were sexed and measured as Carapace Length with a dial calliper to the mm below. Then the carapace was opened at stomach level to verify the presence of gastroliths. To standardize as much as possible observations made by each team, it was decided to consider as "present" only gastroliths where crystals were noticeable by the touch.

All the data were sent to IRPEM team (Adriatic Sea) for further elaboration made using Microsoft Excel 5.0 programme.

As a rule, frequency of molt is higher in juveniles, and obviously no molt can occur in females during the period they are carrying external eggs (Conan,1985). Therefore frequency of gastroliths is considered separately for the two sexes and three size groups. The first group (**A**) includes only young specimens (CL<25 mm), while the third one (**C**) includes the larger animals, properly adults (CL≥35 mm). The intermediate group (**B**, 25≥CL>35 mm) may include both juveniles and adults, because growth rate and mean size at first sexual maturity can differ in the different regions.

For each sex, group and month, frequency of molt was calculated as the percentage of specimens with gastroliths on the total of specimens of the same size.

As gastroliths frequency was almost always low (less than 30 - 35 %), it was decided to assume as "molt months" those months where frequency of gastroliths was over or around 10%, and as "molt periods" the sequences of two or more months showing peaks in gastroliths frequency.

RESULTS

Greece - N. Euboikos Gulf (Tables 2.1, 2.2; Fig. 2.1)

A high number of specimens form all the samples. In juveniles of both sexes there are at least two molting periods per year: the first in winter-early spring, the second in summer-early autumn. The same periods are evident in group **B** males; in group **C**, the second molting period (August-September) assumes high importance (F > 20%), while the first one seems to disappear.

In females, the late summer period does not already stand out in group **B**, while the winter period gets high significance and in adult females is clearly evidenced. Therefore in females it seems to exist only one molt period per year in winter (January-March).

Italy - C. Adriatic Sea (Tables 2.3, 2.4; Fig. 2.2)

Molting specimens are found all year round. Trends are very muddled in both sexes for juvenile and intermediate groups, with very wide fluctuations in gastroliths frequency between months. It could mean that no synchronism in molt is present in part of the population. Only in young males it is possible to see three molt peaks (November, March and June-September). Adult males have a main molt peak between June and September in both years.

In adult females, frequency of gastroliths is always very low, reaching a maximum of 8.3% in February '94, so that nothing can be said on molt cycle, except that adult females do not molt between August and January, when they carry external eggs (Froglia and Gramitto, 1981).

Italy - N. Tyrrhenian Sea (Tables 2.5, 2.6; Fig. 2.3)

Monthly samples cover all the experimental period: Oct '93 - Sep '95, plus Oct '95 and are quite good in specimens' number.

Juvenile males (**A** group) clearly show three peaks in gastroliths frequency: winter, late spring and late summer. As these peaks are present in both years, they have to represent three annual molt periods. The intermediate group shows a shifting to two, wider periods: winter-early spring (November-May) and late summer (August-October). Between adults, this shifting is more evident in '95 (the first period is restricted to March-April), than in '94 when the frequency of gastroliths is quite low (around 10%) in spite of the high number of specimens examined.

Between females, in juveniles the trend is the same than in young males (three molt periods), but it is hidden by paucity of specimens in some months, making frequency of gastroliths very high but not significative. In **B** group, molt periodicity is more evident. There is only one molt period per year (winter-early spring), confirmed in adult class (molt peak is restricted to March). The late summer molt period, characteristic of males, is totally absent.

Italy - Ligurian Sea (Tables 2.7, 2.8; Fig. 2.4)

Unfortunately, until January '95 samples are too scattered to allow any conclusion on frequency of gastroliths. Frequency of gastroliths shows a maximum in April-May followed by a descendent trend in both sexes and lets presume a molt period in late spring (April-June) for males and females.

Spain, Catalan Sea (Tables 2.9, 2.10; Fig. 2.5)

Monthly samples cover all the experimental period: October '93 - September '95, plus October '95 and are quite good in specimens' number. On the whole, the situation of this *Nephrops* population looks like the Adriatic one.

Frequency of gastroliths presents wide fluctuations between the two years and between months in **A** and **B** groups of both sexes, so that a molt periodicity does not stand out.

In adult males frequency of gastroliths is always very low (less than 8%), and molt seems to occur the year round with a maximum in September (F = 10% in both years).

Adult females are the less abundant, but the percentage of specimens with gastroliths reaches peak values in February and March (14-15% in '94, 13-24% in '95). This means that, as in the other areas examined, adult females molt once per year, in late winter. At least for a small fraction of females' population, this period seems to extend till August, when females become ovigerous (Sardà, 1991), and obviously do not molt till eggs hatching.

Spain, Alboran Sea (Tables 2.11, 2.12; Fig. 2.6)

The *Nephrops* population sampled off Malaga seems to be quite different from all the others. It is formed by large specimens and has also a higher mean size at first maturity. From data presented in this Report, the females first maturity size is about 35 mm CL. Therefore only for this area the lower size limit of group **C**, that includes only adult specimens, was placed at 40 mm CL.

Young specimens (**A** group, CL < 25 mm) are almost completely absent, except in February and March '95 samples. The F% of gastroliths obtained in other months are meaningless, due to paucity of specimens in the samples.

In males of intermediate class (**B**) frequency of gastroliths has a different trend in the two years. Two peaks (winter and spring) can be seen in the first year of sampling, but not in the second one. In adults (**C**) only a small peak is detectable in spring '94.

For intermediate females, in 1994 the highest frequency of gastroliths was observed between January and April (F% max = 19%, in February). In the second year the period is wider, extending from November '94 to April '95. In adult females (**C**) the trend is the classic one, with one single molt period per year, from January to April (F% max > 25%, in March).

Portugal, Atlantic (Tables 2.13, 2.14; Fig. 2.7)

As the former area, also this one is characterized by the almost complete absence of young specimens. The rather small size of the samples examined for the presence of gastroliths and an unusually low frequency of gastroliths makes difficult the identification of molting periods. In an attempt to increase sample size, "soft" specimens were included in F% calculations. "Soft" specimens are animals in the first post-ecdysis stage, whose exoskeleton is not yet completely hardened (parchment-like).

Even so, the number of molting specimens is very low, and it makes difficult to recognise molt periodicity. Available data let suppose a molting period between March and May for females and between March and July for males (both adult and intermediate classes).

DISCUSSION AND CONCLUSIONS

The choice of the 10% threshold to define molting periods is a subjective one, owing to the low frequency of gastroliths, common to almost all the studied areas. A higher percentage (around 20%) as suggested by Sardà (1991) would mean the impossibility to determinate molting periods through presence of gastroliths from present data. The low frequencies observed in most of the samples can be due to extended molting periods or to sampling periodicity, inappropriate to follow molting events.

As the period of presence of well-developed gastroliths is about 15 days before molt (Sardà and Cros, 1984), and the NEMED programme aimed the study of several aspects of *Nephrops* biology in the Mediterranean basin with budget constrains, that did not allow a higher intensity of sampling, most appropriate for this special subject.

Slight shifts in molt peaks are evident between the two studied years. This is due to influence of environmental factors on molt cycle regulation (Conan, 1985; Skinner, 1985). Even so, the seasonal molt pattern appears to be quite stable particularly in adult specimens.

Juveniles - Young specimens generally spend more time than adults in burrows because probably they can find enough food from digging in the sediment (Chapman, 1980). So this group presents fluctuations in number that are linked more to their catchability than to real periodicity in frequency of gastroliths. Overall, young specimens do not show differences in molt periodicity between sexes, confirming a common growth pattern between males and females in the juvenile phase. There are two or three molting periods per year as results from Euboikos Gulf and Tyrrhenian Sea data: a "winter" molt (December-March), a "late summer" molt (August-September) and, eventually, a "spring" molt (April-May). In some areas (Catalan Sea, Adriatic Sea) molt peaks are less evident, hidden by an asynchronous molting of part of young population (see Sardà, 1991 for the Catalan Sea).

Adults - Differences in molting periodicity between males and females are evident in adult specimens. It is known from literature that molt cycles differ between sexes after the onset of sexual maturity (Charuau and Conan, 1977; Froglia and Gramitto, 1988; Sardà, 1995).

Mature females present only one molting period per year between December and March, except for Ligurian Sea and Atlantic, where it seems slightly moved to spring (March-May). This period is situated immediately after eggs hatching, and in literature is reported that adult females undergo molt before mating (Conan, 1985; Sardà, 1991).

Males present two distinct molting periods: the first common to females, the second in late Summer-Autumn (August-October). In some areas (Euboikos Gulf, Adriatic Sea, Catalan Sea) this second period seems to get more weight than the first one. Again, in the Ligurian Sea and Atlantic there is a single period in late Spring.

In conclusion, the existence of a common seasonal pattern of molt (Sardà, 1995) can be confirmed in almost all the studied areas. Results obtained for the Ligurian Sea and the Atlantic could be due to paucity of samples or to a different response of *Nephrops* to different environmental conditions.

The study on presence of gastroliths as indicators of molt frequency confirms the results obtained with other techniques as percentage of occurrence of "soft" specimens in size frequency distributions (Conan, 1975; Sardà, 1991) or studies in aquaria (Thomas, 1965; Conan, 1978; Sardà, 1985). An adequate frequency of samples could lead to better results.

REFERENCES

Aiken, D.E.- 1973. Proecdysis, setal development, and molt prediction in the American lobster (*Homarus americanus*). *J. Fish. Res. Board Can.*, 30: 1337-1344.

Chapman, C.J.- 1980. Ecology of juvenila and adult *Nephrops*. In: J.S. Cobb and B.F. Phillips (eds.), New York,: *The biology and management of lobsters*, 2: 143-178.

Charuau, A. and G.Y Conan - 1977. Growth at moult of Norway lobster: methods of assessment of sexual dimorphism and geographic trends. *ICES* CM 1977/K: 34.

Conan, G.Y. - 1975. Périodicité des mues, croissance et cycle biologique de *Nephrops norvegicus* dans le Golfe de Gascogne. *C. R. Acad. Sc. Paris*, 281: 1349-1352.

Conan, G.Y. - 1978. *Life history, growth, production and biomass modelling of Emerita analoga, Nephrops norvegicus and Homarus vulgaris (Crustacea, Decapoda)*. Ph.D. Dissertation, University of California, San Diego, 349 pp.

Conan, G.Y. - 1985. Periodicity and phasing of molting. In: A.M. Wenner (ed.): *Crustacean Issues, 3: Factors in adults growth.*: 73-99. A.A. Balkema, Rotterdam.

Drach, P. - 1939. Mue et cycle d'intermue chez les Crustacés Décapodes. *Ann. Inst. Oceanogr.*, 19: 103-391.

Froglia, C. and M.E. Gramitto - 1981. Summary of biological parameters on the Norway lobster *Nephrops norvegicus* (L.) in the Adriatic. *FAO Fish. Rep.*, 253:165-168.

Froglia, C. and M.E. Gramitto - 1988. An estimate of growth and mortality parameters for Norway lobster (*Nephrops norvegicus*) in the Central Adriatic Sea. *FAO Fish. Rep.*,394: 189-203.

Hartnoll, R.G. - 1982. Growth. In: D.E. Bliss and L.G. Abele (eds.): *The biology of Crustacea*, 2: 111-196. Academic Press. New York.

Sardà, F. - 1983.Determinacion de los estados de intermuda de *Nephrops norvegicus* (L.) mediante la observacion de los pleopodos. *Inv. pesq.*, 47(1): 95-112.

Sardà, F. - 1985. Estudio de la edad, crecimiento y frequencia de muda, en cautividad, de *Nephrops norvegicus* L. del mar Catalan. *Inv. Pesq.*, 49(2): 139-154.

Sardà, F. - 1991. Reproduction and moult synchronism in *Nephrops norvegicus* (L.) (Decapoda, Nephropidae) in the western mediterranean: is spawning annual or biennial? *Crustaceana*, 60 (2): 186-199.

Sardà, F. - 1995. A review (1967-1990) of some aspects of the life history of Nephrops norvegicus. *ICES mar. Sci. Symp.*, 199: 78-88.

Sardà, F.and L. Cros - 1984. El metabolismo del calcio y del magnesio en la cigala *Nephrops norvegicus* (L.) durante las etapas del ciclo de intermuda. *Inv. Pesq.*, 48(3): 377-397.

Skinner, D.M. - 1985. Molting and Regeneration. In: D.E. Bliss and L.G Abele (eds.): *The biology of Crustacea*, 9: 43-146. Academic Press. New York.

Thomas, H.J. - 1965. The growth of Norway lobsters in aquaria. *Rapp. P.-V. Réun. CIEM*, 156: 209-217.

Table 2.1 - Frequency of gastroliths; N. Euboikos Gulf, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	35	1	2.9	78	5	6.4	166	12	7.2
Nov 93	61	2	3.3	149	3	2.0	264	15	5.7
Dec 93	40	1	2.5	59	3	5.1	129	4	3.1
Jan 94	41	3	7.3	81	8	9.9	123	6	4.9
Feb 94	49	3	6.1	66	7	10.6	88	7	8.0
Mar 94	54	9	16.7	56	8	14.3	96	6	6.3
Apr 94	40	2	5.0	63	5	7.9	105	5	4.8
May 94	41	1	2.4	69	5	7.3	126	9	7.1
Jun 94	41	4	9.8	57	3	5.3	111	1	0.9
Jul 94	11	3	27.3	37	7	18.9	153	5	3.3
Aug 94	51	3	5.9	60	6	10.0	92	7	7.6
Sep 94	30	5	16.7	70	3	4.3	109	22	20.2
Oct 94	42	1	2.4	37	0	0.0	101	7	6.9
Nov 94	38	1	2.6	44	2	4.6	120	2	1.7
Dec 94	18	1	5.6	41	2	4.9	124	6	4.8
Jan 95	41	5	12.2	45	3	6.7	93	2	2.2
Feb 95	40	4	10.0	44	2	4.6	104	4	3.9
Mar 95	34	1	2.9	36	4	11.1	76	2	2.6
Apr 95	26	0	0.0	47	1	2.1	153	6	3.9
May 95	24	8	33.3	39	11	28.2	87	7	8.1
Jun 95	8	0	0.0	30	0	0.0	85	0	0.0
Jul 95	8	0	0.0	38	1	2.6	69	0	0.0
Aug 95	28	1	3.6	45	6	13.3	49	12	24.5
Sep 95	15	3	20.0	72	4	5.6	152	27	17.8

Table 2.2 - Frequency of gastroliths; N. Euboikos Gulf, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	23	0	0.0	46	0	0.0	86	0	0.0
Nov 93	64	4	6.3	132	2	1.5	145	0	0.0
Dec 93	60	1	1.7	66	1	1.5	88	0	0.0
Jan 94	35	3	8.6	95	9	9.5	58	3	5.2
Feb 94	57	8	14.0	72	14	19.4	70	37	52.9
Mar 94	47	12	25.5	67	9	13.4	82	14	17.1
Apr 94	37	3	8.1	75	2	2.7	107	1	0.9
May 94	40	3	7.5	74	3	4.1	102	3	2.9
Jun 94	36	5	13.9	68	3	4.4	89	0	0.0
Jul 94	26	0	0.0	79	1	1.3	108	3	2.8
Aug 94	49	2	4.1	69	3	4.4	85	2	2.4
Sep 94	42	5	11.9	82	2	2.4	87	0	0.0
Oct 94	42	2	4.8	52	1	1.9	81	0	0.0
Nov 94	44	1	2.3	43	0	0.0	62	0	0.0
Dec 94	22	0	0.0	43	2	4.7	60	0	0.0
Jan 95	29	2	6.9	43	2	4.7	40	0	0.0
Feb 95	37	7	18.9	65	7	10.8	61	9	14.8
Mar 95	46	3	6.5	46	11	23.9	71	4	5.6
Apr 95	42	2	4.8	89	6	6.7	168	3	1.8
May 95	29	5	17.2	46	8	17.4	65	6	9.2
Jun 95	14	0	0.0	49	0	0.0	74	0	0.0
Jul 95	14	1	7.1	40	4	10.0	57	1	1.8
Aug 95	24	2	8.3	55	2	3.6	47	3	6.4
Sep 95	32	1	3.1	82	6	7.3	102	7	6.9

Table 2.3 - Frequency of gastroliths; C. Adriatic Sea, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	21	1	4.8	22	1	4.6	44	1	2.3
Nov 93	14	2	14.3	28	1	3.6	38	0	0.0
Dec 93	15	1	6.7	21	1	4.8	43	4	9.3
Jan 94	30	0	0.0	25	2	8.0	52	3	5.8
Feb 94	53	2	3.8	27	3	11.1	47	3	6.4
Mar 94	32	4	12.5	27	2	7.4	58	2	3.5
Apr 94	36	0	0.0	31	6	19.4	64	1	1.6
May 94	37	1	2.7	26	4	15.4	48	2	4.2
Jun 94	37	8	21.6	33	3	9.1	68	4	5.9
Jul 94	38	8	21.1	39	9	23.1	54	5	9.3
Aug 94	34	10	29.4	45	10	22.2	51	12	23.5
Sep 94	31	6	19.4	36	4	11.1	62	5	8.1
Oct 94	34	3	8.8	32	9	28.1	53	2	3.8
Nov 94	58	9	15.5	39	2	5.1	69	3	4.4
Feb 95	51	13	25.5	35	0	0.0	71	6	8.5
Apr 95	56	10	17.9	45	9	20.0	106	6	5.7
May 95	42	9	21.4	44	9	20.5	89	7	7.9
Jun 95	38	8	21.1	43	10	23.3	64	10	15.6
Jul 95	43	9	20.9	36	4	11.1	69	8	11.6
Aug 95	72	16	22.2	84	9	10.7	101	11	10.9
Sep 95	47	7	14.9	38	1	2.6	70	0	0.0

Table 2.4 - Frequency of gastroliths; C. Adriatic Sea, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	23	4	17.4	21	0	0.0	18	0	0.0
Nov 93	16	2	12.5	29	2	6.9	17	0	0.0
Dec 93	15	1	6.7	22	0	0.0	13	0	0.0
Jan 94	38	6	15.8	31	3	9.7	14	1	7.1
Feb 94	61	8	13.1	32	1	3.1	12	1	8.3
Mar 94	32	1	3.1	30	0	0.0	17	0	0.0
Apr 94	28	3	10.7	31	3	9.7	36	2	5.6
May 94	39	3	7.7	43	0	0.0	37	0	0.0
Jun 94	32	7	21.9	39	3	7.7	40	1	2.5
Jul 94	33	2	6.1	47	1	2.1	32	1	3.1
Aug 94	31	8	25.8	56	1	1.8	34	0	0.0
Sep 94	42	5	11.9	44	3	6.8	45	0	0.0
Oct 94	40	3	7.5	35	1	2.9	27	0	0.0
Nov 94	53	3	5.7	39	0	0.0	23	0	0.0
Feb 95	47	9	19.2	35	6	17.1	8	0	0.0
Apr 95	51	7	13.7	50	4	8.0	19	1	5.3
May 95	55	16	29.1	49	7	14.3	46	1	2.2
Jun 95	49	12	24.5	44	7	15.9	35	1	2.9
Jul 95	37	12	32.4	34	1	2.9	42	2	4.8
Aug 95	66	20	30.3	94	3	3.2	54	0	0.0
Sep 95	29	4	13.8	46	0	0.0	28	0	0.0

Table 2.5 - Frequency of gastroliths; N. Tyrrhenian Sea, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	1	0	0.0	37	3	8.1	117	23	19.7
Nov 93	12	2	16.7	94	12	12.8	44	5	11.4
Dec 93	21	6	28.6	49	12	24.5	78	8	10.3
Jan 94	3	0	0.0	107	16	15.0	40	2	5.0
Feb 94	2	0	0.0	80	13	16.3	66	1	1.5
Mar 94	9	1	11.1	81	17	21.0	60	2	3.3
Apr 94	63	9	14.3	71	12	16.9	123	10	8.1
May 94	14	3	21.4	64	10	15.6	124	5	4.0
Jun 94	12	2	16.7	58	3	5.2	130	6	4.6
Jul 94	11	1	9.1	55	3	5.5	129	6	4.7
Aug 94	24	0	0.0	58	1	1.7	116	1	0.9
Sep 94	8	1	12.5	34	6	17.7	119	14	11.8
Oct 94	16	0	0.0	54	6	11.1	130	11	8.5
Nov 94	31	3	9.7	116	10	8.6	53	5	9.4
Dec 94	38	4	10.5	94	7	7.5	68	4	5.9
Jan 95	11	1	9.1	107	18	16.9	82	7	8.5
Feb 95	4	0	0.0	93	11	11.8	103	9	8.7
Mar 95	1	0	0.0	59	17	28.8	90	22	24.4
Apr 95	15	3	20.0	78	24	30.8	107	23	21.5
May 95	27	6	22.2	92	14	15.2	81	5	6.2
Jun 95	7	0	0.0	51	5	9.8	142	12	8.5
Jul 95	21	2	9.5	72	4	5.6	107	5	4.7
Aug 95	8	2	25.0	100	20	20.0	92	9	9.8
Sep 95	28	4	14.3	78	7	9.0	94	19	20.2
Oct 95	22	1	4.6	64	2	3.1	113	6	5.3

Table 2.6 - Frequency of gastroliths; N. Tyrrhenian Sea, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	1	0	0.0	112	1	0.9	43	0	0.0
Nov 93	11	2	18.2	128	8	6.3	11	0	0.0
Dec 93	38	14	36.8	157	22	14.0	24	0	0.0
Jan 94	6	0	0.0	143	25	17.5	36	2	5.6
Feb 94	2	1	50.0	135	15	11.1	26	1	3.9
Mar 94	13	5	38.5	132	24	18.2	15	3	20.0
Apr 94	70	4	5.7	157	16	10.2	106	2	1.9
May 94	14	3	21.4	117	4	3.4	68	1	1.5
Jun 94	18	3	16.7	92	6	6.5	90	2	2.2
Jul 94	18	0	0.0	112	2	1.8	70	0	0.0
Aug 94	23	2	8.7	122	5	4.1	70	0	0.0
Sep 94	8	1	12.5	153	4	2.6	87	0	0.0
Oct 94	39	0	0.0	152	5	3.3	9	0	0.0
Nov 94	57	2	3.5	141	5	3.6	2	0	0.0
Dec 94	65	18	27.7	134	13	9.7	1	0	0.0
Jan 95	7	1	14.3	170	32	18.8	23	0	0.0
Feb 95	4	1	25.0	142	26	18.3	59	12	20.3
Mar 95	1	1	100.0	104	41	39.4	45	19	42.2
Apr 95	13	3	23.1	100	28	28.0	86	4	4.7
May 95	40	6	15.0	111	10	9.0	49	0	0.0
Jun 95	19	1	5.3	104	9	8.7	77	0	0.0
Jul 95	17	1	5.9	100	0	0.0	83	0	0.0
Aug 95	29	5	17.2	146	10	6.9	25	0	0.0
Sep 95	33	1	3.0	142	9	6.3	25	0	0.0
Oct 95	17	0	0.0	150	3	2.0	33	0	0.0

Table 2.7 - Frequency of gastroliths; Ligurian Sea, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Nov 93	12	0	0.0	58	2	3.5	59	2	3.4
Feb 94	5	0	0.0	161	13	8.1	348	10	2.9
Mar 94	0	0		58	6	10.3	307	21	6.8
May 94	12	2	16.7	15	1	6.7	70	4	5.7
Jun 94	1	0	0.0	106	8	7.6	230	15	6.5
Sep 94	2	0	0.0	75	2	2.7	116	9	7.8
Oct 94	31	0	0.0	51	7	13.7	43	3	7.0
Nov 94	138	7	5.1	153	8	5.2	199	7	3.5
Jan 95	116	10	8.6	171	15	8.8	148	4	2.7
Feb 95	39	4	10.3	64	2	3.1	105	2	1.9
Apr 95	40	11	27.5	82	25	30.5	49	2	4.1
May 95	32	9	28.1	88	11	12.5	39	5	12.8
Jun 95	48	9	18.8	304	25	8.2	125	11	8.8
Jul 95	413	37	9.0	582	46	7.9	163	7	4.3
Aug 95	199	25	12.6	284	31	10.9	77	7	9.1
Sep 95	120	9	7.5	333	20	6.0	26	2	7.7
Oct 95	38	1	2.6	198	17	8.6	137	11	8.0

Table 2.8 - Frequency of gastroliths; Ligurian Sea, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Nov 93	10	0	0.0	76	4	5.3	14	0	0.0
Feb 94	6	1	16.7	308	33	10.7	121	13	10.7
Mar 94	0	0		172	26	15.1	181	19	10.5
May 94	8	0	0.0	28	5	17.9	51	2	3.9
Jun 94	0	0		169	13	7.7	308	2	0.7
Sep 94	0	0		107	4	3.7	66	1	1.5
Oct 94	31	0	0.0	53	1	1.9	19	1	5.3
Nov 94	137	1	0.7	188	2	1.1	45	0	0.0
Jan 95	131	9	6.9	187	10	5.4	27	0	0.0
Feb 95	31	2	6.5	55	4	7.3	21	0	0.0
Apr 95	59	15	25.4	87	24	27.6	34	6	17.7
May 95	40	8	20.0	95	10	10.5	31	2	6.5
Jun 95	47	8	17.0	285	28	9.8	103	6	5.8
Jul 95	432	55	12.7	624	43	6.9	120	0	0.0
Aug 95	204	28	13.7	257	12	4.7	29	0	0.0
Sep 95	177	12	6.8	311	16	5.1	46	1	2.2
Oct 95	41	1	2.4	256	14	5.5	43	0	0.0

Table 2.9 -Frequency of gastroliths; Catalan Sea, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	8	1	12.5	60	1	1.7	38	1	2.6
Nov 93	55	8	14.6	570	47	8.3	255	6	2.4
Dec 93	34	7	20.6	207	40	19.3	112	0	0.0
Jan 94	16	0	0.0	114	11	9.7	79	0	0.0
Feb 94	74	8	10.8	346	20	5.8	76	2	2.6
Mar 94	11	2	18.2	127	12	9.5	56	0	0.0
Apr 94	81	7	8.6	159	22	13.8	53	3	5.7
May 94	103	7	6.8	78	11	14.1	41	0	0.0
Jun 94	114	7	6.1	166	12	7.2	83	6	7.2
Jul 94	70	14	20.0	129	13	10.1	100	1	1.0
Aug 94	49	2	4.1	151	8	5.3	107	1	0.9
Sep 94	45	6	13.3	306	38	12.4	90	9	10.0
Oct 94	36	2	5.6	121	12	9.9	40	1	2.5
Nov 94	42	1	2.4	160	4	2.5	47	1	2.1
Dec 94	39	2	5.1	155	6	3.9	42	0	0.0
Jan 95	82	3	3.7	255	15	5.9	38	0	0.0
Feb 95	44	4	9.1	176	19	10.8	59	0	0.0
Mar 95	56	8	14.3	239	10	4.2	66	1	1.5
Apr 95	101	10	9.9	147	10	6.8	42	2	4.8
May 95	141	24	17.0	144	23	16.0	50	1	2.0
Jun 95	146	11	7.5	229	14	6.1	96	1	1.0
Jul 95	73	8	11.0	253	9	3.6	127	1	0.8
Aug 95	19	3	15.8	215	14	6.5	61	3	4.9
Sep 95	52	4	7.7	270	23	8.5	60	6	10.0
Oct 95	47	7	14.9	253	26	10.3	164	4	2.4

Table 2.10 - Frequency of gastroliths; Catalan Sea, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	11	0	0.0	77	0	0.0	3	0	0.0
Nov 93	60	0	0.0	569	0	0.0	26	0	0.0
Dec 93	58	15	25.9	195	47	24.1	10	1	10.0
Jan 94	37	4	10.8	109	12	11.0	5	0	0.0
Feb 94	82	7	8.5	416	23	5.5	56	8	14.3
Mar 94	26	1	3.9	211	23	10.9	44	7	15.9
Apr 94	84	20	23.8	274	21	7.7	41	1	2.4
May 94	87	8	9.2	93	8	8.6	23	1	4.4
Jun 94	126	10	7.9	232	6	2.6	48	0	0.0
Jul 94	88	12	13.6	171	12	7.0	25	1	4.0
Aug 94	58	0	0.0	155	1	0.7	24	1	4.2
Sep 94	73	9	12.3	290	27	9.3	4	0	0.0
Oct 94	46	0	0.0	172	8	4.7	1	0	0.0
Nov 94	41	0	0.0	131	6	4.6	2	0	0.0
Dec 94	59	2	3.4	178	5	2.8	2	0	0.0
Jan 95	133	7	5.3	260	19	7.3	2	0	0.0
Feb 95	56	9	16.1	181	22	12.2	15	2	13.3
Mar 95	83	15	18.1	375	40	10.7	33	8	24.2
Apr 95	126	14	11.1	230	19	8.3	37	1	2.7
May 95	178	30	16.9	152	17	11.2	43	1	2.3
Jun 95	206	15	7.3	311	10	3.2	70	3	4.3
Jul 95	101	18	17.8	228	3	1.3	42	3	7.1
Aug 95	32	1	3.1	178	6	3.4	6	0	0.0
Sep 95	62	3	4.8	244	3	1.2	4	0	0.0
Oct 95	70	8	11.4	233	7	3.0	46	0	0.0

Table 2.11 - Frequency of gastroliths; Alboran Sea, Males

	CL <25 mm			25≤CL<40mm			CL ≥40 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	1	0	0.0	155	14	9.0	0	0	
Nov 93	0	0		70	17	24.3	98	7	7.1
Dec 93	0	0		87	22	25.3	138	6	4.4
Jan 94	0	0		21	4	19.1	95	2	2.1
Feb 94	0	0		7	0	0.0	61	1	1.6
Mar 94	1	0	0.0	82	5	6.1	67	5	7.5
Apr 94	0	0		28	4	14.3	77	8	10.4
May 94	1	1	100.0	40	5	12.5	154	6	3.9
Jun 94	0	0		46	0	0.0	119	1	0.8
Jul 94	0	0		69	1	1.5	129	2	1.6
Aug 94	0	0		46	4	8.7	104	2	1.9
Oct 94	2	0	0.0	27	0	0.0	52	2	3.9
Nov 94	7	0	0.0	55	4	7.3	44	1	2.3
Dec 94	0	0		86	2	2.3	64	1	1.6
Jan 95	13	0	0.0	75	6	8.0	75	1	1.3
Feb 95	59	5	8.5	79	2	2.5	63	3	4.8
Mar 95	13	1	7.7	65	7	10.8	78	1	1.3
Apr 95	6	3	50.0	89	7	7.9	72	4	5.6
May 95	6	1	16.7	28	1	3.6	44	1	2.3
Jun 95	0	0		53	8	15.1	67	2	3.0
Aug 95	2	0	0.0	127	10	7.9	50	1	2.0
Sep 95	0	0		111	21	19.0	24	1	4.2
Oct 95	0	0		83	25	30.1	53	4	7.6

Table 2.12 - Frequency of gastroliths; Alboran Sea, Females

	CL <25 mm			25≤CL<40mm			CL ≥40 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Oct 93	1	0	0.0	249	0	0.0	0	0	
Nov 93	0	0		107	0	0.0	6	0	0.0
Dec 93	1	0	0.0	135	0	0.0	47	0	0.0
Jan 94	0	0		30	5	16.7	26	2	7.7
Feb 94	0	0		145	28	19.3	102	33	32.4
Mar 94	1	0	0.0	113	17	15.0	40	10	25.0
Apr 94	0	0	0.0	80	8	10.0	90	7	7.8
May 94	0	0		50	2	4.0	112	1	0.9
Jun 94	1	0	0.0	56	1	1.8	160	0	0.0
Jul 94	1	0	0.0	110	1	0.9	92	0	0.0
Aug 94	1	0	0.0	60	2	3.3	74	0	0.0
Oct 94	1	0	0.0	62	0	0.0	35	0	0.0
Nov 94	14	2	14.3	65	8	12.3	19	0	0.0
Dec 94	0	0		105	8	7.6	8	0	0.0
Jan 95	9	2	22.2	133	8	6.0	26	0	0.0
Feb 95	75	5	6.7	91	5	5.5	25	2	8.0
Mar 95	20	6	30.0	62	9	14.5	29	8	27.6
Apr 95	4	2	50.0	102	13	12.8	54	10	18.5
May 95	5	0	0.0	44	1	2.3	76	0	0.0
Jun 95	1	0	0.0	76	11	14.5	72	1	1.4
Aug 95	2	0	0.0	174	8	4.6	27	1	3.7
Sep 95	0	0		154	9	5.8	10	0	0.0
Oct 95	0	0		103	12	11.7	2	0	0.0

Table 2.13 - Frequency of gastroliths and "soft" specimens; Atlantic, Males

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Nov 93	6	0	0.0	20	0	0.0	41	1	2.4
Dec 93	1	0	0.0	17	1	5.9	20	0	0.0
Jan 94	0	0		24	0	0.0	42	1	2.4
Feb 94	0	0		29	0	0.0	43	2	4.7
Mar 94	1	1	100.0	21	8	38.1	53	2	3.8
Apr 94	3	0	0.0	14	1	7.1	44	3	6.8
May 94	2	0	0.0	9	0	0.0	48	10	20.8
Jun 94	5	0	0.0	11	1	9.1	44	9	20.5
Jul 94	1	0	0.0	20	2	10.0	45	3	6.7
Aug 94	1	0	0.0	13	0	0.0	39	0	0.0
Sep 94	3	0	0.0	21	0	0.0	49	0	0.0
Nov 94	0	0		32	2	6.3	64	8	12.5
Dec 94	0	0		10	0	0.0	45	3	6.7
Jan 95	0	0		2	0	0.0	36	1	2.8
Mar 95	0	0		1	0	0.0	44	5	11.4
Apr 95	2	0	0.0	12	0	0.0	45	1	2.2
May 95	1	0	0.0	15	3	20.0	48	2	4.2
Jun 95	5	1	20.0	19	1	5.3	51	7	13.7
Jul 95	1	0	0.0	25	6	24.0	43	5	11.6

Table 2.14 - Frequency of gastroliths and "soft" specimens; Atlantic, Females

	CL <25 mm			25≤CL<35 mm			CL ≥35 mm		
Month	Total examined	With gastrolith	%	Total examined	With gastrolith	%	Total examined	With gastrolith	%
Nov 93	7	0	0.0	24	0	0.0	18	0	0.0
Dec 93	1	0	0.0	19	0	0.0	4	0	0.0
Jan 94	2	0	0.0	25	0	0.0	17	0	0.0
Feb 94	3	0	0.0	25	0	0.0	11	1	9.1
Mar 94	1	1	100.0	31	11	35.5	24	12	50.0
Apr 94	1	0	0.0	24	5	20.8	23	2	8.7
May 94	2	0	0.0	21	4	19.1	25	6	24.0
Jun 94	5	0	0.0	33	1	3.0	26	1	3.9
Jul 94	3	0	0.0	34	1	2.9	34	0	0.0
Aug 94	0	0		27	3	11.1	24	0	0.0
Sep 94	1	0	0.0	37	1	2.7	20	0	0.0
Nov 94	2	1	50.0	47	5	10.6	34	1	2.9
Dec 94	0	0		12	0	0.0	21	0	0.0
Jan 95	0	0		15	1	6.7	23	0	0.0
Mar 95	0	0		14	6	42.9	23	11	47.8
Apr 95	3	0	0.0	28	7	25.0	28	8	28.6
May 95	2	0	0.0	43	3	7.0	35	5	14.3
Jun 95	5	0	0.0	37	2	5.4	39	3	7.7
Jul 95	3	1	33.3	24	2	8.3	32	1	3.1

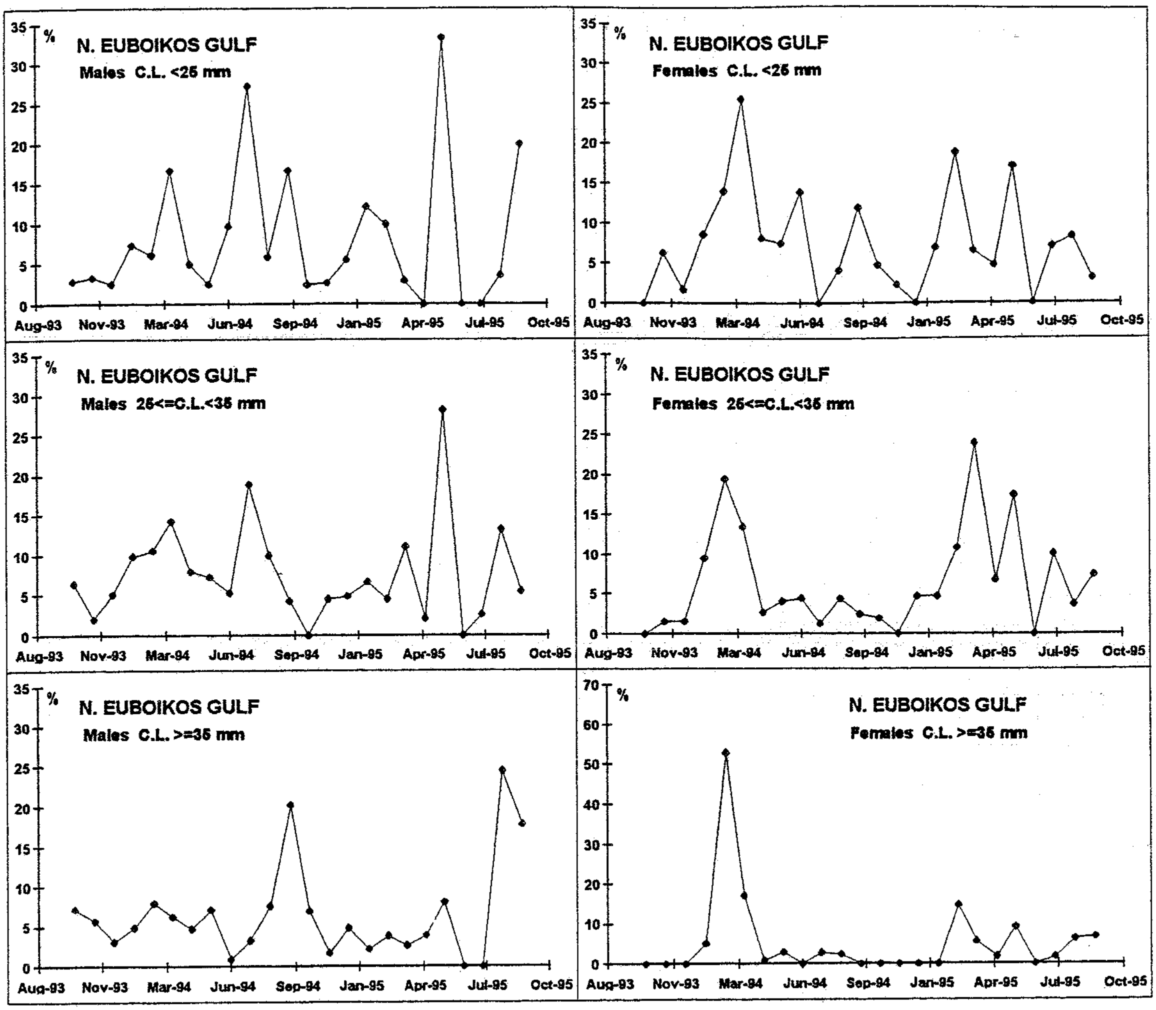


Fig. 2.1 - N. Euboikos Gulf; frequency of gastroliths per sex and size

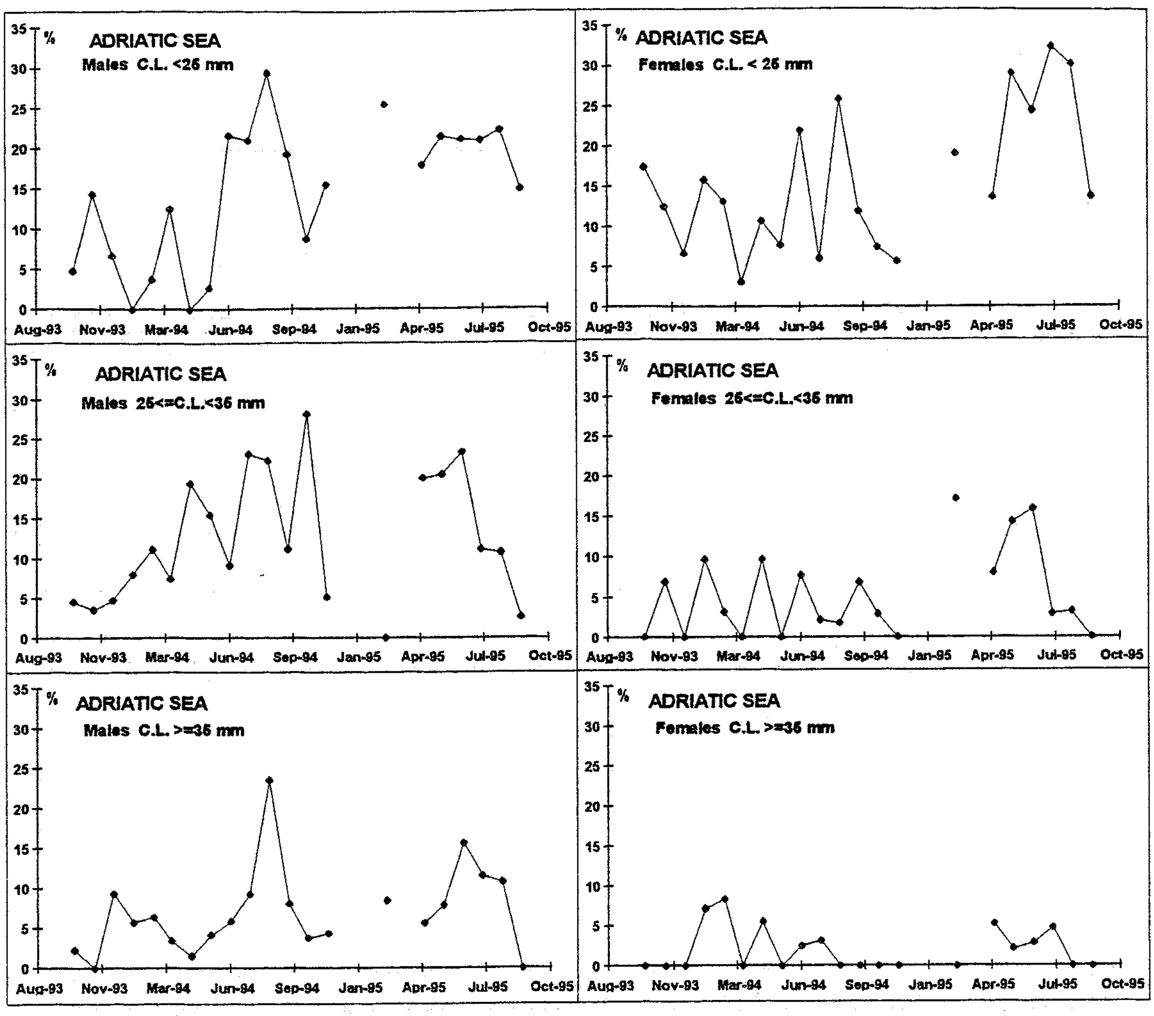


Fig. 2.2 - C. Adriatic Sea; frequency of gastroliths per sex and size group

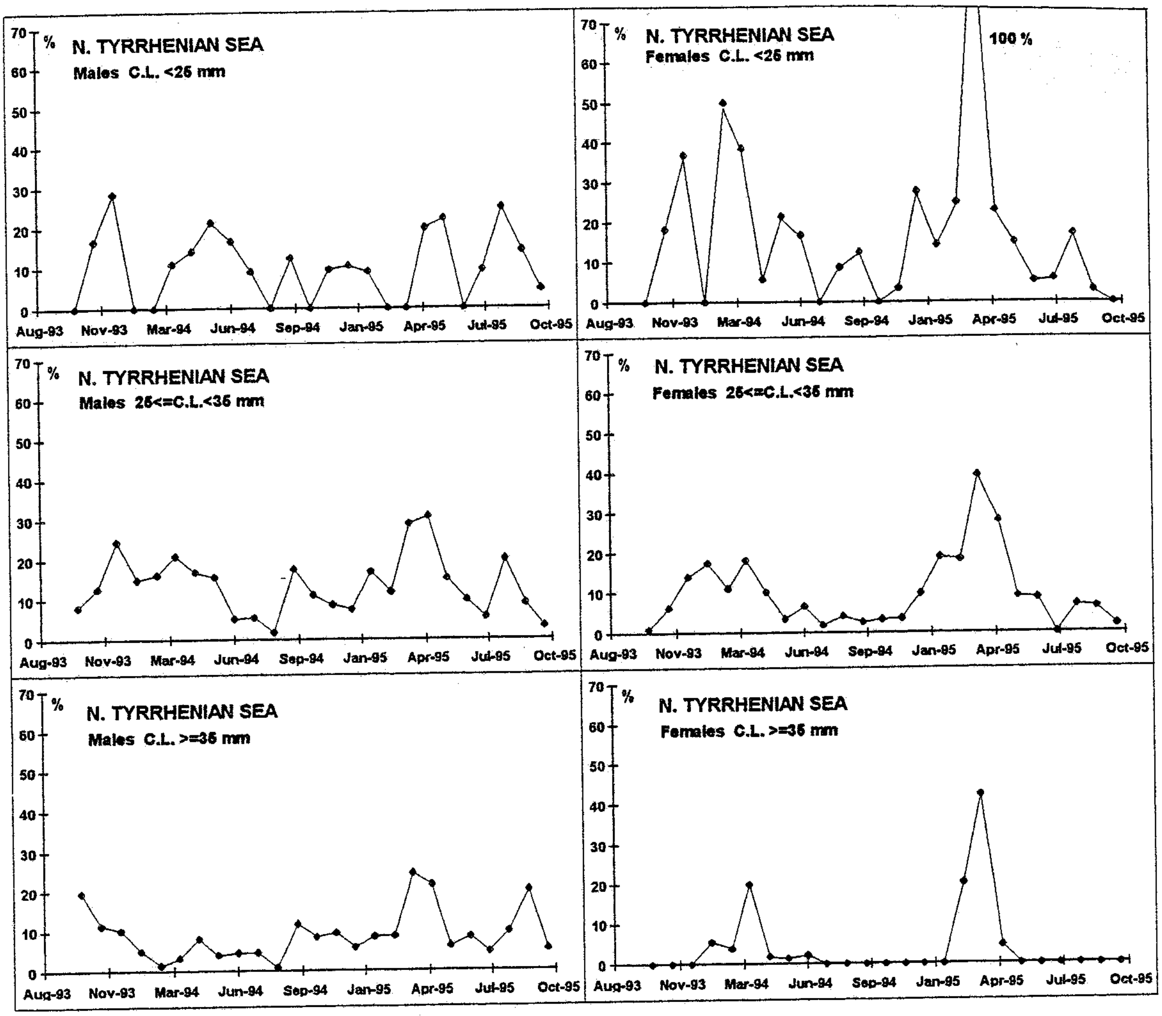


Fig. 2.3 - N. Tyrrhenian Sea; frequency of gastroliths per sex and size group

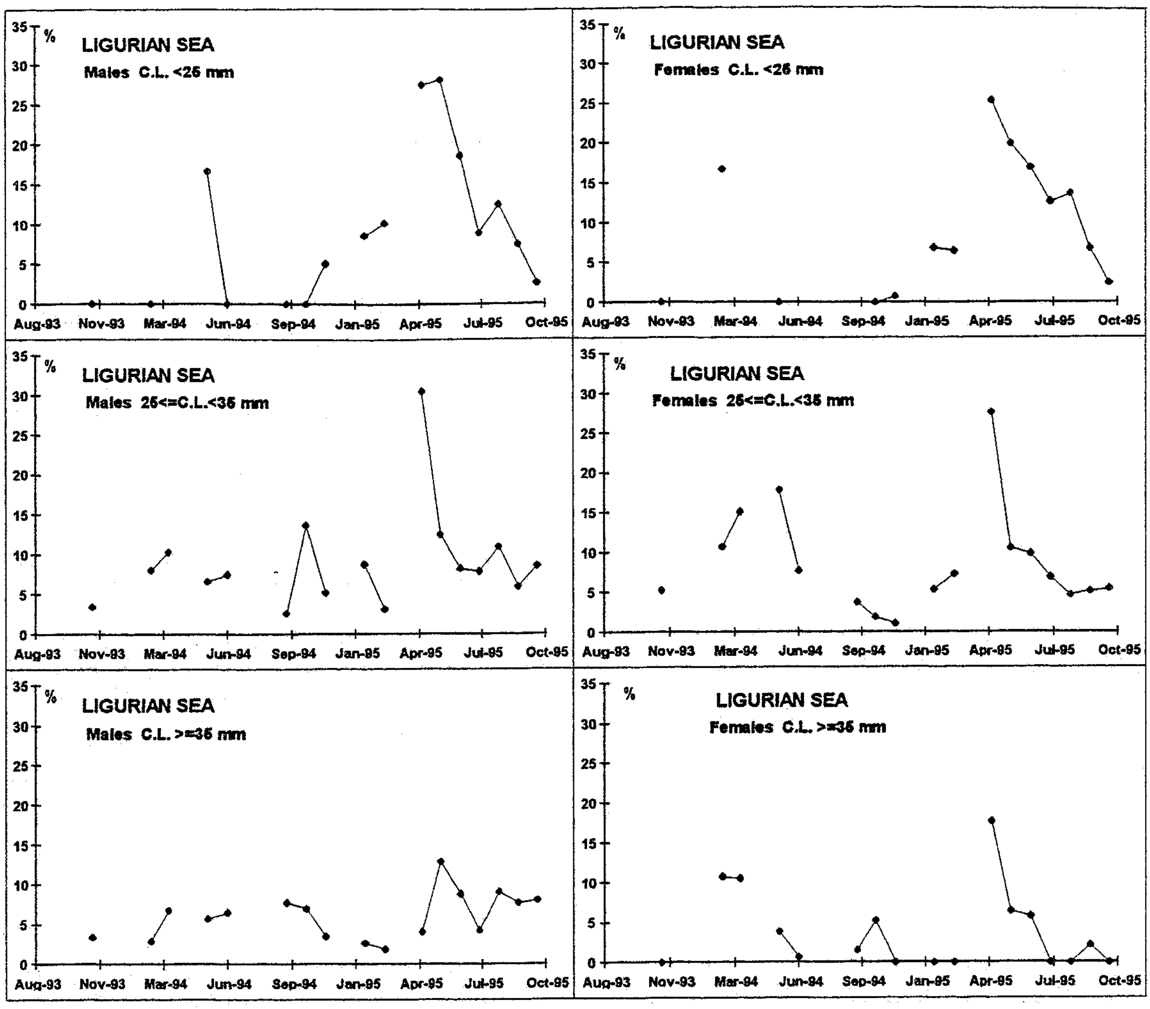


Fig. 2.4 - Ligurian Sea; frequency of gastroliths per sex and size group

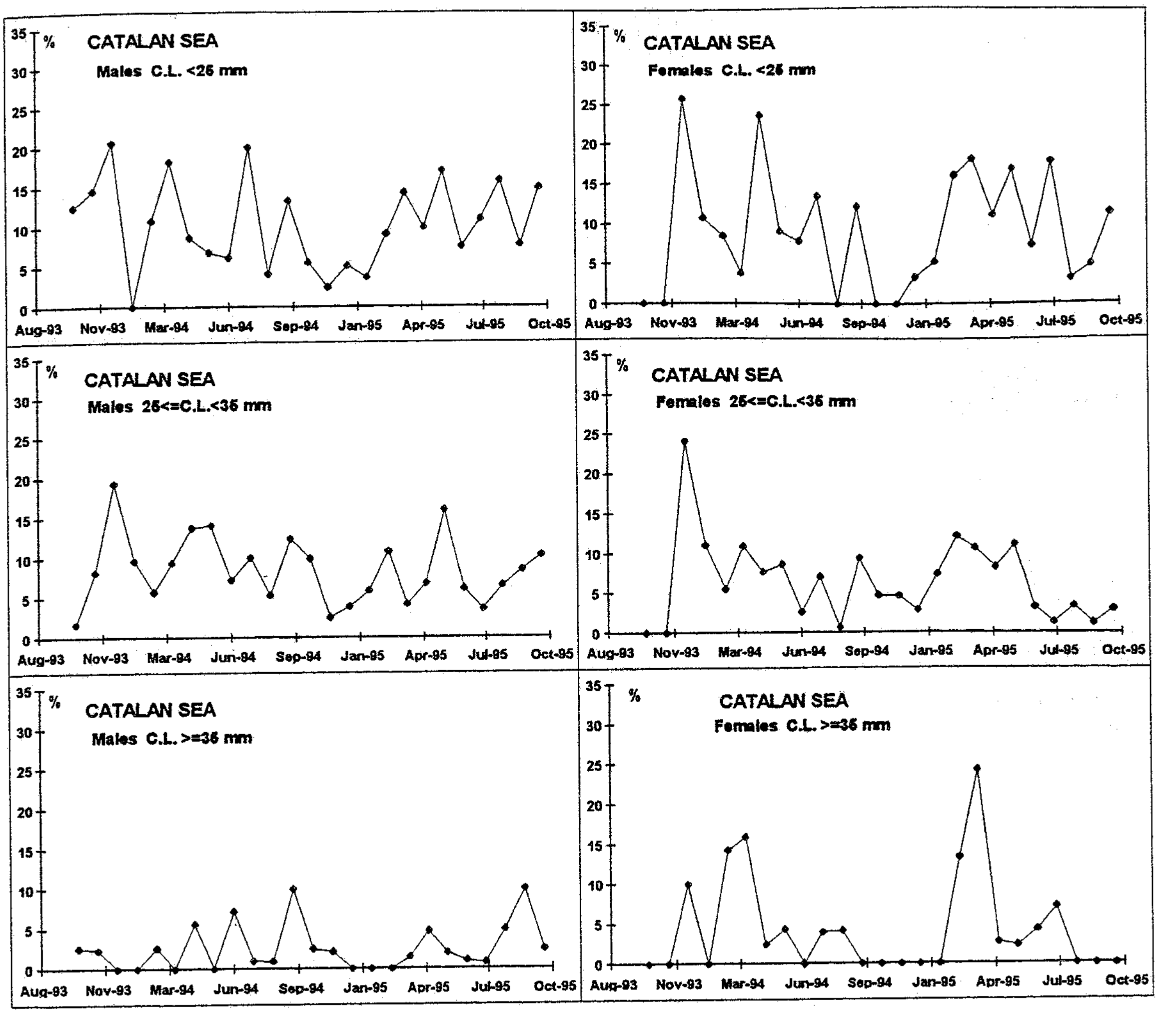


Fig. 2.5 - Catalan Sea; frequency of gastroliths per sex and size group

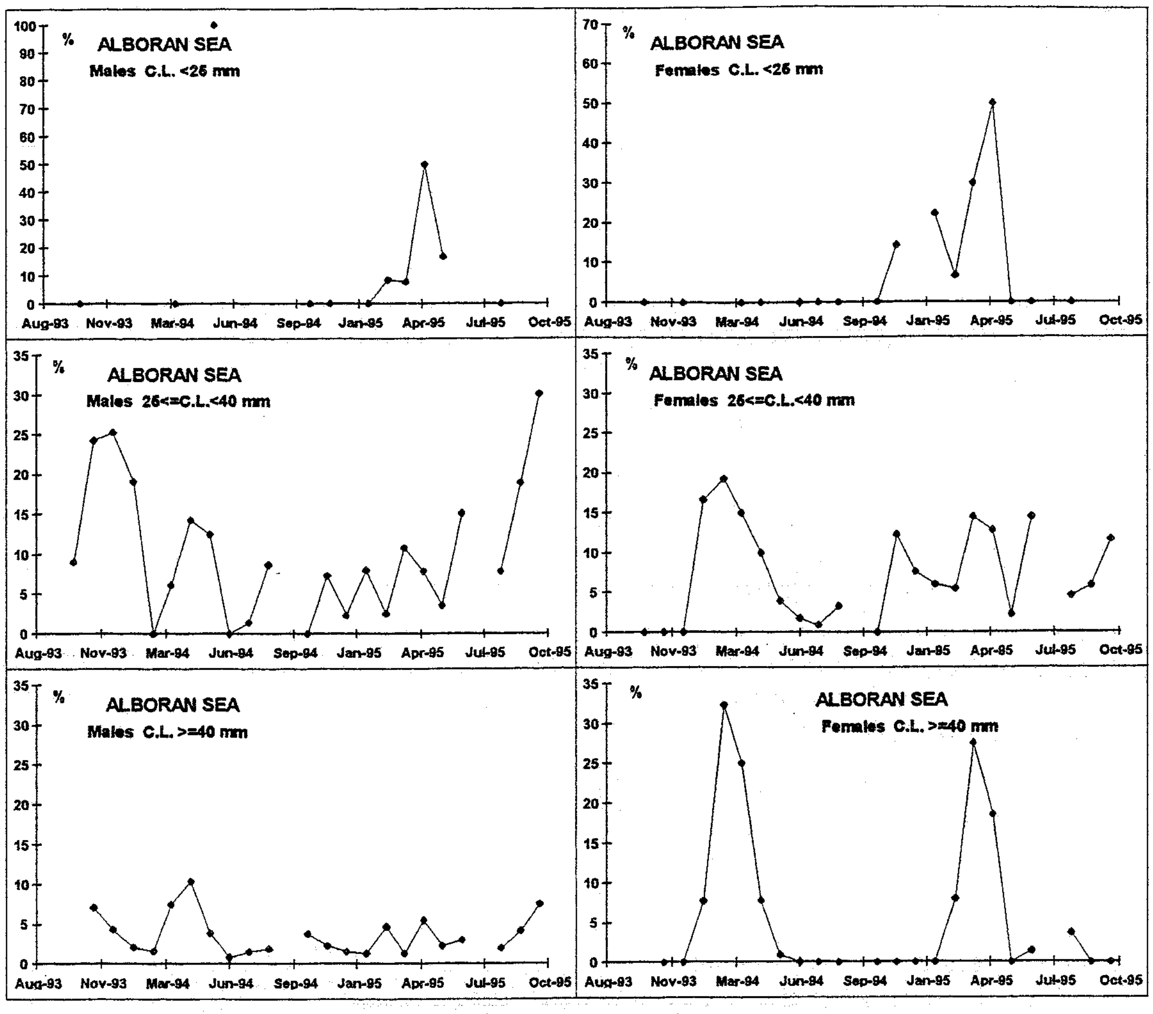


Fig. 2.6 - Alboran Sea; frequency of gastroliths per sex and size group

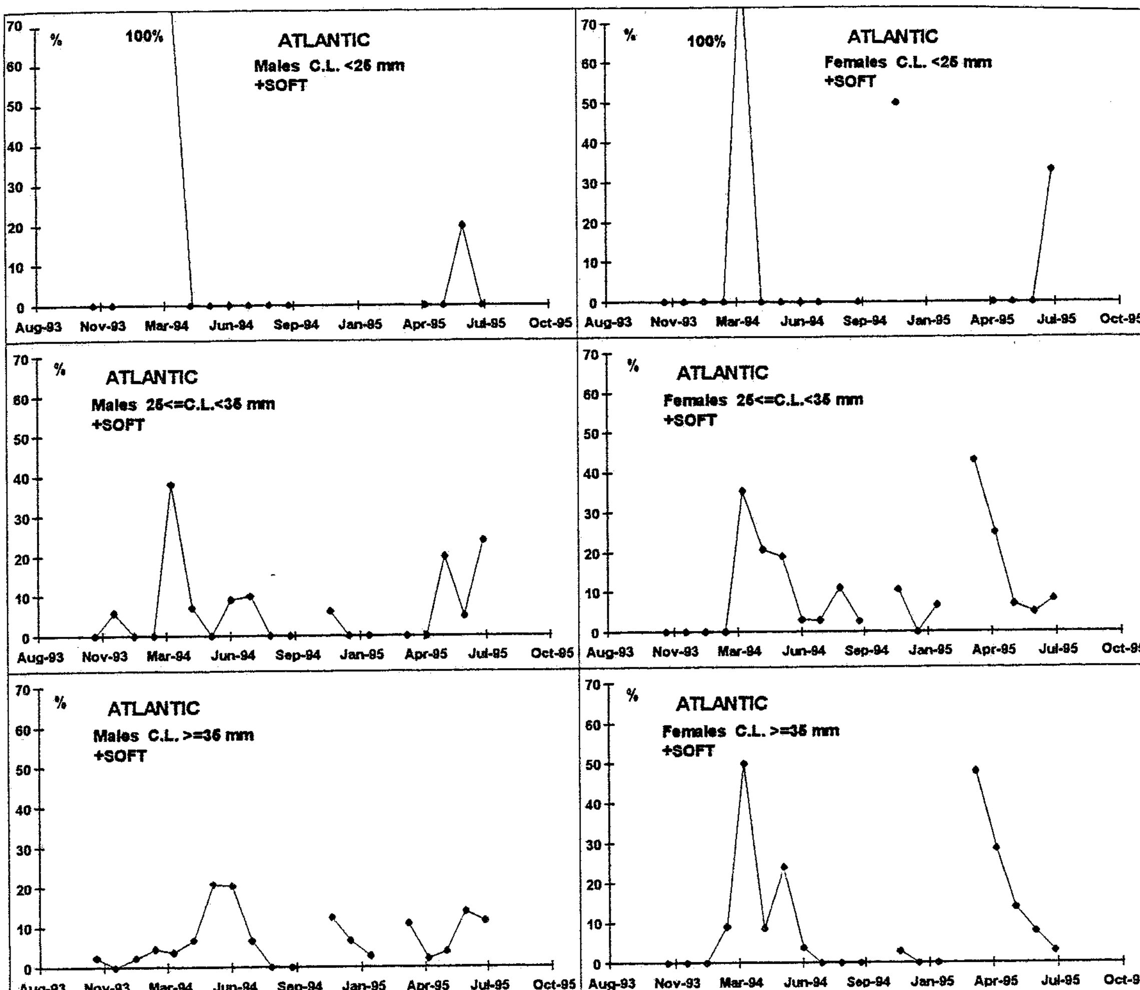


Fig. 2.7 - Atlantic; frequency of gastroliths per sex and size group

REPRODUCTION

INTRODUCTION

The E.C. funded research NEMED promoted in 1993, the study of the reproductive biology of Norway lobsters in seven mediterranean areas: five of these had slope population(s) (Algarve, Alboran, Catalan, Ligurian and Tyrrhenian Seas), one had a neritic population (Middle Adriatic) and the last (Euboikos Gulf) a mixed population i.e. Norway lobsters were found both at neritic and bathyal levels. The latitudinal range was about 8° between the Southern (Alboran) and the Northern area (Ligurian); the longitudinal range was about 31° from the Western (Algarve) to the Eastern area (Euboikos Gulf).
For a comparative assessment of the reproductive patterns in the areas under study, the following subjects have been considered:
a) timing of ovarian maturation;
b) female maturity at length ogive;
c) presence during the year of berried females;
d) size range of berried females and reproductive effort;
e) fecundity.

MATERIALS AND METHODS

From October 1993 to September 1995 (October 1995 in some areas) each operative units involved NEMED Programme collected monthly samples to obtain biological data. The total size of these samples had to be at least 150 males and 150 females. Unfortunately this amount was not always reached for *Nephrops* paucity in some areas or in some year periods. Sometime it was impossible to have regular samples all around the year for rough sea, trawler unavaliability, etc.

Specimens were measured as carapace length (CL) at the inferior millimeter and sex was identified. Females were dissected dorsally and the colour of the ovary was used to assign a maturative stage according to the following scale:
Stage I- white - juvenile or adult not developed;
stage II- cream - at beginning of maturation;
stage III- pale green - intermediate stages of ovoverdins storage;
stage IV- dark green - near to the extrusion on pleopods.

To facilitate the stage evaluation, a reference table with colour prints was prepared and circulated among the operative units.

The presence of eggs on the pleopods was annotated. For comparisons of fecundity among areas, females sized between 30 and 35 mm CL were fixed in formalin and their recently extruded eggs (totally green in coulor) counted.

For identification of the maturative period, the ratio between number of females at stage IV and total number of females larger than the minimum size at stage IV, was calculated monthly.

Estimates of female maturity at ogive were made according to two different approaches:

1) the use of proportions of stage IV females at each size in the month of highest mature females occurrence;
2) the use of proportions of stage III and IV females plus berried at each size in the month of highest mature occurrence plus the two following ones, considering only 1995 samples.

The calculation of the ogive curves was performed according to the linearized method described by Sparre *et al.* (1989).
In each area the breeding period was identified considering the ratio between number of berried females and number of females larger than the minimum berried size for each month.

The cumulative percentage frequency of berried females at each size was calculated to allow comparison of size ranges of berried females of different areas.
The relationship between fecundity and size was expressed by means of linear regressions, calculated for the size range 25-35 mm CL.

To have an idea of the relationship between such relative fecundity and terminal (i.e. near hatching) fecundity, also power functions derived in two areas have been reported.

RESULTS

a) Timing of ovarian maturation
During two years, the maturative stages of the sampled population(s) have been counted each month. As detailed before, a four point scale has been used, corresponding to the storage of ovoverdins; however, as the stages form a continuum and some bias are possible due to personal interpretations, to present the final results we prefer to focalize on the dark green stage which represents the end of maturation processes.
The presence of mature females (as percentage of dark green ovaries in respect of total adult females) in temporal sequence is presented in figs. 1 to 7.

October 1993-October 1995 Stage IV/adult female

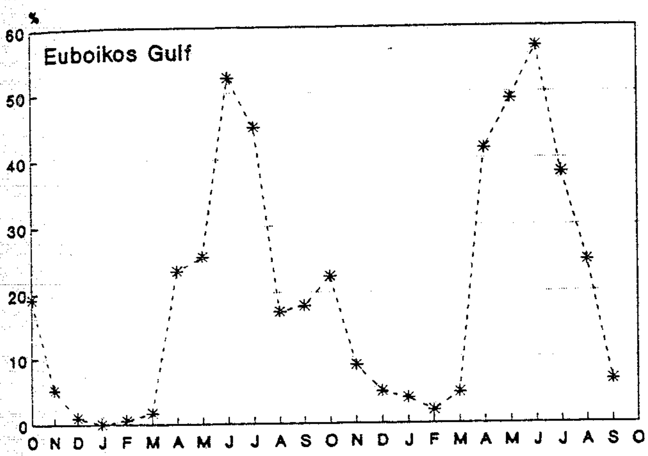


Fig. 1

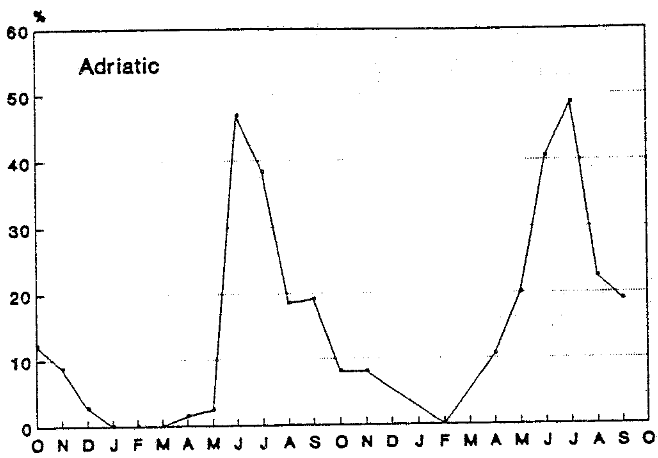


Fig. 2

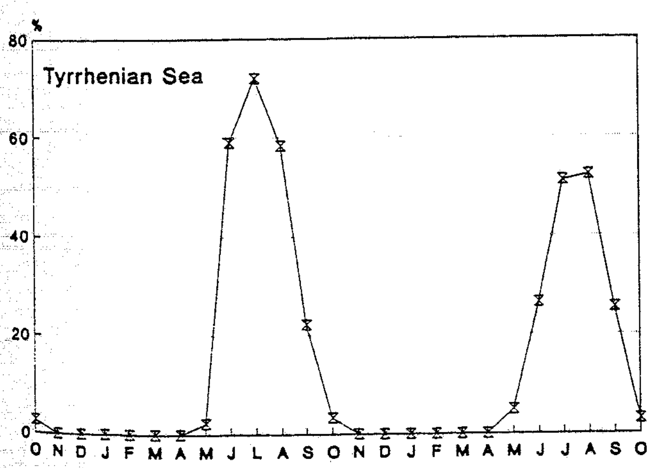


Fig. 3

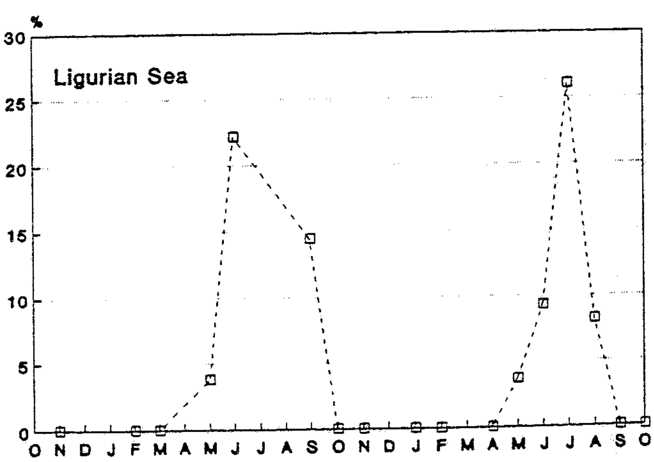


Fig. 4

The following patterns deserve attention:

1) the seasonality of reproduction. The timing is a little advanced in Algarve, Alboran, Cataluna, Adriatic, Greece in respect of Ligurian and Tyrrhenian area.

2) The lasting of reproduction (in terms of advanced maturation): six months for Cataluna, Ligurian and Tyrrhenian, a longer time for the remaining 4 areas.

In spite of little local variations, the general synchronization of these reproductive aspects is clear (fig. 8) and can probably be considered characteristic of the studied latitudinal range. In fact at northern latitudes the reproduction is delayed (Farmer, 1975).

The percentages of mature females in consecutive years appear different (Alboran, Catalan Sea) or approximately similar (the remaining areas). The meaning of such difference is till now not clear.

October 1993-October 1995 Stage IV/adult female

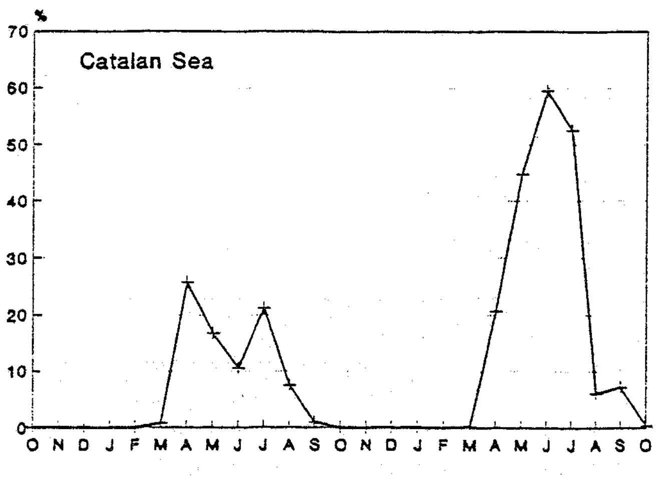


Fig. 5

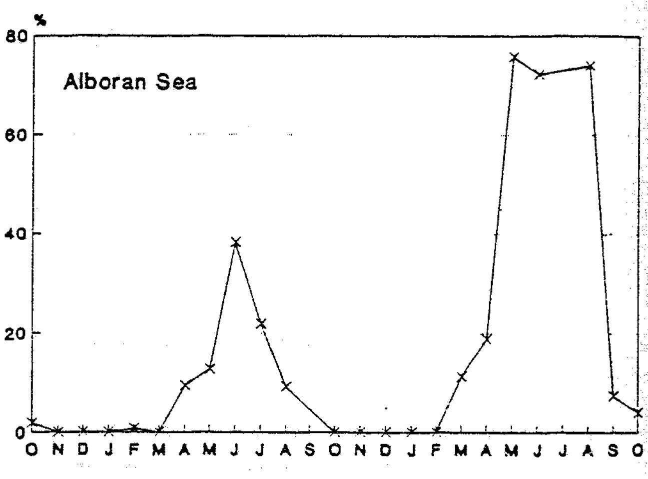


Fig. 6

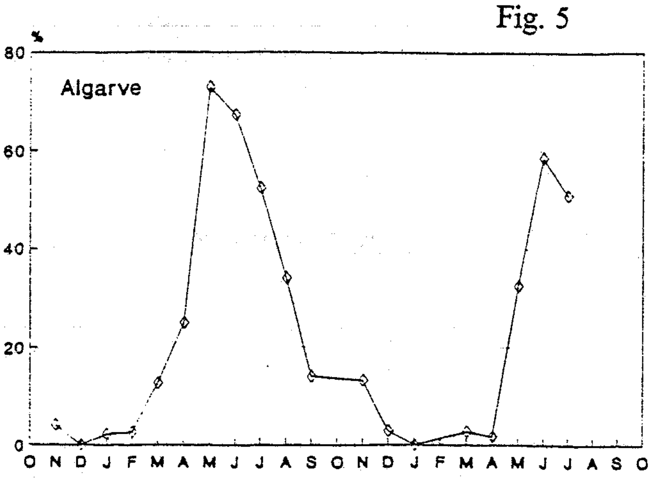
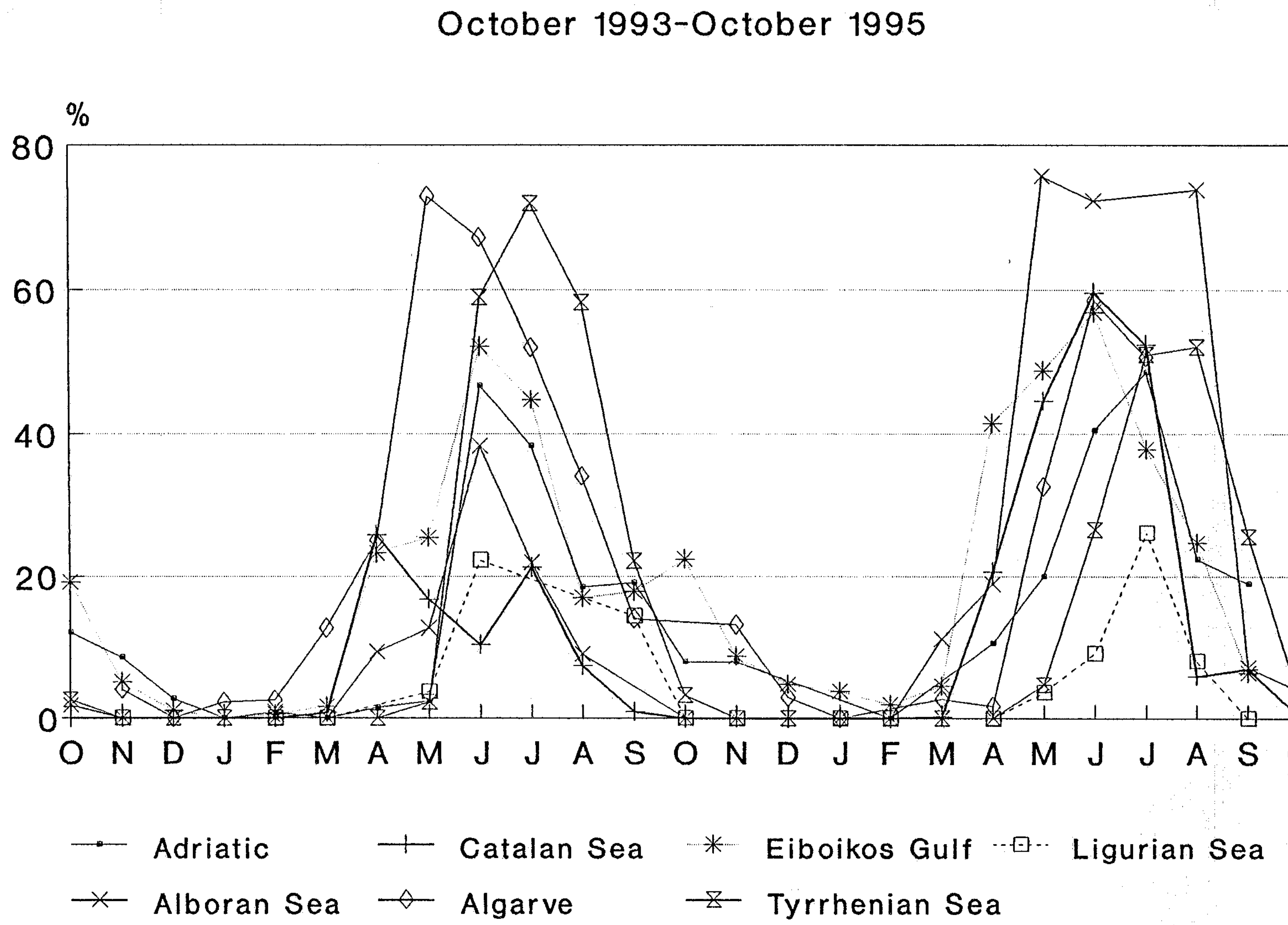


Fig. 7



mature females/adult females

Fig. 8

b) Female maturity at length ogives.

Minimum reproductive sizes (in terms of advanced ovarian maturation) registered in each area are shown in table 1.

Table 1 - Carapace length of smallest female with dark green gonads in each area.

AREA	C. L. (mm)
Adriatic Sea	25 mm
Alboran Sea	30 mm
Catalan Sea	24 mm
Algarve	25 mm
Euboikos Gulf	19 mm
Ligurian Sea	29 mm
Tyrrhenian Sea	27 mm

However these data have a limited value in demoecology.

Using the percentages of females in advanced maturation in respect of total adult females per size, maturation ogives were calculated. Several trials were effected, among which:

a) 1 month data (month of maximum occurrence of mature females in each area).
b) sum of three months: month of maximum occurrence plus two following months.

The set of raw data of case a) is shown in figs. 9 to 15. When possible, the maturation ogive has been calculated according Sparre *et al.* (1989).
The curve is:

$$\% \text{ of mature females} = \frac{1}{1 + e^{[s_1 - (s_2 C.L.\ )]}}$$

The parameters derived from case a) are shown in table 2.

Table 2 - Maturation ogive parameters obtained using the IV stage females (dark green) collected during the month of maximum occurrence.

AREA	Maximum occurrence months	L_{50}	s_1	s_2
Algarve	May 1994	-	-	-
Alboran Sea	May 1995	-	-	-
Catalan Sea	June 1995	29.10	12.6726	0.4356
Ligurian Sea	July 1995	38.00	13.1100	0.3449
Tyrrhenian Sea	July 1995	31.70	19.3172	0.6094
Adriatic Sea	July 1994	35.75	5.9709	0.1670
Euboikos Gulf	June 1994	-	-	-

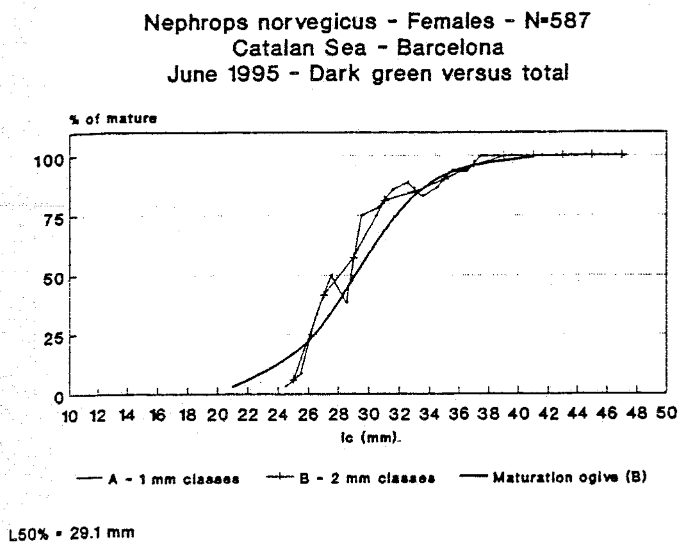


Fig. 9

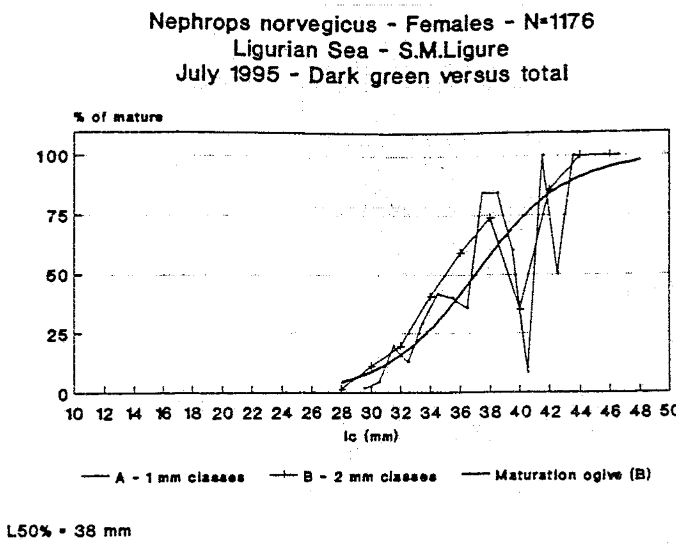


Fig. 10

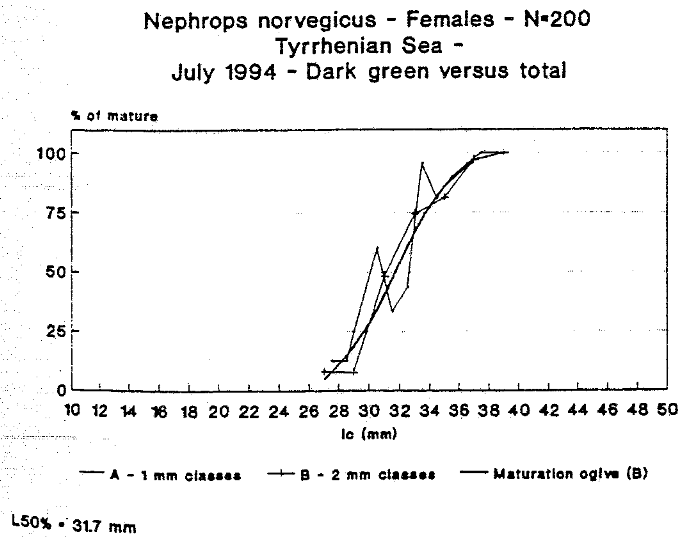


Fig. 11

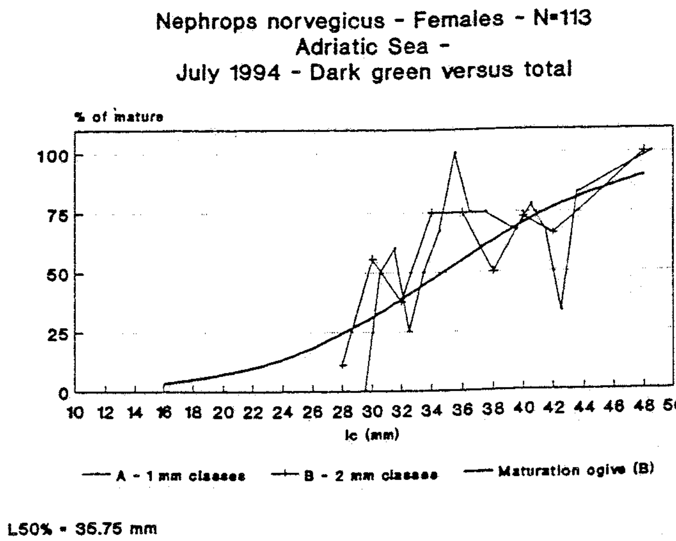
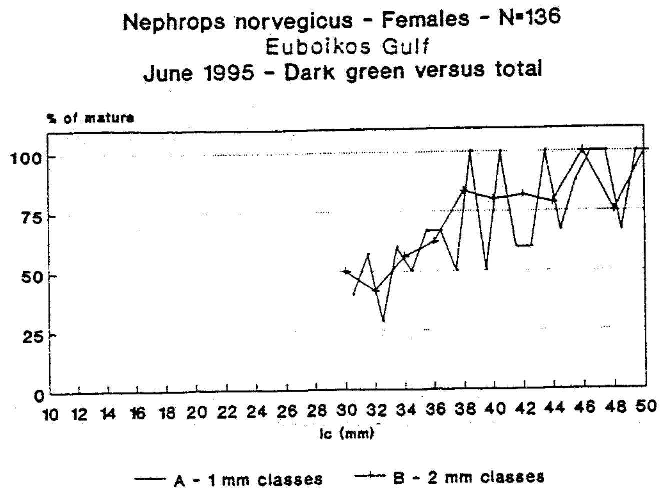
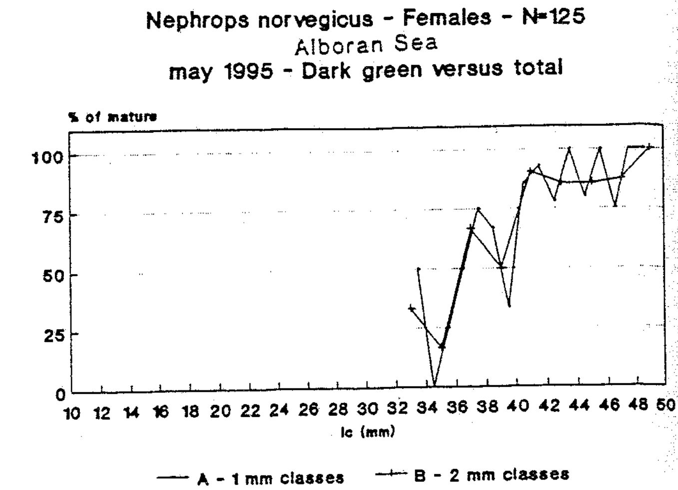


Fig. 12



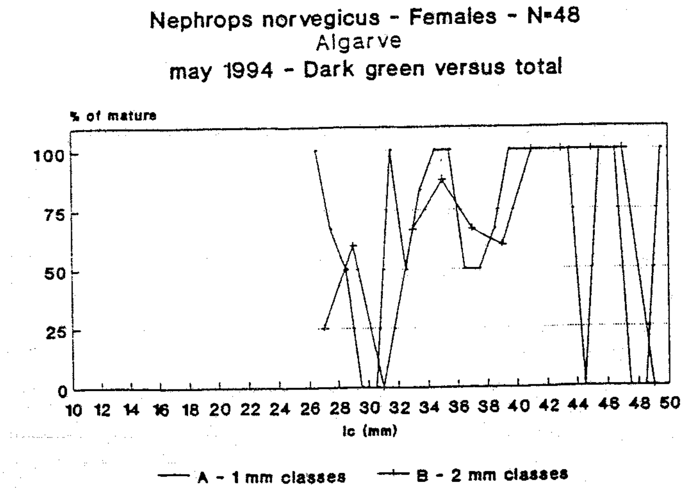
L50% = mm

Fig. 13



L50% = mm

Fig. 14



L50% = mm

Fig. 15

From case b (fig. 16 raw data) the following curves were derived (fig. 17 and table 3).

Table 3 - Maturation ogive parameters obtained using the III (light green) and IV (dark green) stages plus berried females collected during a three months period (the maximum of occurence and the following two months).

AREA	Period	L_{50}	s_1	s_2
Algarve	May,June,July 1995	29.4	10.4279	0.3551
Alboran Sea	May, June, August 1995	36.0	32.8042	0.9109
Catalan Sea	June, July, August 1995	29.9	20.2081	0.6767
Ligurian Sea	July, August, September 1995	32.1	23.3594	0.7269
Tyrrhenian Sea	July, August, September 1995	31.6	20.1200	0.6362
Adriatic Sea	July, August, September 1995	29.5	24.8890	0.8442
Euboikos Gulf	July, August, September 1995	33.2	15.8838	0.4788

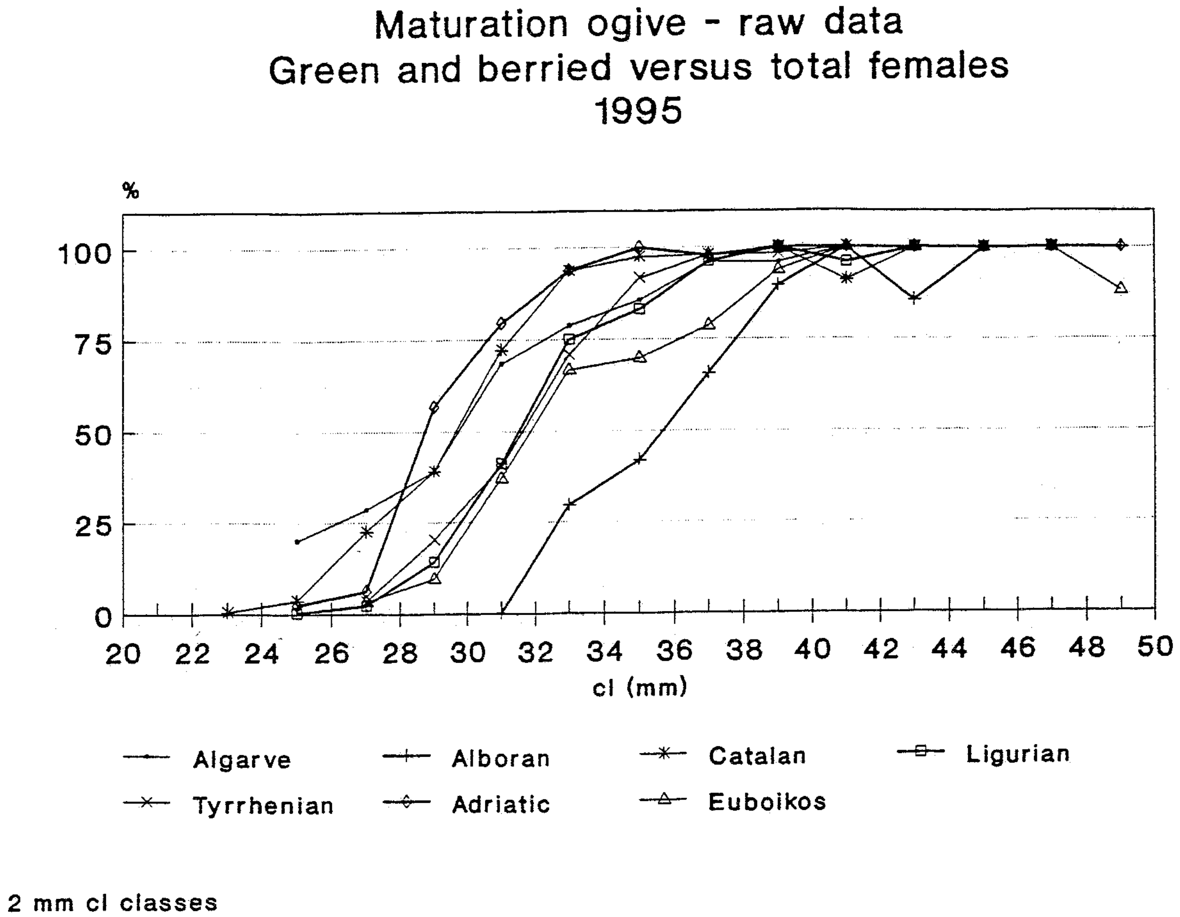

Maturation ogive - raw data
Green and berried versus total females
1995
%
100
75
50
25
0
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
cl (mm)
Algarve
Alboran
Catalan
Ligurian
Tyrrhenian
Adriatic
Euboikos
2 mm cl classes

Fig. 16

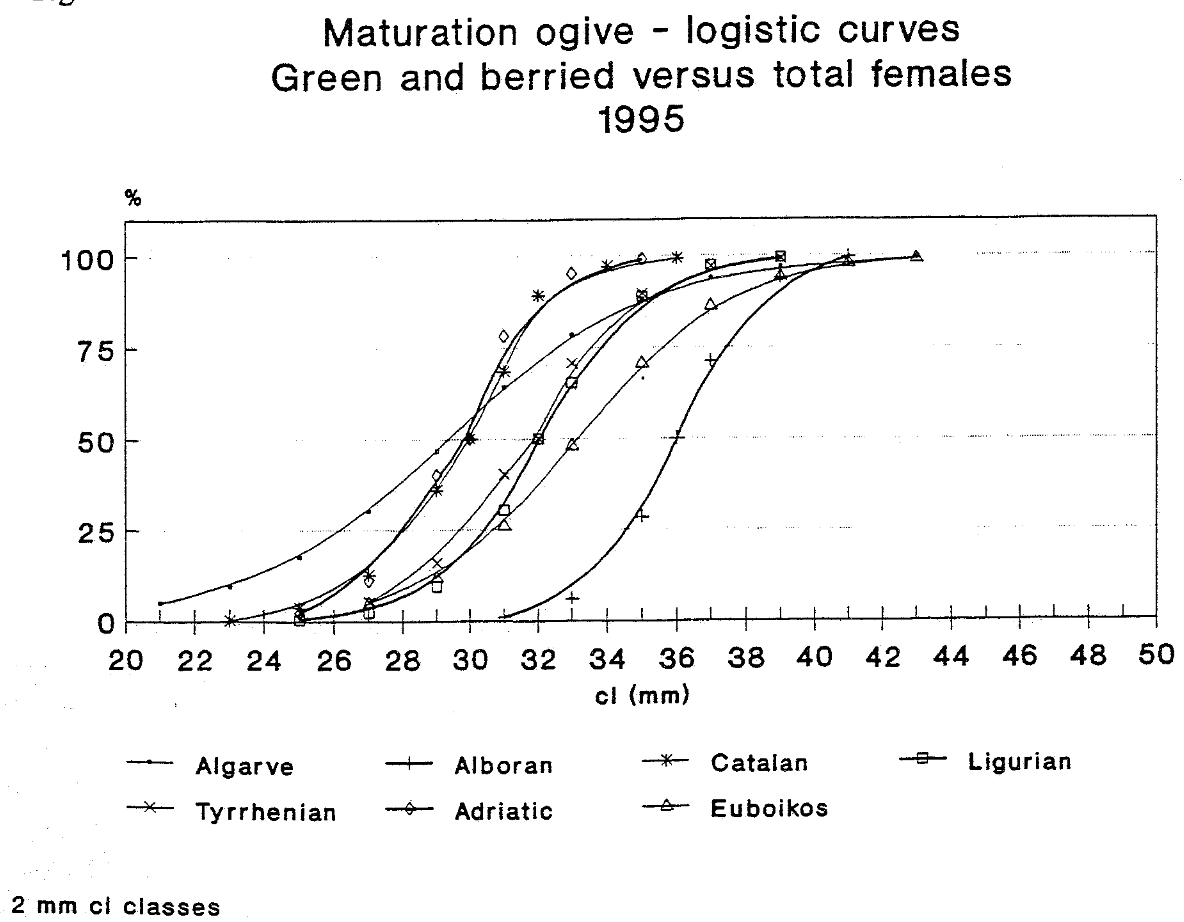

Maturation ogive - logistic curves
Green and berried versus total females
1995
%
100
75
50
25
0
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
cl (mm)
Algarve
Alboran
Catalan
Ligurian
Tyrrhenian
Adriatic
Euboikos
2 mm cl classes

Fig. 17

c) Presence during the year of berried females

Minimum sizes of berried females per area are shown in table 4.

Table 4 - Carapace length of smallest berried female in each area.

AREA	C. l. (mm)
Adriatic Sea	24 mm
Alboran Sea	30 mm
Catalan Sea	27 mm
Algarve	24 mm
Euboikos Gulf	23 mm
Ligurian Sea	27 mm
Tyrrhenian Sea	27 mm

These minimun sizes have been used as reference point to separate potentially berried females in each area. Percentages of berried females on total potentially berried females per month are illustrated in figs. 18 to 24.

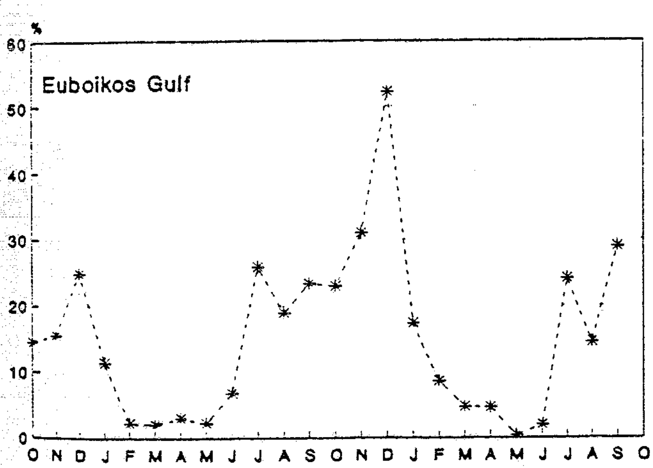


Fig. 18

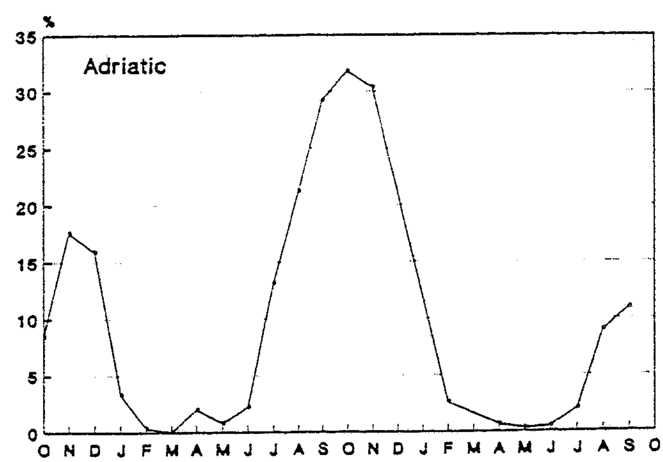


Fig. 19

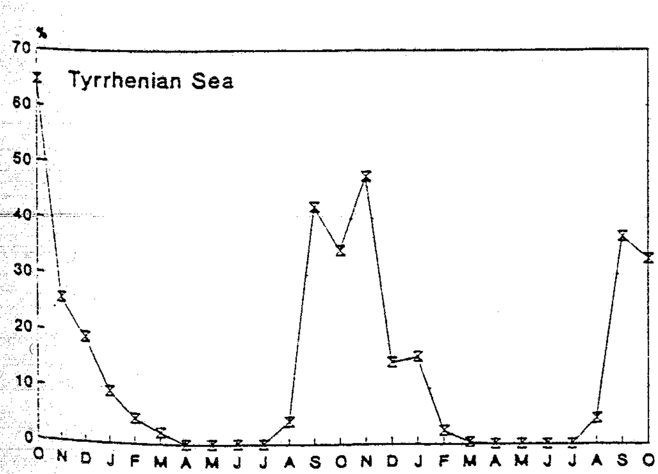


Fig. 20

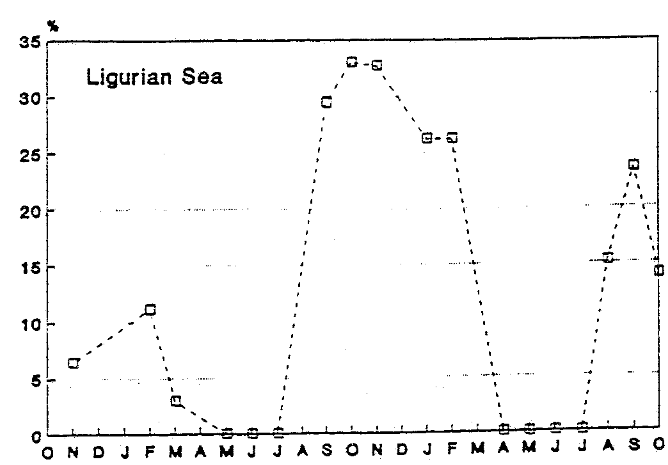


Fig. 21

October 1993-October 1995 Berried female/adult female

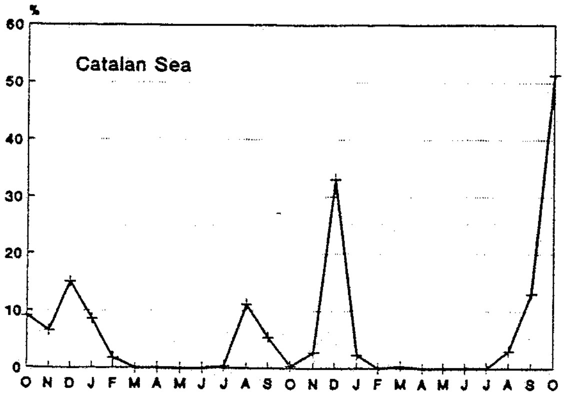


Fig. 22

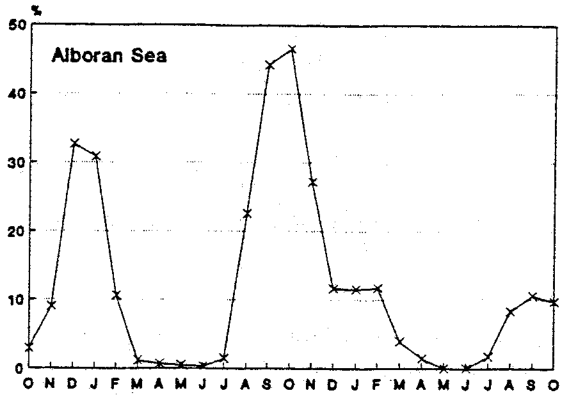


Fig. 23

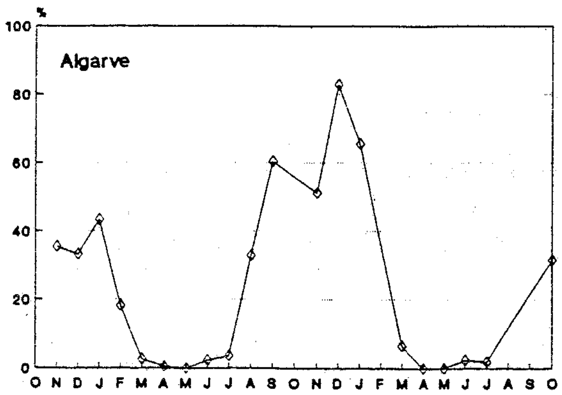
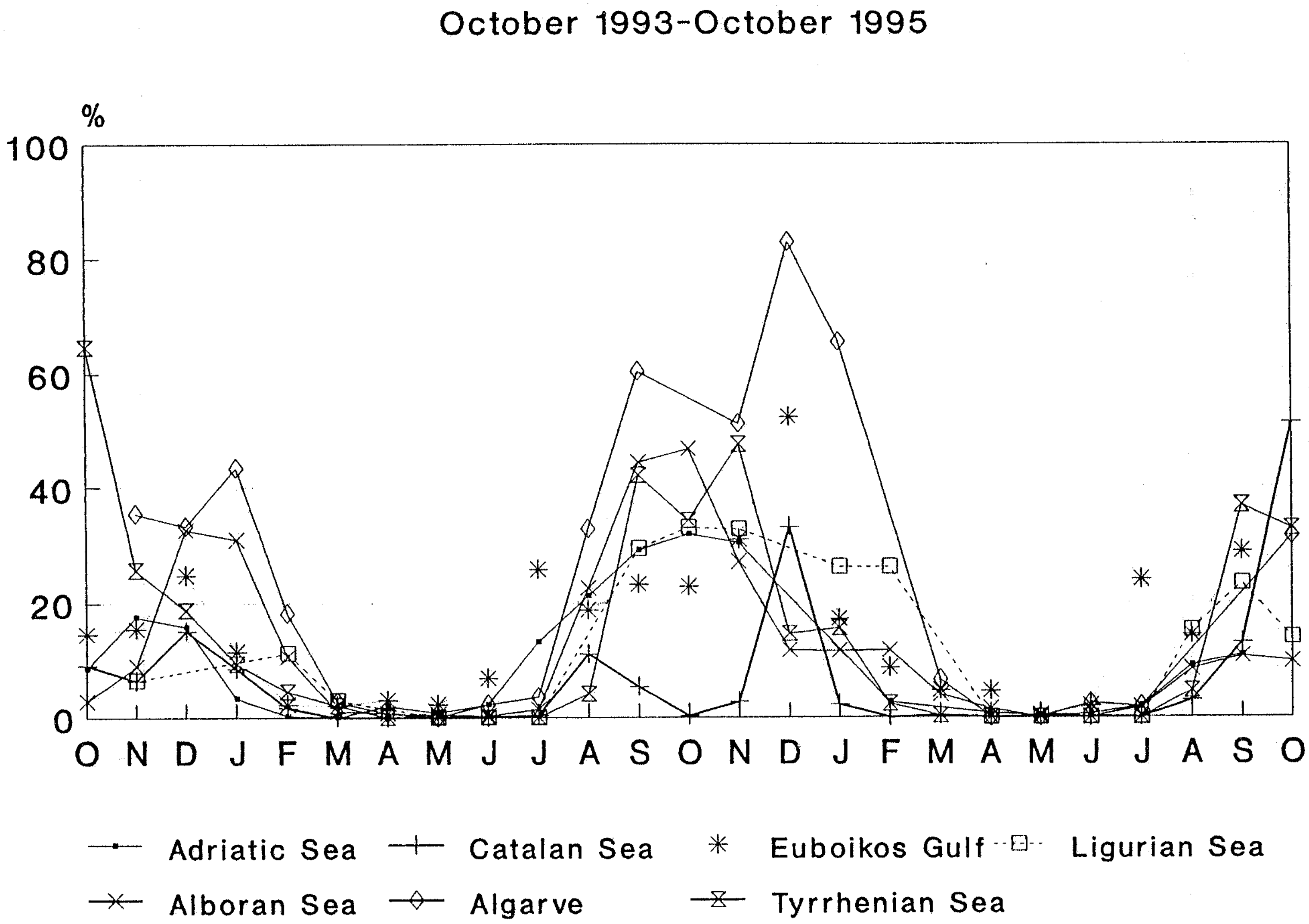


Fig. 24

The seasonal character of reproduction is confirmed also by this approach; the lasting of the presence of embryos on female pleopods is longer of the records of mature females. The delay between advanced maturation (dark green ovaries) and the presence of embryos seems about 3 months: the clearest results regard Catalan, Ligurian and Tyrrhenian Sea were advanced maturation starts in May and embryos are present from August onward (to February or March) and are absent from April to July.
This 4 months period in which no births are possible, plus some other months in which no advanced embryos were found, allows the reading of length frequency distributions for age. The overall patterns are summarised in fig. 25.



Berried females/adult females

Fig. 25

d) Size range of berried females and reproductive effort

An index of reproductive effort in different areas was obtained as cumulative frequency of berried females. Calculations were made according to the following routine:
berried females of the month of maximum occurrence plus the previous and the following months have been summed using all available data (1993+1994+1995) and transformed in percentage of berried / total berried females per size.
An example is shown in table 5.
The cumulative percentage per area are shown in fig. 26.
Reproduction is mainly effected by small females in Catalan and Adriatic areas, by very large females in Alboran and Euboikos Gulf, with intermediate situations in the others.
This datum in correlation with fecundity, is usefull to estimate the strength of reproduction in each area, it is necessary to introduce fecundity.

Table 5 - Calculation of berried cumulative length distribution for Euboikos Gulf.

	october 93		november 93		december 93		november 94		december 94		january 94						
C. L.	tot	B	tot	B	tot	B	tot	B	tot	B	tot	B	Total	Tot. B	Bcl/Btot.*100		C.L.
24	105	1	186	0	107	0	29	0	3	0	14	0	444	1	0,07675	0,07675	24
25	122	0	176	0	75	0	31	0	7	0	26	0	437	0	0	0,07675	25
26	122	0	220	0	109	0	28	0	13	1	32	0	524	1	0,07675	0,15349	26
27	112	1	222	0	87	0	24	0	10	0	27	0	482	1	0,07675	0,23024	27
28	169	0	218	0	101	0	28	0	31	3	24	1	571	4	0,30698	0,53722	28
29	159	1	184	0	80	0	43	1	27	3	22	2	515	7	0,53722	1,07444	29
30	165	0	150	1	73	2	21	0	41	9	33	3	483	15	1,15119	2,22563	30
31	93	0	117	4	72	3	33	3	37	11	38	9	390	30	2,30238	4,52801	31
32	80	4	92	20	80	11	21	3	30	18	30	5	333	61	4,6815	9,20952	32
33	56	8	70	11	67	15	16	8	20	10	37	6	266	58	4,45127	13,6608	33
34	46	18	52	14	53	24	13	7	24	16	17	2	205	81	6,21642	19,8772	34
35	38	8	55	25	45	17	16	11	28	21	18	5	200	87	6,6769	26,5541	35
36	26	17	53	33	54	17	21	14	19	17	8	3	181	101	7,75134	34,3054	36
37	35	24	45	25	48	27	26	18	17	12	10	4	181	110	8,44206	42,7475	37
38	35	18	21	16	44	30	18	12	18	16	5	2	141	94	7,21412	49,9616	38
39	37	22	36	23	29	23	8	6	10	10	9	3	129	87	6,6769	56,6385	39
40	32	17	23	16	29	29	20	17	15	13	7	4	126	96	7,36761	64,0061	40
41	39	26	28	15	28	28	8	3	12	11	6	2	121	85	6,52341	70,5295	41
42	22	16	14	14	25	25	11	8	7	7	3	1	82	71	5,44896	75,9785	42
43	16	14	13	13	15	9	7	5	6	6	4	2	61	49	3,76055	79,7391	43
44	14	7	9	5	15	15	9	5	2	2	1	0	50	34	2,60936	82,3484	44
45	16	12	43	29	25	14	6	4	8	7	2	2	100	68	5,21873	87,5672	45
46	10	4	34	20	12	9	4	2	9	9	4	3	73	47	3,60706	91,1742	46
47	7	1	11	11	11	8	6	4	2	1	4	2	41	27	2,07214	93,2464	47
48	20	5	15	4	4	4	8	5	1	1	1	0	49	19	1,45817	94,7045	48
49	0	0	8	3	3	3	3	3	1	1	4	4	19	14	1,07444	95,779	49
50	0	0	15	15	3	3	2	2	1	1	2	2	23	23	1,76516	97,5441	50
51	0	0	7	7	2	2	2	2	0	0			11	11	0,84421	98,3883	51
52	3	1	0	0	2	2			2	2			7	5	0,38373	98,7721	
53	0	0	3	3	3	0			0	0			6	3	0,23024	99,0023	
54	2	0	4	0	2	2			0	0			8	2	0,15349	99,1558	
55	0	0	3	3	5	2			2	2			10	7	0,53722	99,693	
56	0	0	0	0									0	0	0	99,693	
57	1	1	0	0									1	1	0,07675	99,7698	
58			3	3									3	3	0,23024	100	
59													0	0	0	100	
total	1582	226	2130	333	1308	324	462	143	403	210	388	67	6273	1303			

Table. 5.- Calculation of berried cumulative length distribution (Euboikos)

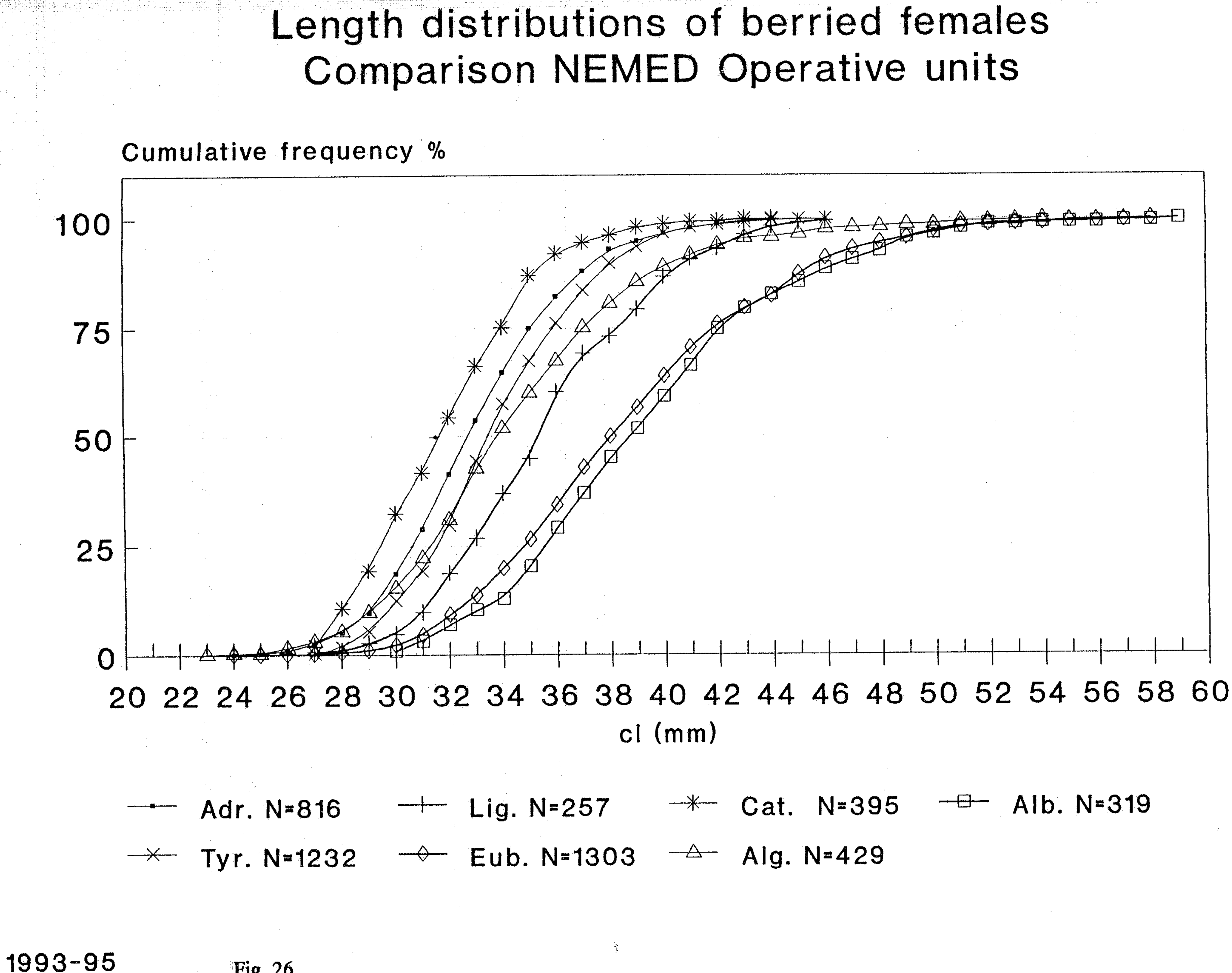

Length distributions of berried females
Comparison NEMED Operative units
Cumulative frequency %
100
75
50
25
0
20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
cl (mm)
Adr. N=816
Lig. N=257
Cat. N=395
Alb. N=319
Tyr. N=1232
Eub. N=1303
Alg. N=429
1993-95

Fig. 26

e) Fecundity

The aim of this study was to check possible differences among the areas, not to assess real fecundity. In fact several studies have established that during the long development of embryos there are losses which have been evaluated as a 10% per month or more. In the present study counts of embryos were made in an early stage of development (no visible eyes) and on females of a young size range (to 36 mm C.L).
Collected data evidence different relative fecundities per area, which can be compared by means of the regression lines of number of embryos per sizes (Fig. 27 to 33). According the above mentioned common procedure, the higher fecundity was registered in Algarve, the lower on the Catalan coast; Ligurian, Adriatic, Alboran, Greece and Tyrrhenian set of data were apparently very close each other (fig. 34).
However when the "b" figures were tested by the "t-test", a significant affinity was evidenced only between Euboikos Gulf and Tyrrhenian ($t=0.6917$; $p>0.05$). Therefore we consider that the calculation of a common function is of scarce significance. The different fecundity/ size relationships are reported in table 6.

Table - 6. Main statistical parameters of fecundity/size relationships ($F= a + b$ C.L.).
^ Including specimen larger than 36 mm C.L. * Non significative

Areas	a	b	N	r	s.e.a	s.e.b
Algarve	-3797.059	160.889	45	0.761	357.698	20.892
Alboran^	-5851.416	204.203	50	0.817	765.178	20.828
Catalan	-778.28	49.285	46	0.221*	------------	------------
Catalan^	-2852.615	113.464	50	0.553	511.614	24.660
Ligurian	-4998.149	188.247	19	0.653	275.772	52.919
Ligurian^	-7426.780	255.392	53	0.677	522.254	25.742
Tyrrhenian	-2061.939	94.654	46	0.411	298.544	31.658
Tyrrhenian^	-3311.398	132.270	50	0.620	342.859	24.14
Adriatic	-2862.498	120.791	54	0.627	253.793	20.803
Euboikos	-1752.364	90.117	52	0.507	209.091	21.656

Literature data on fecundity at an advanced stage of embryoogenesis (stage D according Figueiredo and Barraca, 1963) are available for Adriatic and Ligurian Sea (Gramitto and Froglia,1980; Orsi Relini and Relini,1989) and for an intermediate stage - stage C according Figueiredo and Barraca (1963) - in the Tyrrhenian (Biagi *et al.*, 1990). In the Adriatic fecundities obtained from embryos at an early stage of development (no visible eyes) are about double in respect of embryos near to hatching (Fig.35); in the Ligurian material (NEMED) a fecundity curve from early stage is now calculated with all available data for sake of comparison with a previous curve obtained from the hatching stage (fig. 35). In this case the loss is even more severe, especially for large sizes.
In conclusion the real fecundity seems at least half of that predicted by the above indicated functions (table 6).

The fecundity of Mediterranean Norway lobsters seems lower than that of the northern european populations (Farmer, 1975; Froglia and Gramitto , 1979); however here

Eggs/size relationship

Algarve - N = 45

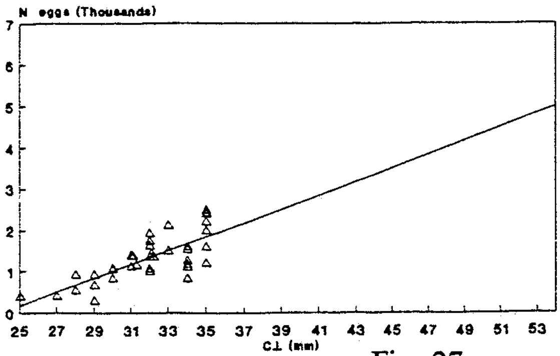


Fig. 27

Eggs/size relationship

Alboran Sea - N = 50

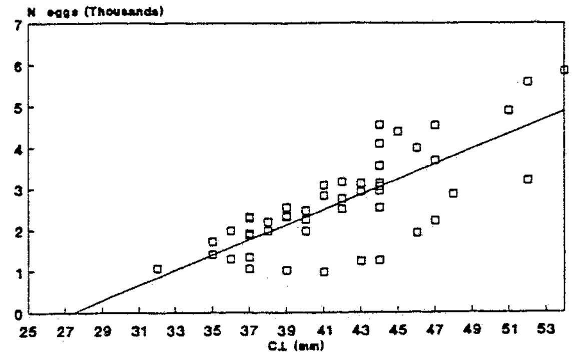


Fig. 28

Catalan Sea - N = 50

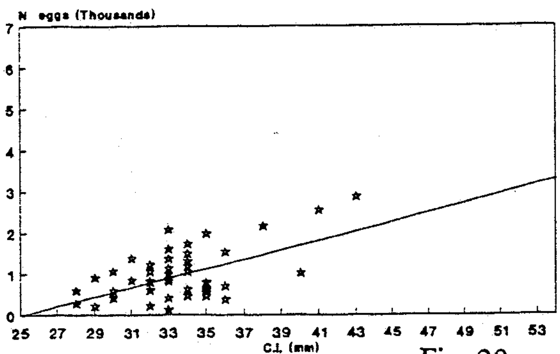


Fig. 29

Ligurian Sea - N = 53

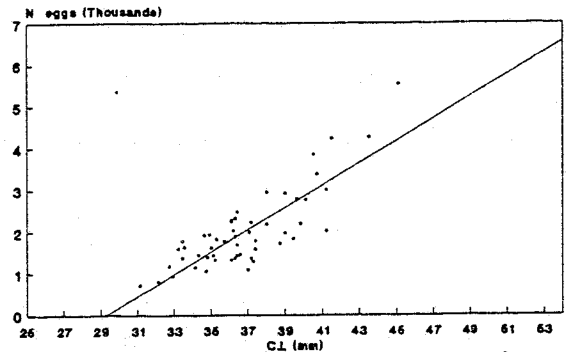


Fig. 30

Tyrrhenian Sea - N = 50

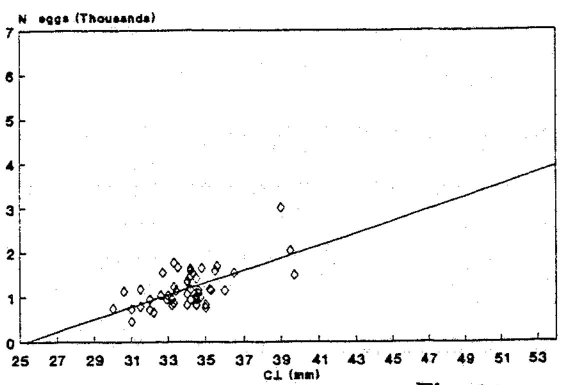


Fig. 31

Adriatic Sea - N = 54

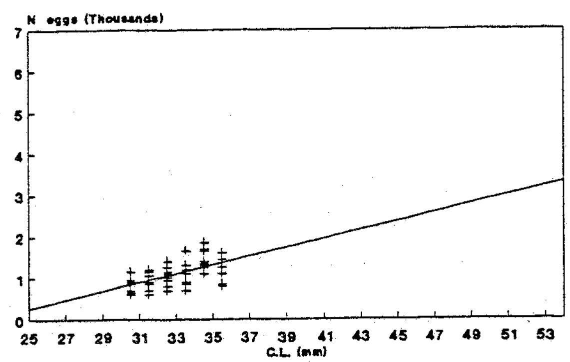


Fig. 32

Greece - N = 52

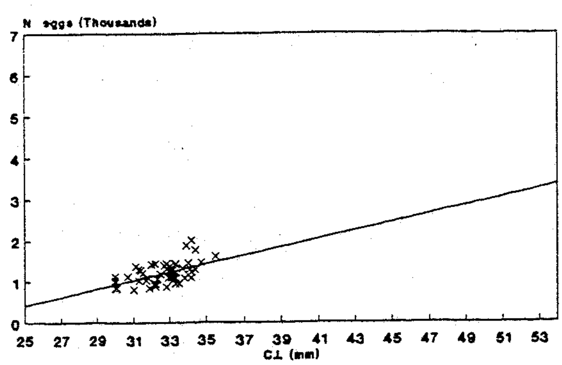


Fig. 33

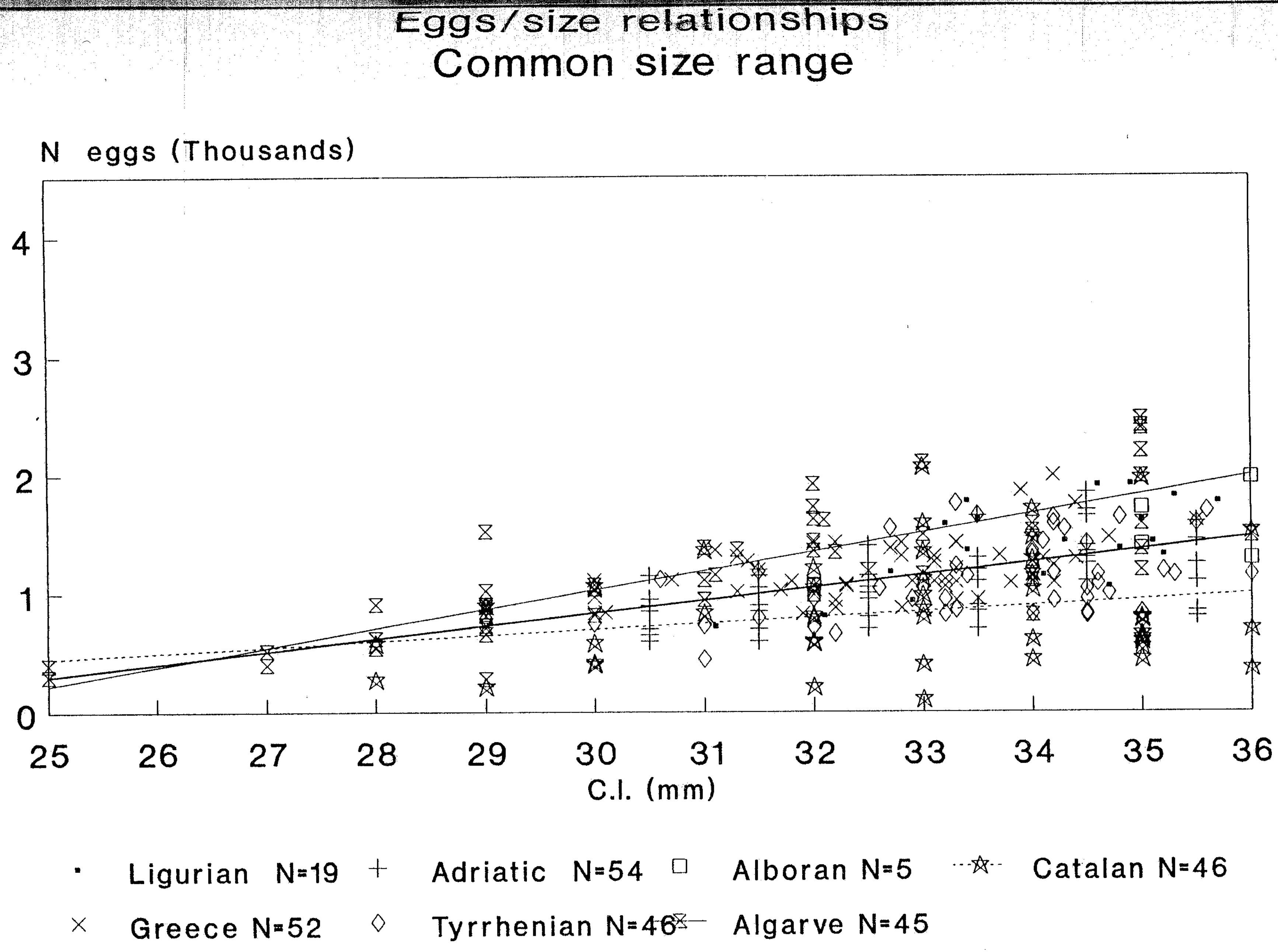

Eggs/size relationships
Common size range
N eggs (Thousands)
0
1
2
3
4
25
26
27
28
29
30
31
32
33
34
35
36
C.l. (mm)
Ligurian N=19
Adriatic N=54
Alboran N=5
Catalan N=46
Greece N=52
Tyrrhenian N=46
Algarve N=45

Fig. 34

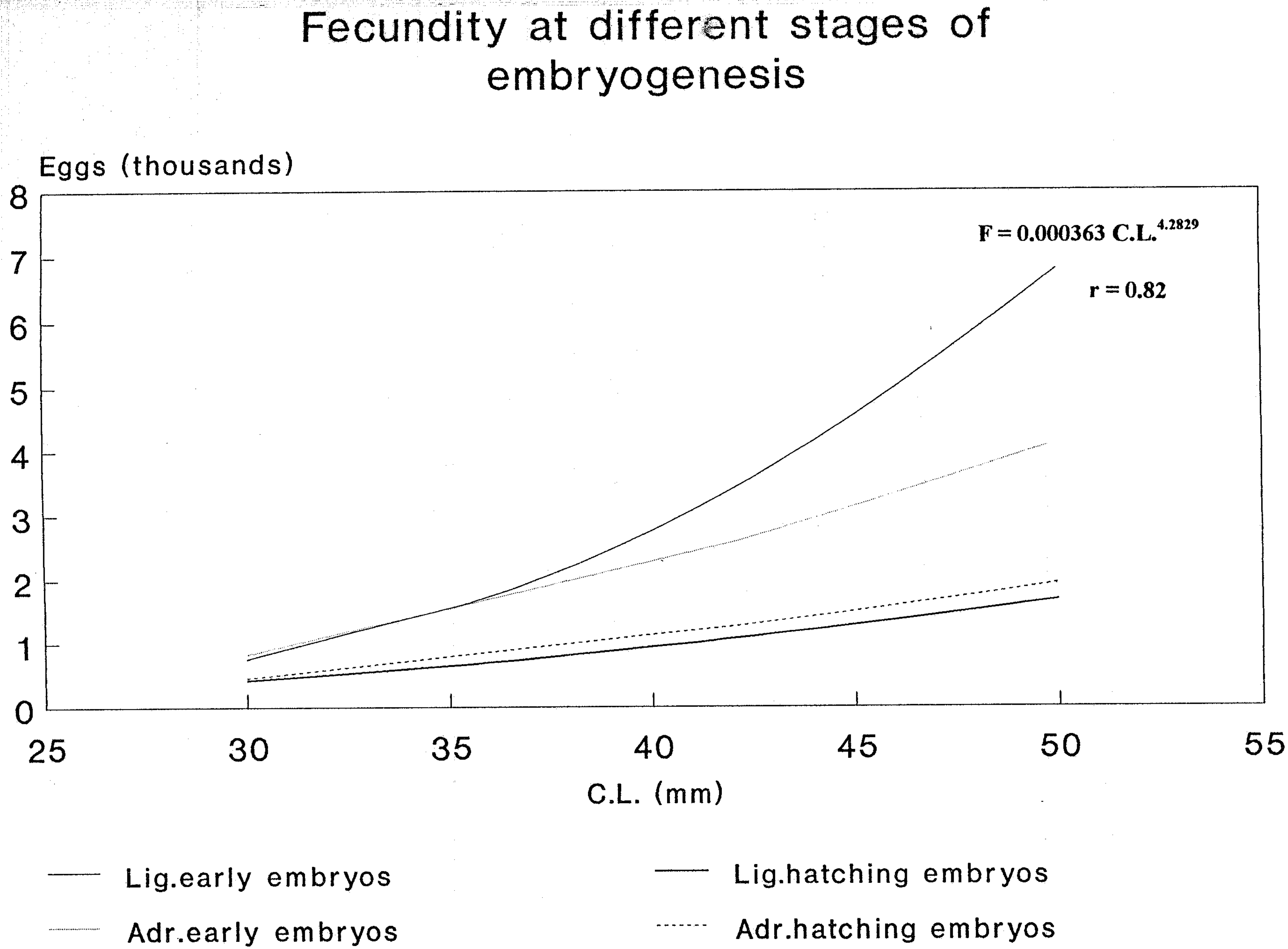

Fecundity at different stages of
embryogenesis
Eggs (thousands)
8
7
6
5
4
3
2
1
0
25
30
35
40
45
50
55
C.L. (mm)
F = 0.000363 C.L.4.2829
r = 0.82
Lig.early embryos
Adr.early embryos
Lig.hatching embryos
Adr.hatching embryos

Fig. 35

Algarve is distinguished from other areas, presenting a fecundity similar to the Irish Sea (Farmer, 1975).

DISCUSSION AND CONCLUSIONS

The NEMED programme has represented a good opportunity for a comparative study of reproduction in mediterranean Norway lobsters, although gaps exist, due to irregular sampling or to oversimplified working schemes because of economic constraints.
The study has excluded male reproduction and the trasmission of spermatophores, a subject not negligible at all. On the other hand, the programme includes a special chapter on moult, which is strictly related to reproduction.

According to the classification of Hartnoll (1985) the Norway lobster is characterized by indeterminate growth, in which laying occurs in each postpuberty instar. The timing of the basic processes of reproduction, i.e. maturation and laying of embryos on pleopods resulted almost synchronized in the studied areas; however at lower latitudes or in shallow waters a little advanced timing was noted. Ligth and temperature are the factors possibly involved: as temperature is lower in winter in shallow waters (Adriatic, Euboikos) and in Algarve in respect of the Mediterranean slope stations, we suppose that ligth is the main factor in causing an advanced maturation and spawning.

The sizes at maturity (50%) ranged between 29.4 and 36 mmCL with three patterns: Algarve, Catalan and Adriatic are very close each other with the smallest size; the intermediate size was found in Ligurian, Tyrrhenian and Euboikos Gulf ; and finally Alboran has a population composed by large females, with the larger maturity size. This complex picture suggest that local factors are involved, for instance the density of population, the food availability and so on.

The study of fecundity seem to present only one important difference: Algarve in respect of other areas, an Atlantic versus Mediterranean trends. However the result could be biased by the scarcity of data.

As an overall picture, the study of reproduction evidence that Mediterranean Norway lobsters, with their short times of maturation, embryogenesis and births are a better subject for studies on population dynamics than the North Atlantic populations. This is especially true for some locations on the Mediterranean slope (Ligurian, Tyrrhenian and Catalan) where the Levantine water flowing to west establishes an isothermal situation during the year (13.5°C; 38.5‰).

REFERENCES

BIAGI F., DE RANIERI S., MORI M. - 1990 - Reproductive Biology of the Females of *Nephrops norvegicus* in the northern Tyrrhenian Sea. *Rapp. Comm. int. Mer Medit.*, 32 (1): 33.

EKMAN S. - 1935 - *Tiergeographie des meeres*. Akademische verlagsgesellschaft M.B.H.; Leipzig: 542 pp.

FARMER A.S.D. - 1975 - *Synopsis of biological data on the Norway lobster Nephrops norvegicus (L.). FAO Fish. Synop.* 112: 97 pp.

FIGUEIREDO M.J., BARRACA I.F. - 1963 - Contribucao para o conhecimento da pesca e da biologia do langostim (*Nephrops norvegicus* L.) na costa portuguesa. *ICES C.M.* 1982/K 28: 16 pp.

FROGLIA C., GRAMITTO M.E. - 1979 - An estimate of the fecundity of the Norway lobster (Nephrops norvegicus) in the Adriatic Sea. *Rapp. Comm. int. Mer Medit.* 25/26 (4): 227 - 229.

FROGLIA C., Gramitto M.E. - 1981 - Summary of biological parameters on the Norway lobster, *Nephrops norvegicus* (L.) in the Adriatic. *FAO Fish. Rep.*, 253: 165-169.

GRAMITTO M.E., FROGLIA C. - 1980 - Osservazioni sul potenziale riproduttivo dello scampo (*Nephrops norvegicus*) in Adriatico. *Mem. Biol. mar. Oceanogr.*, suppl.10: 213 - 218.

HARTNOLL R.G. - 1985 - Growth, sexual maturity and reproductive. In: Wenner A.M. (ed.) Factors in adult growth. *Crustacean Issues* 3. A.A. Balkema, Rotterdam, Netherland: 101 - 128.

ORSI RELINI L., RELINI G. - 1989 - Reproduction of *Nephrops norvegicus* L. in isothermal Mediterranean waters. In : Ryland S., Tyler P.A. (eds.) *Reproduction, Genetics and distributions of Marine Organisms. 23th European Marine Biology Symposium. Olsen & Olsen . Fredensborg, Denmark:* 153 - 160.

SARDÀ F. - 1991 - Reproduction and moult synchronism in *Nephrops norvegicus* (L.) (Decapoda, Nephropidae) in the Western Mediterranean: Is spawning annual or biennal? *Crustaceana* 60 (2): 186 - 199.

SARDÀ F. (Ed) - 1994 - Primer informe anual. *Nephrops norvegicus*: biologia comparada y pesca (MED/92/008) DIR. GRAL. 14.

SARDÀ F. - 1985 - A review (1967 - 1990) of some aspects of the life history of *Nephrops norvegicus. ICES mar. Sci. Symp.*, 199: 78 - 88.

SPARRE P., URSIN E., VENEMA S.C. - 1989 - *Introduction to tropical fish stock assessment Part 1. Manual. FAO Fish. Tech. Pap.* 306/1: 337 pp.

GROWTH

INTRODUCTION

The age structure of a population and the growth parameters that characterise each stock constitute basic information for stock assessment. The estimation of these parameters is considerably difficult in crustaceans, due to the absence of permanent hard parts where age can be registered. In such a situation length frequency analysis has often been chosen to estimate mean lengths-at-age and growth parameters.

The authors chose two widely used techniques for separation of groups in a length distribution, MIX (MACDONALD & GREEN, 1988) and the BHATTACHARYA's (1967) method implemented in the package FiSAT (GAYANILO et al, 1996). These approaches were chosen because they were familiar to the authors and had proved to be useful in estimating mean lengths of the groups present in length distributions of *Nephrops* (CHARUAU, 1975; NICHOLSON, 1979; FIGUEIREDO, 1984; TULLY et al., 1989; MYTILINEOU et al., 1993; CASTRO, 1995; MYTILINEOU & SARDÁ, 1995).

The approach used in this work consists in a comparative study of growth among different areas of the Mediterranean and adjacent Atlantic. It is assumed that any bias that could possibly be introduced by the length frequency analysis techniques used, and arbitrary decisions that such approaches require, will affect all the samples equally, and therefore, the comparative aspects of the study will be valid. Sampling strategies were kept as similar as possible among the different areas.

MATERIALS AND METHODS

Sampling strategy

The data consisted of monthly length frequencies for a period of two years, October 1993 to September 1995 or November 1995 in some areas. The areas sampled were the south coast of Portugal off the Port of Faro in the Atlantic (P), the Alboran Sea off Malaga (M), the Catalan Sea off Barcelona (B), the Ligurian Sea off Genoa (L), the Tyrrhenian Sea off P.S. Stefano (T), the Adriatic Sea off Ancona (A) and the Euboikos Gulf off Athens (G). In some areas such as Portugal, Malaga, Barcelona and the Adriatic the samples were kept within a small area in the same fishing grounds and were obtained in a single fishing trip or within a few days in each month. In the other areas, the monthly samples integrated data from wider areas and from several days.

All samples were obtained by bottom commercial trawlers (except in the Adriatic where a research boat was used) and the mesh of the codend was 40 mm except for Greece (32 mm) and Portugal (55 mm). In all cases the length of the carapace was measured to the mm below with digital callipers and the data for males, females and ovigerous females were registered separately. Biological samples were also obtained and one of the aspects studied included the number of soft individuals or individuals with gastroliths as well as the number of mature females; information that allowed an estimate of the moulting and reproduction season for each area. This information is discussed in detail in other sections of this report and was used in some aspects of the length frequency analysis discussed further.

Length frequency analysis

Two independent approaches, MIX and BHATTACHARYA's method, were used by two independent teams. In both cases the objective was to estimate mean length-at-age for the age groups present in the distributions by sex, month and area. Some general guidelines were followed during the application of these methods.

Data were used in two different ways by both teams. Team 1, using the FiSAT program, entered the data directly as collected, in 1 mm length classes. Team 2, using the program MIX transformed the length frequencies using moving averages of 3 classes on the basic 1 mm length class distributions. This was done to reduce some of the noise introduced by sampling procedures.

BHATTACHARYA's method implemented by FiSAT

The BHATTACHARYA's (1967) method implemented by the Program FiSAT (GAYANILO et al., 1996) is a method of separation of normal curves and consists of a sequential identification of the components of a distribution with estimation of the mean, the standard deviation, the separation index and ultimately the proportions of each one of the components. Although Bhattacharya is an old method, it could still be considered quite objective, quick and easily applied, especially because of the advantages offered by the computer programs. In order to obtain the most objective results the application of the method was based on the following criteria:

a) The identified age groups to be derived from regressions based on at least three data points (PAULY & CADDY, 1985).
b) The separation index values (GAYANILO et al., 1988) of the different age groups to be ≥2, in order to obtain well separated components.
c) The standard deviation values of the different age groups to be increasing with age.
d) The x^2 values at the 95% confidence level, indicating the difference between the identified and the observed distribution, to be as low as possible.
e) The number of identified age groups to be as high as possible in relation to the above criteria.
f) The increments between the obtained mean lengths-at-age for each sample to be decreasing with age.
g) The obtained mean lengths-at-age for the same year class to be increasing with time in order to follow as clearly as possible the process of growth during both years of sampling.
h) The time of increase in length, found in the results of the analysis, to coincide with the time of moulting.
i) Many repetitions of the analysis have been done for each sample.

Since all these criteria did not always and at the same time occurred, the best combination of them conducting to the best statistically and biologically acceptable results was selected every time.

MIX.

MIX (MACDONALD & GREEN, 1988) a program that uses a combination of maximum likelihood and non-linear estimation methods for estimation of the mean, standard deviation and proportion of each one of the components of the distribution. In this case it was assumed that each component had a normal distribution.
The program MIX was used in the following manner for each sample:

a) Initial estimation of mean and standard deviation for each component. Initial estimates where based on visual analysis of the distributions. All peaks in the graphs or deviations from normality where considered.
b) Estimation of proportions keeping mean and standard deviation fixed.
c) Estimation of means and standard deviation keeping proportions fixed.
d) Repetition of steps b) and c) until the value of χ^2 stops decreasing.
e) Release of all parameters and global estimation of mean, standard deviation and proportion of each component.

Some times this process would have to be repeated with a smaller number of components because one or more of the components considered was totally enclosed within another one.

Modes that characterised well represented age groups in the samples were therefore identified for further analysis. A criterion was established to select these modes. They were considered to be the ones visually corresponding to modes in the distributions, and with standard deviations of magnitude not greater than 3 mm. These criteria excluded modes with large standard deviations, occurring in particular at larger mean lengths-at-age and attributed to mixtures of more than one age group, not possible to separate with length frequency analysis.

Once the well represented groups were chosen, a relative age in months was attributed to each mean. In all areas two or three cohorts were well represented and could be followed along most of the samples. The ageing and following of age groups was guided by the following principles:

a) Components identified in the same sample were considered to be at least one year apart. This assumption derives from the fact that this species has a single recruitment period per year (see chapter 3).
b) The mean length-at-age of around 15 to 18 mm showing up for the first time in the Winter-Spring, were considered to be age 1. The birthday was considered to be 1st February, as indicated by the study of the reproductive cycle (see chapter 3), of the year before. Persistent peaks around the same time and with values close to 21-25 mm were considered to be age 2.
c)Growth was considered to be of the type modelled by the von Bertalanffy growth curve, that is, decelerating with time. Therefore the difference between two consecutive modes in the same sample should decrease from smaller to larger sizes.

This assumption allowed some of the modes identified in the same sample to be considered more than one year apart.
d)Moulting periods identified for the same samples (see chapter 2) were taken into consideration for interpreting the progression of mean lengths over time. For mature females information from the reproductive cycle (see chapter 3) was also taken in consideration, assuming that ovigerous females can not moult.
For each area sex and month, a set of pairs of values of age-length was obtained.

Estimation of growth parameters.

Growth parameters of the von BERTALANFFY (1957) growth curve were estimated by using non-linear fitting procedures. In one case, when MIX was applied to estimate mean lengths-at-age, the Gauss-Newton method implemented by the program Statistical Analysis System (SAS Institute Inc., 1985) was used. In the other case, when the Bhattacharya's method was applied for estimation of mean lengths-at-age, the FISHPARM program implemented by the software package FSAS (SAILA et al., 1988) was used. Both approaches of non-linear estimating operate under similar assumptions and produce similar results.

Apart from the age-length pairs of values these fitting methods require as input a range of possible values and a step for each parameter. The first step consists in a grid search where all possible combinations of the parameters are evaluated. The best one is chosen as a starting point for the iteration part of the method. If the data fit the chosen model, the iterations converge fast to a set of parameter estimates that minimises SSE, the Sum of Squares of the Error. In this situation the program prints the message "Convergence criterion met" and an asymptotic variance-covariance matrix is obtained as well as standard errors and consequently confidence intervals for all the parameters estimated.

The two approaches differed however in the data considered for the fitting and in the type of estimates obtained.

Interval estimates of the growth parameters (MIX and SAS)

Growth parameters were estimated for each area, sex and month. In many cases the convergence criterion was not met and/or the estimated parameters were totally unreasonable. Some times extremely high values of L_∞ and low values of K were obtained. This happened in situations when only a few pairs of values corresponding to younger ages were considered. In these cases the samples clearly did not well represent the size structure of the population. In the case of the von Bertalanffy growth equation this situation corresponds to cases when the growth does not decelerate with time or when there is no data in older ages and therefore the asymptotic length can not be estimated. This absence of information makes the estimation of the parameters of the von Bertalanffy growth curve impossible mathematically. This problem has been discussed extensively by KNIGHT (1968).
A criterion for acceptance of values was therefore established. Only fits that met the convergence criterion were accepted. Parameter estimates that produced values of L_∞ larger than 80 mm for females or 100 mm for males were also dropped. Once the

months with samples containing information for parameter estimation were selected, a global estimate for each area and sex was obtained.

Point estimates of the growth parameters (BHATTACHARYA and FISHPARM)

Growth parameters were estimated for each area, sex and month separately using the mean lengths-at-age and the corresponding biological age. The results obtained for many months were found unreasonable (L_∞ lower than the maximum observed length or higher than any value mentioned in the bibliography-higher than 100 mm). All the months with unreasonable growth parameter estimates were discarded. Since the estimation of the growth parameters is related to the quality of the analysed sample and to the quality of the identified mean lengths-at-age the following criteria have been used for the selection of the samples to be analysed:

- high number of specimens in the sample without many gaps in its length composition,
- presence of the young mean lengths-at-age,
- presence of the old mean lengths-at-age,
- absence of gaps between the identified mean lengths-at-age,
- increments between the mean lengths-at-age decreasing with age.

Under these conditions, the use of most monthly samples was found to be impossible therefore only one month, producing the best estimates and characterised by the above criteria, was decided to be used.
Furthermore, the fact that different months have been chosen for the estimation of the growth parameters for the different areas does not affect the results because the real biological age of the mean lengths-at-age has been attributed to each monthly sample.

Statistical comparison of the results.

Pairwise comparisons of the growth parameters obtained by the Gauss-Newton method for each area and within each sex were made using Hotelling's T^2 tests for globally comparing the sets of estimated parameters without assuming equal variance-covariance matrices (BERNARD, 1981; HANUMARA & HOENIG, 1987). Since only the parameters L_∞ and K are important (t_0 will only change the relative age and not affect the growth rate), the test was repeated considering only these two parameters and the corresponding variance-covariance estimates. The matrix algebra language IML (SAS Institute Inc., 1990) was used to perform the calculations, using as base data the results of the non-linear procedure PROC NLIN (SAS Institute Inc., 1985) as described by HANUMARA & HOENIG (1987)

Other methodologies

Along this work, many variations of the described methodologies were tried and abandoned. These included different grouping of the base data, estimation of growth parameters based on the increments of each cohort followed over time, estimation of growth parameters forcing L_∞ over given values and the use of the Ford-Walford method (WALFORD, 1946). When a methodology led to unreasonable results, it was abandoned. The original length data were also used for the direct estimation of growth parameters, applying ELEFAN I (GAYANILO et al.,1988) and SHEPHERD's (1987) method implemented by the FISAT package (GAYANILO et al., 1996). In most cases, k was found very high and some times L_∞ too. The option of choosing or forcing L_∞ to more reasonable values resulted to bad fitting curves. For this reason, these two methods were also abandoned.

RESULTS

According to the BHATTAHARYA's method, the maximum identified number of age groups during the two years of study was for males: 9 for P, 9 for M, 8 for B, 10 for L, 9 for T, 8 for A and 10 for G and for females: 6 for P, 8 for M, 6 for B, 7 for L, 8 for T, 7 for A and 9 for G. In most cases it was difficult to detect the youngest age groups (0+ and 1), whereas the identification of the oldest age groups (>5 for males and >4 for females) was more difficult or impossible.

According to MIX, the maximum identified number of age groups during the two years of study was for males: 7 for P, 8 for M, 8 for B, 8 for L, 9 for T, 8 for A and 11 for G and for females: 6 for P, 8 for M, 7 for B, 7 for L, 6 for T, 7 for A and 8 for G. In most cases it was difficult to detect the youngest age groups (0+ and 1), whereas the identification of the oldest age groups (>5 for males and >4 for females) was more difficult or impossible.

An example of the mean lengths-at-age estimated by the two approaches is presented in Fig. 4.3.1. In Annex 4.A. all values and graphs of the estimated by the two procedures results are included.

Table 4.3.1. includes the growth parameter estimates for each area and sex for males, using the Gauss-Newton method. Table 4.3.2. includes the same estimates, using the FISHPARM program.

The pairwise comparisons of growth parameters between different areas (within the same sex) using the Hotelling's T^2 tests were all significant both when the three parameters and when only K and L_∞ where compared. A significance level of α=0.05 was considered. Plots of simultaneous confidence limits obtained for $L\infty$ and K are represented in Figure 4.3.2.

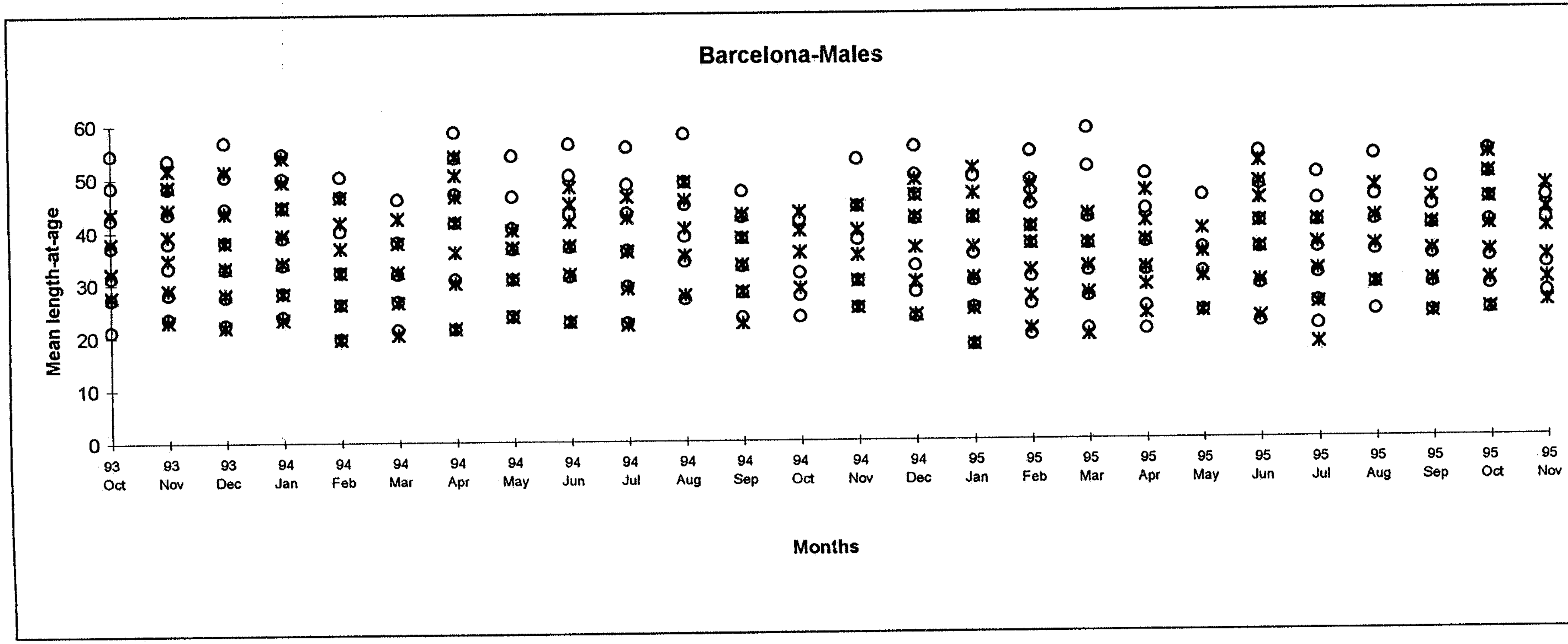


Figure 4.3.1. Mean lengths-at-age estimated by MIX and BHATTAHARYA's method for the males of Barchelona

a) Males

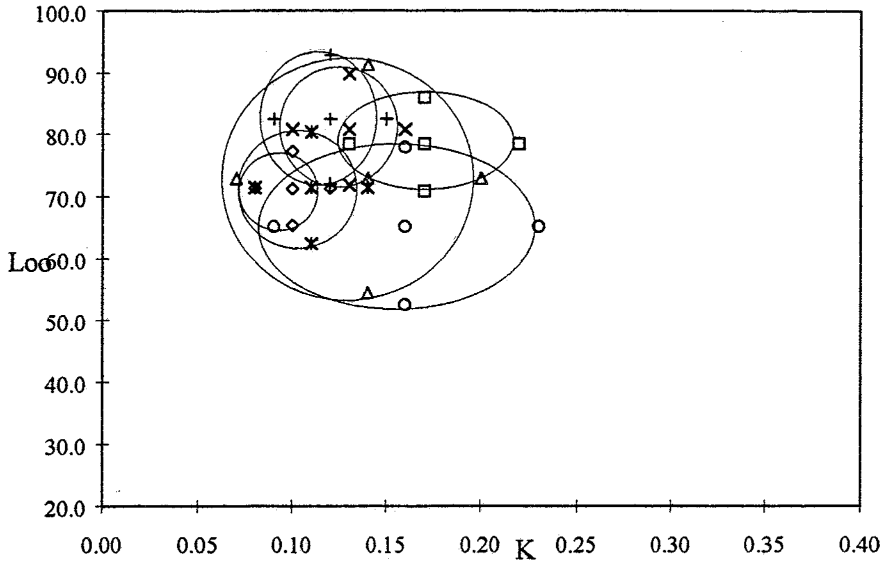
AREA	Loo	K	to	n	MSE
Atlantic	71.3	0.10	-2.45	59	1.12
Malaga	78.4	0.17	-0.38	39	0.85
Barcelona	72.9	0.14	-1.43	40	1.96
Thyrreno	80.8	0.13	0.07	61	1.63
Adriatico	71.4	0.11	-1.18	88	3.29
Ligurio	65.2	0.16	-0.96	32	2.94
Grécia	82.4	0.12	-0.01	79	2.55

b) Females

AREA	Loo	K	to	n	MSE
Atlantic	62.4	0.14	-1.19	39	1.79
Malaga	59.4	0.20	-0.92	49	4.99
Barcelona	54.9	0.18	-1.36	38	2.06
Thyrreno	69.4	0.12	-0.64	46	2.29
Adriatico	68.0	0.14	-0.21	30	1.99
Ligurio	54.5	0.22	0.03	37	2.78
Grécia	75.8	0.12	-0.11	79	2.76

Table 4.3.1. Estimated parameters for all areas studied for each sex. The information contained in the table includes the identification of the study area, the estimated parameters using non-linear fitting, the number of pairs of age-length values used to produce the estimates and the Mean Square Error value for the fitting. In all cases the fitting procedure corresponds to a situation where the convergence criterion was met.

a) Males



b) Females

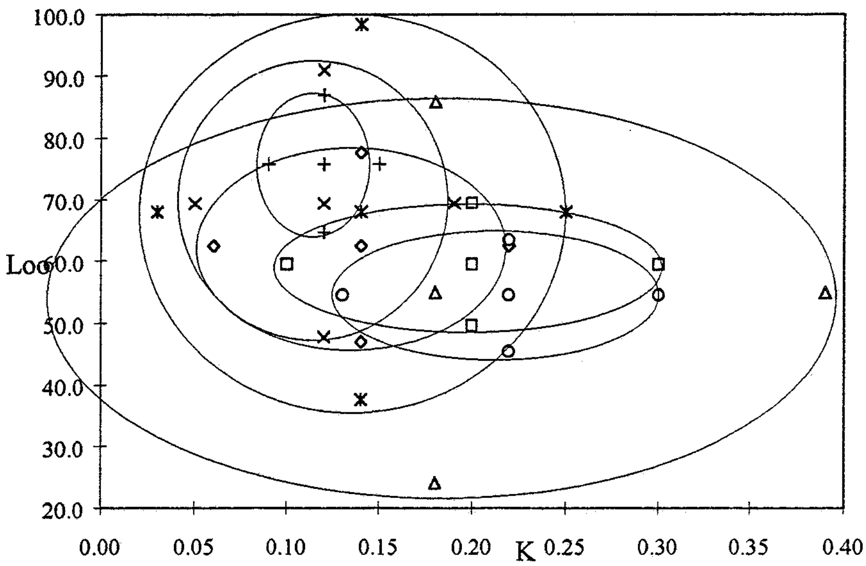


Figure 4.3.2. Plots of the estimated growth parameters L_∞ and K and 95% confidence limits are expressed in the form of an ellipse. The height of the ellipse corresponds to the confidence limits for K and the width to the confidence limits for L_∞.

Table 4.3.2. Growth parameters of *N. norvegicus* for each area and sex, using the FISHPARM program

a) Males

AREA	Loo	k	to
Portugal	83.36	0.129	-0.329
Malaga	86.81	0.14	-0.842
Barcelona	86.85	0.1	-0.305
Ligurian	83.18	0.12	-0.872
Tyrrhenian	81.62	0.129	-0.886
Adriatic	81.52	0.112	-0.946
Euboikos	82.67	0.121	-0.953

b) Females

AREA	Loo	k	to
Portugal	70.7	0.12	-1.36
Malaga	72.57	0.161	-0.872
Barcelona	66.96	0.146	-0.328
Ligurian	63.18	0.154	-0.101
Tyrrhenian	65.03	0.149	-0.765
Adriatic	67.04	0.143	-0.881
Euboikos	73.89	0.144	-0.366

DISCUSSION

Length frequency analysis is influenced by many factors. In the present work, a great effort was made to apply this analysis under the most correct conditions. Since the length-based analysis is applied on length frequencies their structure is of great importance. Some problems that may affect the structure of the length frequencies are:

a) The size of the sample (MACDONALD & PITCHER, 1979; PAULY, 1984 in HOENING et al., 1987; ERZINI, 1990 etc.); for this purpose, large samples were collected every month in the most of cases (>200 individuals per sex each month).
b) Poor sampling of small and large length classes, which affects their representation in the frequencies; this fact explains the difficulty of identification of the youngest and oldest age groups in all the samples of this work.

) Gear selectivity and fishing mortality conditioned by the mesh size are factors influencing the structure of a frequency. It must be noted that the mesh size for the sampling in the present work changed from area to area. More specifically, in the samples of P, collected with a large mesh size (55mm), it was difficult to identify the age groups 0+ and 1. On the contrary, in the samples of G, collected with a small mesh size (32mm), the age groups 0+ and 1 were better represented and consequently easier to be distinguished.

d) The purity of the samples. It is known that the length structure of *Nephrops* populations changes between adjacent areas and consequently the accumulation of samples from extended areas could result in a larger range of classes represented and peaks that may not correspond to true age groups. For the present work, the samples were collected from a single station in most cases with the exception of T and G, where the sampling covered more than one stations in a restricted, however, area.

e) The size of the class interval (ERZINI, 1990); in the present work the 1mm interval has been used by both teams, as has already been done by other authors (e.g. TULLY et al., 1989) in the bibliography. The same class interval has also been approved by CASTRO (1990; present work) with simulated data and by MYTILINEOU & SARDA (1995) with original data as the most adequate for the *N. norvegicus* length frequencies.

Furthermore, the assumption that the modes in a given sample should correspond to cohorts poses some problems. One of these problems is the uncertainty if the different identified components correspond to the real number of age groups composing the populations under study. In the present work, the consideration of the age groups by both teams was done using a series of criteria, analysed in the chapter of the methodology. These criteria were introduced in order to avoid or limit the subjective interpretation of the results. A confirmation for the accuracy of our results was the continuity of the presence of the different modes during the time and during the two years of sampling. This fact gave the possibility of following the different year classes during the time. Moreover, the consideration of the different components as age 0+, 1, 2 etc. was reasonable if compared to the information given in the bibliography concerning the larva cycle of the species (FARMER, 1973) and the age groups estimated by other authors (FARMER, 1973; HILLIS, 1979; TULLY et al., 1989 etc.).

The visual comparison of the results of the two approaches (MIX and BHATTACHARYA's) used in the present work (Fig.4.3.1, Appendix 4.A), showed no significant differences between them. From all the analyses it was obvious that the main problem in the length-based methods is not the selected method, but firstly the sample structure and secondly the way of applying this method (criteria used). Some further remarks regarding the two approaches could also be reported. MIX was found to be more efficient for the detection of the youngest and oldest age groups and it was not so much affected by the presence of gaps in the structure of frequencies. An other remark is that the use of moving averages for the structure of frequencies led to best fits in the analyses than the use of the original data, probably because of the elimination of the noise. However, in some cases, this application did not permit the easy detection of adjacent age groups characterised by high overlap.

The comparison of the results of the length frequency analyses among sexes and areas was also done visually. Their interpretation was difficult, however, it was obvious that a difference exists between the two sexes in all the areas. The females always presented fewer age groups and lower increments than the males. This could be attributed to the effect of maturation of the females on their growth pattern, fact already mentioned in the bibliography (e.g. FARMER, 1973; CHARUAU, 1975; HILLIS, 1979; SARDA, 1985 etc.). Furthermore, among the different areas, M and B presented the largest and smallest mean lengths-at-age, respectively. The mean lengths-at-age of L, T, A and G seemed to be more close, although more differences existed among the females. This could be attributed to the differences in the reproductive cycle of females of these areas (e.g. differences in the length-at-first maturity - see chapter 3).

Regarding the estimation of the growth parameters, it was also proved to be difficult. Their direct estimation based on the original length data was found unreliable. On the other hand, the indirect estimation of the growth curve from the mean lengths-at-age, using the Gauss-Newton method and the FISHPARM program provided better results, although not in all cases was acceptable. In some cases, the estimated by the Gauss-Newton method values of L_∞ were below the expected ones if the maximum sizes present in the catch are considered. This is the result of absence of information for older ages. In most samples there were no identifiable groups in larger sizes. The estimation of L_∞ becomes difficult, and if L_∞ is underestimated, K will necessarily be overestimated, with all the consequences in posterior use in assessment models. The alternative to this problem would be to force L_∞ to be a chosen value. In this case the estimation of K would have little meaning, as discussed by Knight (1968) due to the correlation that exists between both parameters, one would basically be choosing the parameters based only on the maximum size present in the catch (or anticipating knowledge of such maximum size), a parameter which is very dependent on sampling, and leaving out most of the information contained in the length distributions. The fact that L_∞ is slightly below maximum size is not serious if one considers L_∞ as an average maximum length for the individuals of a population and not a asymptotic length for the whole population. In any case the comparative aspects would still hold because all areas studied were treated the same way.

More specifically, the estimation of the von Bertalanffy growth curve parameters proved difficult. In many samples the number of age groups identified was small and included only young groups. In other cases the increments between adjacent modes did not decrease from smaller to larger sizes, showing no deceleration in growth, a condition necessary for the application of the von Bertalanffy growth model. In this situation, the second most frequent, the data of the corresponding months were simply removed from the calculations. This poses the problem of the adequacy of the von Bertalanffy growth model. If this model is not appropriate for this species, as suggested by studies with simulated data (Castro, 1992), the removal of data that does not fit the von Bertalanffy model would lead to erroneous results. The alternative could be the use of another growth model, and in fact during stages of this work the Gompertz model was also used. In the end the authors suggested that the radical approach of refusing the von Bertalanffy growth model was not appropriate. First, it is biologically very difficult to consider non decelerating growth in adult phases.

The indicators that this may happen in some periods of the life of slow growth decapods are not sufficient yet for retiring the von Bertalanffy growth curve. Such a situation would need evidence from natural populations that is not available. Second, the von Bertalanffy growth curve, even if it is not the best possible model, is of easy application in fisheries models, has parameters with biological meaning and easy interpretation, and is no doubt the most widely used growth model in fisheries. The estimated parameters, even with questionable absolute values when resulting solely from length frequency analysis, will be useful for comparative purposes. Since the objective of this project was a comparative study among several areas of the Mediterranean and adjacent Atlantic, the estimation of von Bertalanffy growth parameters was kept as the final objective of the data analysis.

The parameters obtained were necessarily dependent on the data structure. If older ages are well represented in the catch the estimation of the parameters is more accurate. If only younger ages are present, large standard errors for the parameters will result. We believe that this is expressed in Figure 4.3.2. where males have estimates of growth parameters with much narrower confidence limits than females. This may be the result of better representation of older ages in the catch, with no significant change of behaviour along the year, absence of synchronised moulting with slow progression of mean length-at-age along the year and faster growth. All these aspects make the estimation of their growth parameters easier. It was also observed, that even if the differences in parameters are significant statistically, from the practical point of view this is not the case. For male lobsters (and excluding the Ligurian Sea which had much less information available), all estimates of L_∞ obtained by the two approaches (Gauss-Newton and FISHPARM) are between 71 and 87 mm, a narrow range taking in consideration the differences in population structure shown in the studied areas. For K the range of estimated parameters was 0.10 to 0.17. Females show very wide ranges for the estimated parameters, a sign of poor results for this sex. Some of the facts that contribute to this may include behavioural aspects, and difficulty in separating ages during the moulting season. Behavioural patterns affect the population structure since the availability to the gear decreases for ovigerous females. For age classes that do not reach 100% maturity, this could result in bias in the estimation of mean lengths-at-age during the ovigerous season. After hatching of the larvae, mature females are well represented in the catch. But this is also the period when moulting occurs. Data from this project indicates that mature females tend to show synchronous moulting and moult only once a year (see chapter 3). During the moulting season it will be very difficult to separate ages because a given individual starts in one mode and ends in the next one, while still belonging to the same age group. When attributing ages to the identified groups along the moulting period, bias will necessarily occur. We believe that these difficulties are shown in the wide confidence limits both for L and K of females.

Following modes over time may be a problem because the modes may not correspond to true age groups. In this case, the approach should be to identify modes within each sample and combine data that is not affected by moulting season in order to estimate growth parameters. If growth parameters are used for stock assessment and management purposes, perhaps ranges of values, not point estimates, should be taken into consideration.

The results of this work generally let us suggest that more consideration should be given to :

a) the use of length frequency analysis in the absence of information of individual growth in wild populations.
and b) the research of alternative models that could express the growth of decapods.

REFERENCES

BERNARD, D.R.-1981. Multivariate analysis as a mean of comparing growth in fish. Can. J. Fish. Aquat. Sci., 38: 233-236.

BERTALANFFY, L.von.-1957. Quantitative laws in the metabolism and growth. Q. Rev. Biol., 32: 217-231.

BHATTACHARYA, C.G.-1967. A simple method of resolution of a distribution into Gaussian components. Biometrics, 23: 115-135.

CASTRO,M.- 1990. The use of length frequency analysis for estimation of the age structure of the catch of *Nephrops norvegicus* . Rapp. P-v Reun. Int. Explor. Mer (in press).

CASTRO, M.- 1992. A methodology for obtaining information on the age structure and growth rates of the Norway lobster, *Nephrops norvegicus* (L.) (Decapoda, Nephropoidea). Crustaceana, 63: 29-43.

CASTRO, M.. - 1995. The use of length-frequency analysis for estimating the age structure of the catch of Nephrops norvegicus (Crustacea: Nephropidae). ICES mar. Sci. Symp., 199: 301-309.

CHARUAU, A.-1975. Croissance de la langoustine sur les fonds du Sud-Bretagne. ICES. Shell. Comm., CM. 1975/K: 11, 15pp.

FARMER, A.S.D.- 1973. Age and growth in *Nephrops norvegicus* (Decapoda: Nephropidae). Mar. Biol., 23: 315-325.

FIGUEIREDO, J.M..-1984. Attempts to estimate growth and instantaneous matural mortality of Nephrops norvegicus off the Portuguese coast. ICES. Shell. Comm., C.M. 1984/K:28. 19 pp.

ERZINI, K.-1990. Sample size and grouping of data for length-frequency analysis. Fish. Res., 9: 355-366.

GAYANILO, F.C., J.M. SORIANO and D. PAULY.-1988. A draft guide to the COMPLEAT ELEFANT. ICLARM Software Project 2, 65 pp.

GAYANILO, F.C., P. SPARRE and D. PAULY.-1996. The FAO-ICLARM Stock Assessment Tools (FISAT) User's Guide. FAO Computerized Information Series, Fisheries. FAO, Rome, 126 pp.

HANUMARA, R.C. and N.A. HOEING - 1987. An empirical comparison of a fit of linear and non-linear models for seasonal growth in fish. Fish. Res., 5: 359-381.

HILLIS, J.P.- 1979. Growth studies on the prawn, *Nephrops norvegicus,* Rapp. P-v. Reun. Int. Expor. Mer, 1975:170-175.

HOENING, J.M>, J. CSIRKE, M.J. SANDRES, A. ABELLA, M.G. ANDREOLI, D. LEVI, S. RAGONESE, M. AL-SHOUSHANI and M.M. AE-MUSA.-1987. Data aquisition for length-based stock assessment: Report of working group I. In D. PAULY and G.R. MORGAN (Editors), Length-based methods in Fisheries Research. ICLARM Conf. Proc. 13, February 1985, Mazzara del Vallo, Sicily, Italy. International Centre for Living and Aquatic Resources Management, Manila, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait, pp. 343-352.

KNIGHT, W. - 1968. Asymptotic growth: an example of nonsense disguised as mathematics. J. Fish. Res. Board Canada 25: 1303-1307.

MACDONALD, P.M.D. and P.E.J. GREEN.-1985. User's Guide to program MIX: An interactive program for fitting mixtures of distributions. Ichthus Data Systems, Hamilton, Ontario, Canada.

MACDONALD, P.D.M. and T.J. PITCHER.-1979. Age groups from size-frequency data: a versatile and efficient method of analysing distribution mixtures. J. Fish. Res. Board Can., 36: 987-1001.

MYTILINEOU, CH., A. FOURTOUNI and C. PAPACONSTANTINOU - 1993. Data on the biology of Norway lobster, Nephrops norvegicus (L., 1758) in the North Aegean Sea. Proceedings of the 4th Panhellenic Symposium on Oceanography and Fisheries, April 1993, Rhodes, Greece, pp. 493-494.

MYTILINEOU, CH. and F. SARDA.-1995. Age and growth of Nephrops norvegicus in the Catalan Sea, using length-frequency analysis. Fish. Res. 23: 283-299.

NICHOLSON, M.D. - 1979. The use of length frequency distributions for age determination of Nephrops norvegicus (L.). Rapports et Procés Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 175: 176-181.

PAULY, D. and CADDY, J.-1985. A modification of BHATTACHARYA's method for the separation of normal distributions. FAO Fish. Circ. 781, Rome, 16 pp.

PAULY, D. and N. DAVID.-1981. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequencies data. Meeresforsch., 28(4): 205-211.

SAILA, S.B., C.W. RECKSIEK and M.H. PRAGER.-1988. Basic Fishery Science programs: A Compledium of microsoft programs and manual of operation. Developments in Aquaculture and Fisheries Science, 18, Elsevier, Oxford.

SARDA, F.- 1985. Estudio de la edad, crecimiento y frequencia de muda, en cautividad, de *Nephrops norvegicus* (L.) del Mar Catalan. Invest. Pesq., 49(2): 139-154.

SAS INSTITUTE INC. - 1988. SAS/STAT a User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1029pp.

SHEPHERD, J.G.-1987. A weakly parametric method for estimating growth parameters from length composition data, p. 113-119.*In* D.PAULY and G.R. MORGAN (eds). Length-based methods in fisheries research. ICLARM Conf. Proc. 13.

TULLY, O., J.P. HILLIS and D. MCMULLAN - 1989. Fitting normal curves to polymodal length frequencies to assess growth in Nephrops. ICES C.M. 1989/K:32, 18pp.

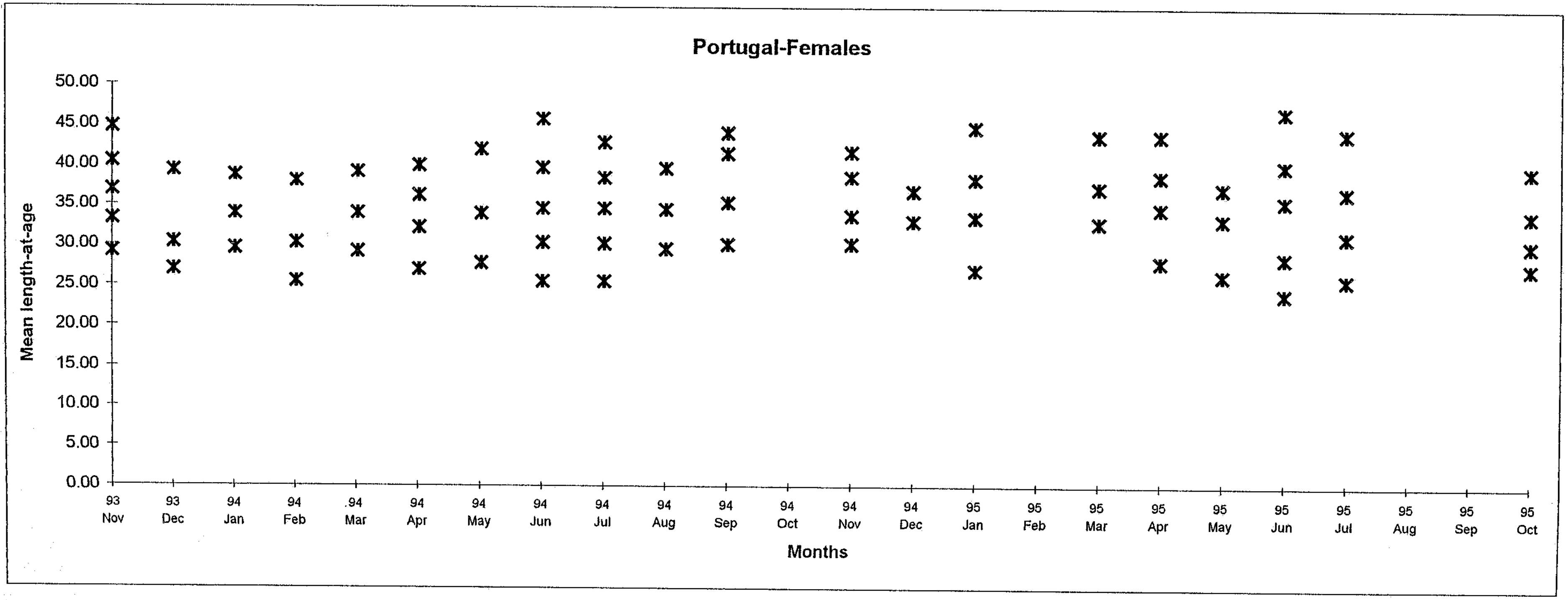
WALFORD, L. A. - 1946. A new graphic method of describing the growth of animals. Biol. Bull.

Annex

Mean length-at-age obtained with BHATTACHARYA

PORTUGAL-FEMALES

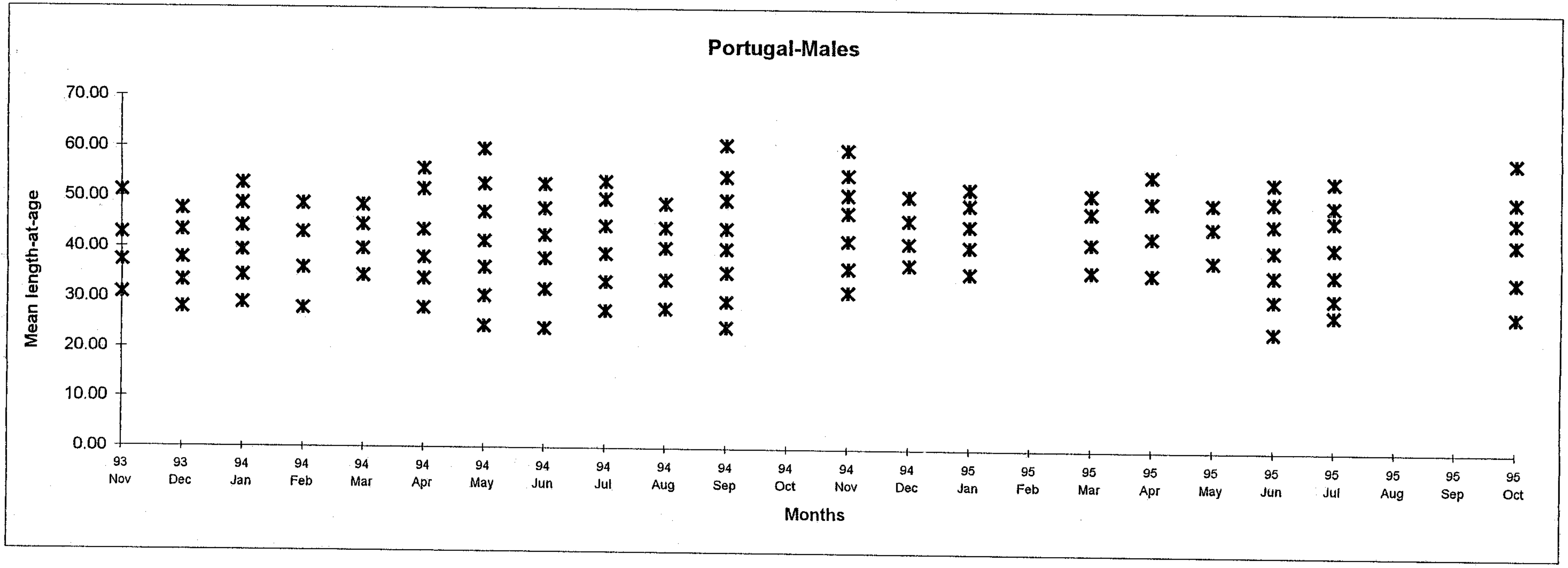
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
29.19	27	29.63	25.5	29.17	27	27.77	25.47	25.47	29.5	30.11		30.19	33	27		32.84	28	26.33	24.06	25.77			27.31
33.23	30.34	33.9	30.28	33.95	32.16	33.88	30.35	30.22	34.44	35.31		33.71	36.75	33.5		37.19	34.55	33.2	28.5	31.16			30.11
36.87	39.33	38.73	38	39.12	36.18	41.97	34.59	34.55	39.63	41.5		38.51		38.26		43.67	38.59	37.11	35.49	36.65			33.82
40.47					39.94		39.65	38.37		44		41.71		44.7			43.67		39.93	43.93			39.31
44.67							45.69	42.81											46.67				



Mean length-at-age obtained with BHATTACHARYA

PORTUGAL-MALES

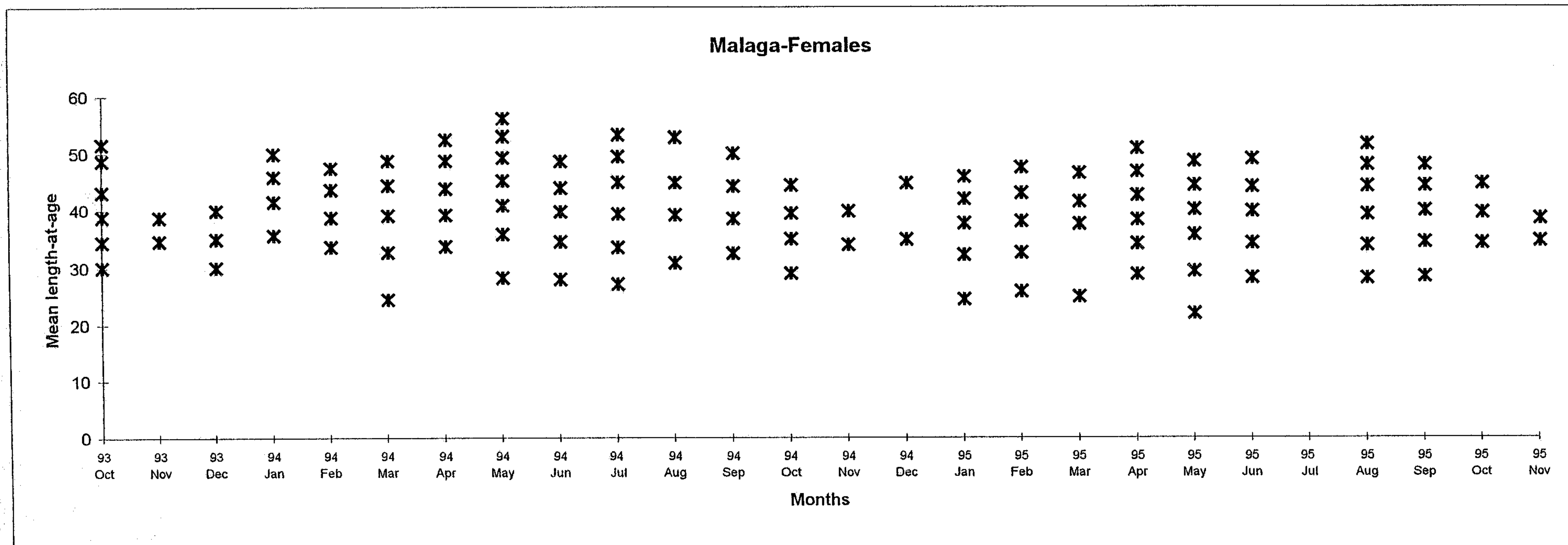
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
30.91	28	29	27.91	34.5	28	24.5	24	27.61	28	24.33		31.59	37	35.39		36.00	35.51	38.11	24.00	27.51			27.52
37.31	33.34	34.41	36	39.79	33.89	30.44	31.9	33.34	33.87	29.49		36.28	41.32	40.67		41.52	42.82	44.84	30.50	30.80			34.45
42.99	37.89	39.54	43.2	44.71	38.14	36.21	37.97	38.93	40.1	35.29		41.76	45.9	44.83		47.70	49.80	49.59	35.33	35.59			41.84
51.26	43.52	44.37	48.77	48.57	43.67	41.46	42.75	44.58	44.21	40.05		47.31	50.7	49.09		51.23	55.02		40.21	40.88			46.30
	47.69	48.71			51.69	47.21	47.95	49.81	48.99	44.16		50.85		52.21					45.51	46.22			50.34
		52.67			55.67	52.71	52.67	53.27		49.74		54.77							49.93	49.32			58.00
						59.67				54.34		59.76							53.67	54.02			
										60.67													



Mean length-at-age obtained with BHATTACHARYA

MALAGA-FEMALES

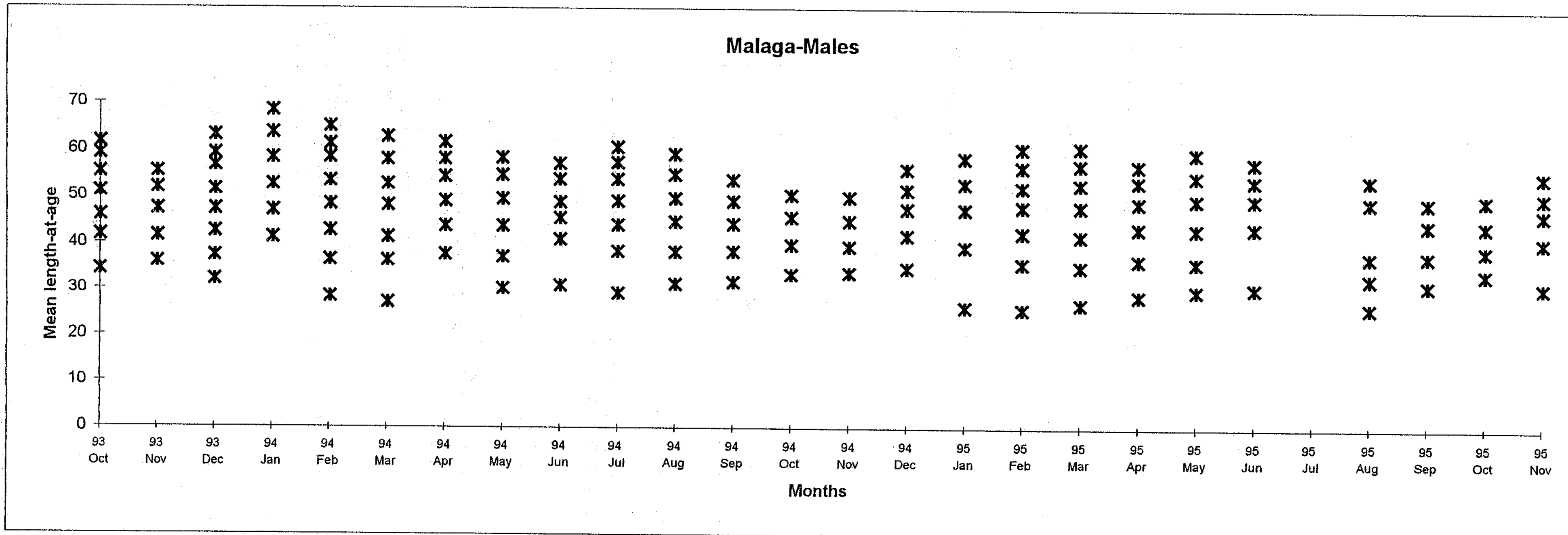
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
30.01	34.68	30.06	35.7	33.63	24.5	33.79	28.33	28	27.2	30.92	32.57	29	34	34.94	24.53	25.86	25	28.83	22	28.29		28.23	28.49	34.34	34.65
34.49	38.73	35	41.52	38.73	32.72	39.24	35.87	34.57	33.58	39.18	38.53	35	39.85	44.7	32.24	32.67	37.66	34.24	29.43	34.33		33.89	34.46	39.6	38.55
38.86		39.98	45.9	43.66	39.1	43.81	40.86	39.72	39.35	44.81	44.22	39.49			37.76	38.12	41.55	38.36	35.81	39.84		39.3	39.96	44.67	
43.22			49.94	47.42	44.39	48.7	45.18	43.9	44.92	52.77	50	44.34			41.99	43.02	46.51	42.63	40.08	44.07		44.2	44.26		
48.75					48.71	52.44	49.28	48.63	49.48						45.84	47.49		46.8	44.35	49		48	48		
51.58							52.96		53.24									50.82	48.59			51.61			
							56.09																		



Mean length-at-age obtained with BHATTACHARYA

MALAGA-MALES

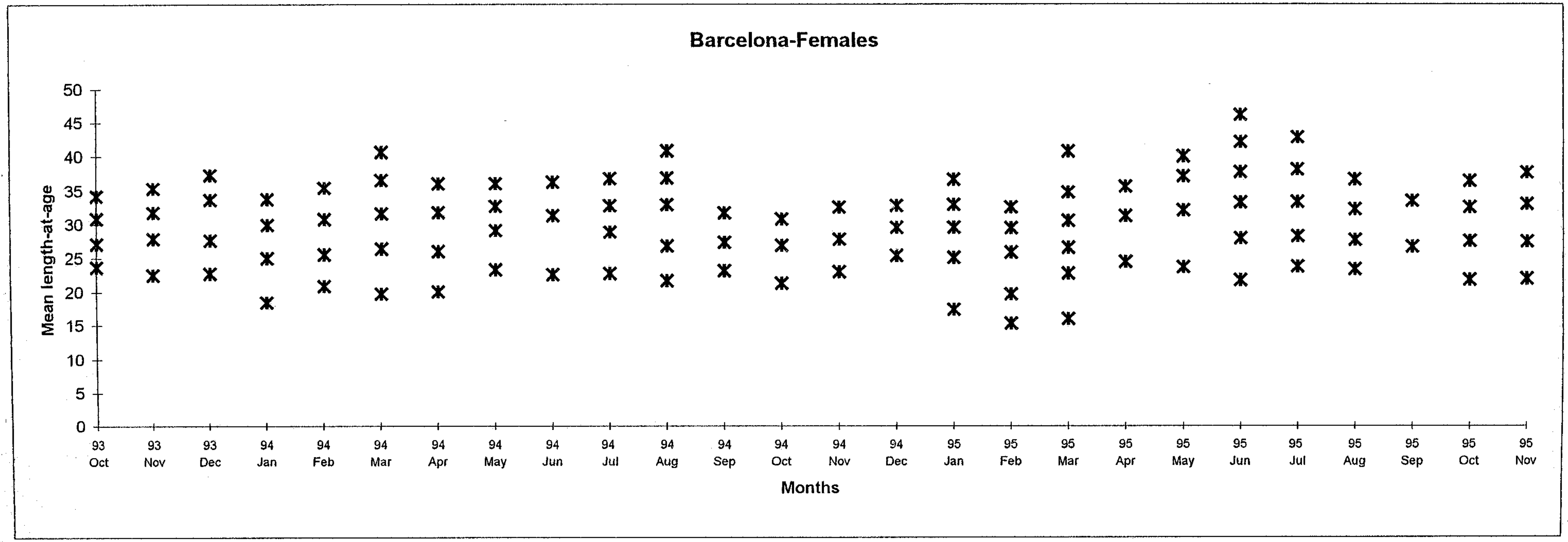
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
34.3	36.03	32.16	41.25	28.5	27.26	37.67	30.3	30.9	29.28	31.33	31.77	33.38	33.8	34.81	26.32	25.91	27.04	28.76	29.88	30.5		26.33	31.28	33.79	31
41.8	41.52	37.39	47.07	36.41	36.36	43.74	37.13	40.96	38.38	38.28	38.43	39.81	39.49	41.9	39.37	35.82	35.12	36.55	36.06	43.5		32.6	37.64	38.87	40.7
45.88	47.29	42.57	52.71	42.71	41.41	49.08	43.82	45.45	44	44.65	44.24	45.68	44.94	47.44	47.41	42.42	41.72	43.49	43.21	49.57		37.31	44.35	44.11	46.64
51.08	51.89	47.29	58.45	48.44	48.13	54.32	49.47	48.85	49.05	49.65	49.08	50.4	49.98	51.55	52.87	47.96	47.9	48.84	49.54	53.62		49.06	49.03	49.62	50.16
55.26	55.38	51.51	63.67	53.45	52.73	58.16	54.75	53.77	53.75	54.76	53.67			56.1	58.46	52.1	52.77	53.3	54.49	57.51		53.76			54.67
59.24		56.73	68.37	58.55	58.12	61.7	58.46	57.17	57.36	59.18						56.46	56.95	56.84	59.47						
61.67		59.26		61.32	62.77				60.67							60.49	60.67								
		63.14		65.09																					



Mean length-at-age obtained with BHATTACHARYA

BARCELONA-FEMALES

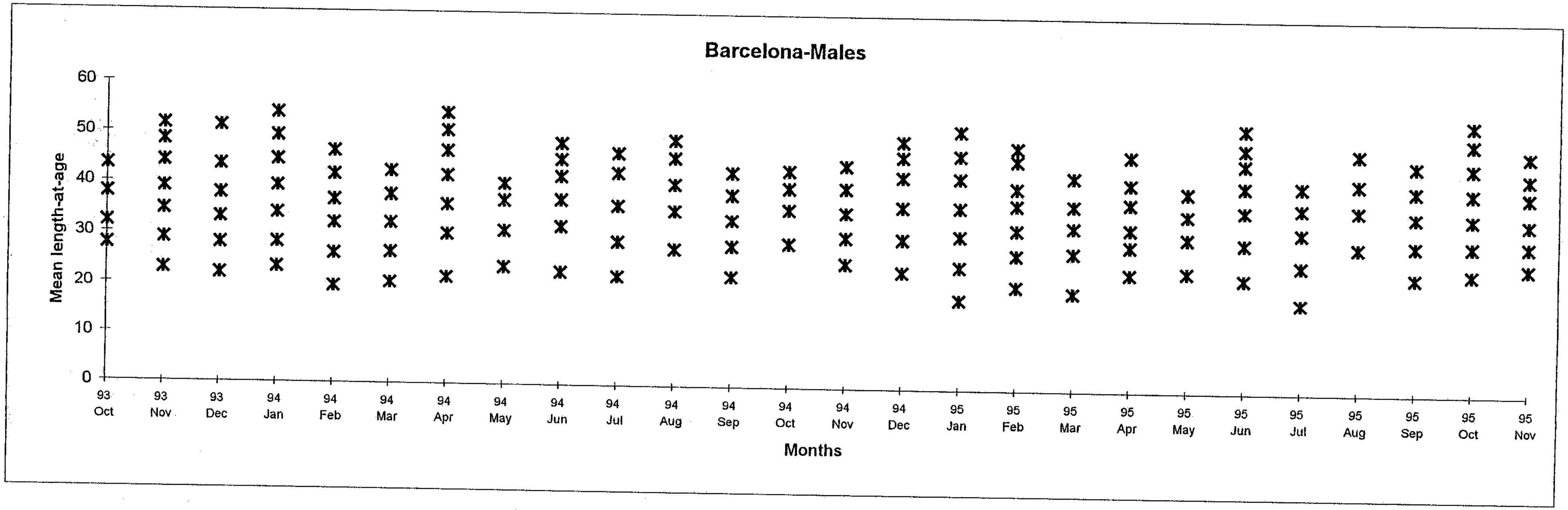
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
23.71	22.54	22.79	18.5	20.9	19.8	20.09	23.29	22.66	22.81	21.7	23.13	21.35	23	25.39	17.38	15.33	16	24.47	23.68	21.8	23.78	23.38	26.67	21.84	22.01
27.07	27.87	27.58	24.98	25.57	26.4	26.01	29.1	31.31	28.81	26.79	27.33	26.83	27.79	29.49	25.04	19.69	22.75	31.23	32.07	27.9	28.24	27.66	33.4	27.54	27.42
30.81	31.76	33.63	29.94	30.77	31.59	31.75	32.64	36.25	32.71	32.87	31.66	30.73	32.5	32.72	29.55	25.81	26.57	35.6	37.11	33.17	33.28	32.2		32.5	32.98
34.22	35.32	37.33	33.78	35.45	36.61	36.07	36.04		36.84	36.9					32.89	29.47	30.49		40	37.72	38.15	36.63		36.41	37.67
					40.67					40.81					36.68	32.49	34.74			42.13	42.78				
																	40.73			46.14					



Mean length-at-age obtained with BHATTACHARYA

BARCELONA-MALES

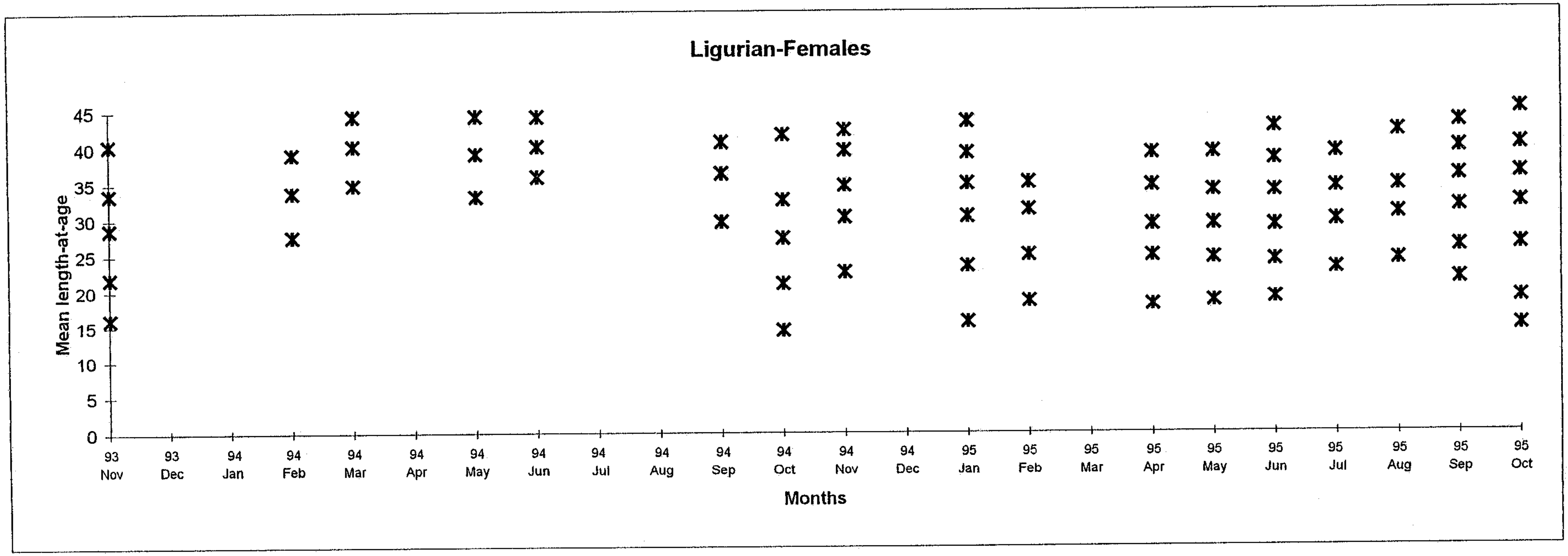
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
27.75	22.98	21.99	23.33	19.55	20.39	21.48	23.7	22.71	22.03	27.59	22.23	28.86	25.04	23.6	18.1	20.91	19.76	23.7	24.06	22.88	18	29.3	23.48	24.27	25.46
32.15	28.94	28.08	28.23	26.12	26.4	30.14	30.8	31.71	28.91	35.15	28.23	35.65	30.25	30.03	24.65	27.09	27.66	29.12	30.7	29.83	25.49	36.52	29.72	29.81	29.85
37.87	34.73	33.22	34.1	32.16	32.28	35.98	36.84	37.1	36	40.31	33.37	39.83	35.1	36.49	30.67	32.06	32.71	32.44	35.3	36.2	31.93	41.8	35.46	35.15	34.17
43.51	39.16	37.92	39.44	36.78	37.78	41.7	40.17	41.68	42.48	45.57	38.44	43.32	39.89	42.29	36.5	37.08	37.1	37.59	39.78	41.04	36.87	47.67	40.51	40.19	39.67
	44.19	43.61	44.66	41.76	42.47	46.47		45.03	46.35	49.05	42.84		44.43	46.27	42.14	40.36	42.57	41.33		45.43	41.19		45.5	45.14	43.18
	48.48	51.31	49.35	46.4		50.53		48.23						49.33	46.67	45.73		46.9		48.5				49.98	47.67
	51.62		53.98			54.1									51.47	48.34				52.4				53.69	



Mean length-at-age obtained with BHATTACHARYA

LIGURIAN-FEMALES

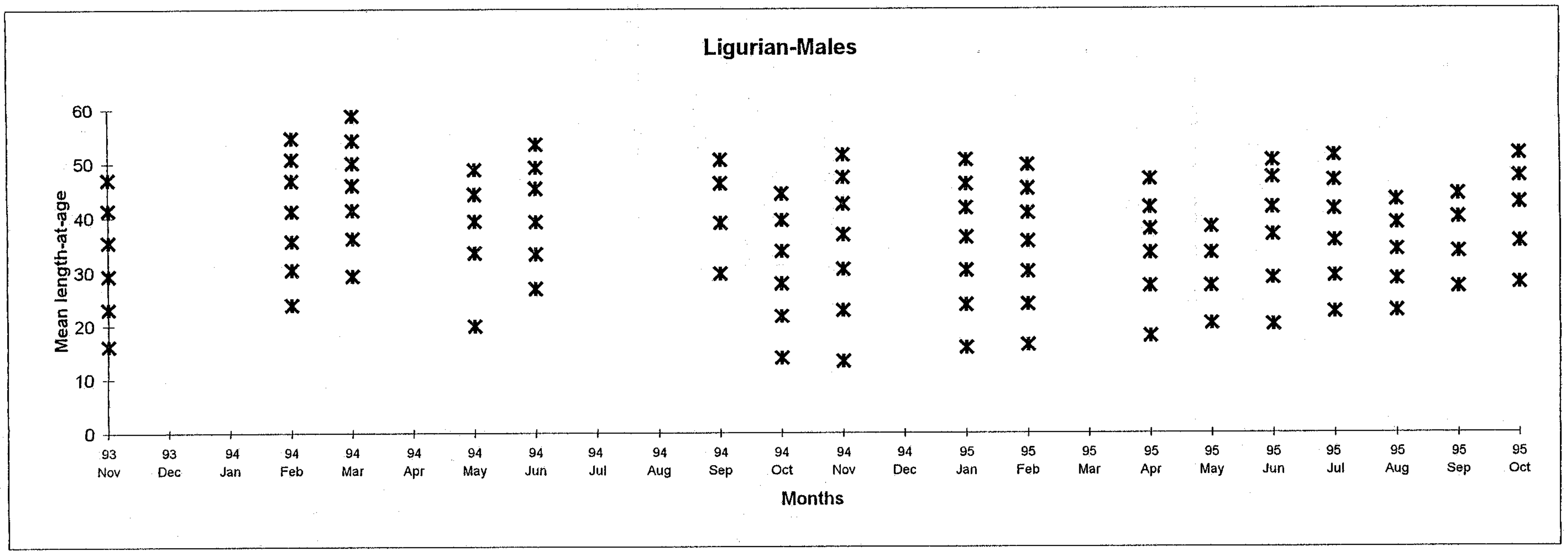
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
16.02			27.67	34.79		33.18	35.98			29.61	14.42	22.64		15.59	18.5		18	18.5	19			21.63	15
21.86			33.73	40.25		39.11	40.16			36.33	21.11	30.28		23.47	25.02		24.85	24.54	24.21	23.09	24.29	26.11	19
28.73			39.02	44.33		44.28	44.26			40.68	27.37	34.63		30.37	31.25		29.16	29.23	29	29.68	30.64	31.57	26.38
33.5											32.68	39.54		34.87	35.04		34.6	33.85	33.83	34.32	34.61	35.88	32.14
40.4											41.67	42.33		39.12			39.04	39.13	38.2	39.1		39.76	36.17
														43.45					42.58		42	43.2	40.13



Mean length-at-age obtained with BHATTACHARYA

LIGURIAN-MALES

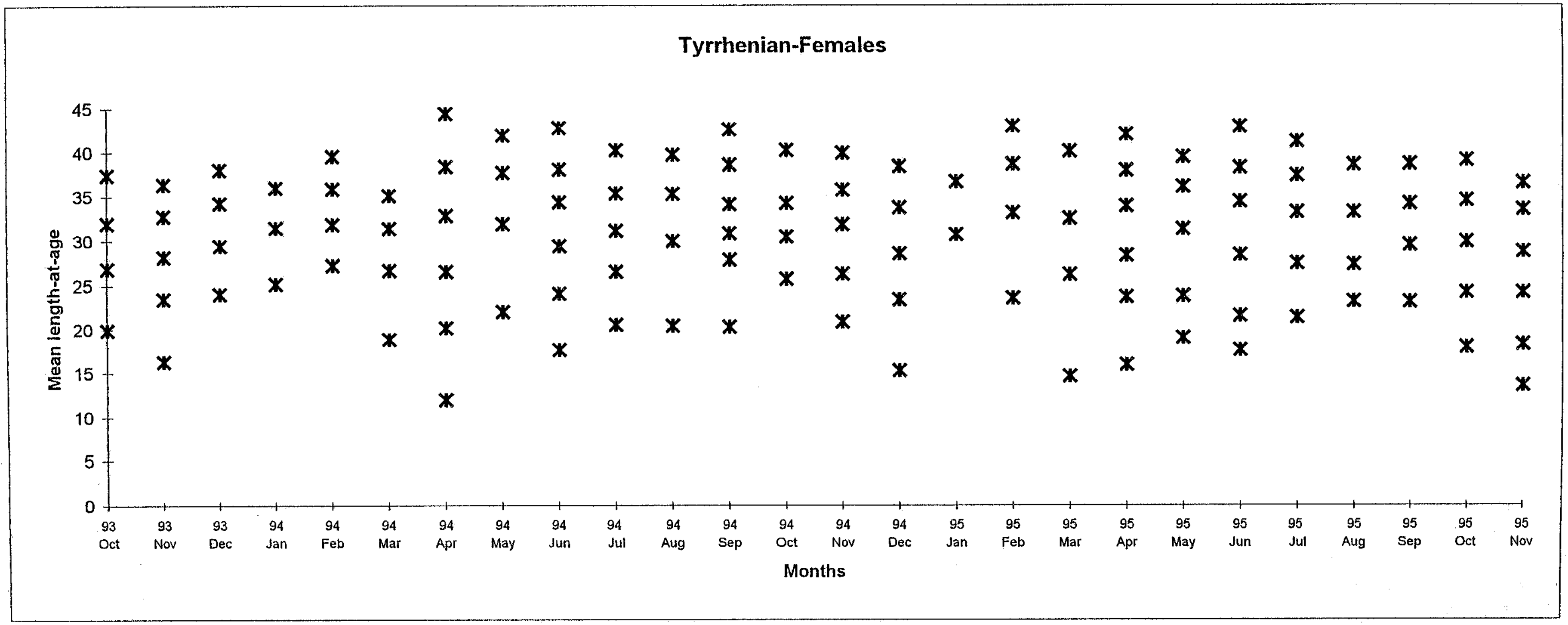
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
16.19			24	29.33		20	27			29.75	14	13.33		16	16.42		18.12	20.5	20.31	22.62	22.88	27.26	28
23.13			30.51	36.27		33.5	33.3			39.14	21.82	22.99		23.93	24.12		27.47	27.53	28.95	29.38	28.67	33.8	35.57
29.29			35.71	41.5		39.41	39.35			46.35	27.9	30.55		30.35	30.17		33.6	33.54	36.96	35.78	34.2	40.09	42.78
35.51			41.26	46		44.34	45.42			50.69	33.86	36.91		36.41	35.75		37.94	38.41	42.02	41.63	39.06	44.33	47.63
41.51			46.87	50.13		48.88	49.28				39.62	42.64		41.84	41.01		42		47.43	46.91	43.3		51.83
47.01			50.79	54.37			53.67				44.42	47.49		46.17	45.35		47.17		50.61	51.58			
			54.79	58.9								51.68		50.74	49.8								
			58.07																				



Mean length-at-age obtained with BHATTACHARYA

TYRRHENIAN-FEMALES

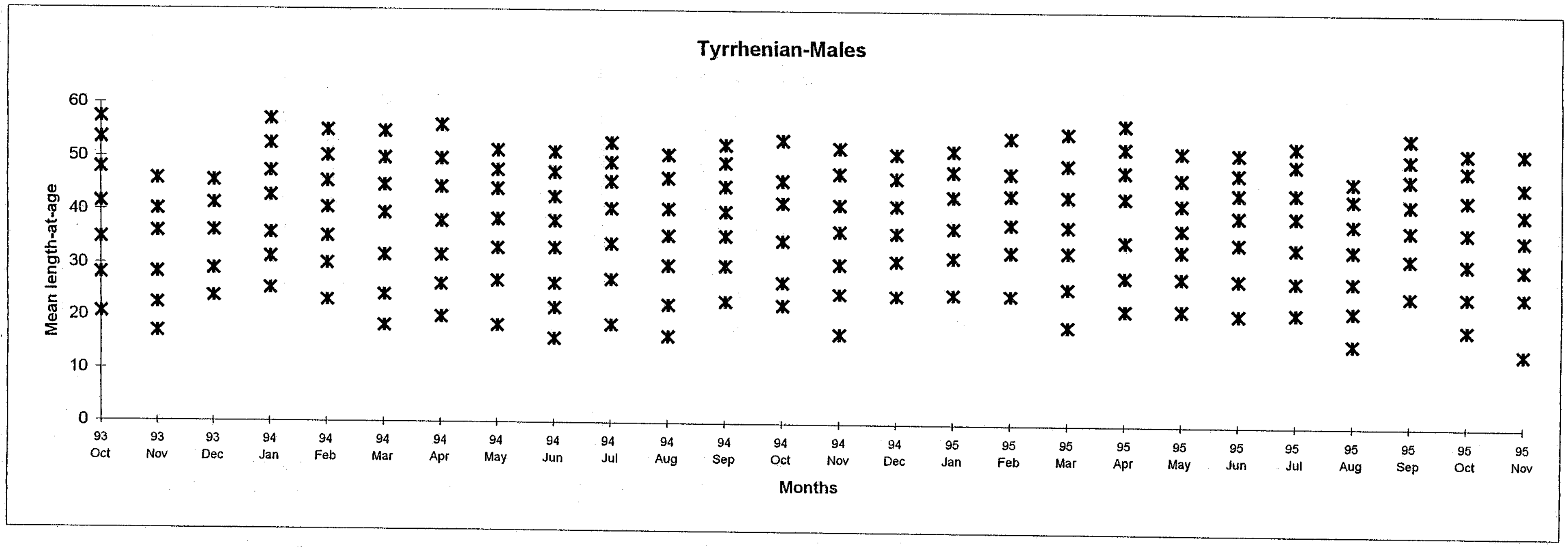
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
19.97	16.33	24.05	25.14	27.21	18.91	12	22	17.67	20.6	20.43	20.33	25.75	20.91	15.33	30.74	23.58	14.67	16	19.06	17.67	21.4	23.24	23.18	18	13.64
26.87	23.48	29.45	31.5	31.91	26.65	20.19	31.92	24.12	26.57	30.03	27.87	30.53	26.3	23.44	36.69	33.19	26.22	23.71	23.87	21.61	27.5	27.37	29.55	24.24	18.33
32.01	28.18	34.26	36.03	35.91	31.47	26.56	37.73	29.45	31.18	35.31	30.86	34.26	31.88	28.57		38.69	32.58	28.39	31.39	28.45	33.26	33.27	34.18	29.92	24.21
37.44	32.84	38.04		39.52	35.14	32.91	41.91	34.41	35.37	39.73	34.14	40.24	35.76	33.75		43	40.12	33.93	36.12	34.45	37.38	38.59	38.67	34.58	28.79
	36.41					38.39		38.12	40.25		38.58		39.9	38.43				37.94	39.46	38.3	41.24			39.08	33.55
						44.45		42.82			42.62							42.07		42.92					36.6



Mean length-at-age obtained with BHATTACHARYA

TYRRHENIAN-MALES

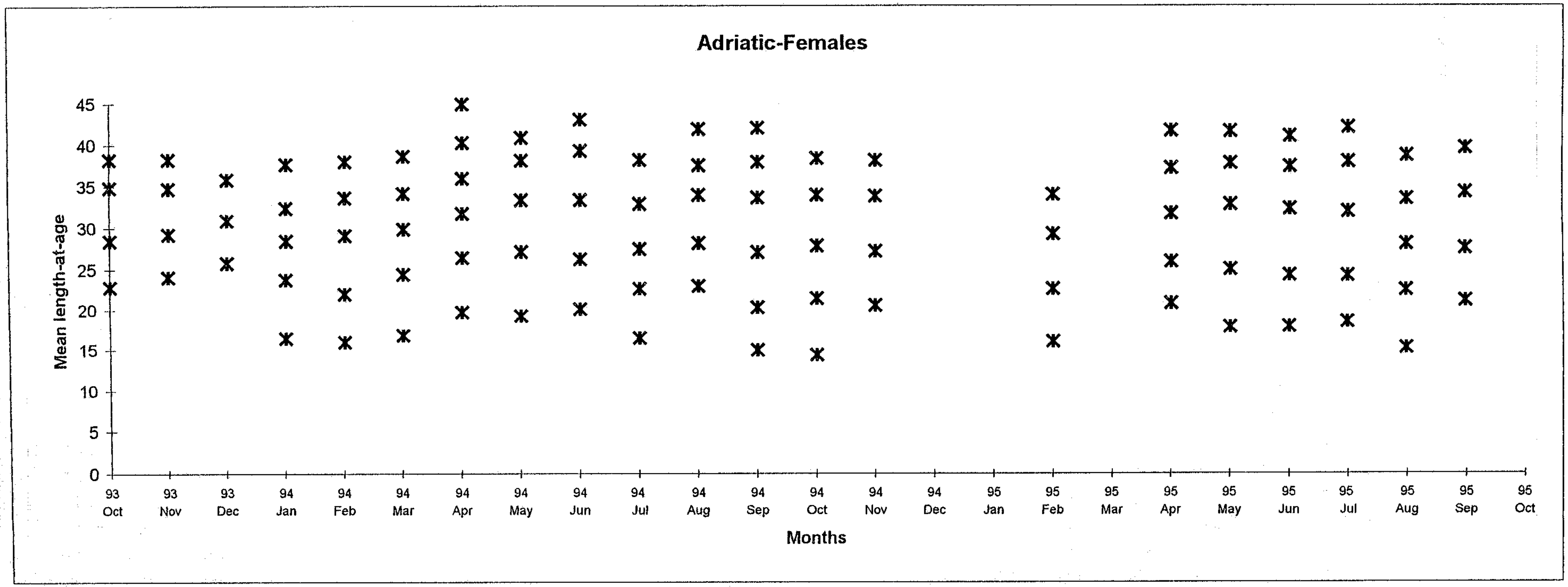
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
20.7	17	23.89	25.39	23.2	18.28	19.99	18.4	16	18.65	16.5	23.17	22.42	17	24.43	24.75	24.67	18.67	21.92	21.95	21.21	21.51	15.67	24.84	18.5	14
28.18	22.5	29.09	31.31	30.19	24.25	26.27	27	21.73	27.33	22.5	30	26.9	24.75	31	31.7	32.82	26.04	28.29	28.17	27.9	27.62	21.85	31.92	24.83	24.79
34.9	28.34	36.3	35.83	35.26	31.7	31.72	33.07	26.5	34.01	29.92	35.61	34.71	30.33	36.25	37.27	37.99	32.78	34.85	33.18	34.65	33.81	27.56	37.22	30.99	30.16
41.54	36.07	41.35	42.83	40.63	39.65	38.15	38.54	33.24	40.56	35.57	40.11	41.77	36.51	41.42	43.18	43.43	37.61	43.07	37.24	39.72	39.66	33.49	42.1	36.98	35.6
47.94	40.22	45.57	47.38	45.52	44.86	44.49	44.24	38.25	45.61	40.62	44.8	45.95	41.51	46.5	47.8	47.45	43.28	47.88	41.84	43.99	44.07	38.33	46.69	42.93	40.44
53.48	45.9		52.5	50.29	49.82	49.76	47.69	42.77	49.15	46.32	49.17	53.39	47.31	50.95	51.59	54.06	49.06	52.26	46.64	47.58	49.27	42.96	50.35	48.34	45.38
57.32			57.03	54.95	54.78	55.92	51.33	47.25	52.83	50.68	52.49		51.98				55	56.51	51.5	51.33	52.57	46.18	54.29	51.65	51.67
								51.04																	



Mean length-at-age obtained with BHATTACHARYA

ADRIATIC-FEMALES

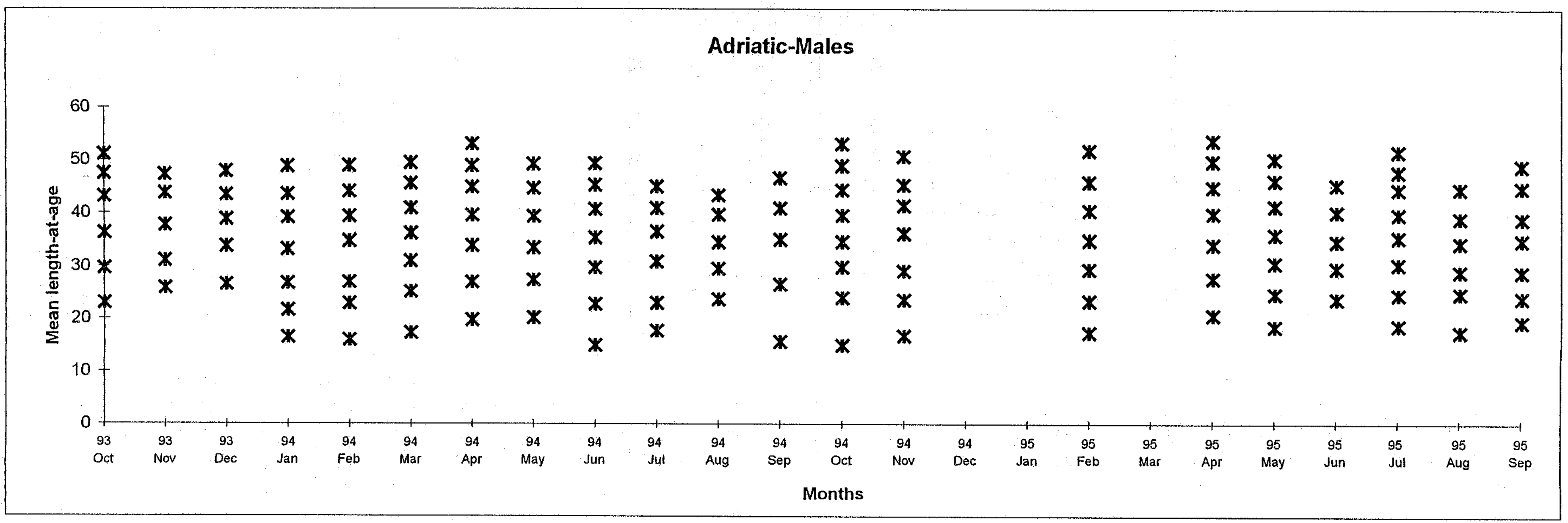
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
22.82	24.06	25.76	16.44	16.02	16.86	19.79	19.29	20.16	16.5	22.98	15	14.44	20.59			16.1		20.88	17.98	18.04	18.58	15.33	21.21	
28.43	29.18	30.89	23.74	21.95	24.37	26.37	27.1	26.18	22.61	28.18	20.36	21.43	27.2			22.63		25.94	25.06	24.29	24.23	22.48	27.6	
34.84	34.73	35.82	28.41	29.1	29.82	31.72	33.34	33.33	27.43	33.93	27.06	27.85	33.84			29.29		31.71	32.87	32.33	32	28.1	34.24	
38.22	38.23		32.39	33.63	34.17	35.95	38.1	39.3	32.92	37.52	33.64	33.93	38.11			34		37.17	37.77	37.42	37.97	33.52	39.62	
			37.63	38	38.6	40.25	40.81	43.07	38.19	41.88	37.91	38.39						41.66	41.61	41.02	42.05	38.7		
						44.91					42.04													



Mean length-at-age obtained with BHATTACHARYA

ADRIATIC-MALES

93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
22.98	25.84	26.57	16.5	15.94	17.33	19.79	20.21	15	17.71	23.67	15.67	15	16.8			17.42		20.77	18.52	23.82	18.78	17.5	19.49
29.71	31.13	33.78	21.7	22.89	25.16	27.01	27.4	22.76	23.04	29.57	26.64	23.99	23.64			23.44		27.72	24.73	29.68	24.68	24.8	24.05
36.27	37.72	38.83	26.84	26.99	31.01	33.95	33.47	29.81	30.97	34.57	35.07	29.86	29.18			29.49		34.09	30.61	34.75	30.44	29.05	28.92
43.22	43.85	43.53	33.2	34.77	36.16	39.57	39.38	35.37	36.47	39.66	40.95	34.64	36.14			34.96		39.92	35.96	40.22	35.46	34.46	34.95
47.56	47.32	47.92	39.2	39.4	40.88	44.91	44.75	40.75	40.91	43.42	46.65	39.56	41.4			40.52		44.91	41.3	45.37	39.76	39.08	39.01
51.17			43.6	44.13	45.66	49.02	49.3	45.4	45.03			44.43	45.32			46		49.84	46.14		44.51	44.67	44.8
			48.85	48.92	49.52	53.11		49.33				48.93	50.69			51.84		53.67	50.18		47.86		48.96
												53.13									51.6		

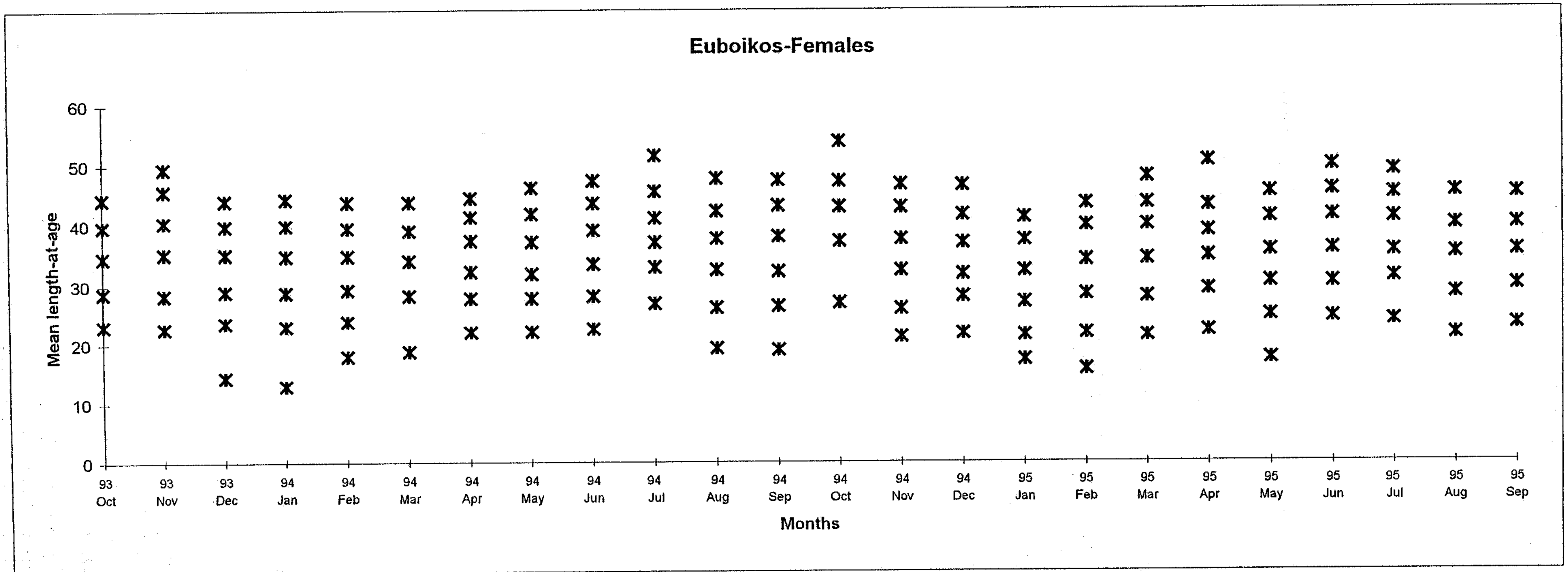


Mean length-at-age obtained with BHATTACHARYA

EUBOIKOS-FEMALES

93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec
23.12	22.66	14.37	13	17.94	18.77	22.06	22.11	22.62	26.9	19.3	19	27.02	21.24	21.78
28.69	28.32	23.68	23.04	23.87	28.24	27.83	27.84	28.15	32.95	26.18	26.47	37.23	26.05	28.05
34.58	35.16	28.97	28.77	29.25	34.03	32.3	31.87	33.47	37.07	32.5	32.24	42.98	32.47	31.86
39.7	40.42	35.1	34.81	34.85	38.98	37.37	37.19	39.07	41.16	37.65	38.03	47.25	37.59	36.97
44.36	45.65	39.83	39.93	39.46	43.83	41.35	41.85	43.68	45.64	42.34	43.2	53.84	42.96	41.73
	49.45	44.07	44.32	43.83		44.54	46.26	47.36	51.6	47.77	47.51		46.75	46.59
		48.4	48.42	47.14		48.08	51.58	50.45		53.7	53.58			50.71

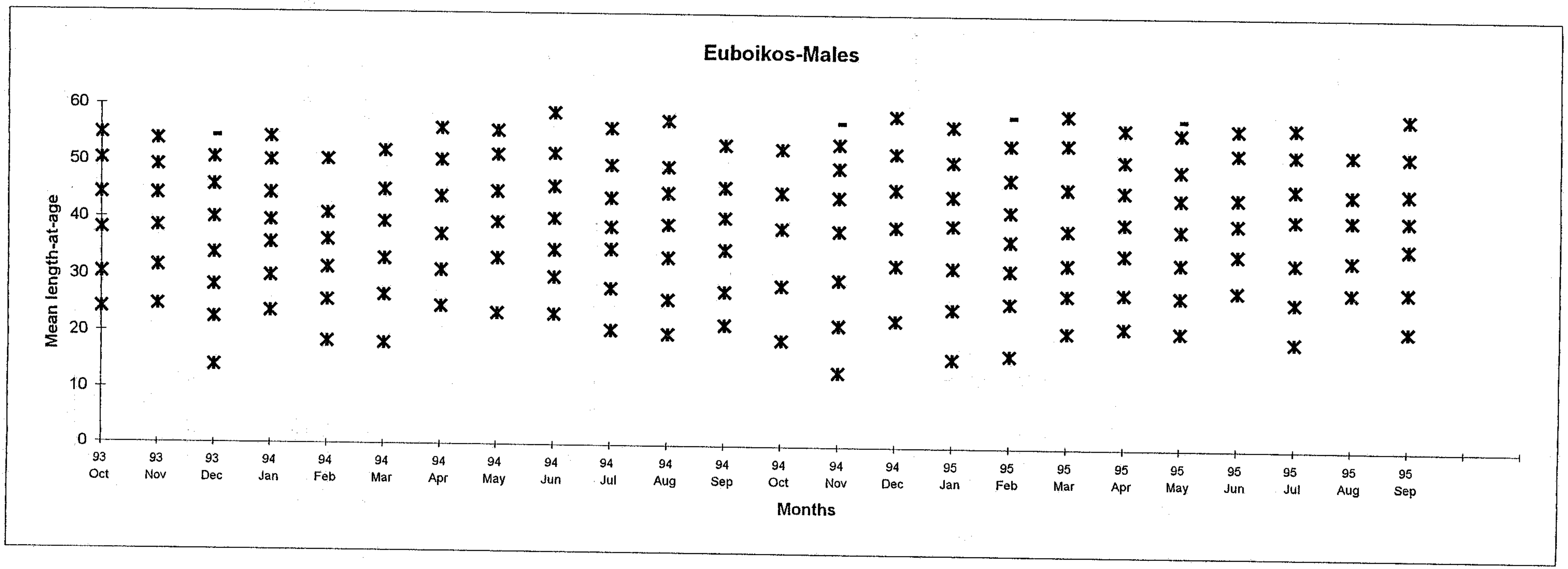
95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
17.29	15.77	21.42	22.24	17.52	24.51	24	21.64	23.28
21.53	21.91	28.04	29.27	24.89	30.37	31.31	28.54	29.86
27.1	28.45	34.33	34.73	30.48	35.92	35.56	35.17	35.52
32.33	34.12	40.02	38.94	35.61	41.5	41.14	40	40.1
37.39	39.94	43.68	43.21	41.24	45.78	45.18	45.46	45.12
41.28	43.54	48.02	50.58	45.44	49.9	48.96		
46.76				50.37		53.42		



Mean length-at-age obtained with BHATTACHARYA

EUBOIKOS-MALES

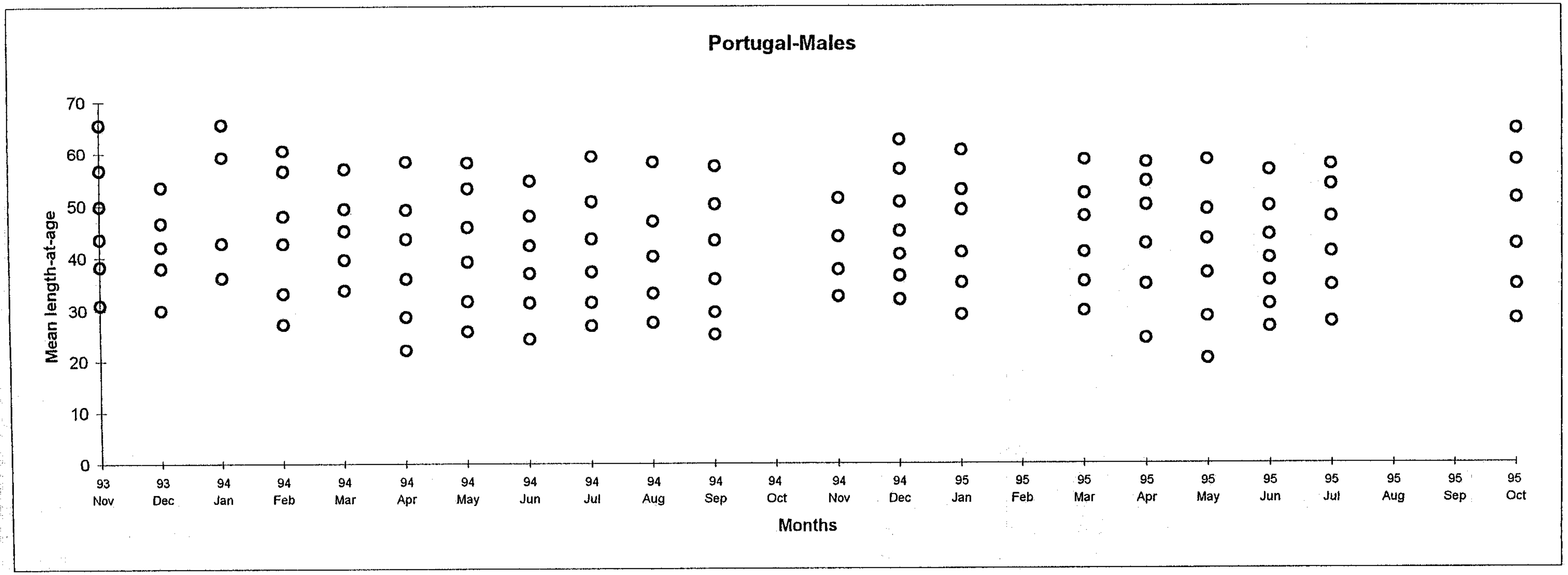
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
24.24	24.76	14.00	23.70	18.46	18.12	24.70	23.53	23.42	20.67	20.00	21.67	19.04	13.33	22.67	15.92	16.72	20.81	21.76	20.98	28.33	19.33	28.21	21.50
30.43	31.59	22.54	29.91	25.75	26.64	31.06	33.20	29.91	27.99	26.08	27.55	28.65	21.76	32.43	24.80	25.86	27.48	27.71	27.31	34.64	26.37	33.82	28.38
38.05	38.53	28.25	35.68	31.43	32.97	37.22	39.43	34.62	34.87	33.48	34.87	38.66	29.74	39.06	32.05	31.66	32.82	34.56	33.11	40.03	33.31	40.81	35.97
44.31	44.28	33.87	39.63	36.21	39.42	43.92	44.91	40.15	38.74	39.20	40.49	44.96	38.24	45.73	39.46	36.82	38.74	39.99	38.82	44.64	40.86	45.30	40.81
50.35	49.23	40.08	44.38	40.89	45.09	50.30	51.36	45.79	43.84	44.77	45.81	52.60	44.26	51.97	44.60	41.95	46.05	45.66	44.41	52.33	46.17	52.29	45.64
54.84	53.84	45.80	50.11	50.32	51.87	55.92	55.57	51.60	49.63	49.28	53.24		49.33	58.66	50.63	47.56	53.82	51.00	49.33	56.70	52.16		52.07
		50.57	54.24					58.83	56.16	57.50			53.52		56.87	53.62	59.00	56.63	55.86		56.93		58.67
		54.40											57.36			58.65			58.28				



Mean length -at-age obtained with MIX

PORTUGAL-MALES

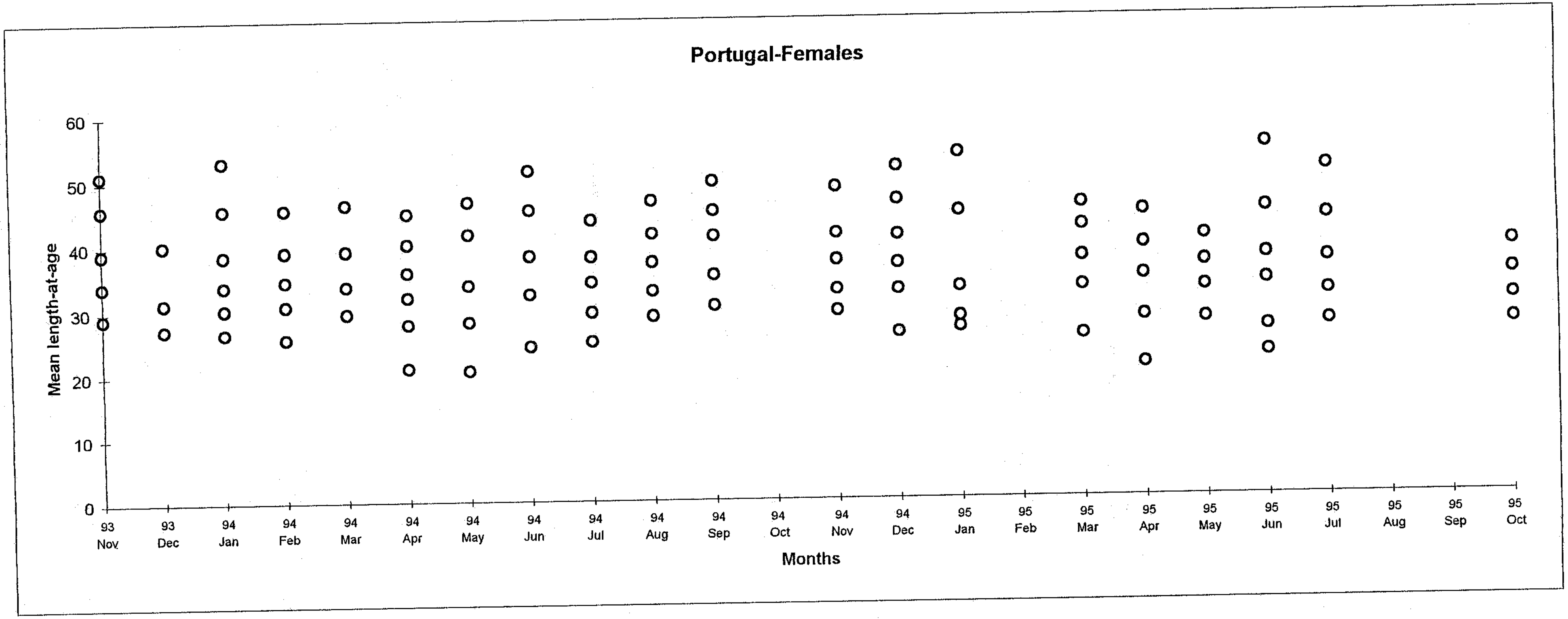
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
30.96	29.96	36.17	27.26	33.76	22.09	25.8	24.36	26.91	27.57	25.26		32.61	31.94	29.08		29.76	24.43	20.44	26.66	27.66			28.13
38.36	38.06	42.89	33.22	39.58	28.7	31.67	31.36	31.46	33.19	29.59		37.76	36.54	35.23		35.45	34.88	28.68	31.09	34.66			34.84
43.63	42.16	59.2	42.77	45.17	35.99	39.25	37.03	37.35	40.2	35.89		44.07	40.68	41.08		41.07	42.69	37.03	35.59	41.14			42.5
49.89	46.65	65.56	47.98	49.39	43.61	45.91	42.31	43.68	47	43.35		51.34	45.06	49.13		47.9	50	43.55	39.93	47.8			51.29
56.77	53.52		56.5	56.9	49.2	53.16	47.98	50.64	58.2	50.19			50.6	52.87		52.22	54.5	49.16	44.33	53.87			58.49
65.56			60.55		58.31	58.12	54.57	59.35		57.42			56.84	60.56		58.65	58.14	58.6	49.79	57.72			64.56
													62.56						56.59				



Mean length -at-age obtained with MIX

PORTUGAL-FEMALES

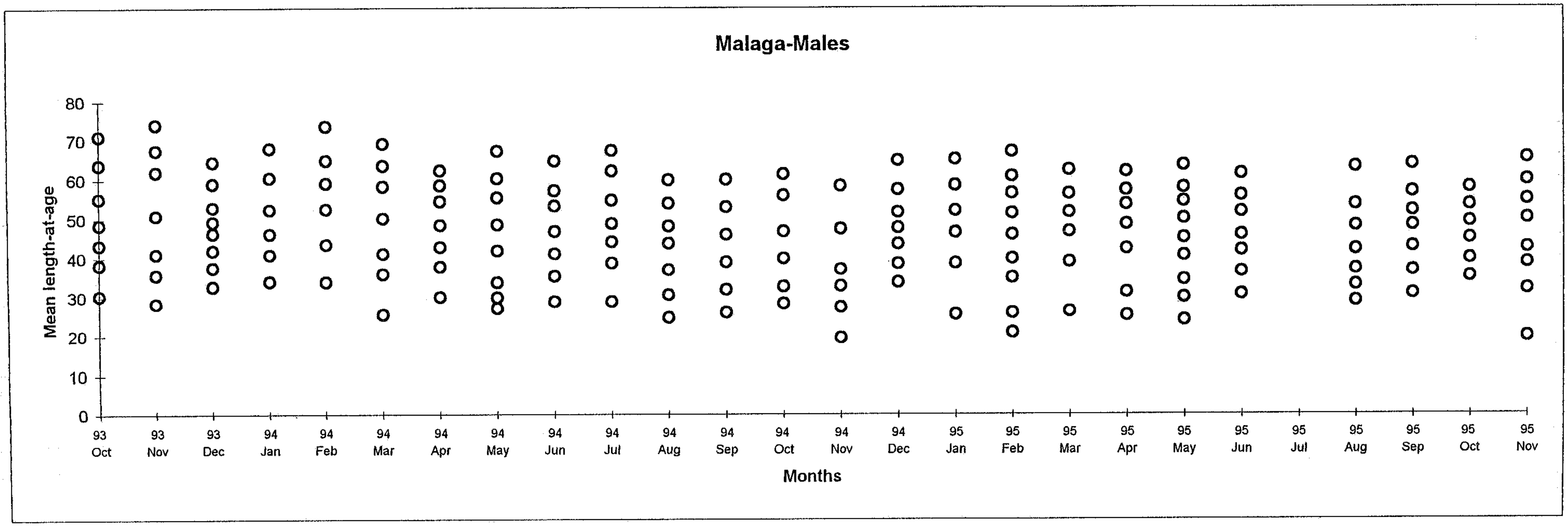
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
28.99	27.27	26.63	25.75	29.58	21.01	20.64	24.32	25.07	28.98	30.47		29.48	26.08	26.87		25.58	20.86	27.8	22.47	27.28			27.1
33.99	31.32	30.33	30.82	33.78	27.86	28.24	32.42	29.6	32.87	35.27		32.83	32.76	33.1		33.06	28.34	32.87	26.5	31.96			30.82
39.04	40.2	33.9	34.6	39.18	32.01	33.85	38.3	34.25	37.28	41.18		37.37	36.76	28.49		37.55	34.73	36.64	33.69	36.99			34.78
45.71		38.59	39.16	46.37	35.92	41.61	45.36	38.13	41.53	45.08		41.41	41.07	44.61		42.3	39.34	40.59	37.63	43.51			39.09
51.04		45.59	45.6		40.21	46.67	51.44	43.78	46.69	49.55		48.52	46.52	53.61		45.72	44.51		44.72	51.05			
		53.07			44.86								51.56						54.56				



Mean length -at-age obtained with MIX

MALAGA-MALES

93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
30.46	28.41	32.85	34.12	33.95	25.61	30.07	27.2	28.9	28.91	24.84	26.2	28.36	19.58	33.91	25.54	20.89	26.4	25.29	24.12	30.75		29.03	30.96	35.36	19.82
38.26	35.76	37.65	40.87	43.57	35.94	37.9	30	35.49	38.8	30.69	31.96	32.78	27.5	38.7	38.79	25.96	39.25	31.32	29.98	36.66		33.14	36.91	40.06	32.11
43.3	41.1	42.03	46.25	52.67	41.26	42.9	33.82	41.19	44.21	37.02	39.01	39.98	33	43.7	46.63	35.06	47	42.5	34.54	42.12		37.4	43.08	45.24	38.92
48.54	50.92	46.34	52.54	59.23	50.21	48.56	41.98	47	48.99	43.84	46.11	46.93	37.22	47.9	52.22	40.04	51.87	48.77	40.81	46.1		42.45	48.6	49.46	42.84
55.35	62.01	49.34	60.49	64.93	58.39	54.61	48.62	53.51	54.87	48.32	53.15	56.1	47.64	51.84	58.71	46.14	56.6	53.89	45.37	51.94		48.43	52.33	53.7	50.31
63.73	67.44	53.13	68.05	73.62	63.58	58.7	55.6	57.31	62.31	54.19	60.19	61.53	58.53	57.54	65.22	51.61	62.5	57.44	50.32	56.19		53.82	57.07	58.1	55.12
71.04	74.03	59.01			69.19	62.37	60.43	64.76	67.5	60				64.89		56.72		62.11	54.72	61.66		63.28	63.97		59.94
		64.55					67.33									60.92			58.14						65.56
																67.24			63.68						

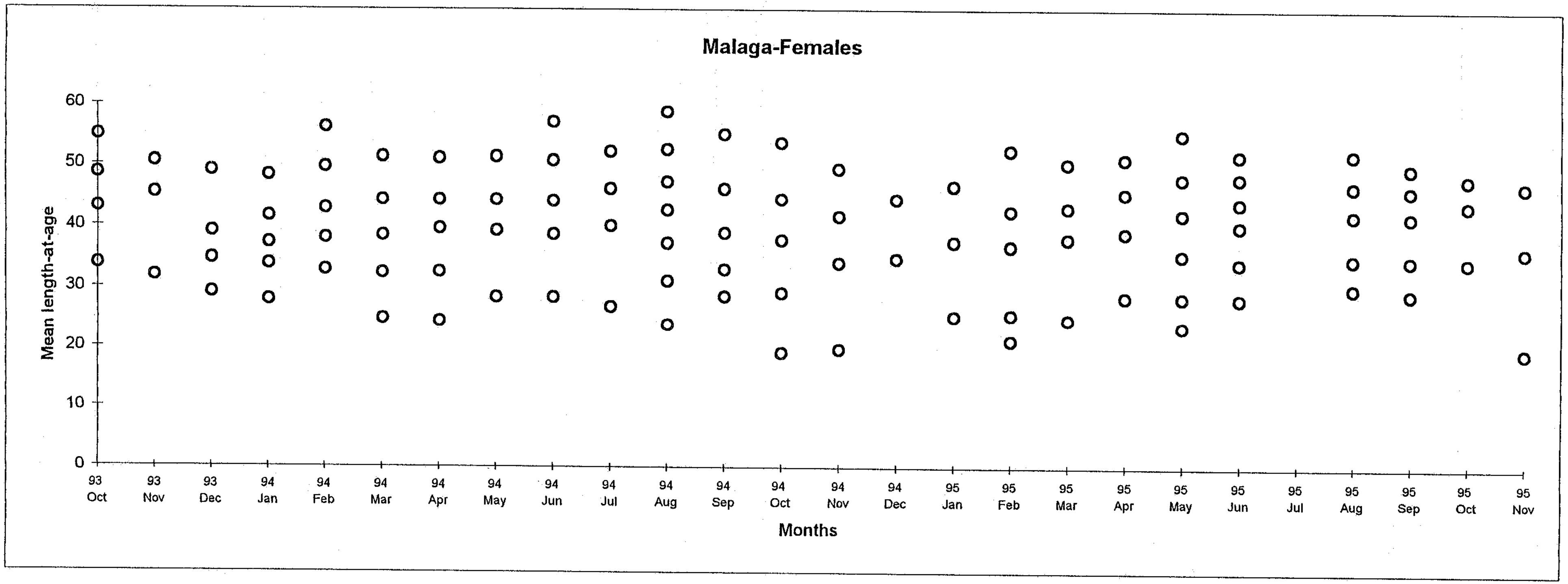


Mean length -at-age obtained with MIX

MALAGA-FEMALES

93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct
33.88	31.92	29.26	28	32.98	24.86	24.44	28.48	28.47	26.92	23.97	28.57	19.27
43.11	45.42	34.77	33.92	38.05	32.46	32.62	39.29	38.67	40.08	31.17	33.01	29.24
48.67	50.57	39.14	37.3	42.93	38.5	39.6	44.31	44.1	46.13	37.26	38.93	37.83
54.92		49.08	41.62	49.72	44.33	44.29	51.33	50.76	52.22	42.67	46.1	44.52
			48.33	56.15	51.37	51.04		57.09		47.25	55.02	53.7
										52.57		
										58.75		

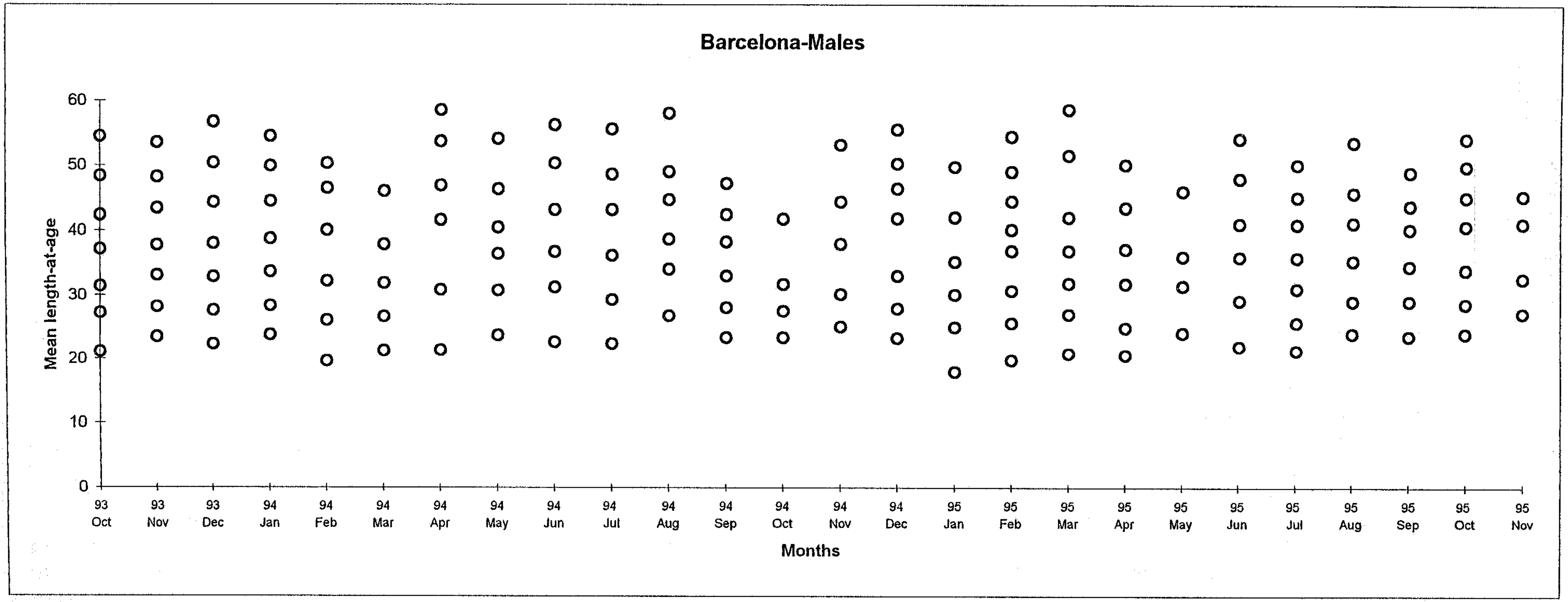
94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
19.82	34.84	25.37	21.37	24.9	28.62	23.64	28.31		30.09	29.19	34.4	19.48
34.12	44.5	37.54	25.7	38.05	39.02	28.51	34.14		34.87	34.69	43.58	36.13
41.69		46.62	36.83	43.12	45.42	35.48	40.16		41.94	41.68	47.82	46.73
49.38			42.55	50.27	51.05	42.01	43.87		46.61	45.92		
			52.5			47.87	47.92		51.89	49.63		
						55.06	51.66					



Mean length -at-age obtained with MIX

BARCELONA-MALES

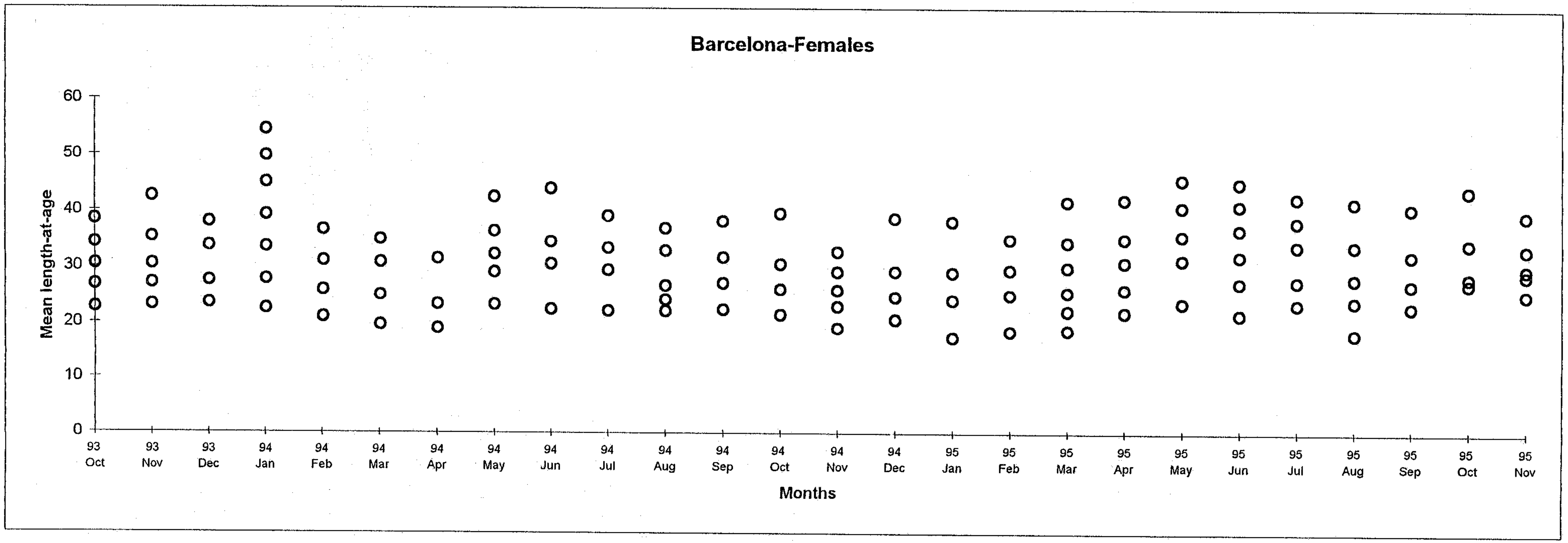
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
21.11	23.5	22.35	23.8	19.67	21.31	21.37	23.68	22.62	22.39	26.82	23.35	23.38	25.12	23.29	17.92	19.82	20.84	20.66	24.11	22.04	21.39	24.02	23.6	24.02	27.32
27.21	28.14	27.64	28.33	26.1	26.61	30.88	30.76	31.27	29.34	34.07	28.06	27.49	30.21	27.96	24.97	25.65	27.04	24.96	31.52	29.2	25.76	29.17	29.14	28.77	32.7
31.39	33.16	32.91	33.69	32.22	31.91	41.63	36.46	36.82	36.21	38.74	33.03	31.73	38.01	33.03	30.1	30.81	31.88	31.85	36.02	35.99	31.11	35.42	34.62	34.05	41.19
37.16	37.81	38.07	38.84	40.09	37.94	46.95	40.53	43.16	43.2	44.73	38.36	41.79	44.38	41.88	35.24	36.97	36.95	37.22	46.03	41.05	35.92	41.22	40.25	40.75	45.36
42.42	43.46	44.35	44.5	46.51	46	53.72	46.39	50.37	48.6	49	42.44		53.2	46.47	42.03	40.23	42.06	43.52		47.97	41.01	45.77	43.85	45.13	
48.43	48.19	50.43	49.94	50.34		58.56	54.17	56.24	55.58	58.08	47.27			50.22	49.75	44.52	51.55	50.08		54.16	45.18	53.56	48.98	49.82	
54.52	53.58	56.76	54.57											55.56		49.03	58.62				50.09			54.13	
																54.44									



Mean length -at-age obtained with MIX

BARCELONA-FEMALES

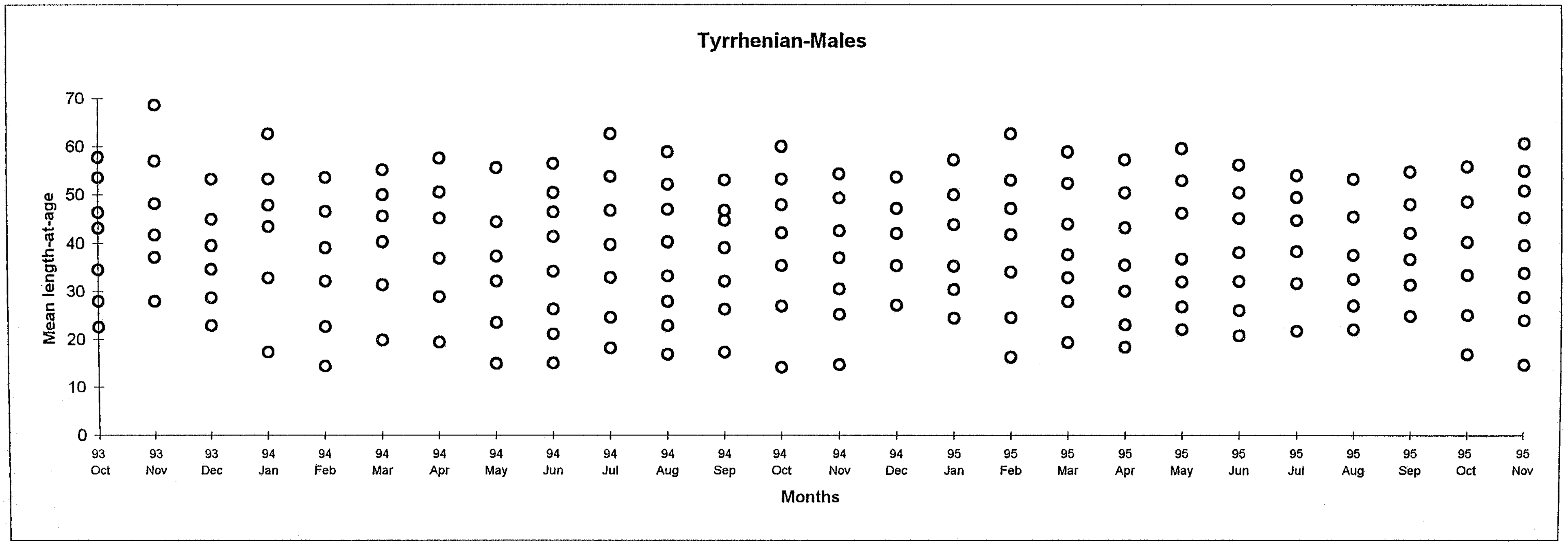
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
22.66	23.15	23.52	22.49	21.02	19.69	19.1	23.23	22.46	22.14	22.16	22.43	21.55	19.13	20.69	17.5	18.58	18.8	21.98	23.59	21.62	23.47	18.17	22.95	28.24	29.76
26.84	27.11	27.55	27.77	25.93	25.01	23.36	29.08	30.57	29.41	26.69	27.13	26.09	22.94	24.74	24.18	25.04	22.28	26.04	31.38	27.31	27.53	23.93	26.99	27.19	25.27
30.43	30.46	33.72	33.56	31.13	30.83	31.48	32.29	34.45	33.39	32.94	31.69	30.53	25.94	29.27	29.11	29.55	25.54	30.91	35.63	31.97	33.84	28	32.16	34.28	28.754
34.27	35.27	38.05	39.32	36.67	34.92		36.37	43.98	39.12	36.93	38.25	39.59	29.15	38.75	38.22	35	29.98	35.14	40.8	36.71	38.11	33.87	40.61	43.68	33.28
38.46	42.56		45.07				42.49			24.2			32.76				34.46	42.09	45.56	41.05	42.44	41.58			39.31
			49.81														41.74			44.94					
			54.49																						



Mean length -at-age obtained with MIX

TYRRHENIAN-MALES

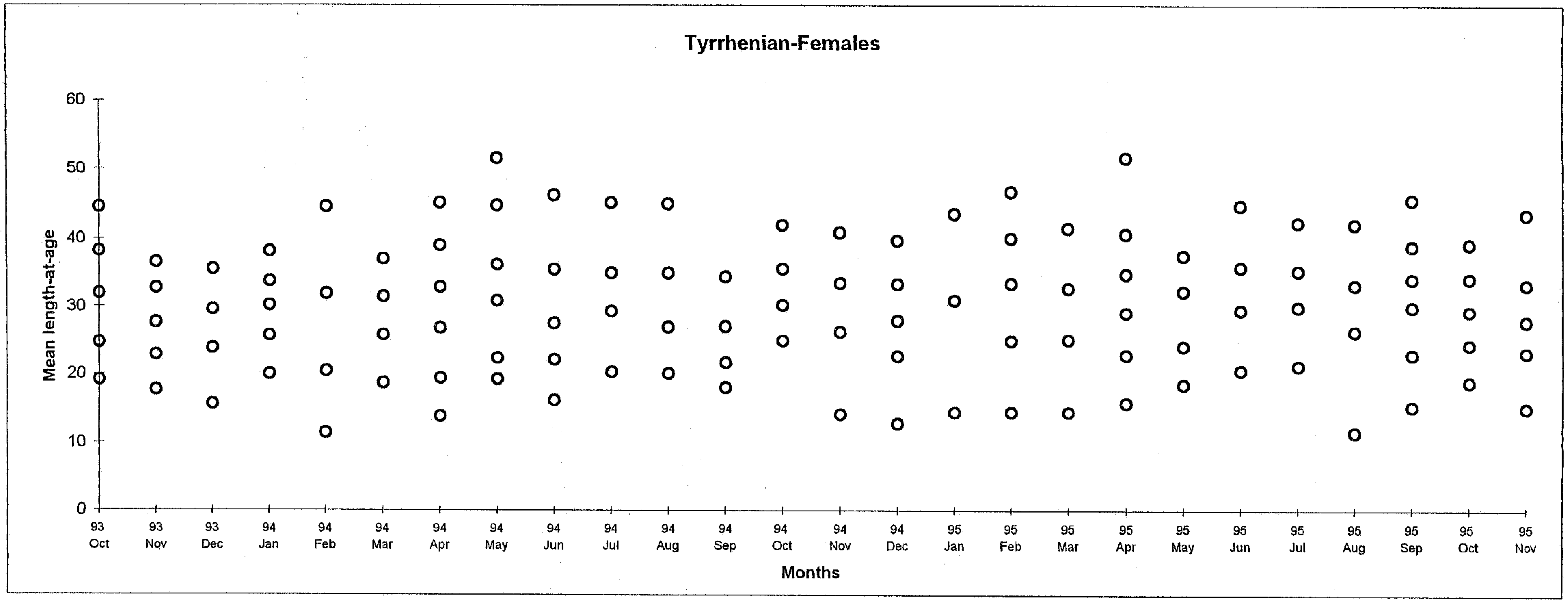
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
22.58	27.94	22.94	17.34	14.45	19.85	19.42	15.02	15.15	18.25	16.94	17.34	14.23	14.83	27.26	24.5	16.44	19.47	18.48	22.14	20.83	21.81	22.16	24.97	16.98	14.83
27.95	37.2	28.77	32.79	22.64	31.46	28.98	23.51	21.14	24.63	22.93	26.36	27.02	25.23	35.39	30.49	24.66	27.95	23.16	26.91	26.17	31.73	27.08	31.43	25.12	24.11
34.6	41.75	34.64	43.38	32.15	40.29	36.98	32.22	26.32	32.99	27.97	32.17	35.45	30.53	42.05	35.3	34.12	32.93	30.12	32.06	32.15	38.31	32.65	36.75	33.54	28.95
43.15	48.15	39.59	47.85	39.14	45.55	45.17	37.33	34.25	39.7	33.22	39.12	42.18	37.08	47.24	43.83	41.79	37.74	35.55	36.82	38.1	44.67	37.62	42.09	40.33	33.91
46.39	57.06	44.95	53.26	46.6	50	50.59	44.41	41.33	46.77	40.28	44.74	47.92	42.52	53.71	50	47.17	43.99	43.19	46.28	45.14	49.48	45.51	48.07	48.63	39.67
53.56	68.56	53.23	62.51	53.59	55.21	57.55	55.59	46.48	53.78	47.03	46.79	53.21	49.36		57.3	53.09	52.43	50.5	52.93	50.44	53.96	53.23	54.76	55.83	45.32
57.79								50.41	62.59	52.14	53	59.99	54.34			62.56	58.88	57.28	59.56	56.16					50.87
								56.55		58.89															54.94
																									60.56



Mean length -at-age obtained with MIX

TYRRHENIAN-FEMALES

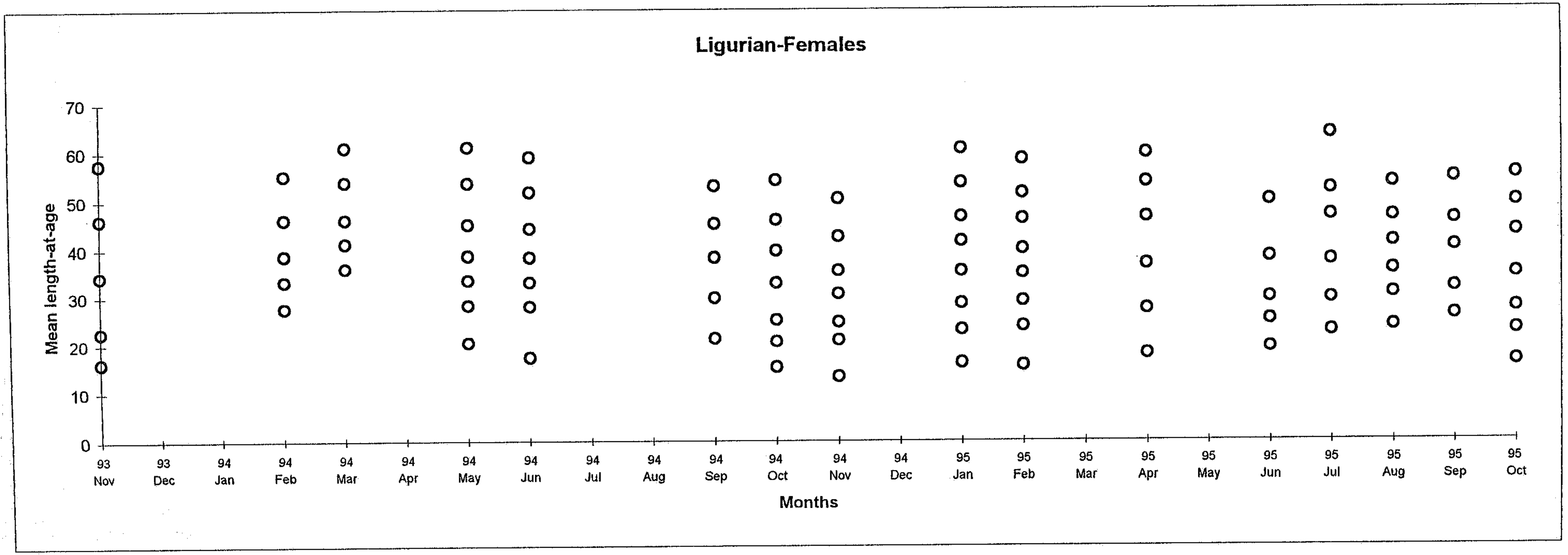
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct	95 Nov
19.18	17.69	15.63	20.05	11.44	18.72	13.82	19.26	16.18	20.32	20.09	18.05	25.04	14.08	12.73	14.42	14.44	14.46	15.84	18.46	20.54	21.22	11.44	15.29	18.87	15.03
24.77	22.96	23.94	25.77	20.47	25.86	19.44	22.43	22.19	29.3	27.01	21.69	30.21	26.3	22.68	30.95	24.98	25.17	22.85	24.14	29.47	29.9	26.36	22.93	24.37	23.28
31.97	27.73	29.62	30.24	31.91	31.42	26.85	30.88	27.54	34.92	34.88	27.1	35.56	33.42	27.9	43.51	33.39	32.67	29.06	32.19	35.79	35.25	33.15	29.89	29.3	27.85
38.19	32.76	35.52	33.76	44.56	36.96	32.87	36.15	35.41	45.13	44.99	34.39	41.9	40.79	33.32		39.99	41.41	34.77	37.45	44.64	42.2	41.99	34.06	34.15	33.19
44.55	36.54		38.16			38.97	44.73	46.18						39.66		46.66		40.6					38.8	39.13	43.46
						45.13	51.55											51.56					45.53		



Mean length -at-age obtained with MIX

LIGURIAN-MALES

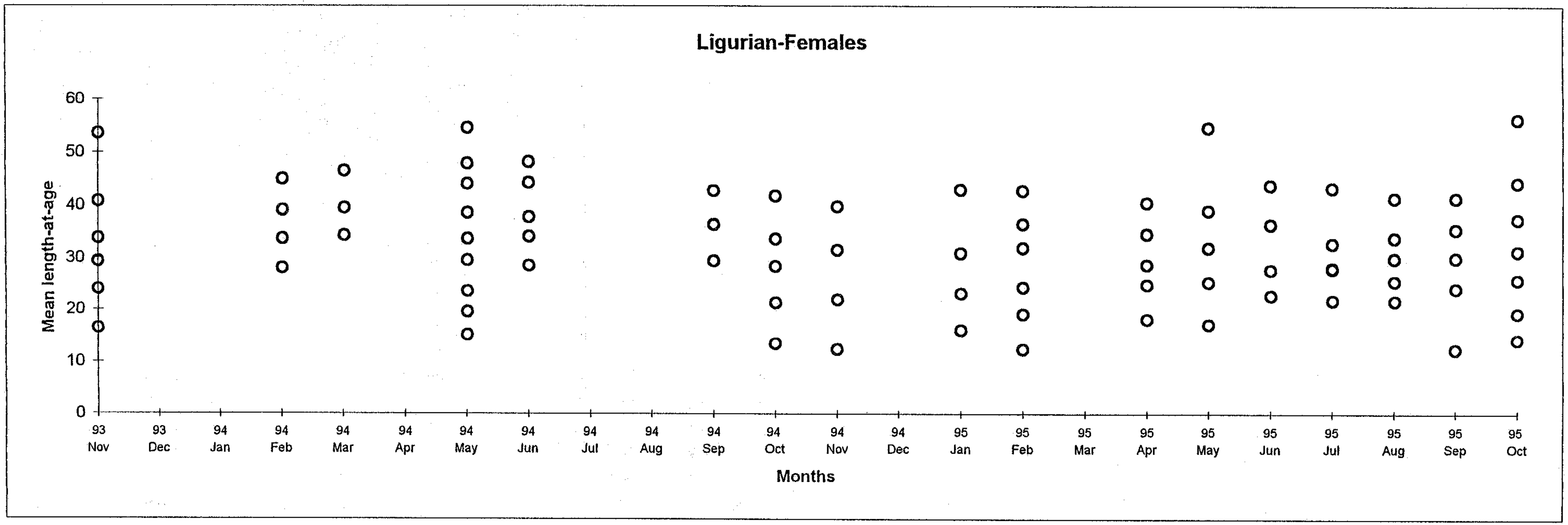
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
16.23			27.67	36.04		20.45	17.44			21.33	15.34	13.38		16.17	15.7		18.07		19.35	22.83	23.82	26.14	16.38
22.59			33.25	41.14		28.28	28.05			29.78	20.61	20.94		23.1	23.87		27.46		25.17	29.64	30.66	31.92	23.05
34.38			38.69	46.11		33.61	33.17			38.28	25.18	24.73		28.63	29.12		36.8		29.82	37.61	35.62	40.45	27.64
46.16			46.18	53.86		38.65	38.33			45.23	32.94	30.68		35.41	35.03		46.54		38.29	46.92	41.33	46.06	34.81
57.63			55.16	60.91		45.13	44.29			53.09	39.61	35.57		41.58	40		53.76		50.03	52.25	46.62	54.56	43.48
						53.66	51.82				46.05	42.6		46.69	46.26		59.63			63.61	53.56		49.74
						61.04	59				54.2	50.5		53.68	51.54								55.34
														60.57	58.48								



Mean length -at-age obtained with MIX

LIGURIAN-FEMALES

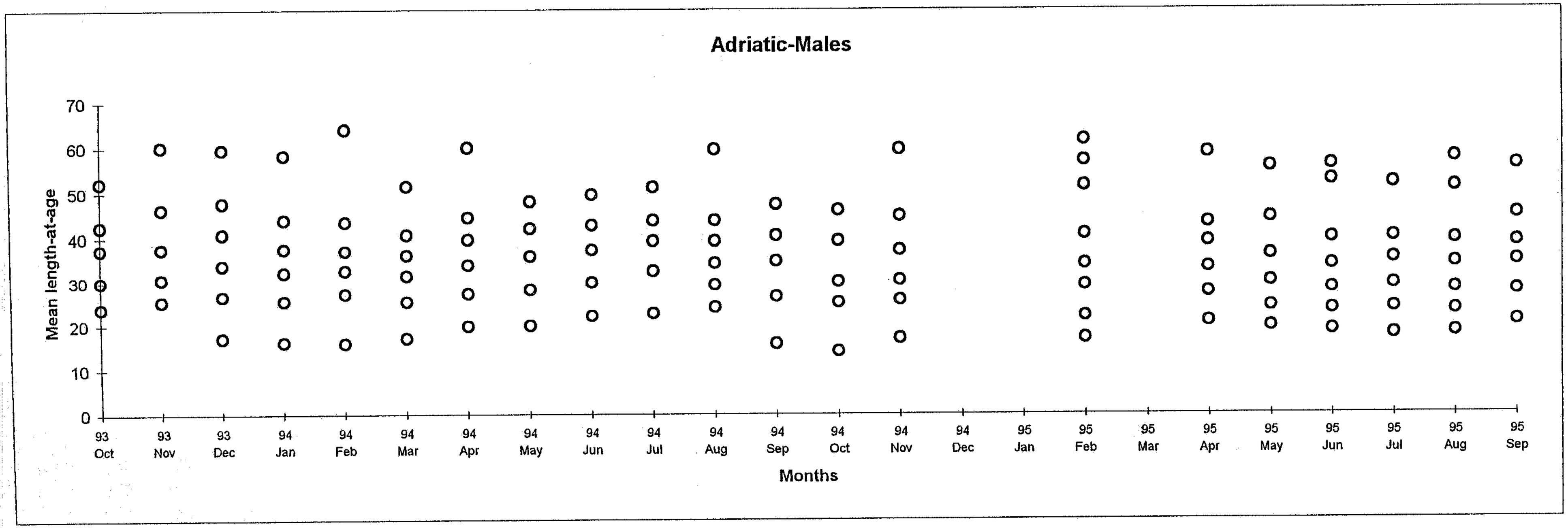
93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep	95 Oct
16.413			28.07	34.331		15.079	28.645			29.496	13.534	12.385		16.1	12.44		18.25	17.23	22.77	21.943	21.78	12.38	14.26
24.016			33.685	39.539		19.597	34.099			36.378	21.353	21.977		23.22	19.17		24.94	25.4	27.85	28.013	25.63	24.25	19.45
29.353			39.105	46.494		23.631	37.762			42.814	28.474	31.564		31	24.43		28.82	31.99	36.39	32.833	29.99	30.11	25.89
33.836			45.012			29.564	44.318				33.677	39.809		42.96	31.96		34.63	39.01	43.82	28.239	33.86	35.46	31.398
40.824						33.735	48.189				41.753				36.52		40.46	54.56		43.31	41.44	41.37	37.421
53.555						38.554									42.8								44.321
						44.149																	56.23
						47.9																	
						54.555																	



Mean length -at-age obtained with MIX

ADRIATIC-MALES

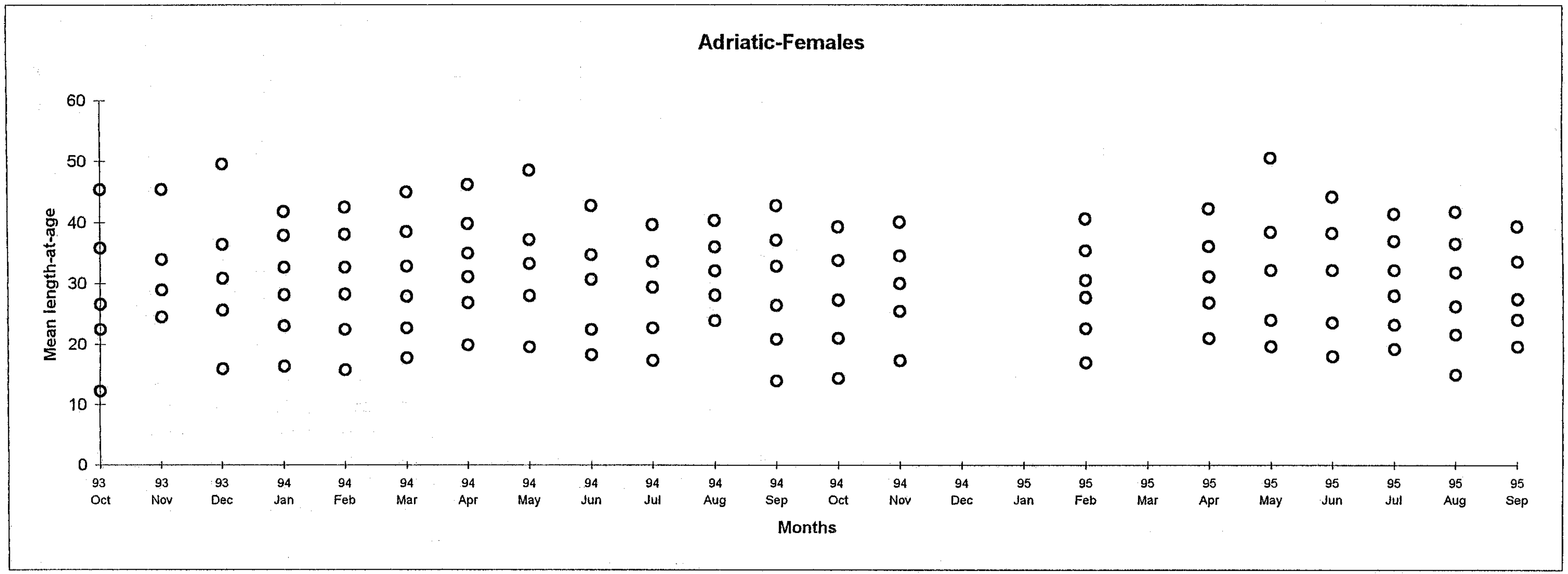
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
23.83	25.55	17.18	16.26	16.07	17.21	19.91	19.99	22.19	22.86	24.21	15.92	14.21	17.06			17.13		20.82	19.67	18.86	17.86	18.39	20.86
29.91	30.62	26.74	25.62	27.23	25.53	27.41	28.31	29.97	32.55	29.33	26.71	25.23	25.85			22.16		27.59	24.33	23.66	23.95	23.42	27.86
37.32	37.54	33.82	32.18	32.61	31.49	33.93	35.93	37.36	39.37	34.34	34.82	30.14	30.45			29.26		33.24	30.07	28.39	29.42	28.32	34.69
42.5	46.39	40.85	37.61	37.09	36.14	39.63	42.19	42.86	43.85	39.36	40.47	39.31	37.25			34.08		39.04	36.15	33.88	35.26	34.17	38.85
52.24	60.19	47.74	43.96	43.59	40.71	44.62	48.06	49.62	51.25	43.91	47.35	46.14	44.83			40.75		43.27	44.39	39.83	39.98	39.44	45.01
59.31		53.34	49.69	48.53	45.07	53.63	54.03	58.56		52.12	57.23	59.56	51.49			47.09		49.57	49.48	47.43	46.21	45.48	49.62
		59.56	58.3	64.02	51.47	60.1				59.56			59.63			51.46		58.73	55.64	52.68	51.99	51.2	55.92
																56.97				56.05		57.58	
																61.57							



Mean length -at-age obtained with MIX

ADRIATIC-FEMALES

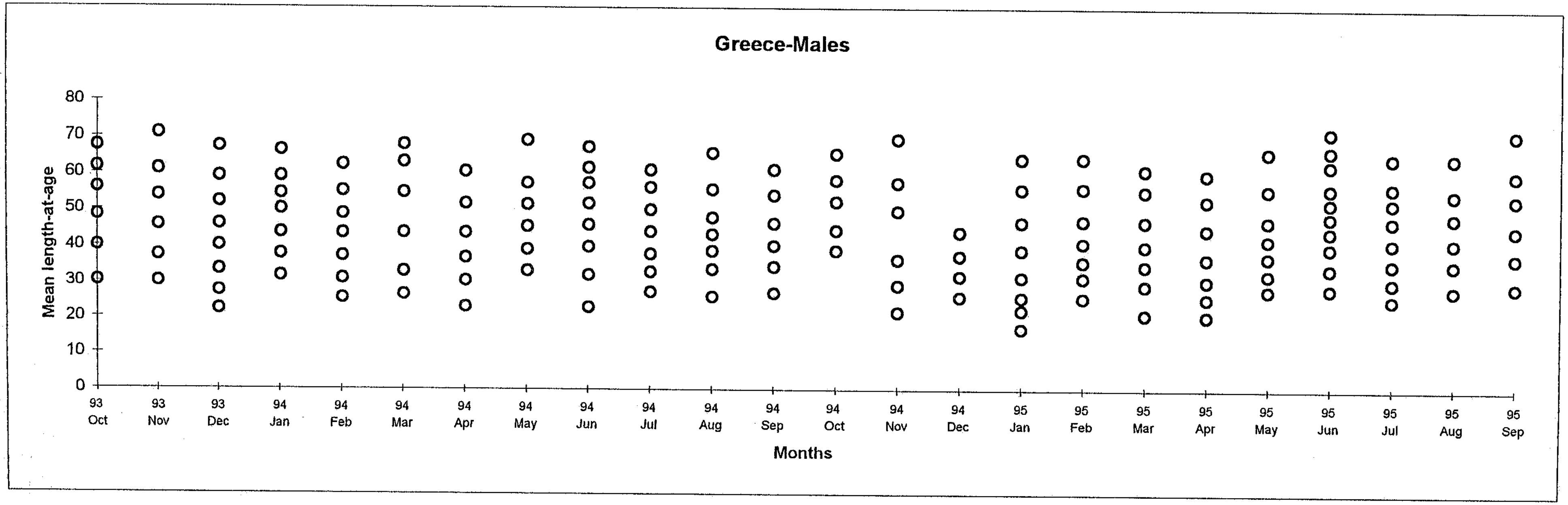
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
12.25	24.54	15.94	16.38	15.74	17.74	19.91	19.54	18.24	17.37	23.95	13.97	14.42	17.36			16.95		21.02	19.69	18.05	19.25	14.98	19.65
22.54	28.93	25.67	23.08	22.52	22.8	26.93	28.05	22.5	22.73	28.07	20.83	21.01	25.52			22.64		26.91	24.06	23.62	23.24	21.65	24.12
26.64	33.97	30.86	28.19	28.26	27.93	31.12	33.3	30.68	29.37	32.04	26.43	27.32	29.98			27.76		31.09	32.19	32.14	28.02	26.28	27.54
35.9	45.45	36.47	32.66	32.65	32.86	35.04	37.26	34.73	33.64	36.03	32.87	33.83	34.61			30.49		36.11	38.48	38.3	32.16	31.85	33.61
45.43		49.56	37.91	38.11	38.5	39.79	48.57	42.8	39.64	40.36	37.18	39.35	40.11			35.43		42.25	50.56	44.14	37.01	36.57	39.39
			41.82	42.52	44.96	46.22					42.77					40.59					41.4	41.76	
											48.95										48.73		



Mean length -at-age obtained with MIX

GREECE-MALES

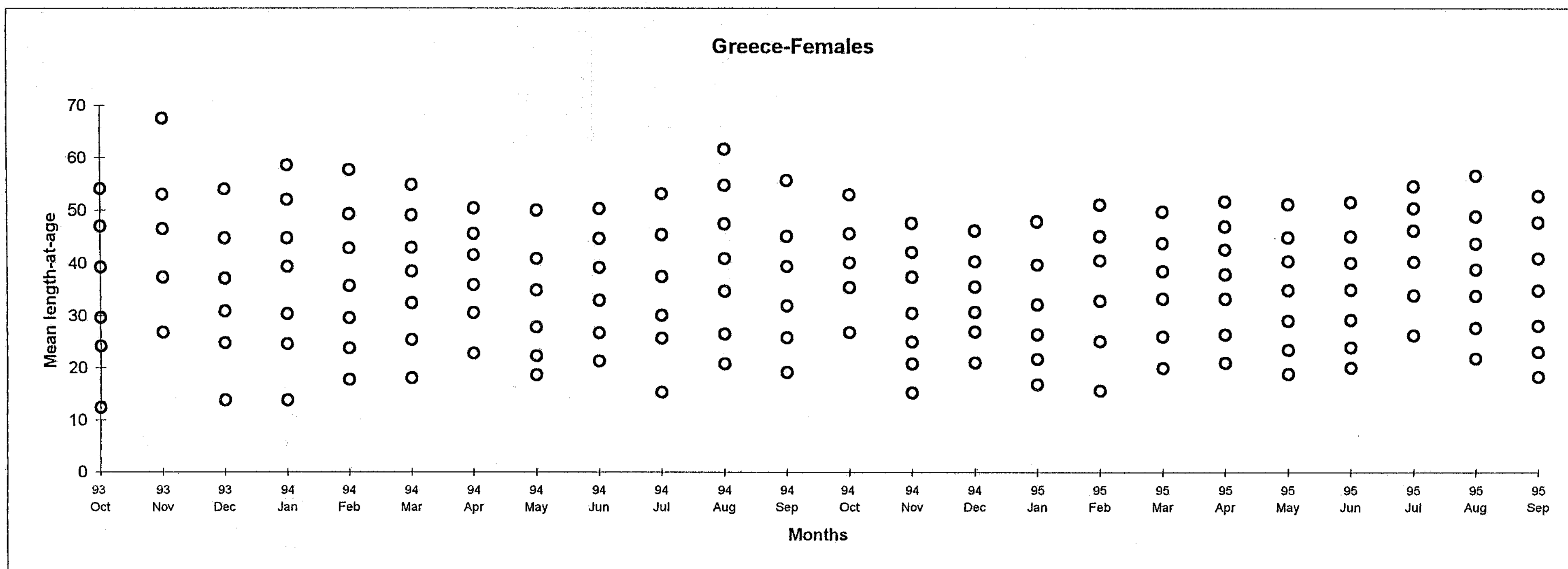
93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
30.26	30.15	22.23	31.68	25.5	26.48	23.04	33.14	22.91	27.19	25.91	26.86	38.78	21.62	25.83	17.1	25.59	20.98	20.54	27.72	28.21	25.18	27.87	28.91
39.94	37.37	27.54	37.82	30.9	32.93	30.43	39.12	32	32.91	33.57	34.27	44.43	29.09	31.72	22.11	31.29	29.14	25.39	32.07	33.87	29.96	35.04	37.1
48.5	45.68	33.4	43.71	37.13	43.68	36.8	45.4	39.84	37.74	38.56	40.12	52.39	36.32	37.32	25.68	35.72	34.6	30.4	37.09	39.64	35.17	41.06	44.67
56.11	53.94	40.09	50.19	43.54	54.88	43.68	51.43	45.82	44.03	43.19	46.29	58.34	49.7	44.03	31.33	40.96	40.02	36.6	41.77	44.09	40.95	48.2	53.19
61.79	61.14	46.04	54.54	48.91	63.28	51.8	57.38	51.83	50.07	47.91	54.17	65.49	57.53		38.96	47.15	46.85	44.74	47.07	48.24	47.07	54.59	59.86
67.62	70.97	52.28	59.27	55.32	68.01	60.57	69.21	57.39	56.21	55.7	61.13		69.65		46.75	56.11	55.3	52.73	55.67	52.11	52.06	64.55	71.07
		59.34	66.36	62.56				61.66	61.07	65.64					55.8	64.35	61.15	59.82	65.91	56.01	56.41		
		67.44						67.3							64.21					62.5	64.52		
																				66.44			
																				71.52			



Mean length -at-age obtained with MIX

GREECE-FEMALES

93 Oct	93 Nov	93 Dec	94 Jan	94 Feb	94 Mar	94 Apr	94 May	94 Jun	94 Jul	94 Aug	94 Sep	94 Oct	94 Nov	94 Dec	95 Jan	95 Feb	95 Mar	95 Apr	95 May	95 Jun	95 Jul	95 Aug	95 Sep
12.42	26.87	13.9	13.86	17.82	18.06	22.84	18.68	21.31	15.39	20.87	19.18	26.88	15.29	21.04	16.94	15.64	20.07	21.06	18.9	20.13	26.37	21.99	18.42
24.3	37.3	24.88	24.67	23.85	25.51	30.62	22.37	26.84	25.8	26.65	25.93	35.4	20.79	26.98	21.76	25.22	26.09	26.5	23.56	24.09	34.02	27.81	23.21
29.71	46.53	30.99	30.47	29.63	32.43	35.86	27.88	32.98	30.1	34.71	31.97	40.09	25.08	30.76	26.54	32.89	33.3	33.28	29.1	29.29	40.23	33.87	28.18
39.2	53	37.15	39.32	35.72	38.4	41.61	34.94	39.1	37.42	40.89	39.4	45.58	30.5	35.51	32.13	40.5	38.48	37.82	34.85	34.99	46.25	38.88	34.93
47.06	67.56	44.78	44.81	42.86	43.02	45.64	40.83	44.68	45.42	47.42	45.16	52.94	37.33	40.25	39.69	45.14	43.81	42.61	40.36	40.02	50.37	43.84	40.92
54.12		53.99	52.02	49.23	49.1	50.35	50	50.27	53.1	54.71	55.6		42.1	46.14	47.82	50.96	49.69	46.9	44.93	45.11	54.55	48.88	47.72
			58.56	57.65	54.81					61.59			47.57					51.62	51.07	51.5		56.56	52.74



BIOMETRICS

INTRODUCTION

Biometrics studies have been used to find differences among populations of the same species that may be due to genetic and/or environmental factors. Statistical techniques for detection of biometrical differences range from simple comparisons of regression lines between several groups to multivariate statistical analysis, dealing simultaneously with a large number of variables. The use of regression models for biometrics studies in crustaceans is discussed in LOVETT & FELDER (1989) and CLAYTON (1990).

The approach used in this work will be one of dealing with the largest number of variables possible, using multivariate analysis. This was done in the hope of finding differences of neutral adaptive value with biological meaning that may indicate population segregation or adaptation to different environments.

MATERIALS AND METHODS

Sampling procedure

The areas sampled were the same as for all other aspects of the biology discussed in this report, namely: the south coast of Portugal off the port of Faro in the Atlantic (P), the Alboran sea off Malaga (M), the Catalan Sea off Barcelona (B), the Ligurian Sea off Genoa (L), the Tyrrhenian Sea off P.S. Stefano (T), the Adriatic Sea off Ancona (A) and the Euboikos Gulf off Athens (G).

Only males were used in this study to avoid noise introduced by the changes in body proportions expected at the onset of maturity in females. Whenever possible only individuals with carapace length between 30 and 35 mm where chosen.

In all the studied areas 50 male specimens were collected in the Fall of 1993. Each specimen was placed in an individual bag so that broken appendices where not lost. They were frozen and shipped to the same lab were the measurements were taken on all individuals.

In each animal 97 measurements where made including dimensions of several body parts, counts of the numbers of spines in rows of spines and registration of the side with the more robust chelae. Measurements were made using digital callipers with precision of 0.01 mm. Figures 1, 2 and 3 show the position of all measurements. Table 1 lists variables and the corresponding variable codes that were used during this work. The data base including all measurements is included in the CD annex to this report.

Variable	Description	Variable	Description
ID	Identification Number	+ ASW6	6th Abdominal Somite Width
YEAR	Year	+ ASH1	1st Abdominal Somite Height
CODE	Area Code	+ ASH2	2nd Abdominal Somite Height
+ CSL	Carapace Standard Length	+ ASH3	3rd Abdominal Somite Height
CTL	Carapace Total Length	+ ASH4	4th Abdominal Somite Height
+ CPL	Carapace Posterior Length	+ ASH5	5th Abdominal Somite Height
CLL	Carapace Lateral Left Length	+ ASH6	6th Abdominal Somite Height
+ CRL	Carapace Lateral Right Length	ASPL2	2nd Left Abdominal Somite Pleura Length
+ CW	Carapace Width	ASPL3	3rd Left Abdominal Somite Pleura Length
+ CH	Carapace Height	ASPL4	4th Left Abdominal Somite Pleura Length
ANTSL	Antenna Scaphocerite Left Lenght	ASPL5	5th Left Abdominal Somite Pleura Length
ANTSR	Antenna Scaphocerite Right Lenght	ASPL6	6th Left Abdominal Somite Pleura Length
QR	Robust chela	ASPR2	2nd Right Abdominal Somite Pleura Length
TAL1D	1st Left Thoracic Appendice Dactyl	ASPR3	3rd Right Abdominal Somite Pleura Length
TAL1P	1st Left Thoracic Appendice Propodus	ASPR4	4th Right Abdominal Somite Pleura Length
TAL1C	1st Left Thoracic Appendice Carpus	ASPR5	5th Right Abdominal Somite Pleura Length
TAL1M	1st Left Thoracic Appendice Merus	ASPR6	6th Right Abdominal Somite Pleura Length
TAL1IB	1st Left Thoracic Appendice Ischium&Basis	EXLL	Left Exopod Lenght
TAL1X	1st Left Thoracic Appendice Coxa	EXLH	Left Exopod Height
TAR1D	1st Right Thoracic Appendice Dactyl	+ ENLL	Left Endopod Lenght
TAR1P	1st Right Thoracic Appendice Propodus	+ ENLH	Left Endopod Height
TAR1C	1st Right Thoracic Appendice Carpus	+ TL	Telson Lenght
TAR1M	1st Right Thoracic Appendice Merus	TH	Telson Heigth
TAR1IB	1st Right Thoracic Appendice Ischium&Basis	EXRL	Right Exopod Lenght
TAR1X	1st Right Thoracic Appendice Coxa	EXRH	Right Exopod Height
TAL2D	2nd Left Thoracic Appendice Dactyl	+ ENRL	Right Endopod Lenght
TAL2P	2nd Left Thoracic Appendice Propodus	+ ENRH	Right Endopod Height
TAL2C	2nd Left Thoracic Appendice Carpus	RLS	Rostrum Left Lateral Spines
TAL2M	2nd Left Thoracic Appendice Merus	RRS	Rostrum Right Lateral Spines
TAL2I	2nd Left Thoracic Appendice Ischium	RBS	Rostrum Basis Spines
TAL2B	2nd Left Thoracic Appendice Basis	+ CGLS	Cervical Groove Left Spines
TAL2X	2nd Left Thoracic Appendice Coxa	+ CGRS	Cervical Groove Rigth Spines
TAR2D	2nd Right Thoracic Appendice Dactyl	CRSL1	1st Left Carapace Row Spines
TAR2P	2nd Right Thoracic Appendice Propodus	CRSL2	2nd Left Carapace Row Spines
TAR2C	2nd Right Thoracic Appendice Carpus	CRSL3	3rd Left Carapace Row Spines
TAR2M	2nd Right Thoracic Appendice Merus	CRSL4	4th Left Carapace Row Spines
TAR2I	2nd Right Thoracic Appendice Ischium	+ CRSR1	1st Right Carapace Row Spines
TAR2B	2nd Right Thoracic Appendice Basis	+ CRSR2	2nd Right Carapace Row Spines
TAR2X	2nd Right Thoracic Appendice Coxa	+ CRSR3	3rd Right Carapace Row Spines
+ ASL1	1st Abdominal Somite Length	+ CRSR4	4th Right Carapace Row Spines
+ ASL2	2nd Abdominal Somite Length	QRSL1	1st Left Chela Row Spines
+ ASL3	3rd Abdominal Somite Length	QRSL2	2nd Left Chela Row Spines
+ ASL4	4th Abdominal Somite Length	QRSL3	3rd Left Chela Row Spines
+ ASL5	5th Abdominal Somite Length	LCRS1	1st Left Carpus Row Spines
+ ASL6	6th Abdominal Somite Length	LCRS2	2nd Left Carpus Row Spines
+ ASW1	1st Abdominal Somite Width	QRSR1	1st Right Chela Row Spines
+ ASW2	2nd Abdominal Somite Width	QRSR2	2nd Right Chela Row Spines
+ ASW3	3rd Abdominal Somite Width	QRSR3	3rd Right Chela Row Spines
+ ASW4	4th Abdominal Somite Width	RCRS1	1st Right Carpus Row Spines
+ ASW5	5th Abdominal Somite Width	RCRS2	2nd Right Carpus Row Spines

Table 1 - List of codes and description of the variables measured in this study.

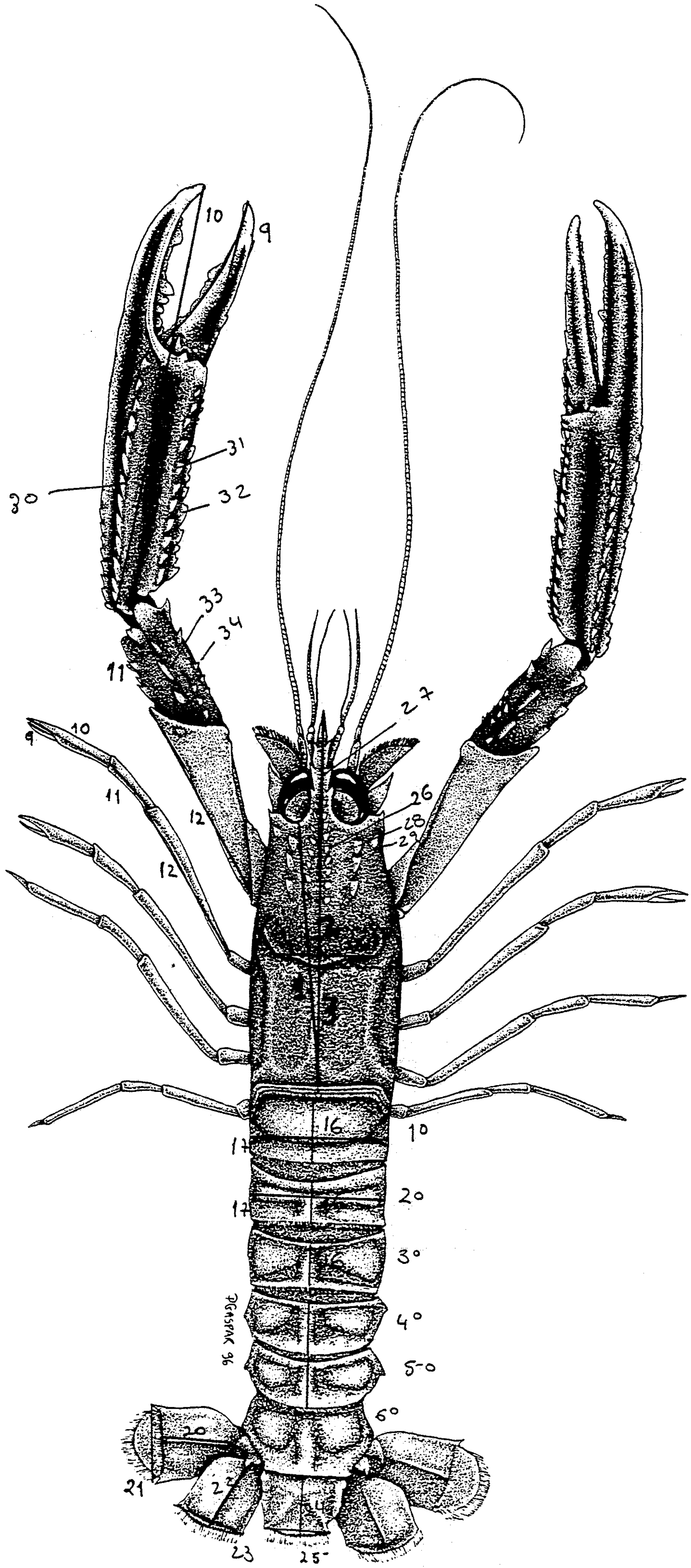


Figure 1.- Measurements for biometrics study - dorsal view

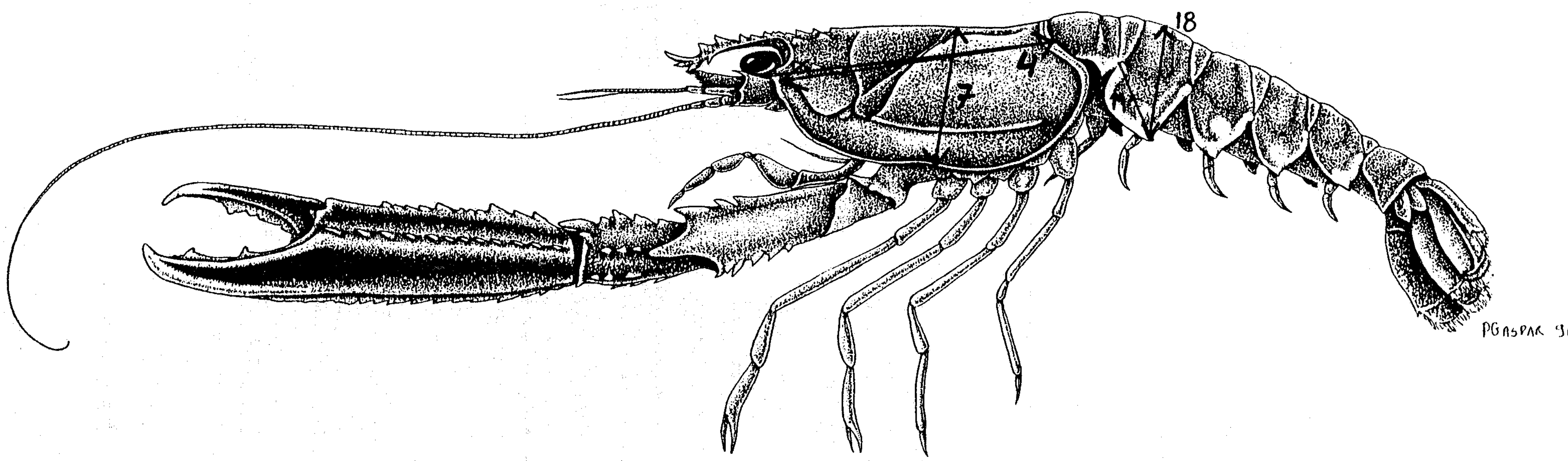


Figure 2.- Measurements for biometrics study - lateral view

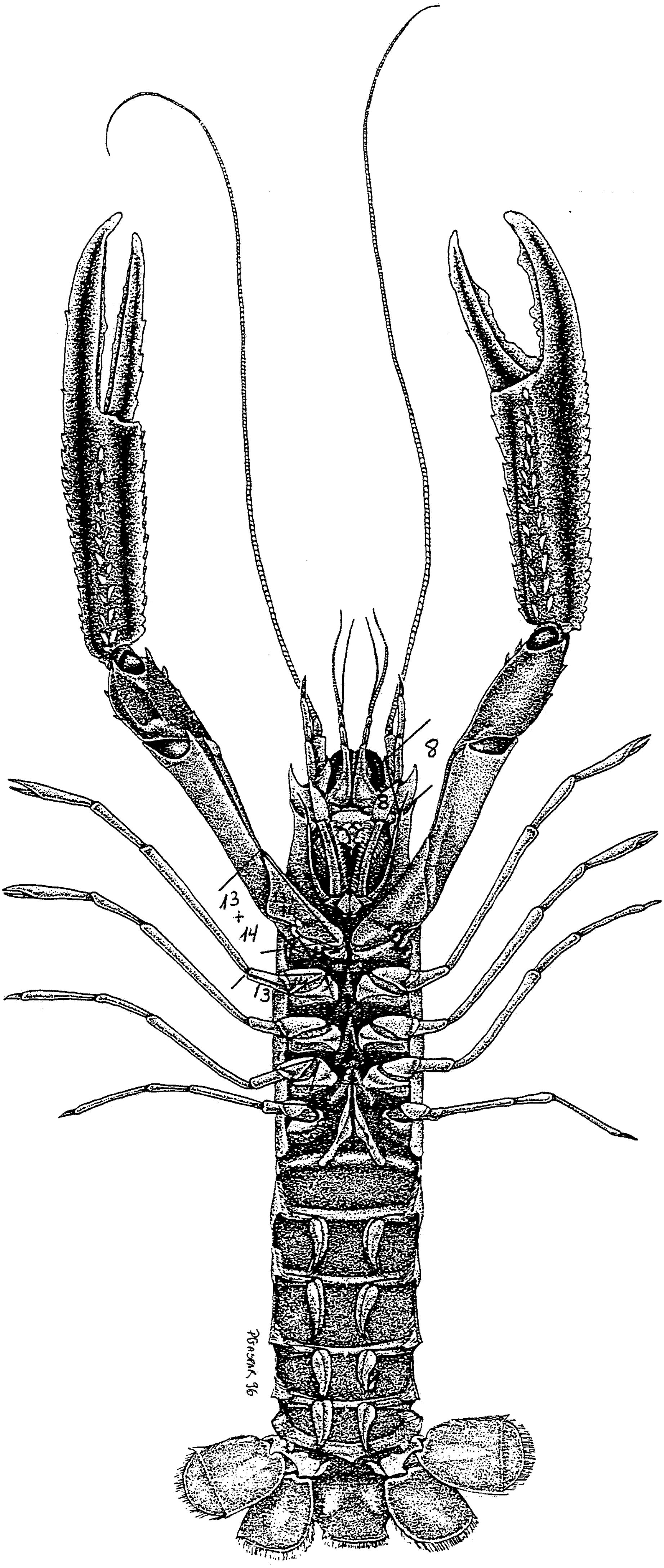


Figure 3.- Measurements for biometrics study - ventral view

To avoid bias due to the measuring procedure considerable care was taken during this phase of the work. In particular:

- all measurements and counts were done by the same person using the same measuring instrument.
- 10 individuals, not part of the study samples, were measured first for training.
- all measurements were taken within 1 week.
- the order of measurement was defined by choosing one individuals from each area at a time.

Statistical analysis

Carapace length was used as the reference measurement to make decisions on the standardisation of the data. Since not all areas included animals within the desired range of carapace length, 30-35 mm, two standardisation criteria were used:

a) Use only individuals within this carapace length range and abandon all others. This led to different sample sizes for each area. Table 2 includes the numbers of individuals within each size class for the different areas.
b) Reduce all measurements to indices resulting from the division of each variable by the carapace length.

Area	Area code	[20-25[	[25-30[	**[30-35[**	[35-40[	[40-45[	[45-50[	[50-55[
Atlantic - Portugal	P	0	16	**33**	1	0	0	0
Alboran Sea - Malaga	M	0	3	**6**	3	16	17	4
Catalan Sea - Barcelona	B	1	12	**31**	6	0	0	0
Ligurian Sea	L	0	4	**40**	6	0	0	0
Tyrrhenian Sea	T	0	12	**33**	5	0	0	0
Adriatic Sea	A	0	4	**34**	12	0	0	0
Euboikos Gulf - Greece	G	0	3	**19**	18	9	1	0
Total		1	54	**196**	51	25	18	4

Table 2 - Number of individuals falling into each 5 mm carapace length class for each area.

Correlation among the different variables.

The first analysis done on the data consisted of a simple correlation study were all possible pairs of variables. Pearson correlation coefficients were calculated for the all the pairs of variables considered for the indication of population differences.

Comparison of the study areas.

Principal component analysis (PCA) was done in order to detect population differences. The analysis was done using the routine PROC PRINCOMP, part of the statistical analysis package SAS (SAS Inc., 1985). All variables were standardised prior to the analysis.

For many of the variables used in this work there were measurements missing in some individuals due to broken parts of the exoskeleton. Since principal components requires no missing values for all the variables included in the analysis, the use of all the variables described in table 1 would result in a considerable decrease in sample size. To avoid this, variables with no or few missing values were chosen to be included in the PCA. These are signalled with a '+' sign in Table 1, and leave out all measurements on claws, pereiopods and pleopods, which are usually the parts of the body where more problems occurred.

RESULTS

Correlation among the different variables.

Results of global correlation coefficients, including individuals from all areas are included in Annex and Table 3. As expected, correlation was very high for all pairs of variables related with body measurements (p-values < 0.0001 for all). With respect to spine counts, correlation values were not significant considering $\alpha=0.05$. Correlation values were also very low between carapace length and counts of spines (Table 3).

Principal component analysis

Table 4 shows some indicators of principal component analysis. In most cases the separation of the populations was very poor. When indices were used the best results were obtained considering spine counts only (Table 5 anf Figure 4). Overall, the best results were obtained using only body measurements and considering only the individuals that had carapace lengths between 30 and 35 mm (Table 6 and Figure 5). In this situation the variables were not standardised by dividing them by the carapace length.

	CSL	RLS	RBS	CGLS	CRSL1	CRSL2	CRSL3	CRSL4	QRSL1	QRSL2	QRSL3	LCRS1	LCRS2
CSL	1	0.06004	-0.0564	0.04292	0.14471	0.0074	0.1834	0.19359	0.14647	0.02844	0.12366	0.06251	0.27624
	0	0.2761	0.3086	0.4241	0.0069	0.8914	0.0007	0.0003	0.0066	0.5997	0.022	0.2489	0.0001
	350	331	328	349	347	343	341	342	343	343	343	342	342
RLS	0.06004	1	0.16436	-0.006	0.0189	0.01827	-0.0762	0.14983	-0.0181	-0.0433	-0.0411	0.02269	0.02236
	0.2761	0	0.0028	0.9132	0.733	0.7432	0.1724	0.007	0.7454	0.4372	0.4602	0.684	0.6885
	331	331	328	330	328	324	322	323	325	325	325	324	324
RBS	-0.0564	0.16436	1	0.00246	0.16232	-0.0112	-0.0795	0.08197	-0.0128	0.00568	-0.0457	0.03729	0.06726
	0.3086	0.0028	0	0.9646	0.0033	0.8423	0.1564	0.1434	0.8186	0.9191	0.4143	0.5056	0.2295
	328	328	328	327	325	321	319	320	322	322	322	321	321
CGLS	0.04292	-0.006	0.00246	1	0.06907	0.03912	-0.0039	0.0052	0.06866	0.13519	0.14573	0.16815	0.05111
	0.4241	0.9132	0.9646	0	0.2	0.4708	0.9434	0.9236	0.2053	0.0123	0.0069	0.0018	0.3467
	349	330	327	349	346	342	341	342	342	342	342	341	341
CRSL1	0.14471	0.0189	0.16232	0.06907	1	0.15754	0.10634	0.1745	0.08692	-0.0636	0.00191	0.04934	0.10566
	0.0069	0.733	0.0033	0.2	0	0.0035	0.0501	0.0012	0.1096	0.2423	0.972	0.3651	0.0519
	347	328	325	346	347	342	340	341	340	340	340	339	339
CRSL2	0.0074	0.01827	-0.0112	0.03912	0.15754	1	0.00852	0.05266	0.05138	-0.033	0.03283	-0.0641	-0.059
	0.8914	0.7432	0.8423	0.4708	0.0035	0	0.8757	0.333	0.3478	0.5467	0.5487	0.2418	0.2818
	343	324	321	342	342	343	340	340	336	336	336	335	335
CRSL3	0.1834	-0.0762	-0.0795	-0.0039	0.10634	0.00852	1	0.04334	0.1337	0.07159	0.14744	0.0197	0.02877
	0.0007	0.1724	0.1564	0.9434	0.0501	0.8757	0	0.425	0.0145	0.1919	0.0069	0.7203	0.6009
	341	322	319	341	340	340	341	341	334	334	334	333	333
CRSL4	0.19359	0.14983	0.08197	0.0052	0.1745	0.05266	0.04334	1	0.08339	-0.1411	0.0285	-0.0311	0.12308
	0.0003	0.007	0.1434	0.9236	0.0012	0.333	0.425	0	0.1277	0.0097	0.6032	0.5715	0.0245
	342	323	320	342	341	340	341	342	335	335	335	334	334
QRSL1	0.14647	-0.0181	-0.0128	0.06866	0.08692	0.05138	0.1337	0.08339	1	0.22238	0.30874	0.21047	0.09793
	0.0066	0.7454	0.8186	0.2053	0.1096	0.3478	0.0145	0.1277	0	0.0001	0.0001	0.0001	0.0705
	343	325	322	342	340	336	334	335	343	343	343	342	342
QRSL2	0.02844	-0.0433	0.00568	0.13519	-0.0636	-0.033	0.07159	-0.1411	0.22238	1	0.42703	0.36501	0.00762
	0.5997	0.4372	0.9191	0.0123	0.2423	0.5467	0.1919	0.0097	0.0001	0	0.0001	0.0001	0.8883
	343	325	322	342	340	336	334	335	343	343	343	342	342
QRSL3	0.12366	-0.0411	-0.0457	0.14573	0.00191	0.03283	0.14744	0.0285	0.30874	0.42703	1	0.18552	0.1736
	0.022	0.4602	0.4143	0.0069	0.972	0.5487	0.0069	0.6032	0.0001	0.0001	0	0.0006	0.0013
	343	325	322	342	340	336	334	335	343	343	343	342	342
LCRS1	0.06251	0.02269	0.03729	0.16815	0.04934	-0.0641	0.0197	-0.0311	0.21047	0.36501	0.18552	1	0.03658
	0.2489	0.684	0.5056	0.0018	0.3651	0.2418	0.7203	0.5715	0.0001	0.0001	0.0006	0	0.5002
	342	324	321	341	339	335	333	334	342	342	342	342	342
LCRS2	0.27624	0.02236	0.06726	0.05111	0.10566	-0.059	0.02877	0.12308	0.09793	0.00762	0.1736	0.03658	1
	0.0001	0.6885	0.2295	0.3467	0.0519	0.2818	0.6009	0.0245	0.0705	0.8883	0.0013	0.5002	0
	342	324	321	341	339	335	333	334	342	342	342	342	342

Table 3 - Person correlation coefficients for counts of spines and carapace length. Values included in the body of the table correspond to correlation coefficient, p-value and sample number.

Type of variable	Variables considered	Number of variables	Number of observations	%explained by 1st component	% explained by first 3 components
Indexes (division by CL)	all variables	33	331	0.3208	0.4670
	only body measurments	27	331	0.3856	0.5133
	only spine counts	6	349	0.4308	0.7189
original variables (CL 30-35)	all variables	33	184	0.5513	0.6368
	only body measurments	27	184	0.6685	0.7511
	only spine counts	6	194	0.2255	0.5848

Table 4 - Table with indications of discrimination power of the different criteria for Principal Component Analysis, using as indicator of separation of the groups the percentage of variance explained by the 1st component and the first 3 components (CL=Carapace length).

a) Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	2.58487	1.62778	0.430812	0.430812
PRIN2	0.95709	0.18575	0.159516	0.590328
PRIN3	0.77135	0.09299	0.128558	0.718886
PRIN4	0.67836	0.12644	0.11306	0.831946
PRIN5	0.55192	.	0.091986	0.923932

b) Eigenvectors

	PRIN1	PRIN2	PRIN3
CGLS	0.454245	-0.214957	-0.298808
CGRS	0.472666	-0.185689	-0.014049
CRSR1	0.420818	0.370829	-0.291804
CRSR2	0.417098	-0.288091	-0.252562
CRSR3	0.363846	-0.23796	0.846496
CRSR4	0.294629	0.80136	0.21219

Table 5 - Eigenvalues and eigenvectors for Principal Component Analysis considering only indices of spine counts.

a) Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	18.7188	17.4756	0.668530	0.668530
PRIN2	1.2433	0.1758	0.044403	0.712933
PRIN3	1.0674	0.0808	0.038123	0.751056
PRIN4	0.9866	0.3097	0.035236	0.786291
PRIN5	0.6769	.	0.024173	0.810465

b) Eigenvectors

	PRIN1	PRIN2	PRIN3
CSL	0.210376	0.037857	-0.052705
CPL	0.189070	0.181615	-0.296106
CRL	0.176539	0.155136	-0.163350
CW	0.121582	0.312963	-0.446365
CH	0.160715	0.252127	-0.342321
ASL1	0.175617	0.049249	0.075934
ASL2	0.205816	-0.060583	0.099314
ASL3	0.215185	0.021712	0.091755
ASL4	0.215726	0.045779	0.060064
ASL5	0.214275	0.053473	0.018625
ASL6	0.200809	0.105698	-0.011535
ASW1	0.219868	0.004594	-0.026459
ASW2	0.215900	-0.067526	-0.020039
ASW3	0.207681	-0.279459	-0.076193
ASW4	0.203416	-0.246802	-0.140966
ASW5	0.186132	-0.436359	-0.104738
ASW6	0.160546	-0.482557	-0.125248
ASH1	0.194714	-0.109511	0.127529
ASH2	0.215103	0.001919	0.079419
ASH3	0.209873	0.005114	0.075487
ASH4	0.207566	0.057931	-0.074512
ASH5	0.014779	0.218682	0.404138
ASH6	0.185290	0.191720	-0.082280
ENLL	0.191613	-0.094380	0.229315
ENLH	0.168404	0.252337	0.225369
TL	0.179904	0.018786	0.160740
ENRL	0.152166	0.072239	0.313649
ENRH	0.172019	0.111074	0.230987

Table 6 - Eigenvalues and eigenvectors for Principal Component Analysis considering only body measurements in individuals with carapace length between 30 and 35 mm.

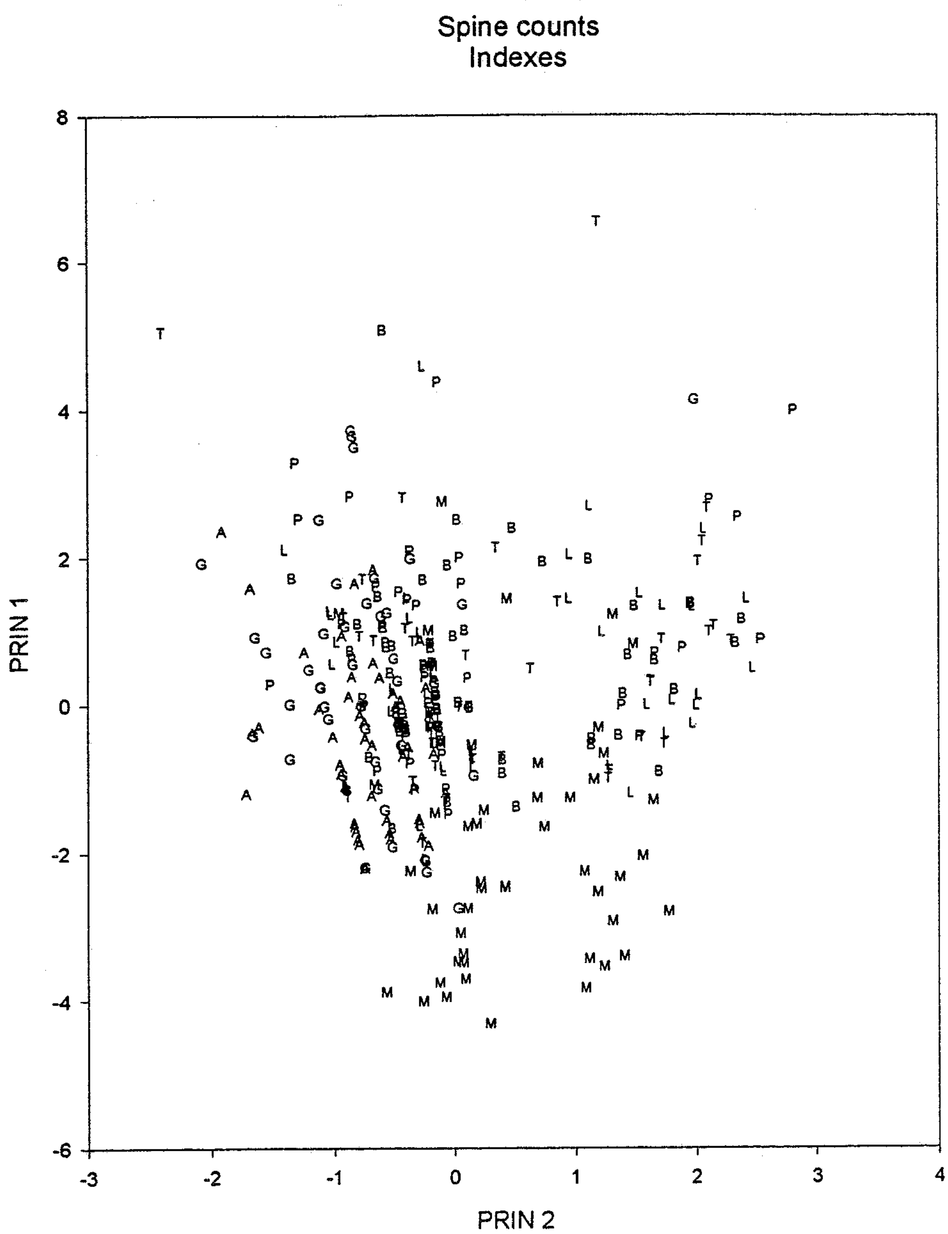


Figure 4 - Plot of the 1st and 2nd principal component for Principal Component Analysis for indices of spine counts.
Legend: A=Adriatic Sea
B=Catalan Sea (Barcelona)
G=Gulf of Euboikos (Greece)
L=Ligurian Sea
M=Alboran Sea (Malaga)
P=Atlantic Ocean (Portugal)
T=Tyrrhenian Sea

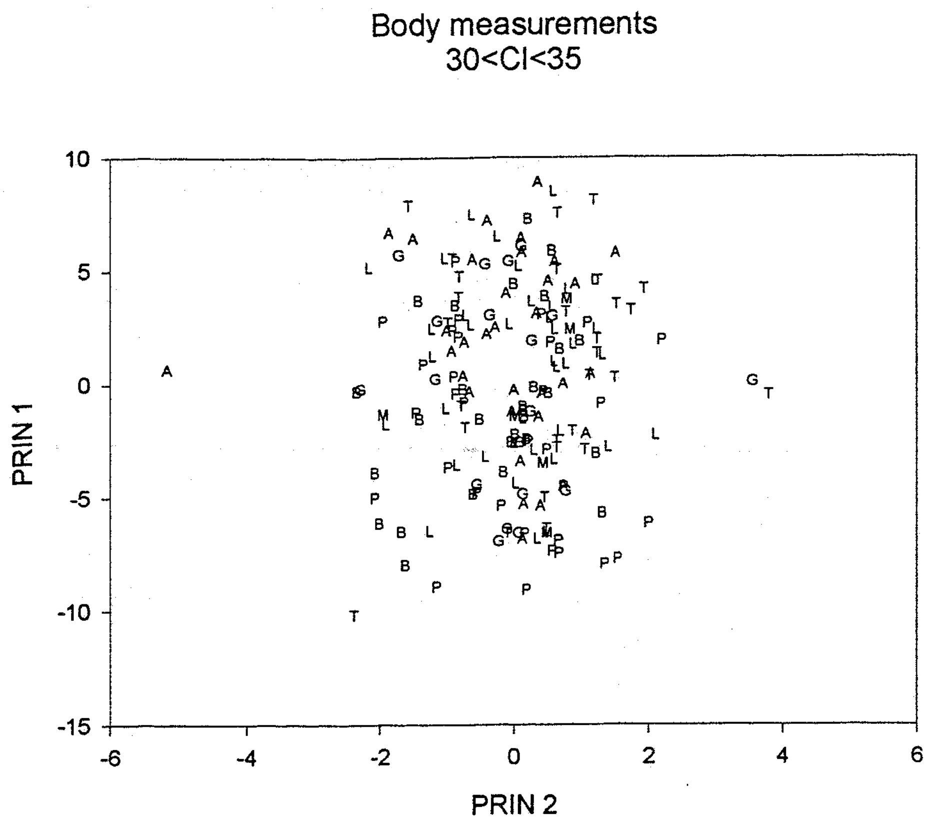


Figure 5 - Plot of the 1st and 2nd principal component for Principal Component Analysis using only individuals with carapace lengths within 30 and 35 mm, without transformation of the variables.
Legend: A=Adriatic Sea
B=Catalan Sea (Barcelona)
G=Gulf of Euboikos (Greece)
L=Ligurian Sea
M=Alboran Sea (Malaga)
P=Atlantic Ocean (Portugal)
T=Tyrrhenian Sea

DISCUSSION

In general the results show very little separation between the different populations compared. The two approaches used to standardise data can not be compared because they are based on different individuals and variables. But, if separation of the populations was clear they would be expected to produce similar results. The analysis of Figures 4 and 5 shows that this is not the case.

The counts of spines in the carapace (Table 5 and Figure 4) shows a large area of overlap for all populations but it is possible to distinguish an area where M (Alboran) individuals predominate. There is also some separation between G and A (Euboikos and Adriatic), with points concentrated at the left of the plot, and P, B and L (Atlantic, Catalan and Ligurian Seas) with points concentrated at the right of the plot. The analysis of the eigenvectors shows a balanced weight among all basic variables contributing to the first component. The values for the Alboran sea, resulting form low scores for the first component, suggest that the number of spines for this population is on average lower than that for the other areas studied. The horizontal separation is due to the second component, with both positive and negative coefficients dominated by the variable CRSR4 (one of the rows of spines in the carapace). The interpretation of this differences does not seem to have any biological meaning.

For body measurements without transformation, considering only individuals with carapace length between 30 and 35 mm (Table 6 and Figure 5) the results are less clear. None of the areas stands out in the plot of the first two principal components. This situation corresponds to a PCA done on much smaller numbers of individuals, and using only measurements on the carapace, abdominal segments and telson.

In general, results of the biometrics study produced results similar to the genetic analysis presented in this report, with no strong evidence of segregated populations among the areas studied.

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REFERENCES

CLAYTON, D.A. - 1990. Crustacean allometric growth: a case for caution. Crustaceana, 58(3): 270-290.

LOVETT, D.L. & D.L. FELDER - 1989. Application of regression techniques to studies of relative growth in Crustaceans. Journal of Crustacean Biology, 9(4) 529-539.

SAS INSTITUTE INC. - 1988. SAS/STAT™ User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1029 pp.

Annex

Biometrics

Annex with correlation coefficients for body measurements

	CSL	CTL	CPL	CLL	CW	CH	ANTSL	TAL1D	TAL1P	TAL1C	TAL1M	TAL1IB	TAL1X	TAL2D	TAL2P	TAL2C	TAL2M	TAL2I	TAL2B	TAL2X	ASL1	ASL2
CSL	1																					
	0																					
	350																					
CTL	0.9549	1																				
	0.0001	0																				
	326	326																				
CPL	0.9734	0.9529	1																			
	0.0001	0.0001	0																			
	350	326	350																			
CLL	0.9748	0.9644	0.9799	1																		
	0.0001	0.0001	0.0001	0																		
	323	301	323	323																		
CW	0.8997	0.8822	0.9139	0.9071	1																	
	0.0001	0.0001	0.0001	0.0001	0																	
	346	322	346	323	346																	
CH	0.9388	0.93	0.9444	0.9502	0.8736	1																
	0.0001	0.0001	0.0001	0.0001	0.0001	0																
	349	325	349	323	345	349																
ANTSL	0.8609	0.8788	0.8816	0.8764	0.8454	0.8627	1															
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0															
	337	314	337	310	333	336	337															
TAL1D	0.7633	0.765	0.7877	0.7825	0.7372	0.7887	0.7495	1														
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0														
	336	314	336	309	332	335	323	336														
TAL1P	0.9055	0.8949	0.9194	0.9153	0.8576	0.9004	0.8181	0.8752	1													
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0													
	334	312	334	307	330	333	321	329	334													
TAL1C	0.9296	0.9311	0.9465	0.9396	0.8964	0.9199	0.8672	0.8088	0.9464	1												
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0												
	336	313	336	309	332	335	323	331	329	336												
TAL1M	0.7804	0.7757	0.7793	0.7793	0.7275	0.7689	0.7036	0.6219	0.7564	0.7941	1											
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0											
	340	317	340	313	336	339	327	335	333	335	340											
TAL1IB	0.9553	0.9525	0.9638	0.9623	0.908	0.9432	0.8859	0.7946	0.9357	0.9682	0.7952	1										
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0										
	338	316	338	311	334	337	325	333	331	333	338	338										
TAL1X	0.5618	0.8704	0.5645	0.5603	0.5291	0.5515	0.5007	0.4707	0.8259	0.5343	0.4446	0.5495	1									
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0									
	345	321	345	318	341	344	332	336	334	336	340	338	345									
TAL2D	0.8586	0.8165	0.882	0.8657	0.8101	0.8576	0.7691	0.7512	0.833	0.8263	0.6887	0.8677	0.4901	1								
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0								
	303	285	303	278	299	302	295	292	292	293	296	295	299	303								
TAL2P	0.9439	0.915	0.958	0.9554	0.8882	0.9384	0.8548	0.8042	0.9088	0.9142	0.743	0.9482	0.5177	0.925	1							
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0							
	307	287	307	282	303	306	297	296	296	297	300	298	303	302	307							
TAL2C	0.9524	0.9427	0.9593	0.9625	0.8971	0.9483	0.884	0.79	0.9065	0.9357	0.7504	0.9604	0.5571	0.8688	0.9484	1						
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0						
	312	292	312	287	308	311	302	300	300	301	305	303	307	300	304	312						
TAL2M	0.9455	0.944	0.9592	0.9586	0.8986	0.9454	0.8719	0.789	0.9054	0.9363	0.9518	0.9635	0.5167	0.8759	0.9534	0.9673	1					
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0					
	315	295	315	290	311	314	304	304	304	305	308	306	311	299	303	309	315					
TAL2I	0.9251	0.9121	0.9276	0.9345	0.8565	0.905	0.8208	0.742	0.8801	0.8989	0.7462	0.9287	0.5256	0.8667	0.9352	0.9316	0.9342	1				
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0				
	318	298	318	293	314	317	307	307	307	308	311	309	314	299	303	308	312	318				
TAL2B	0.7396	0.7203	0.7521	0.7451	0.6689	0.7461	0.6436	0.5876	0.6947	0.7158	0.5755	0.7339	0.4109	0.8399	0.894	0.7383	0.7392	0.7427	1			
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0			
	342	319	342	315	338	341	329	328	326	328	332	330	337	303	307	312	315	318	342			
TAL2X	0.8696	0.864	0.8802	0.8773	0.8174	0.8634	0.8061	0.7284	0.8383	0.8529	0.6976	0.8706	0.5705	0.8328	0.8779	0.8898	0.8686	0.8672	0.7188	1		
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0		
	344	321	344	317	340	343	331	330	328	330	334	332	339	302	306	311	314	317	340	344		

	CSL	CTL	CPL	CLL	CW	CH	ANTSL	TAL1D	TAL1P	TAL1C	TAL1M	TAL1IB	TAL1X	TAL2D	TAL2P	TAL2C	TAL2M	TAL2I	TAL2B	TAL2X	ASL1	ASL2
ASL3	0.9676	0.9549	0.9704	0.9769	0.9004	0.9404	0.865	0.7872	0.9124	0.9349	0.7854	0.9581	0.8879	0.883	0.9561	0.9594	0.9544	0.9348	0.745	0.8948	0.9718	0.9905
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	347	324	347	320	343	346	334	333	332	333	337	335	342	301	305	310	313	315	339	341	344	345
ASL4	0.9707	0.9529	0.9707	0.9775	0.9042	0.9422	0.8671	0.7872	0.912	0.9329	0.7809	0.9575	0.577	0.8851	0.9555	0.9599	0.9544	0.9389	0.7384	0.8926	0.9696	0.9867
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	348	324	348	321	344	347	335	334	332	334	338	336	343	302	306	311	314	316	340	342	345	346
ASL5	0.9697	0.9572	0.9692	0.9777	0.8977	0.945	0.8706	0.7824	0.9122	0.9375	0.7829	0.9585	0.5648	0.8741	0.9498	0.9586	0.9533	0.9375	0.745	0.8956	0.9728	0.9844
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	350	326	350	323	346	349	337	336	334	336	340	338	345	303	307	312	315	318	342	344	347	348
ASL6	0.9448	0.934	0.9459	0.9522	0.8708	0.9203	0.8729	0.7652	0.8784	0.9069	0.7652	0.9335	0.5489	0.8559	0.9181	0.9249	0.9221	0.8957	0.7163	0.8747	0.9458	0.9577
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	350	326	350	323	346	349	337	336	334	336	340	338	345	303	307	312	315	318	342	344	347	348
ASW1	0.9563	0.9658	0.955	0.9633	0.8807	0.9345	0.8638	0.7675	0.9015	0.9294	0.766	0.952	0.5509	0.8537	0.9353	0.9466	0.9434	0.9228	0.7379	0.8688	0.95	0.9632
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	348	324	348	321	344	347	335	334	332	334	338	336	343	301	305	310	313	316	340	342	347	347
ASW2	0.9717	0.9623	0.9694	0.9782	0.9032	0.9507	0.8663	0.7801	0.9214	0.9434	0.7824	0.9658	0.5545	0.8669	0.9543	0.9628	0.9571	0.9346	0.7413	0.8889	0.9674	0.9826
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	325	349	322	345	348	336	335	333	335	339	337	344	302	306	311	314	317	341	343	347	348
ASW3	0.9654	0.9532	0.9661	0.9723	0.8895	0.9376	0.8554	0.7739	0.918	0.9383	0.7704	0.9569	0.8617	0.8606	0.9485	0.9572	0.95	0.9378	0.729	0.8714	0.9602	0.9752
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	326	349	322	345	348	336	335	334	335	339	337	344	302	306	311	314	317	341	343	346	347
ASW4	0.961	0.9492	0.9622	0.9713	0.8879	0.938	0.8576	0.7741	0.914	0.935	0.7684	0.9567	0.5304	0.8598	0.9426	0.9518	0.9469	0.9296	0.7295	0.869	0.9551	0.9685
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	350	326	350	323	346	349	337	336	334	336	340	338	345	303	307	312	315	318	342	344	347	348
ASW5	0.9145	0.9323	0.9166	0.9191	0.8361	0.8811	0.8128	0.7218	0.8671	0.8862	0.7233	0.9016	0.5003	0.7921	0.8833	0.8979	0.8871	0.8934	0.6803	0.8151	0.9051	0.9249
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	325	349	323	345	348	336	335	333	335	339	337	344	302	306	311	314	317	341	343	346	347
ASW6	0.9162	0.9068	0.9203	0.9229	0.8516	0.88	0.8124	0.7311	0.8723	0.8915	0.7189	0.9079	0.508	0.8052	0.8966	0.9117	0.8995	0.8964	0.6857	0.8133	0.9111	0.9347
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	350	326	350	323	346	349	337	336	334	336	340	338	345	303	307	312	315	318	342	344	347	348
ASH1	0.9632	0.9488	0.9586	0.9646	0.8839	0.927	0.8552	0.7807	0.9145	0.9327	0.7712	0.9514	0.5675	0.8645	0.9449	0.9519	0.9466	0.9307	0.7239	0.8669	0.9548	0.9679
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	348	324	348	321	344	347	335	334	332	334	338	336	343	301	305	310	313	316	340	342	347	347
ASH2	0.9695	0.9582	0.9675	0.9756	0.898	0.9434	0.8678	0.789	0.9226	0.9449	0.7773	0.9627	0.5603	0.8699	0.9503	0.9598	0.9553	0.9326	0.7384	0.8825	0.9654	0.9785
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	348	324	348	321	344	347	335	334	332	334	338	336	343	301	305	310	313	316	340	342	346	347
ASH3	0.9661	0.9541	0.9653	0.9726	0.8954	0.9419	0.8618	0.7894	0.9211	0.9431	0.7889	0.9604	0.8775	0.8769	0.9513	0.9597	0.9552	0.9334	0.7388	0.8807	0.9623	0.9757
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	326	349	322	345	348	336	335	334	335	339	337	344	302	306	311	314	317	341	343	346	347
ASH4	0.9624	0.9496	0.9653	0.971	0.8986	0.942	0.8763	0.7873	0.915	0.9393	0.7775	0.9602	0.5166	0.8751	0.9463	0.9551	0.9492	0.9262	0.7378	0.8801	0.9582	0.9679
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	325	349	322	345	348	336	335	333	335	339	337	344	302	306	311	314	317	341	343	346	347
ASH5	0.2319	0.2149	0.236	0.2335	0.2105	0.2278	0.1967	0.7263	0.8297	0.8755	0.7218	0.8872	0.1338	0.8039	0.8625	0.8751	0.8742	0.8569	0.1444	0.2045	0.2346	0.2333
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.013	0.0001	0.0001	0.0001	0.0001	0.0001	0.0076	0.0001	0.0001	0.0001
	349	325	349	322	345	348	336	335	333	335	339	337	344	302	306	311	314	317	341	343	346	347
ASH6	0.9386	0.9245	0.938	0.942	0.8723	0.9238	0.84	0.7578	0.8861	0.9131	0.749	0.9345	0.5056	0.8473	0.9155	0.9278	0.9216	0.8977	0.741	0.8686	0.9336	0.9358
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	325	349	322	345	348	336	335	333	335	339	337	344	302	306	311	314	317	341	343	346	347
EXLL	0.9431	0.9317	0.9384	0.9526	0.8764	0.9098	0.8645	0.776	0.8947	0.9065	0.7482	0.9354	0.5229	0.8414	0.9225	0.9424	0.9317	0.9133	0.7254	0.8582	0.9431	0.9519
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	345	322	345	320	341	345	332	331	329	331	335	333	340	301	304	309	312	315	338	340	342	343
EXLH	0.9574	0.9525	0.9563	0.9645	0.8899	0.9211	0.866	0.7632	0.8933	0.9211	0.7722	0.9492	0.5601	0.8581	0.9333	0.9535	0.9444	0.9323	0.7371	0.8852	0.9524	0.966
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	344	321	344	319	340	344	331	330	328	330	334	332	339	300	303	308	311	314	337	339	341	342
ENLL	0.956	0.9491	0.9527	0.9645	0.8832	0.9194	0.8761	0.7811	0.9075	0.9239	0.7724	0.9501	0.5525	0.8651	0.9448	0.9578	0.951	0.9309	0.7291	0.8777	0.9487	0.9682
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	348	325	348	321	344	347	335	334	332	334	338	336	343	302	305	310	313	316	340	342	345	346
ENLH	0.9412	0.9347	0.9389	0.9495	0.8749	0.918	0.8474	0.7663	0.8817	0.908	0.7696	0.9365	0.5524	0.85	0.9206	0.9322	0.9208	0.9047	0.7312	0.8844	0.9392	0.9509
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	349	326	349	322	345	348	336	335	333	335	339	337	344	303	306	311	314	317	341	343	346	347

ASL3	ASL4	ASL5	ASL6	ASW1	ASW2	ASW3	ASW4	ASW5	ASW6	ASH1	ASH2	ASH3	ASH4	ASH5	ASH6	EXLL	EXLH	ENLL	ENLH	TL	TH
1																					
0																					
347																					
0.9926	1																				
0	0																				
346	348																				
0.9882	0.9898	1																			
0.0001	0.0001	0																			
347	348	350																			
0.9626	0.9649	0.9673	1																		
0.0001	0.0001	0.0001	0																		
347	348	350	350																		
0.965	0.9666	0.9686	0.942	1																	
0.0001	0.0001	0.0001	0.0001	0																	
345	346	348	348	348																	
0.984	0.9834	0.985	0.9602	0.9745	1																
0.0001	0.0001	0.0001	0.0001	0.0001	0																
346	347	349	349	348	349																
0.9757	0.9762	0.9764	0.9469	0.9674	0.9877	1															
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0															
347	347	349	349	347	348	349															
0.9726	0.9726	0.9705	0.9464	0.9632	0.9836	0.99	1														
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0														
347	348	350	350	348	349	349	350														
0.9214	0.9244	0.9267	0.8952	0.9154	0.9362	0.9538	0.956	1													
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0													
346	347	349	349	347	348	348	349	349													
0.9263	0.9257	0.926	0.8901	0.9172	0.9342	0.9557	0.955	0.9474	1												
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0												
347	348	350	350	348	349	349	350	349	350												
0.9732	0.9706	0.9712	0.9497	0.9584	0.9744	0.9715	0.9615	0.921	0.9281	1											
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0											
345	346	348	348	348	348	347	348	347	348	348											
0.9825	0.9815	0.9818	0.9579	0.9685	0.987	0.9793	0.9745	0.9278	0.929	0.9789	1										
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0										
345	346	348	348	347	348	347	348	347	348	347	348										
0.981	0.9776	0.978	0.9536	0.9656	0.983	0.977	0.9737	0.9213	0.9255	0.9751	0.9895	1									
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0									
347	347	349	349	347	348	349	349	348	349	347	347	349									
0.9765	0.9759	0.9751	0.9538	0.9621	0.9786	0.9727	0.9706	0.9189	0.9198	0.9678	0.984	0.9865	1								
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0								
346	347	349	349	347	348	348	349	348	349	347	347	348	349								
0.2362	0.24	0.2252	0.2301	0.2304	0.2387	0.2268	0.2313	0.2211	0.2087	0.2381	0.2515	0.2387	0.237	1							
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0							
346	347	349	349	347	348	348	349	348	349	347	347	348	349	349							
0.9473	0.9438	0.9473	0.9243	0.9323	0.9506	0.9448	0.9449	0.8915	0.8947	0.9435	0.9524	0.9557	0.9532	0.2431	1						
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0						
346	347	349	349	347	348	348	349	348	349	347	347	348	349	349	349						
0.9543	0.9529	0.9519	0.9311	0.939	0.9516	0.9448	0.9404	0.8946	0.901	0.9391	0.9508	0.9459	0.9466	0.217	0.914	1					
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0					
342	343	345	345	343	344	344	345	344	345	343	343	344	344	344	344	345					
0.9684	0.9686	0.969	0.95	0.9544	0.9675	0.9578	0.9524	0.9083	0.914	0.9561	0.9669	0.9595	0.9565	0.2307	0.9317	0.9467	1				
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0				
341	342	344	344	342	343	343	344	343	344	342	342	343	343	343	343	344	344				
0.9709	0.9686	0.965	0.9458	0.9559	0.9694	0.9655	0.9584	0.9172	0.9252	0.9598	0.9674	0.9635	0.9587	0.2344	0.929	0.9527	0.9619	1			
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0			
345	346	348	348	346	347	347	348	347	348	346	348	347	347	347	347	344	343	348			
0.9544	0.9543	0.9525	0.943	0.9407	0.9517	0.9345	0.9345	0.8686	0.8752	0.9362	0.9512	0.9472	0.9429	0.2371	0.9222	0.9292	0.9607	0.9435	1		
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0		
346	347	349	349	347	348	348	349	348	349	347	347	348	348	348	348	345	344	348	349		

GENETIC STRUCTURE

INTRODUCTION

The study of the genetic structure of marine organisms reveals the processes contributing to the establishment and maintenance of populations. Species may vary in genetic patterns across their geographical ranges. The knowledge of these patterns is of practical importance for the management of the exploited wild populations.

The Norway lobster, *Nephrops norvegicus* (L., 1758), is a species of high commercial interest in the Mediterranean. It is a marine benthic crustacean with a wide geographical distribution. *N. norvegicus* is present in the North Sea, reaching the northern Norway, in the NE/E Atlantic Ocean from Greenland to the costs of Morocco and in the whole Mediterranean. The bathimetric distribution of the species varies among different geographic areas ranging from 15 to more than 500 meters in depth. At present growing attention exists for this species, both as an exploitable resource and for conservation purpose. Differences in morphological traits (mean individual size, growth rate) and in reproductive characteristics (size at first sexual maturity, latitudinal variation in the ovarian cycle, period of egg incubation and in periodicity of female spawning, fecundity within and among wild populations) have been documented (GAMULIN-BRIDA *et al.*, 1972; FROGLIA & GRAMITTO, 1981, 1987; SARDÀ, 1995). These differences might be due to phenotypic responses both to different environmental conditions and to fishing pressure, or genetic differences. CORNI *et al.* (1989) detected variation in the number of chromosomes in specimens collected at two localities in the Adriatic Sea. However, these results were not supported by a preliminary population genetic study, based on small sample size, for allozyme characterisation of two Adriatic population of Norway lobster (MANTOVANI & SCALI, 1992). Moreover, recent genetic studies on Mediterranean populations of the blue and red shrimp, *Aristeus antennatus*, another decapod showing variability in morphometric traits, detected extensive genetic homogeneity (PLA *et al.*, 1995). Consequently the question of the role that environmental factors play in realizing the biological differences observed among *A. antennatus* populations is under discussion.

Despite the remarkable commercial value of *Nephrops norvegicus*, some characteristics of its life cycle, as for example the larval behaviour and the dispersal capability, are scantily known. If in the different geographical region where the Norway lobster is found there are self-sustaining stocks, a severe exploittion may lead to local extinction of the population. The consequences may be less severe if a major portion of individuals in one area is provided by planktonic larvae spawned elsewhere.

In order to elucidate the general pattern of the population structuring of *Nephrops norvegicus* a program was carried out with the aim of studying the genetic variation among populations of Norway lobster along the European coasts of the Mediterranean and in the Atlantic waters off South Portugal, areas of intensive commercial fishing. Thus we would verify if also the Norway lobster has a wide genetic uniformity or if it is possible to find biochemical markers that could help in identifying genetic stocks.

In this paper the results concerning genetic variation and differentiation among nine populations of *Nephrops norvegicus* distributed along a wide geographic area are presented.

MATERIALS AND METHODS

Sampling

Sampling was designed to determine the genetic structure and the degree of genetic differentiation of Norway lobster in the Mediterranean. Specimens were caught by bottom trawl nets in one Atlantic and eight Mediterranean localities (figure 1 of the introduction; table 1). Every sample from each locality consisted of more than 100 individuals, all coming from only one haul. Specimens were put in individually numbered plastic bags, transferred to the laboratory in dry ice and stored at -80°C until analyses.

Electrophoresis

Samples of chela muscle and hepatopancreas tissue were cut after thawed. Extracts were prepared by mincing tissues in an equal amount of a pH 8.0 extracting buffer (0.2 M Tris, 1 mM EDTA and 25 mM 2-mercaptoethanol) by means of a rotating potter pestle. Homogenates were centrifuged at 9000 RPU for 10 minutes, then the supernatant was separated for electrophoresis. Care was taken to keep samples temperature below 5°C at all stages of preparation. Cellulose acetate electrophoresis was used to survey the enzyme systems listed in table 2. Electrophoresis was performed at 300 volts for 25 minutes, using a Tris-EDTA-Maleate (TEM) buffer system (SCHNEPPENHEIM & MAC DONALD, 1984) for all enzymes. Preliminary analyses were carried on three tissues (abdomen muscle, chela muscle and hepatopancreas). Abdomen and chela muscle gave comparable resolution, thus chela muscle was chosen for its practicality. Hepatopancreas gave for LDH and PGM two additional loci unexpressed in the muscle, thus these two enzyme systems were analysed for both the tissues. Enzyme staining was carried out according to slightly modified procedures described by PASTEUR *et al.* (1988). When an enzyme is encoded by two loci in one tissue, the more anodally migrating enzyme is suffixed as 1. For each locus the most common allele was designed as 100; additional alleles were assigned numerical values according to their distance from the allele 100. An initial electrophoretic screening was carried on thirty specimens for each population in order to detect polymorphic loci; loci showing only one allele in this subsample of individuals were not analysed in the remaining specimens and were considered as monomorphic.

Statistical analyses

Genotypic data for all populations were analysed using the computer package BIOSYS-1 (SWOFFORD & SELANDER, 1981). Allele frequencies, mean number of alleles per locus, percent polymorphic loci (0.99 criterion), and mean heterozygosity (direct count and expected from Hardy-Weinberg equilibrium) were calculated for each population. Genotype frequencies within populations were tested for deviation from Hardy-Weinberg equilibrium values using a chi-square goodness of fit test on observed genotype frequencies. Levels of genetic differentiation between populations were estimated by NEI's (1978) genetic distance:

$$\mathbf{D} = -\ln \frac{\Sigma \frac{x_i y_i}{N}}{\sqrt{\Sigma \frac{x_i^2}{N} \Sigma \frac{y_i^2}{N}}},$$

where x_i and y_i are the allelic frequencies of allele i for a locus in the populations X and Y respectively, and N is the total number of loci. This index takes a range of 0 (total similarity) to infinity (total dissimilarity), and its unbiased estimates take sample size into account.

WRIGHT's (1978) F-statistics was used to estimate the levels of population structuring. The basic formula of F-statistics is:

$$1-F_{IT} = (1-F_{IS})(1-F_{ST})$$

For each locus fixation index was calculated for each locality i:

$$f_i = 1 - \frac{\text{observed heterozygotes}}{\text{expected heterozygotes}}.$$

A mean fixation index over localities was calculated:

$$F_{IS} = \frac{\Sigma n_i p_i q_i f_i}{\Sigma n_i p_i q_i},$$

where n_i is the sample size, p_i is the frequency of the most common allele, and $q_i=1-p_i$ at locality i. The value of F_{IS} is negative when there is an excess of heterozygotes and positive for a deficiency of heterozygotes. We used the standardised genetic variance F_{ST} to measure heterogeneity of allelic frequencies among localities:

$$F_{ST} = \frac{H_T - \overline{H_S}}{H_T},$$

where H_T id the total heterogeneity (H_T=2p[1-p]; p is the overall gene frequency), and $\overline{H}_S=\Sigma n_i p_i/\Sigma n_i$ is the weighted average of heterozygosities at localities. The departure of genotypic frequencies from Hardy-Weinberg equilibrium values was measured by the total fixation index:

$$F_{IT} = 1 - \frac{\text{observed heterozygotes}}{\text{expected heterozygotes}},$$

with genotypes pooled over localities.

Significance of F_{ST}, F_{IT}, and F_{IS} was tested according to WORKMAN & NISWANDER (1970), BROWN (1970) and LI (1955) respectively.

$$\chi^2 = F_{IS}^2 N(k-1) \qquad d.f. = \frac{k(k-1)}{2}$$

$$X = |F_{IT}|\sqrt{N} \qquad \begin{matrix} X > 1.96 & P < 0.05 \\ X > 2.57 & P < 0.01 \end{matrix}$$

$$\chi^2 = 2NF_{ST}(k-1) \qquad d.f. = (k-1)(s-1)$$

where N is the total number of individuals sampled, k is the number of alleles and s is the number of localities analysed for each locus.

RESULTS

Fifteen enzyme systems gave twenty-three consistently recognisable presumptive gene loci. Eleven loci (*SDH-2, SDH-3, LDH-1, LDH-2, ME, G6PDH, XDH-1, XDH-2, AO, PGM-1, PGM-2*) were polymorphic (frequency of most common allele ≤ 0.99) in at least one sample. The allelic frequencies detected for each of the nine samples are shown in table 3. Only *SDH-3* and *ME* were closely fixed for the same allele in all populations sampled. All the other systems had two allelic variants, one of which was relatively rare at loci *LDH-1* and *G6PDH*. The following loci *LDH-2*, *AO*, *PGM-1* and *PGM-2* presented one allele much more frequent than the other in all populations, while for *SDH-2*, *XDH-1* and *XDH-2* the two variants were codominant in several populations. At some polymorphic loci the most common allele was fixed in few populations. For example $SDH\text{-}2^{100}$ was fixed in the Faro and Gulf of Genoa samples, $LDH\text{-}2^{100}$ was fixed in the Catalan Sea sample, $G6PDH^{100}$ was fixed in the Faro sample and AO^{100} was fixed in the Faro and Sicily Channel samples.

The Mediterranean populations had a mean heterozygosity ranging from 0.052 ± 0.025 to 0.142 ± 0.040, the Atlantic populations from Faro had the lower mean heterozygosity (0.052 ± 0.025, table 4). The low genetic variability indicated for Faro population by low mean heterozygosity was also confirmed by the lowest mean number of alleles per locus (1.3 ± 0.1) and the lowest percentage of polymorphic loci (30.1%), whereas in the other samples these values ranged from 1.3 ± 0.1 to 1.5 ± 0.1 and 34.8% to 43.5% respectively (table 4).

The observed mean heterozygosities well agreed with those expected under Hardy-Weinberg equilibrium. This was confirmed by chi-square goodness-of-fit of observed genotype frequencies. Only two samples had deviation from expected values, due to marginally significant heterozygote deficiency (population from Adriatic Sea for *PGM-2* and population from Balearic Islands for *SDH* and *AO*).

Genetic distances among the Mediterranean populations of *Nephrops norvegicus* were small, but relatively high in all pairwise comparisons including Faro, Genoa and northern Tyrrhenian samples.

The dendrogram constructed from the UPGMA analysis (figure 1) failed to reveal strong clustering among samples. A clear pattern of genetic differentiation among investigated populations did not arise. However, within low values of genetic

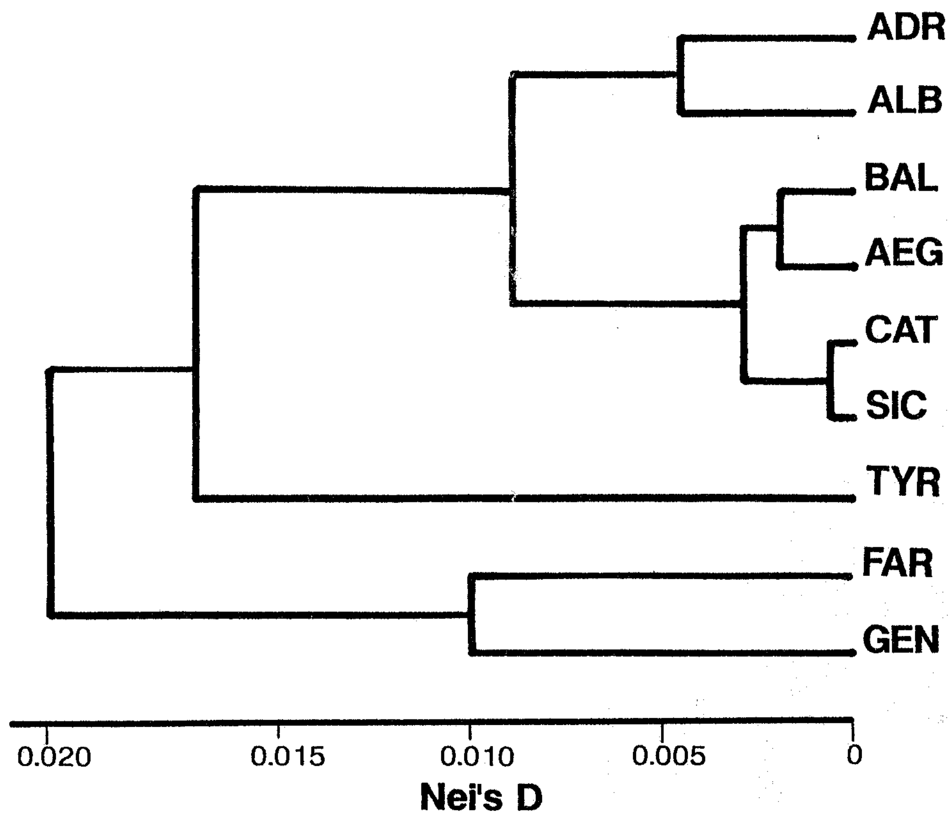


Figure 1.- UPGMA clustering by Nei's (1978) genetic distances among local population
Abbreviations for localities are as in table 1.

Table 1. *Nephrops norvegicus*. Principal characteristics of the sampling trawls. La and Lo are the latitude and the longitude of the beginning of the trawls respectively; D is the average depth of the trawls.

LOCALITY		Date	La	Lo	D
Adriatic Sea	ADR	24/01/1994	43°54'N	13°50'E	70 m
Aegean Sea	AEG	11/01/1994	38°40'N	23°26'E	120 m
Alboran Sea	ALB	10/01/1994	35°30'N	04°20'W	400 m
Balearic Islands	BAL	15/03/1994	39°37'N	02°02'E	430 m
Catalan Sea	CAT	09/01/1994	41°06'N	02°11'E	500 m
Faro	FAR	10/01/1994	36°47'N	07°57'W	400 m
Ligurian Sea	GEN	08/03/1994	44°04'N	09°26'E	520 m
Sicily Channel	SIC	10/02/1994	36°30'N	13°30' E	400 m
N-Tyrrhenian Sea	TYR	10/02/1994	42°26'N	10°44'E	270 m

Table 2. *Nephrops norvegicus*. Enzymes systems used for allozyme electrophoresis.

ENZYME SYSTEM	Abbrev.	EC No.
α-glycerophosphate dehydrogenase	αGPD	EC 1.1.1.8
Sorbitol dehydrogenase	SDH	EC 1.1.1.14
L-Lactate dehydrogenase	LDH	EC 1.1.1.27
Malate dehydrogenase	MDH	EC 1.1.1.37
Malic enzyme	ME	EC 1.1.1.40
Isocitrate dehydrogenase	IDH	EC 1.1.1.42
Phosphogluconate dehydrogenase	PGD	EC 1.1.1.44
Glucose-6-phosphate dehydrogenase	G6PDH	EC 1.1.1.49
Glyceraldehyde-3-phosphate dehydrogenase	G3PDH	EC 1.2.1.12
Xanthine dehydrogenase	XDH	EC 1.2.1.37
Aldehyde oxidase	AO	EC 1.2.3.1
Aldolase	ALD	EC 4.1.2.13
Mannose-phosphate isomerase	MPI	EC 5.3.1.8
Phosphoglucose isomerase	PGI	EC 5.3.1.9
Phosphoglucose mutase	PGM	EC 5.4.2.2

Table 3. *Nephrops norvegicus*. Allele frequencies. (n) is number of individuals analysed for each locus and (SE) is the standard error of allelic frequencies; cm is the chela muscle and hp is the hepatopancreas. Populations abbreviations as in table 1.

Locus	Tissue	All.	ADR	AEG	ALB	BAL	CAT	FAR	GEN	SIC	TYR
αGPD	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SDH-1	hp										
(n)			56	65	80	76	62	71	16	31	64
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SDH-2	hp										
(n)			59	64	33	51	43	38	38	13	28
		100	0.466	0.500	0.485	0.471	0.419	1.000	1.000	0.385	0.536
		98	0.534	0.500	0.515	0.529	0.581	0.000	0.000	0.615	0.464
(SE)			*0.046*	*0.044*	*0.062*	*0.049*	*0.053*	-	-	*0.095*	*0.067*
SDH-3	hp										
(n)			40	21	8	21	36	38	38	16	13
		100	0.825	1.000	1.000	0.976	0.986	1.000	1.000	1.000	1.000
		98	0.175	0.000	0.000	0.024	0.014	0.000	0.000	0.000	0.000
(SE)			*0.042*	-	-	*0.024*	*0.014*	-	-	-	-
LDH-1	cm										
(n)			83	84	82	80	77	83	90	71	70
		100	0.940	0.976	0.945	0.950	0.981	0.952	0.967	0.986	0.964
		98	0.060	0.024	0.055	0.050	0.019	0.048	0.033	0.014	0.036
(SE)			*0.018*	*0.012*	*0.018*	*0.017*	*0.011*	*0.017*	*0.013*	*0.010*	*0.016*
LDH-2	hp										
(n)			69	89	98	67	104	88	77	58	65
		100	0.768	0.876	0.995	0.754	1.000	0.801	0.760	0.991	0.769
		98	0.232	0.124	0.005	0.246	0.000	0.199	0.240	0.009	0.231
(SE)			*0.036*	*0.025*	*0.005*	*0.037*	-	*0.030*	*0.034*	*0.009*	*0.037*
MDH-1	cm										
(n)			99	99	98	89	104	101	92	82	99
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MDH-2	cm										
(n)			79	83	85	52	94	87	66	71	81
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ME	cm										
(n)			102	98	99	109	104	99	96	79	93
		100	1.000	1.000	0.995	0.968	1.000	0.949	1.000	1.000	1.000
		98	0.000	0.000	0.005	0.032	0.000	0.051	0.000	0.000	0.000
(SE)			-	-	*0.005*	*0.012*	-	*0.016*	-	-	-
IDH	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 3 (continued)

Locus	Tissue	All.	ADR	AEG	ALB	BAL	CAT	FAR	GEN	SIC	TYR
PGD	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
G6PDH	hp										
(n)			89	95	73	95	98	59	90	67	77
		100	0.927	0.932	0.890	0.937	0.934	1.000	0.972	0.978	0.922
		98	0.073	0.068	0.110	0.063	0.066	0.000	0.028	0.022	0.078
(SE)			*0.019*	*0.018*	*0.026*	*0.018*	*0.018*	-	*0.012*	*0.013*	*0.022*
G3PDH	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
XDH-1	hp										
(n)			94	89	85	88	88	70	75	52	74
		100	0.697	0.831	0.753	0.841	0.795	0.993	0.527	0.731	0.277
		98	0.303	0.169	0.247	0.159	0.205	0.007	0.473	0.269	0.723
(SE)			*0.034*	*0.028*	*0.033*	*0.028*	*0.030*	*0.007*	*0.041*	*0.043*	*0.037*
XDH-2	hp										
(n)			75	60	50	60	66	34	55	53	23
		100	0.520	0.333	0.470	0.175	0.144	0.338	0.373	0.255	0.152
		98	0.480	0.667	0.530	0.825	0.856	0.662	0.627	0.745	0.848
(SE)			*0.041*	*0.043*	*0.050*	*0.035*	*0.031*	*0.057*	*0.046*	*0.042*	*0.053*
AO	cm										
(n)			69	94	73	88	87	50	83	83	100
		100	0.616	0.947	0.767	0.920	0.937	1.000	0.958	1.000	0.990
		98	0.384	0.053	0.233	0.080	0.063	0.000	0.042	0.000	0.010
(SE)			*0.041*	*0.016*	*0.035*	*0.020*	*0.018*	-	*0.016*	-	*0.007*
ALD	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MPI-1	cm										
(n)			85	90	64	68	66	85	73	61	80
		100	1.000	1.000	1.000	1.000	1.0000	1.000	1.000	1.000	1.000
MPI-2	cm										
(n)			48	69	38	27	38	78	9	17	48
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
PGI	cm										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
PGM-1	cm										
(n)			80	93	95	99	91	80	89	76	59
		100	0.887	0.935	0.832	0.884	0.923	0.994	0.978	0.980	0.890
		98	0.112	0.065	0.168	0.116	0.077	0.006	0.022	0.020	0.110
(SE)			*0.025*	*0.018*	*0.027*	*0.023*	*0.020*	*0.006*	*0.011*	*0.011*	*0.029*

Table 3 (continued)

Locus	Tissue	All.	**ADR**	**AEG**	**ALB**	**BAL**	**CAT**	**FAR**	**GEN**	**SIC**	**TYR**
PGM-2	cm										
(n)			70	69	51	81	87	52	77	62	44
		100	0.150	0.159	0.118	0.074	0.069	0.115	0.136	0.024	0.034
		98	0.850	0.841	0.882	0.926	0.931	0.885	0.864	0.976	0.966
(SE)			*0.030*	*0.031*	*0.032*	*0.021*	*0.019*	*0.031*	*0.028*	*0.014*	*0.019*
PGM-3	hp										
(n)			30	30	30	30	30	30	30	30	30
		100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 4. *Nephrops norvegicus*. General genetic variability in analysed samples (standard error in parentheses). Populations abbreviations as in table 1.

Population	Sample size, mean*	Mean No.of alleles per locus	Percentage of polymorphic loci **	Mean heterozygosity	
				observed	expected
ADR	75.5 (5.2)	1.4 (0.1)	43.5	0.135 (0.040)	0.142 (0.040)
AEG	77.8 (6.9)	1.4 (0.1)	39.1	0.085 (0.029)	0.092 (0.032)
ALB	67.9 (8.8)	1.4 (0.1)	43.5	0.103 (0.033)	0.111 (0.036)
BAL	76.3 (7.6)	1.5 (0.1)	47.8	0.082 (0.023)	0.098 (0.030)
CAT	80.1 (6.9)	1.4 (0.1)	39.1	0.068 (0.024)	0.072 (0.027)
FAR	62.8 (6.8)	1.3 (0.1)	30.4	0.047 (0.021)	0.052 (0.025)
GEN	73.5 (6.2)	1.3 (0.1)	34.8	0.073 (0.029)	0.079 (0.033)
SIC	57.3 (7.1)	1.3 (0.1)	34.8	0.055 (0.026)	0.063 (0.030)
TYR	58.7 (8.6)	1.4 (0.1)	39.1	0.090 (0.032)	0.088 (0.032)

(*) only polymorphic loci were considered
(**) 0.99 polymorphism criterion

Table 5. *Nephrops norvegicus*. Matrix of Nei's genetic distance among sampling sites. Populations abbreviations as in table 1.

	ADR	AEG	ALB	BAL	CAT	FAR	GEN	SIC	TYR
ADR	•••								
AEG	0.009	•••							
ALB	0.004	0.003	•••						
BAL	0.012	0.002	0.008	•••					
CAT	0.015	0.002	0.006	0.003	•••				
FAR	0.027	0.013	0.021	0.016	0.022	•••			
GEN	0.023	0.017	0.021	0.020	0.025	0.010	•••		
SIC	0.014	0.002	0.006	0.004	0.000	0.023	0.023	•••	
TYR	0.023	0.017	0.020	0.015	0.015	0.037	0.016	0.013	•••

Table 6. *Nephrops norvegicus*. Summary of F-statistics.

Locus	F_{IS}	F_{IT}	F_{ST}
SDH-2	0.090	0.281**	0.210**
SDH-3	0.241**	0.337**	0.127**
LDH-1	-0.046	-0.039	0.007
LDH-2	0.020	0.106**	0.088**
ME	-0.043	-0.010	0.032**
G6PDH	-0.080*	-0.060	0.019**
XDH-1	0.127**	0.290**	0.187**
XDH-2	0.114*	0.183**	0.078**
AO	0.024	0.191**	0.171**
PGM-1	-0.076*	-0.036	0.037**
PGM-2	0.118**	0.140**	0.025**
Mean	**0.067****	**0.181****	**0.122****

(*) P<0.05, (**) P<0.01

differentiation detected, a higher affinity is highlighted between samples from Faro and Gulf of Genoa popualtions. Some differences of these two samples from the other collection sites is caused by the presence of an unique allele *SDH-2*^{100} in Faro and Gulf of Genoa populations. Specimens from Northern Tyrrhenian Sea are differentiated from all other populations, because of the dominance of the allele *XDH-1*^{98}, while all the others had *XDH-1*^{100} as most common allele. The six remaining samples cluster together. The cophenetic correlation, a measure of the similarity between the phenogram and the original distance matrix, was 0.871.

Significant mean F_{IT} value, even if few individual loci being significant, demonstrated that there was some structuring within populations (table 6). Over all loci the mean F_{ST} value was 0.122, this means that 12.2% of the total genetic variation results from differences between populations, with 87.8% coming from within-population variation. Highly significant mean F_{ST} value for the total data set demonstrated significant differentiation among populations. All loci but *LDH-1* contributed to the significant mean F_{ST} value.

DISCUSSION

A number of models of population genetic structure have been developed (SLATKIN, 1985) to assist managers in predicting the consequences of the exploitation of a biological resource. For example, the genetic consequences of the loss of one portion of a species are quite different if the species has a panmictic population structure as opposed to a highly subdivided one.

With few exceptions, there was conformity to Hardy-Weinberg expectations, suggesting that the allozyme variants are genetically based. Comparisons of mean heterozygosities per locus reported in this paper with those of previous studies on other decapod species (DE MATTHAEIS *et al.*, 1983; NELSON & HEDGECOCK, 1987; CHOW *et al.*, 1988), highlighted relatively high values in the populations from Adriatic Sea and from Alboran Sea. Mean heterozygosities per locus of the other populations are consistent with those of the above mentioned studies. MANTOVANI & SCALI (1992) analysed two populations of *Nephrops norvegicus* from the Adriatic Sea and found mean heterozygosity per locus values of 0.033 and 0.036. These values, markedly lower than those reported here, could be due to the different set of enzymes studied and to the small number of specimens analysed for each population. The extended range of mean heterozygosity per locus values detected in the populations analysed does not follow any geographical trends and probably these values are determined by the peculiar ecological characteristics of each habitat.

The analysis of genetic differentiation among populations made by NEI's (1978) genetic distance index showed great homogeneity among all populations including the Atlantic one. This high level of genetic homogeneity was also observed by PLA *et al.* (1995) in an other Mediterranean demersal decapod *Aristeus antennatus* and seems to be a characteristic of some Mediterranean species of decapods. Moreover the dendrogram obtained by the UPGMA clustering method, based on NEI's (1978) genetic distance, reflected a low population substructuring and failed in revealing a clear pattern or a geographical trend in the distribution of genetic variation. Separation of populations is not a product of geographical distance and instead of an isolation-by-distance effect, groups of populations form clusters little differentiated among them (figure 1).

The analysis of genetic differentiation made by F_{ST} gave a value of 0.122, indicating a quite low level of species substructuring. The mean F_{ST} value resulted significative by WORKMAN & NISWANDER (1970) test, however the above mentioned test is very sensible with regard to the sample size and the high number of specimens examined in this study made significant many F-statistics values and all the mean values of F_{IS}, F_{IT} and F_{ST} (table 6).

High levels of genetic similarity among populations are consistent with high levels of gene flow. Although we have no direct evidence of dispersal, because little is known about adults movements and on larval dispersal stages, gene flow among local population is expected.

The low genetic diversity observed in the *Nephrops norvegicus* populations cannot be explained by phenomena such as bottleneck or limitation in population size, because of the high density of individuals of each population. Therefore the low levels of genetic differentiation in the Mediterranean Norway lobster could be due to 1) sufficient gene flow to maintain homogeneity among populations, by 2) occasional sweepstakes events such as sporadic recruitment from non-neighbouring areas which could produce high genetic homogeneity, by 3) stabilising selection arising from exposure to similar environments, or by 4) recent divergence of the compared populations.

Despite a low genetic heterogeneity, as pointed out by Nei's genetic distance, there are signals of a certain population substructuring as shown by the mean value of F_{ST}. Therefore Mediterranean Norway lobster populations could not be necessarily seen as a pure single genetic unit. This last image is partially in agreement with the variability, even if low, of vital parameters estimates as well reproductive and morphometric features recorded in several sites within the Mediterranean area. (GAMULIN-BRIDA *et al.*, 1972; FROGLIA & GRAMITTO, 1979, 1981, 1987; ORSI RELINI L.& RELINI G. 1989; BIAGI *et al.* 1990a,b,c; MORI *et al.*, 1993, 1994; SARDÀ, 1995; this study). Therefore there are evidences that local differences could be based on small genetic diversity and not only due to ecological and/or habitat differences (SARDÀ, 1995).

REFERENCES

BROWN, A.H.D.- 1970. The estimation of Wright's fixation index from genotypic frequencies. *Genetica*, **41**: 399-406.

BIAGI, F., DE RANIERI S. AND M MORI.- 1990a. Reproductive biology of the female of *Nephrops norvegicus* (L., 1758) in the northern Tyrrhenian Sea. *Rapp. Comm. int. Mer Medit.*, **32(1)**: 33.

BIAGI F., DE RANIERI S., AND M. MORI.- 1990b. Relative growth of the crusher propodite of *Nephrops norvegicus* (L.) in the northern Tyrrhenian Sea. *Rapp. Comm. int. Mer Medit.*, **32(1)**: 33.

BIAGI F., DE RANIERI S., MORI M. (1990c) Size at sexual maturity for males of *Nephrops norvegicus* (L.) in the northern Tyrrhenian Sea. *Rapp. Comm. int. Mer Medit.*, **32(1)**: 32.

CHOW S., FUJIO Y., NOMURA T. (1988) Reproductive isolation and distinct population structures in two types of the freshwater shrimp *Palaemon paucidens*. *Evolution*, **42(4)**: 804-813

CORNI M.G., TRENTINI M., FROGLIA C. (1989) Karyological study on *Nephrops norvegicus* (L., 1758) (Astacidea, Nephropidae) in the central Adriatic Sea. *Nova Thalassia*, **10**: 127-131

DE MATTHAEIS E., ALLEGRUCCI G., CACCONE A., CESARONI D., COBOLLI SBORDONI M., SBORDONI V. (1983) Genetic differentiation between *Panaeus kerathurus* and *P. japonicus* (Crustacea, Decapoda). *Mar. Ecol. Progr. Ser.*, **12**: 191-197

FROGLIA C., GRAMITTO M.E. (1979) An estimate of the fecundity of Norway lobster, *Nephrops norvegicus* (L.), in the Adriatic Sea. *Rapp. Comm. int. Mer Medit.*, **25/26**: 227.

FROGLIA C., GRAMITTO M.E. (1981) Summary of biological parameters on the Norway lobster, *Nephrops norvegicus* (L.), in the Adriatic. *FAO Fish. Rep.*, **253**: 165-178

FROGLIA C., GRAMITTO M.E. (1987) An estimate of growth and mortality parameters for Norway lobster (*Nephrops norvegicus*) in the central Adriatic Sea. *FAO Fish. Rep.*, **394**: 189-203

GAMULIN-BRIDA H., CRNKOVIC D., JUKIC S., SIMUNOVIC A. (1972) Characteristic and dominant species of Crustacea Decapoda in Adriatic biocenosis "*Nephrops norvegicus - Thenae muricata*". *Thal. Jug.*, **8**: 81-97

LI C.C. (1955) *Population genetics*. Chicago University Press, Chicago

MANTOVANI B., SCALI V. (1992) Allozyme characterization of the Norway lobster, *Nephrops norvegicus*, of two Adriatic trawling grounds. *Acta Adriat.*, **33(1/2)**: 209-213

MORI M., DE RANIERI S., BIAGI F. (1993) Length-weight relationships for *Nephrops norvegicus* (L.) of the northern Tyrrhenian Sea in relation to sex,season,moult and maturity. *Atti Soc. Tosc. Sci.Nat.Mem.,* **Ser.B, 100**: 171-182

MORI M., LATTES A., BIAGI F. (1994) Investigation on the relative growth of the cephalothorax, abdomen and telson for *Nephrops norvegicus* (L.) of the northern Tyrrhenian Sea. *Boll.Mus.Ist.biol.Univ.Genova,* **58-59 (1992-1993):** 171-179

NEI M. (1978) *Molecular evolutionary genetics*. Columbia University Press, New York

NELSON K., HEDGECOCK D. (1980) Enzyme polymorphism and adaptive strategy in the decapod Crustacea. *Amer. Nat.*, **116**: 238-280

ORSI RELINI L., RELINI G. (1989) Reproduction of *Nephrops norvegicus* L., in isothermal Mediterranean waters. In: Reproduction, Genetics and Distributions of Marine Organisms. John.S.Ryland and Paul.A.Tyler (eds). International Symposoum Series. Olsen & Olsen, Fredensborg (Dk): 153-160..

PASTEUR N., PASTEUR G., BONHOMME F., CATALAN J., BRITTON-DAVIDIAN J. (1988) *Practical isozyme genetics*. Ellis Horwood Limited Publ.

PLA C., ROLDÁN M.I., GARCÍA-MARÍN (1995) Biochemical genetics of the pink prawn, *Aristeus antennatus* Risso, in the Western Mediterranean. *Rapp. Comm. int. Mer Médit.*, **34**: 39

SARDÀ F. (1995) A review (1967-1990) of some aspects of the life history of *Nephrops norvegicus*. *ICES mar. Sci. Symp.*, **199**: 78-88

SCHNEPPENHEIM R., MAC DONALD C.M. (1984) Genetic variation and population structure of krill (*Euphausia superba*) in the Atlantic sector of Antarctic waters and off the Antarctic Peninsula. *Polar Biology*, **3**: 19-28

SLATKIN M. (1985) Gene flow in natural populations. *Annu. Rev. Ecol. Syst.,* **16**: 393-430

SWOFFORD D.L., SELANDER R.B. (1981). BIOSYS-1: a FORTRAN program for the comprehensive analysis of electrophoretic data in population genetics and systematics. *Journal of Heredity*, **72**: 282-283

WORKMAN P.L., NISWANDER J.D. (1970). Population studies on southwestern Indian tribes.II.Local genetic differentiation in the Papago. *Am. J. Hum. Genet.* **22**: 24-29

WRIGHT S. (1978) *Evolution and the genetics of populations. Vol. 4. Variability within and among natural populations*. University of Chicago Press, Chicago

FEEDING HABITS

INTRODUCTION

Despite the great commercial importance of *Nephrops norvegicus*, which has been a target species for several biological studies, mainly related with growth, reprodution and moulting which are aspects of major importance for stock assessment and management, there have been few studies on their feeding habits (Lagardaére, 1977; Gual-Frau & Gallardo-Cabello, 1988; Sardà & Valladares, 1990; Mytilineou *et al*, 1992).

One of the objectives of the NEMED project is the comparative study of feeding habits of *Nephrops norvegicus* from different locations and in different seasons.
The results now presented , reflect the analysis of a part of the total sampling, of which the complete study will be part of a Ph. D. Thesis.

MATERIAL AND METHODS

During the first sampling year of the NEMED project, seasonal samplings (Spring, Summer, Autumn and Winter) where collected simultaneously, in every sampling site: South coast of Portugal (P), Alboran Sea - Malaga (M), Catalan Sea-Barcelona (B), Ligurean Sea- (L), Tyrrheanian Sea- Pisa (T), Adriatic Sea - Ancona (A), Aegean Sea - Greece (G). For several reasons, including difficulties in sampling, or in transportation of the samples, we only analysed the samples for all seasons in three places: Portugal, Tyrrheanian Sea and Ancona. For the remaining sites three seasons were analysed except for the Ligurean Sea where only two were analysed .

Seventy (70) individuals of *Nephrops norvegicus* were collected with carapace lengths between 30 and 40 mm, per site and season. They we fixed just after collection or after landing in 10% formalin or 70% alcohol, and preserved in 70% alcohol.

For each individual sex and carapace length was registered with a minimum precision of 1 mm (measurements rounded to the millimeter below), after which stomachs were removed and preserved in 70% alcohol.

For the diet analyses we observed approximately 20 stomachs independently of sex , since there seem to be no major differences in feeding between males and females (Cartes, per. com.; Mytilineou *et al*, 1992).
We chose for the analysis of feeding only stomachs with contents, considering by visual estimation those with a repletion equal to or superior to 20%.

The analysis was carried out, trying to identify the prey-specimens to the lowest taxonomical level; but in the present report the results are presented, considering only major groups (Table 6.1).

For the diet study we collected numerical data, for percentage in number calculation, and point percentage calculation.; in the present report only the frequency of occurrence method will be used (Hyslop, 1980).

For the statistical treatment of data we used a multivariate analysis, since it helps to : i) enhance the data structure; ii) synthesize the data, which permits a better understanding and a better representation of results (Gauch, 1982).
We used a PCA - Principal Component Analysis (Pielou, 1984)
The program used was NTSYS 1.8 (Rohlf, 1993)

RESULTS AND DISCUSSION

Stomach contents are composed mainly of small pieces of crustacean carapace, bivalve and gastropod shells, fish vertebrae and otoliths , and other hard and soft parts of prey, since as carnivores/scavengers *Nephrops norvegicus* break apart the animals they feed on. This composition of the stomach contents, makes identification a difficult task. Among crustaceans other than decapods we found several necrophage Lysianacids and Cirolanids; an observation also reported by Lagardére (1977). In fact these were some of the few organisms that we found in one piece in the stomach.

From the analysis we identified 18 prey-groups, including Not Identified Material, in which decapods are the main group followed by other crustaceans and fish.(Fig. 6.1 a 6.7).

In several stomachs we found pieces of nylon threads, probably from nets. The greatest percentage of this occurrence was in the samples from Greece (Fig 6.8)

For the comparative analysis between the different sampling sites, we used the Principal component Analysis method (PCA), based on the values of frequency of occurrence per site and season (Fig 6.9 and 6.10).

No clear OTUs (site per season) distribution structure can be seen on axes 1,2 and 1,3 (Fig 6.9 and 6.10), which explain 43% of the total variability (Table 6.2).

The contribution of the variables to these principal axis (Figs. 6.11 and 6.12) suggests the presence of a "horse-shoe" effect (GAUCH, 1984) which can be the consequence of the gradient of their occurrence, between the low average values on a reduced number of OTU's and a high average values for a high number of OTU's.
This would explain both the slow decrease in the extracted eigenvalues and the above mentioned lack of a spatial structure among the OTU's (Figs. 6.9 and 6.10).

ACKNOWLEDGEMENTS

Thanks are due to Pro. F. Andrade and Prof. M. Castro for their help in the statistical treatment of data, and to Prof. K. Erzini for the english review of this paper.

REFERENCES

Gauch, H. G., Jr. - 1982. *Multivariate Analysis in Community Ecology.* Cambridge University Press.

Gual-Frau, A. and M. Gallardo-Cabello - 1988. Análisis de la frecuencia y habitos alimenticios de la “cigala”, *Nephrops norvegicus* (Linneo, 1758) en el Mediterraneo Occidental (Crustacea: Nephropsidae). *An. Inst. Cienc. Del Mar Y Limnol. Univ. Nal. Autón. México,* 15 (1): 151-166.

Hyslop, E. J. - 1980. Stomach contents anlysis, A review of methods and their application. *J. Fish. Biol.* 17: 411-429.

Lagardère, J. P. - 1977. Recherches sur la distribution verticale et sur l’alimentation des Crustacés Décapodes benthiques de la pente continentale du Golfe de Gascogne. Analyse des groupements carcinologiques. *Bull. Cent. Etud. Rech. Sci., Biarritz,* 11(4): 367-440.

Mytilineou, Ch, A. Fourtuni and C. Papacostantinou - 1992. Stomach content analysis of Norway Lobster, *Nephrops norvegicus,* in the North Aegean Sea (Greece). *Rapp. Comm. Int. Mer Medite.* 33:46

Pielou, E. C. - 1984. *The interpretation of ecological data.* John Wiley & Sons. U.S.A.

Rohlf, F. J. -1993. NTSYS-pc *Numerical Taxonomy and Multivariate Analysis System, version 1.80.* EXETER Software, New York.

Sardá, F. and F. J. Valladares. - 1990. Gastric evacuation of different foods by *Nephrops norvegicus* (Crustacea: Decapoda) and estimation of soft tissue ingested, maximum food intake and cannibalism in captivity. *Mar. Biol.* 104:25-30.

Fig. 6.1 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in Portugal per season

Fig. 6.2 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in Malaga per season

Fig. 6.3 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in Barcelona per season

Fig. 6.4 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in the Ligurian Sea per season

Fig. 6.5 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in the Tyrrhean Sea per season

Fig. 6.6 - Frequency of Occurrence of different prey groups in the diet of Nephrops norvegicus in Ancona per season

Fig. 6.7 - Frequency of Occurrence of different prey groups in the diet of *Nephrops norvegicus* in Greece per season

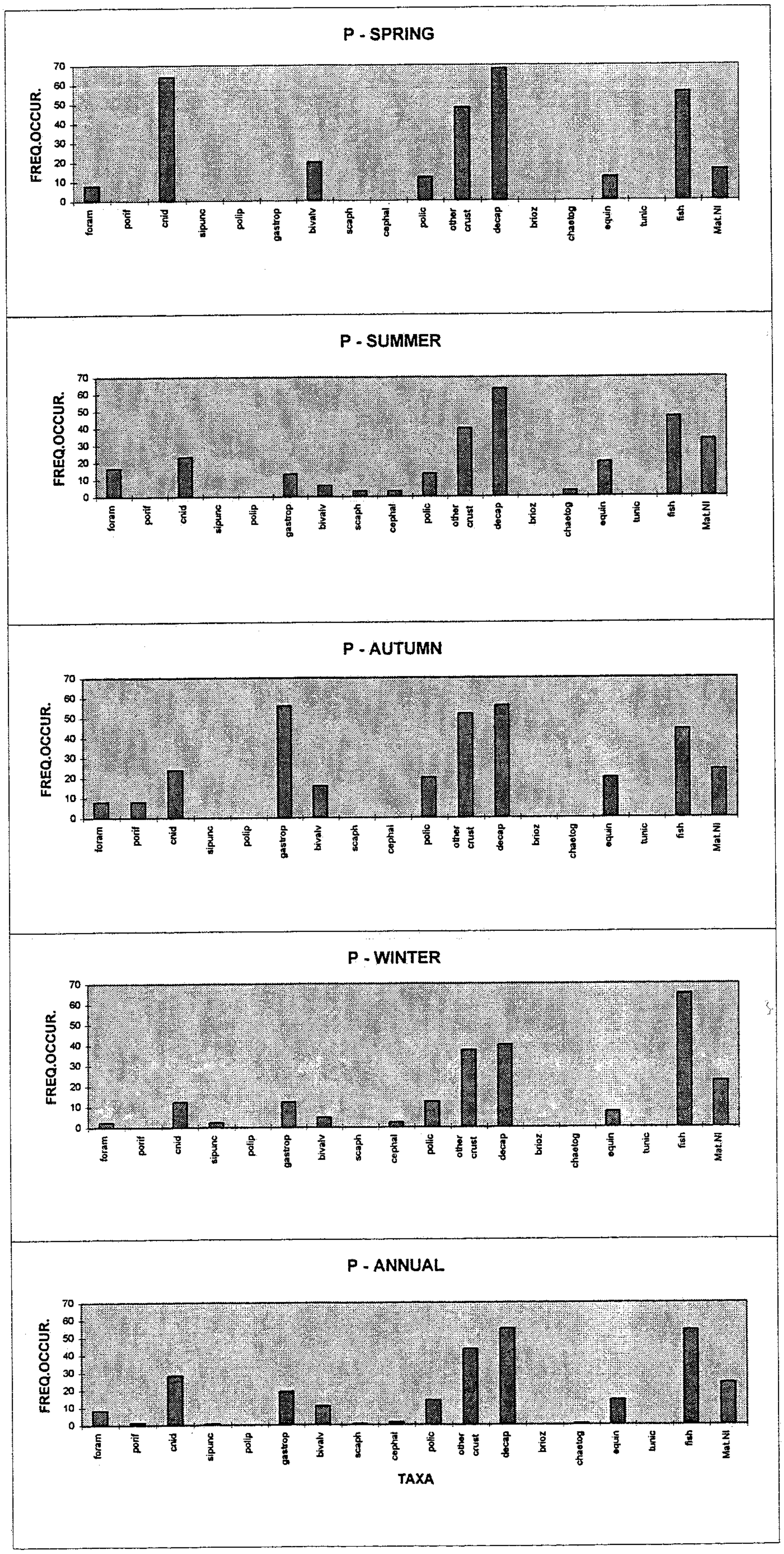

P - SPRING
P - SUMMER
P - AUTUMN
P - WINTER
P - ANNUAL
FREQ.OCCUR.
0
10
20
30
40
50
60
70
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

Fig. 6.1

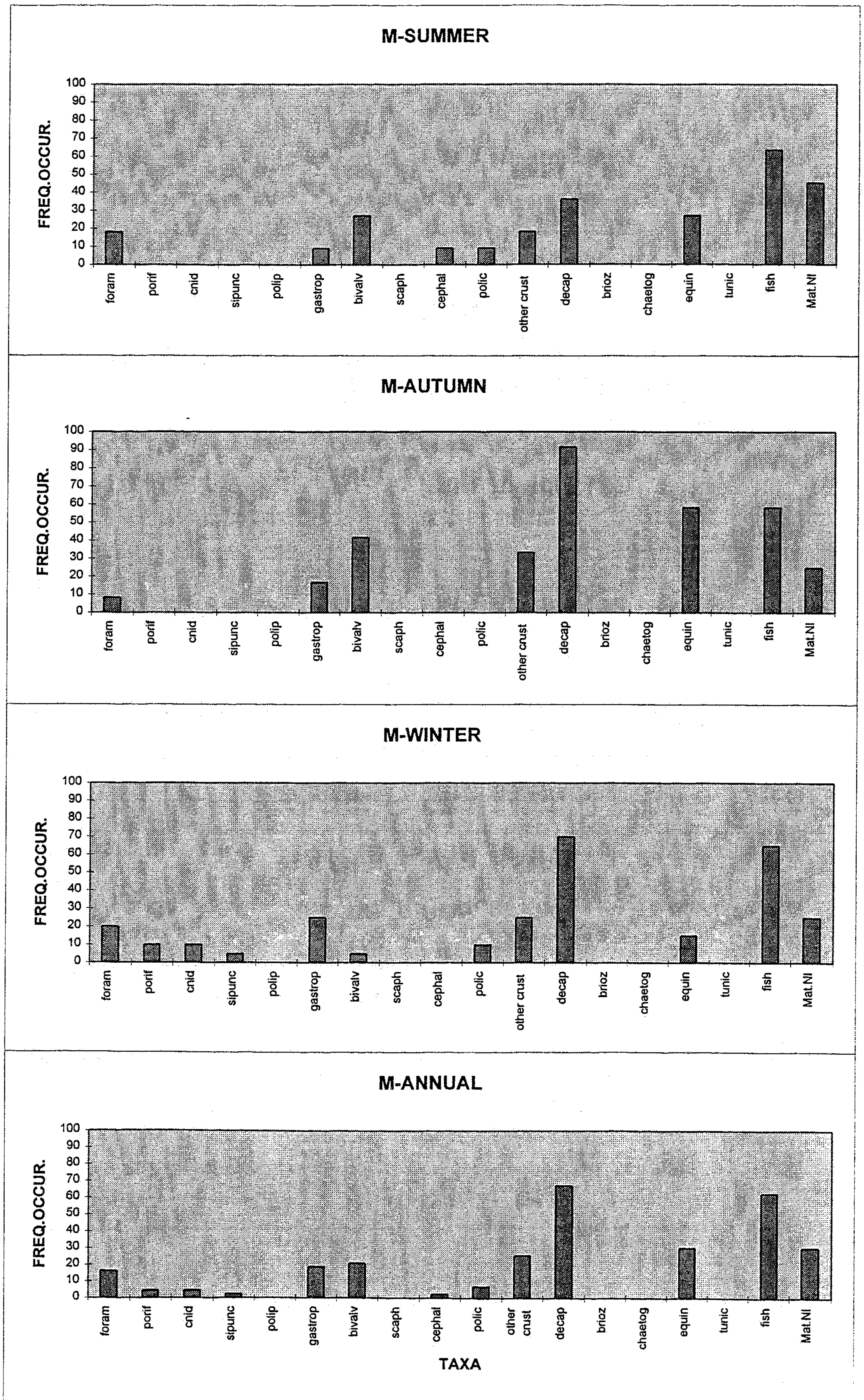

M-SUMMER
M-AUTUMN
M-WINTER
M-ANNUAL
FREQ.OCCUR.
0
10
20
30
40
50
60
70
80
90
100
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

Fig. 6.2

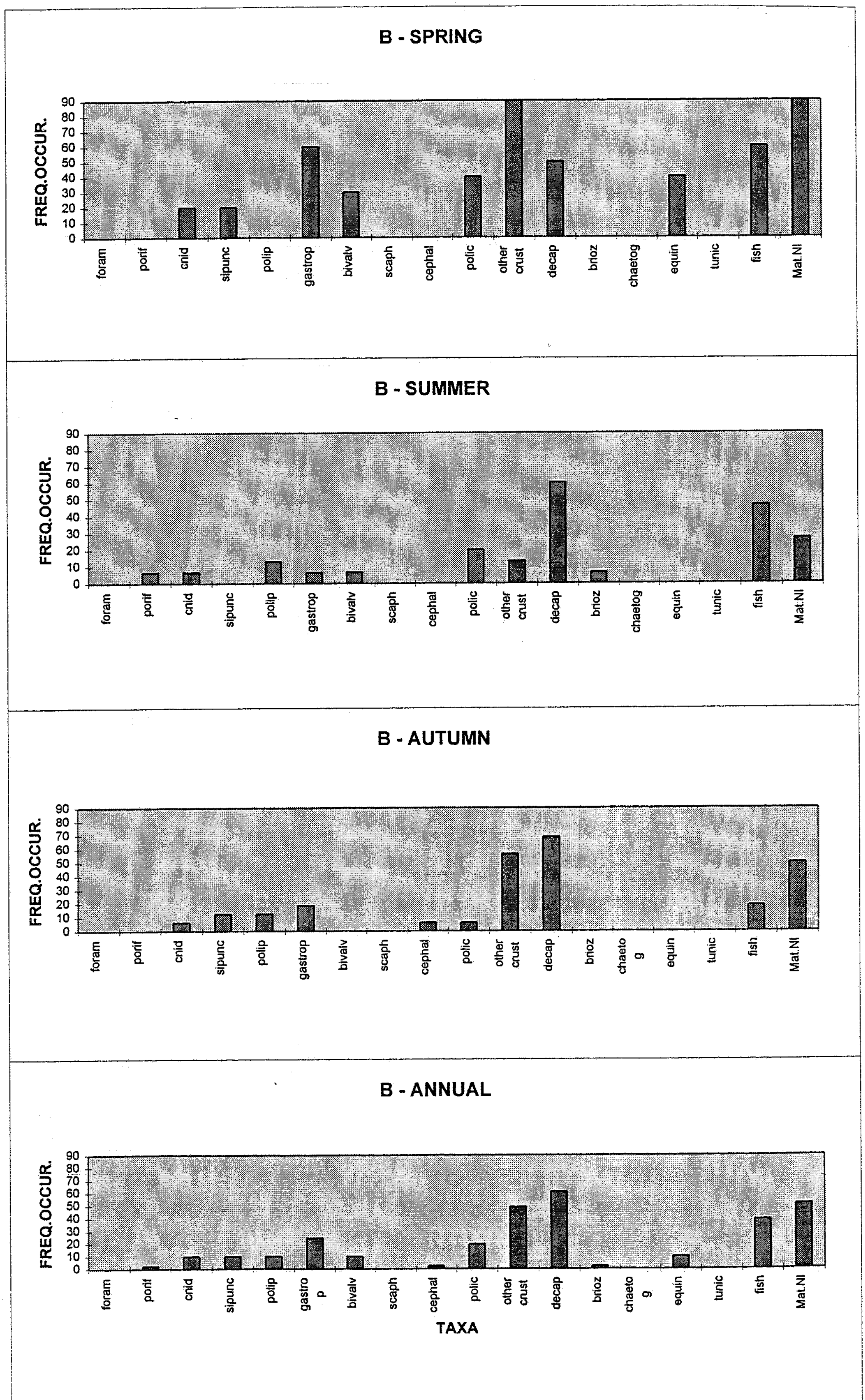

B - SPRING
FREQ.OCCUR.
0 10 20 30 40 50 60 70 80 90
foram porif cnid sipunc polip gastrop bivalv scaph cephal polic other crust decap brioz chaetog equin tunic fish Mat.NI
B - SUMMER
FREQ.OCCUR.
0 10 20 30 40 50 60 70 80 90
foram porif cnid sipunc polip gastrop bivalv scaph cephal polic other crust decap brioz chaetog equin tunic fish Mat.NI
B - AUTUMN
FREQ.OCCUR.
0 10 20 30 40 50 60 70 80 90
foram porif cnid sipunc polip gastrop bivalv scaph cephal polic other crust decap brioz chaetog equin tunic fish Mat.NI
B - ANNUAL
FREQ.OCCUR.
0 10 20 30 40 50 60 70 80 90
foram porif cnid sipunc polip gastrop bivalv scaph cephal polic other crust decap brioz chaetog equin tunic fish Mat.NI
TAXA

FIG.6.3

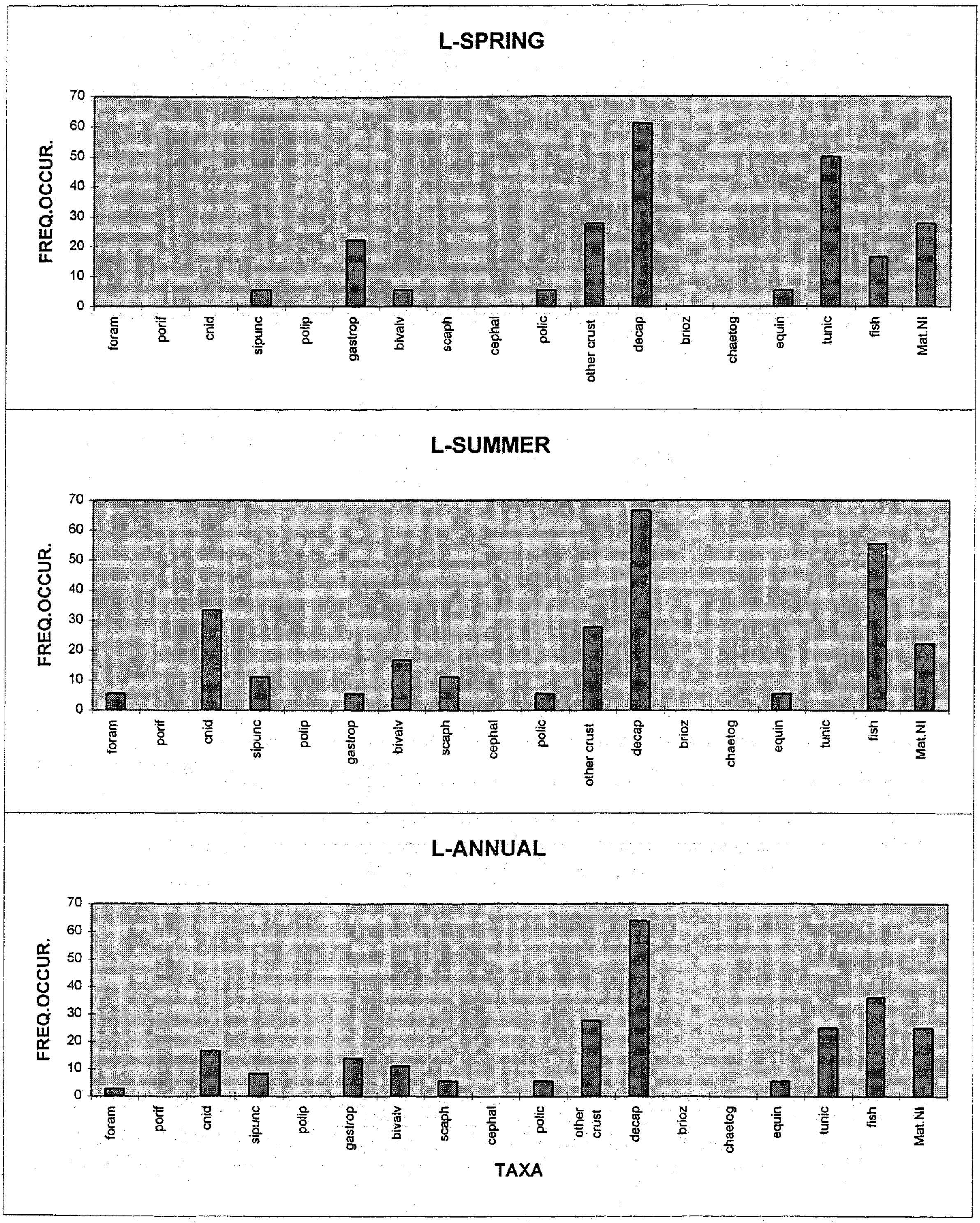

L-SPRING
FREQ.OCCUR.
70
60
50
40
30
20
10
0
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
L-SUMMER
FREQ.OCCUR.
70
60
50
40
30
20
10
0
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
L-ANNUAL
FREQ.OCCUR.
70
60
50
40
30
20
10
0
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

Fig. 6.4

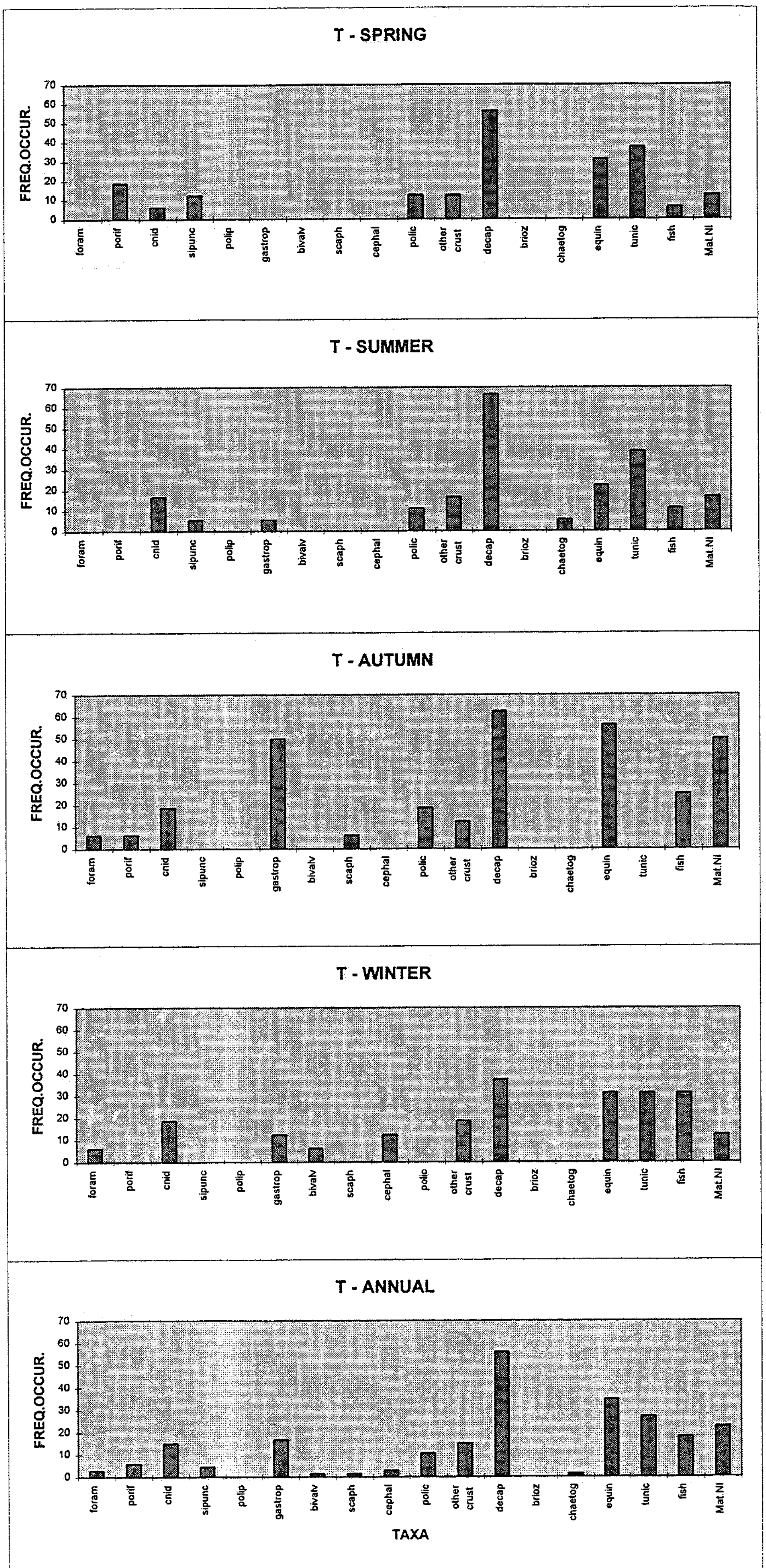
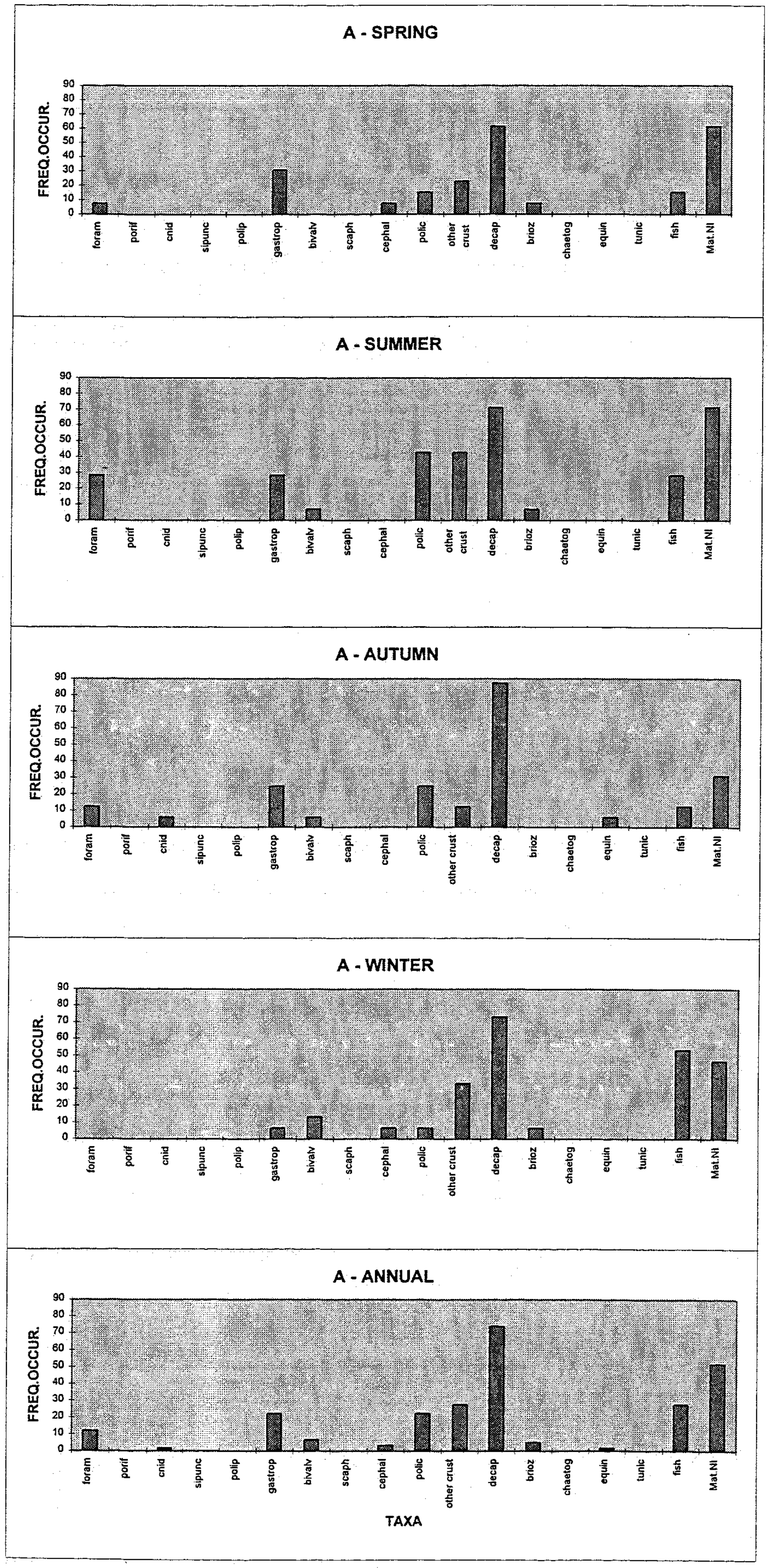

T - SPRING
T - SUMMER
T - AUTUMN
T - WINTER
T - ANNUAL
FREQ.OCCUR.
70
60
50
40
30
20
10
0
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

FIG. 6.5



A - SPRING
A - SUMMER
A - AUTUMN
A - WINTER
A - ANNUAL
FREQ.OCCUR.
0
10
20
30
40
50
60
70
80
90
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

FIG. 6.6

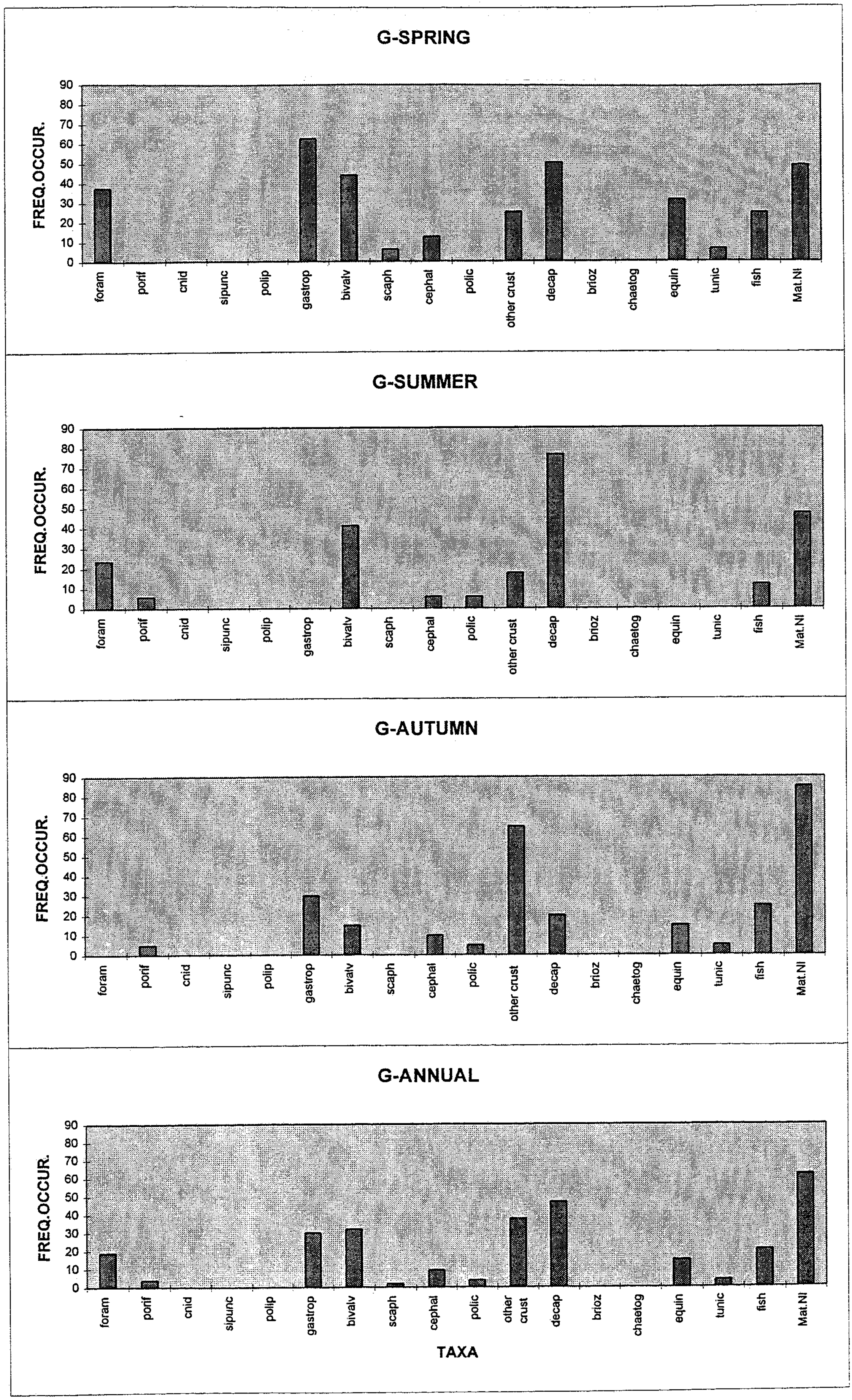

G-SPRING
G-SUMMER
G-AUTUMN
G-ANNUAL
FREQ.OCCUR.
90
80
70
60
50
40
30
20
10
0
foram
porif
cnid
sipunc
polip
gastrop
bivalv
scaph
cephal
polic
other crust
decap
brioz
chaetog
equin
tunic
fish
Mat.NI
TAXA

FIG 6.7

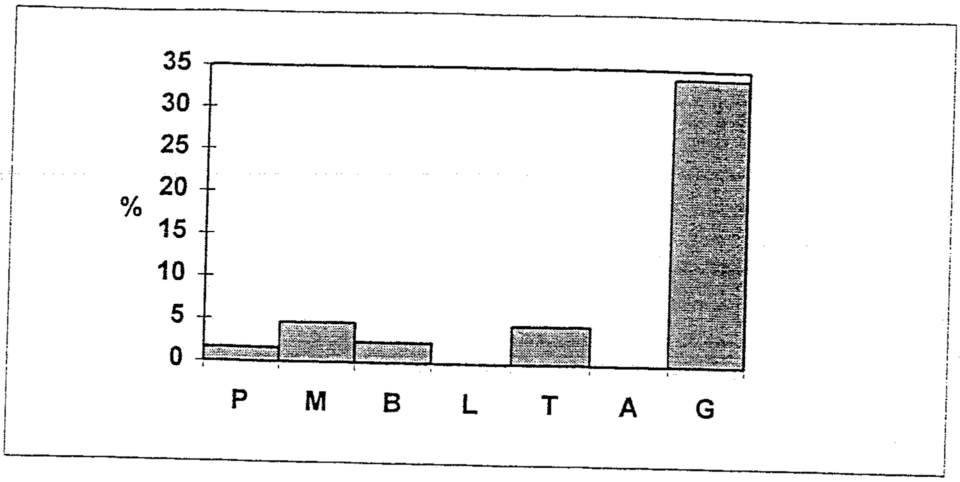


Fig. 6.8 - Percentage of occurrence of nylon threads

in stomach contents per site

Fig. 6.9 - PCA on the matrix of different prey groups per site and season; OTU's : projection over axis 1 and 2.

Fig. 6.10 - PCA on the matrix of different prey groups per site and season; OTU's: projection over axis 1 and 3.

Fig. 6.11 - PCA on the matrix of different prey groups per site and season; variables: projection over axis 1 and 2.

Fig. 6.12 - PCA on the matrix of different prey groups per site and season; variables: projection over axis 1 and 3.

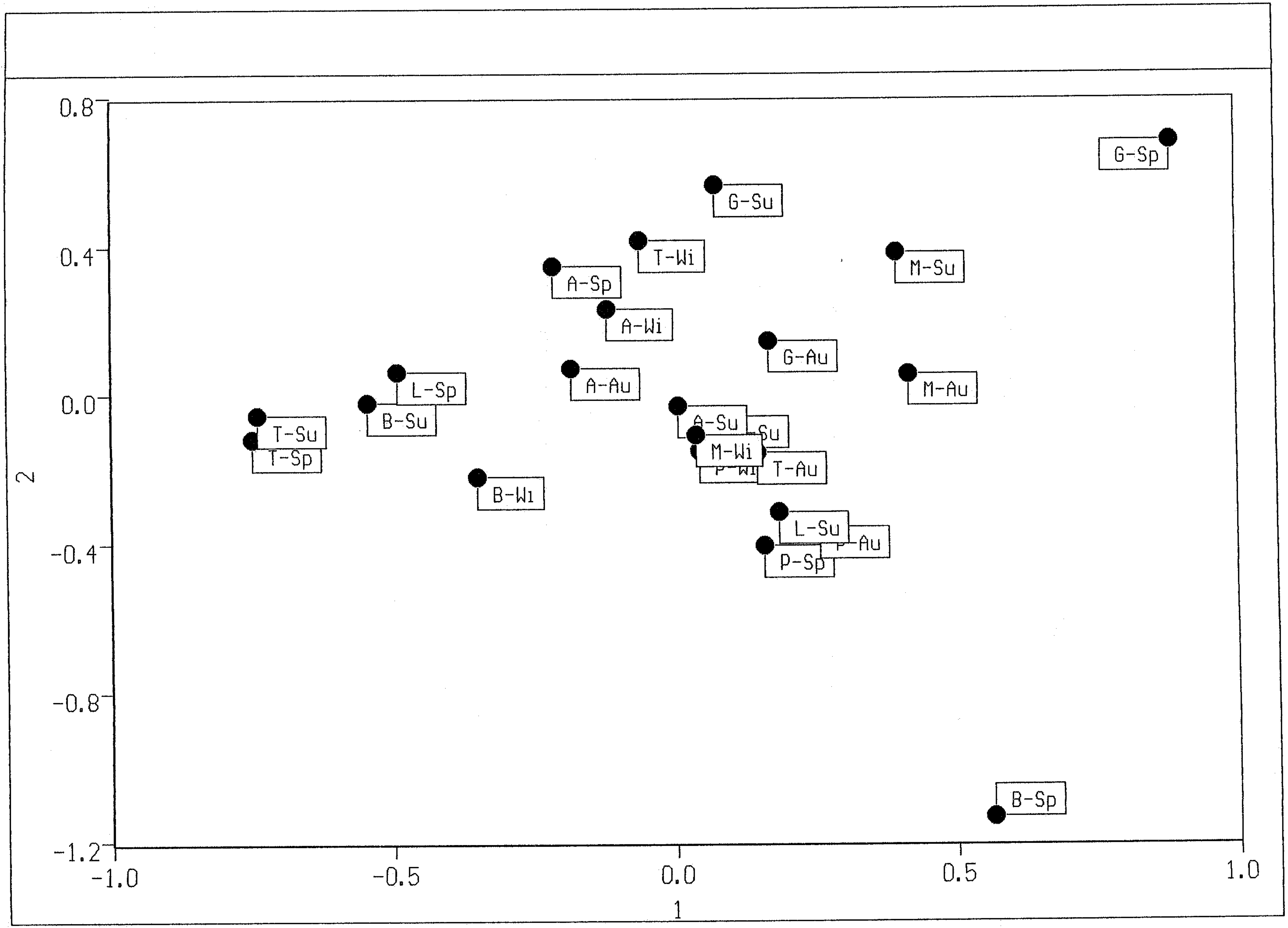
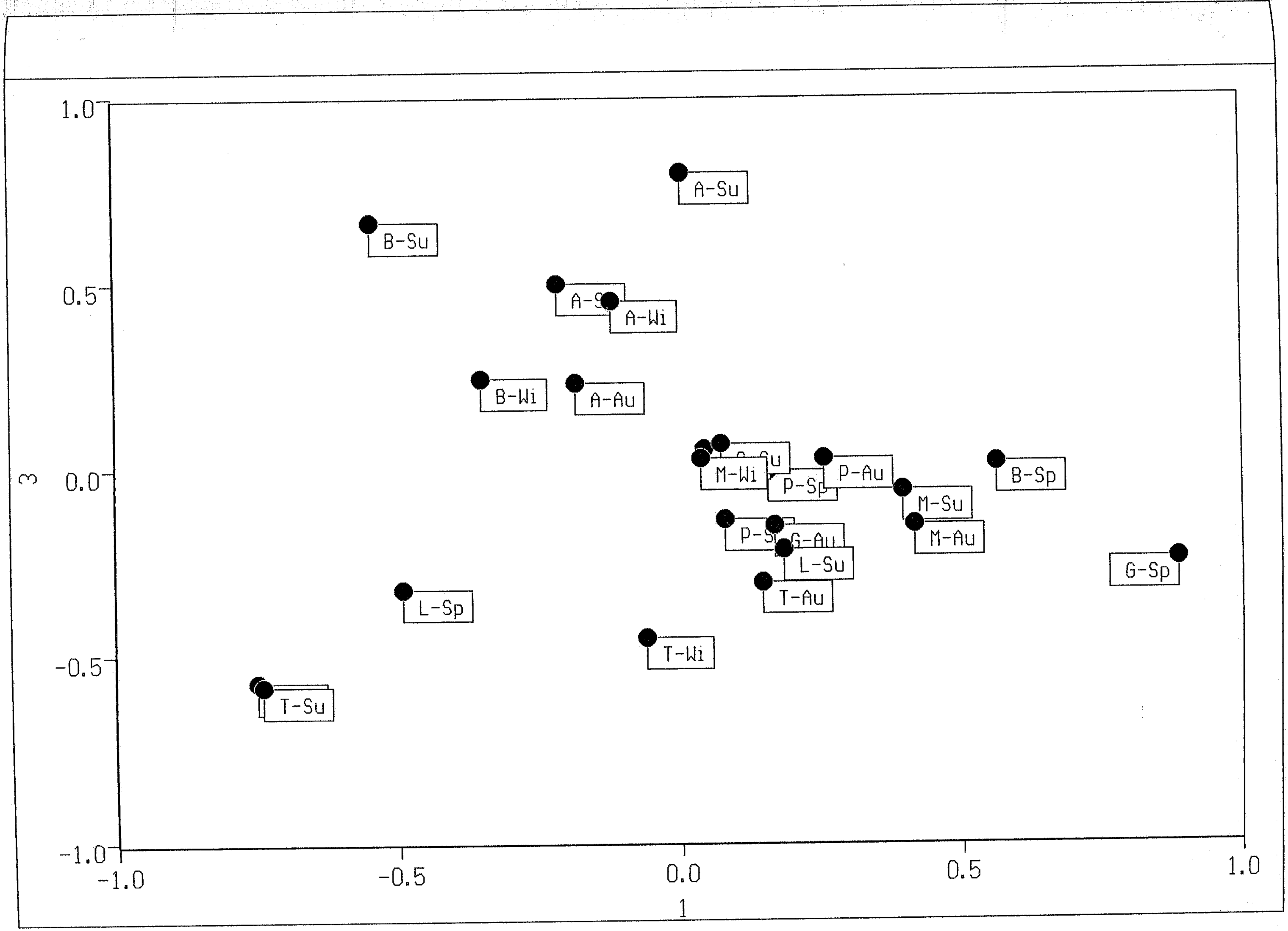
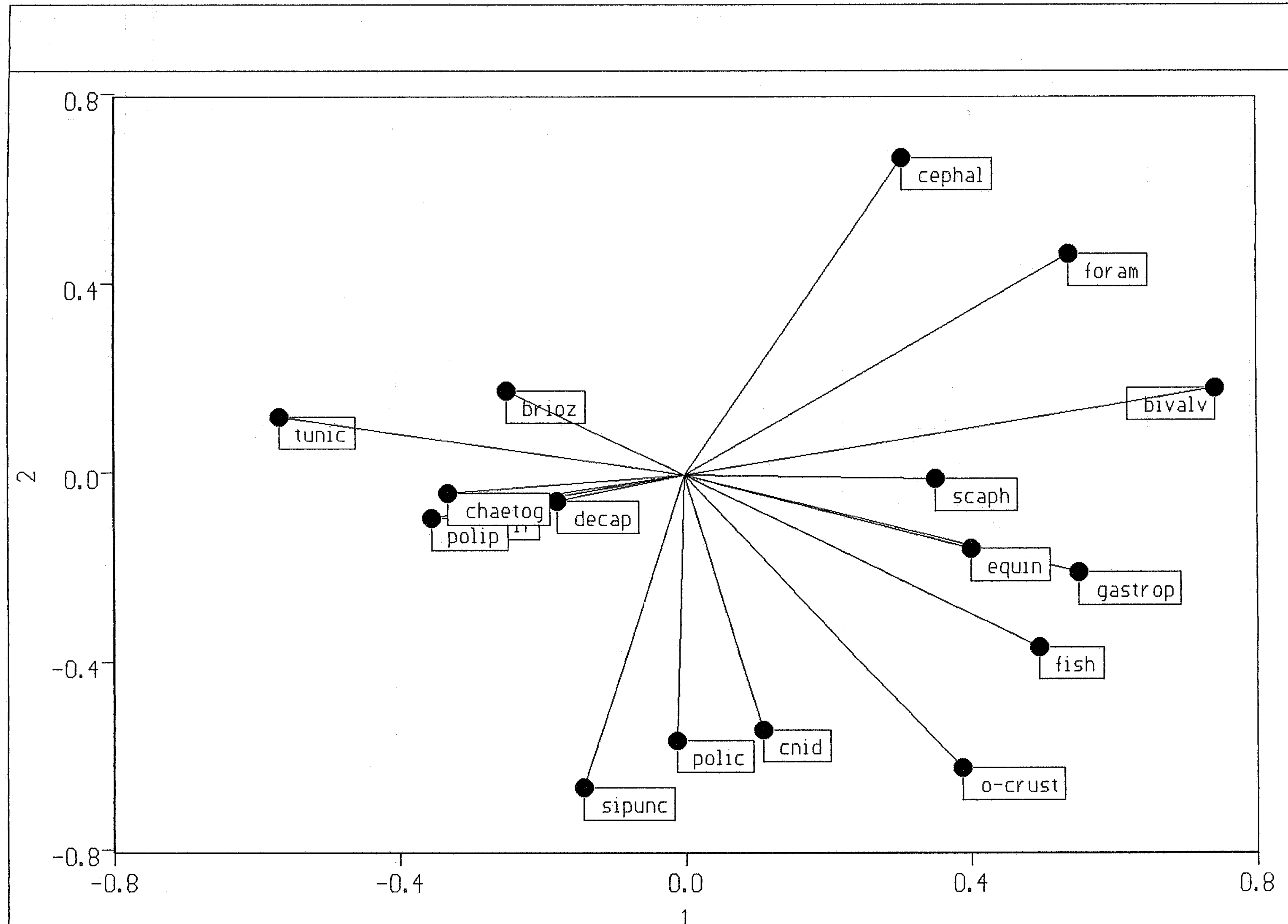

G-Sp
G-Su
T-Wi
M-Su
A-Sp
A-Wi
G-Au
M-Au
A-Au
L-Sp
B-Su
T-Su
T-Sp
A-Su
M-Wi
T-Au
B-Wi
L-Su
P-Sp
B-Sp
0.8
0.4
0.0
-0.4
-0.8
-1.2
-1.0
-0.5
0.0
0.5
1.0
1
2

FIG . 6.9



A-Su
B-Su
A-Wi
B-Wi
A-Au
M-Wi
P-Sp
P-Au
B-Sp
M-Su
M-Au
G-Au
L-Su
T-Au
G-Sp
L-Sp
T-Wi
T-Su
1.0
0.5
0.0
-0.5
-1.0
3
-1.0
-0.5
0.0
0.5
1.0
1

FIG. 6. 10



0.8
0.4
0.0
-0.4
-0.8
2
-0.8
-0.4
0.0
0.4
0.8
1
cephal
foram
bivalv
brioz
tunic
scaph
chaetog
decap
polip
equin
gastrop
fish
polic
cnid
o-crust
sipunc

FIG. 6.11

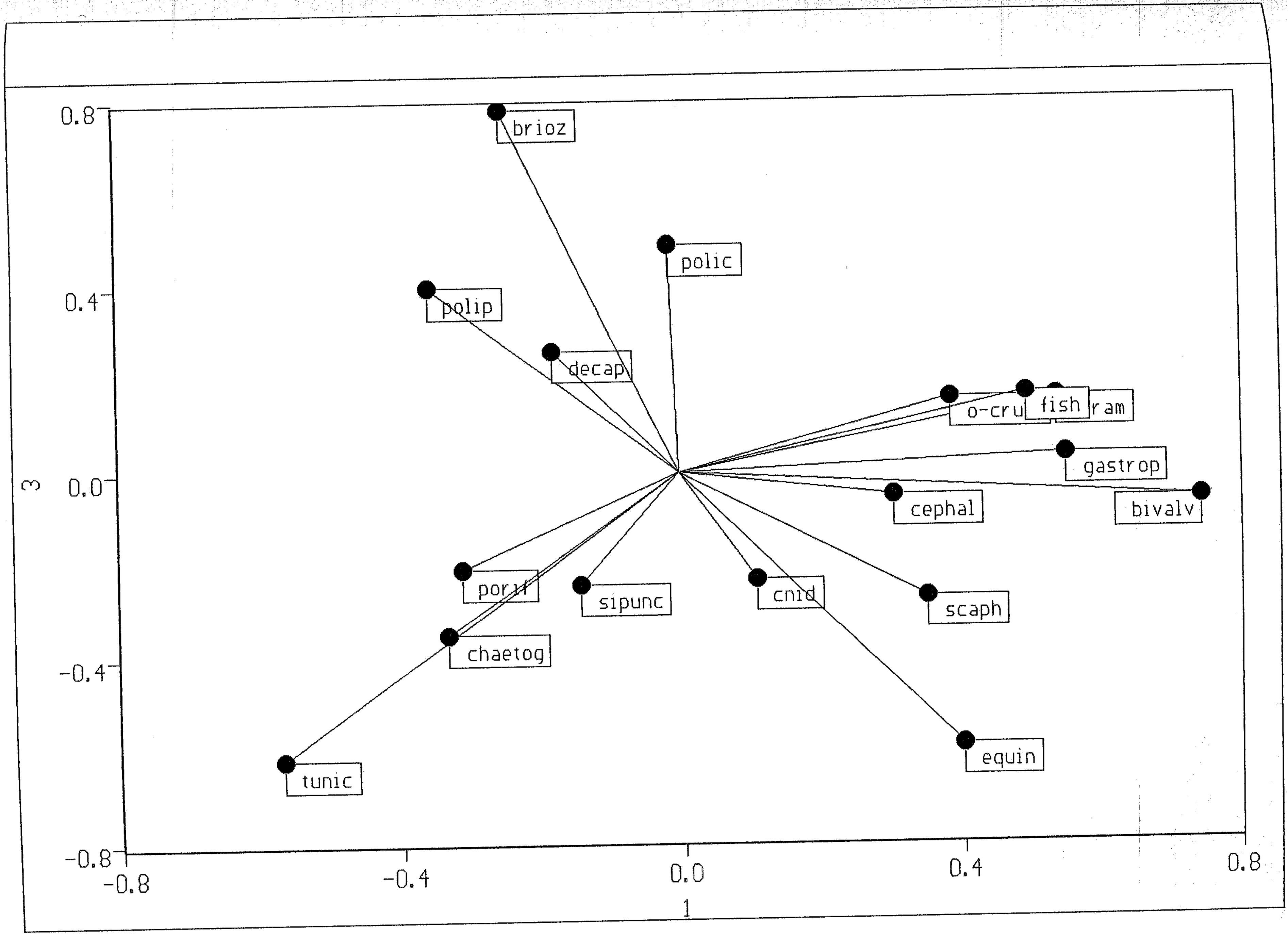

brioz
polic
polip
decap
o-cru
fish
r am
gastrop
cephal
bivalv
porif
sipunc
cnid
scaph
chaetog
equin
tunic
0.8
0.4
0.0
-0.4
-0.8
3
-0.8
-0.4
0.0
0.4
0.8
1

FIG. 6.12

Table 6.1 Frequency of occurrence (%) by site / season

		foram	porif	cnid	sipunc	polip	gastrop	bivalv	scaph	cephal	polic	o-crust	decap	brioz	chaetog	equin	tunic	fish	Mat.NI
P	SPRING	8,0	0,0	64,0	0,0	0,0	0,0	20,0	0,0	0,0	12,0	48,0	68,0	0,0	0,0	12,0	0,0	56,0	16,0
	SUMMER	16,7	0,0	23,3	0,0	0,0	13,3	6,7	3,3	3,3	13,3	40,0	63,3	0,0	3,3	20,0	0,0	46,7	33,3
	AUTUMN	8,0	8,0	24,0	0,0	0,0	56,0	16,0	0,0	0,0	20,0	52,0	56,0	0,0	0,0	20,0	0,0	44,0	24,0
	WINTER	2,5	0,0	12,5	2,5	0,0	12,5	5,0	0,0	2,5	12,5	37,5	40,0	0,0	0,0	7,5	0,0	65,0	22,5
	ANNUAL	8,3	1,7	28,3	0,8	0,0	19,2	10,8	0,8	1,7	14,2	43,3	55,0	0,0	0,8	14,2	0,0	54,2	24,2
M	SPRING																		
	SUMMER	18,2	0,0	0,0	0,0	0,0	9,1	27,3	0,0	9,1	9,1	18,2	36,4	0,0	0,0	27,3	0,0	63,6	45,5
	AUTUMN	8,3	0,0	0,0	0,0	0,0	16,7	41,7	0,0	0,0	0,0	33,3	91,7	0,0	0,0	58,3	0,0	58,3	25,0
	WINTER	20,0	10,0	10,0	5,0	0,0	25,0	5,0	0,0	0,0	10,0	25,0	70,0	0,0	0,0	15,0	0,0	65,0	25,0
	ANNUAL	16,3	4,7	4,7	2,3	0,0	18,6	20,9	0,0	2,3	7,0	25,6	67,4	0,0	0,0	30,2	0,0	62,8	30,2
B	SPRING	0,0	0,0	20,0	20,0	0,0	60,0	30,0	0,0	0,0	40,0	90,0	50,0	0,0	0,0	40,0	0,0	60,0	90,0
	SUMMER	0,0	6,7	6,7	0,0	13,3	6,7	6,7	0,0	0,0	20,0	13,3	60,0	6,7	0,0	0,0	0,0	46,7	26,7
	AUTUMN																		
	WINTER	0,0	0,0	6,3	12,5	12,5	18,8	0,0	0,0	6,3	6,3	56,3	68,8	0,0	0,0	0,0	0,0	18,8	50,0
	ANNUAL	0,0	2,4	9,8	9,8	9,8	24,4	9,8	0,0	2,4	19,5	48,8	61,0	2,4	0,0	9,8	0,0	39,0	51,2
L	SPRING	0,0	0,0	0,0	5,6	0,0	22,2	5,6	0,0	0,0	5,6	27,8	61,1	0,0	0,0	5,6	50,0	16,7	27,8
	SUMMER	5,6	0,0	33,3	11,1	0,0	5,6	16,7	11,1	0,0	5,6	27,8	66,7	0,0	0,0	5,6	0,0	55,6	22,2
	AUTUMN																		
	WINTER																		
	ANNUAL	2,8	0,0	16,7	8,3	0,0	13,9	11,1	5,6	0,0	5,6	27,8	63,9	0,0	0,0	5,6	25,0	36,1	25,0
T	SPRING	0,0	18,8	6,3	12,5	0,0	0,0	0,0	0,0	0,0	12,5	12,5	56,3	0,0	0,0	31,3	37,5	6,3	12,5
	SUMMER	0,0	0,0	16,7	5,6	0,0	5,6	0,0	0,0	0,0	11,1	16,7	66,7	0,0	5,6	22,2	38,9	11,1	16,7
	AUTUMN	6,3	6,3	18,8	0,0	0,0	50,0	0,0	6,3	0,0	18,8	12,5	62,5	0,0	0,0	56,3	0,0	25,0	50,0
	WINTER	6,3	0,0	18,8	0,0	0,0	12,5	6,3	0,0	12,5	0,0	18,8	37,5	0,0	0,0	31,3	31,3	31,3	12,5
	ANNUAL	3,0	6,1	15,2	4,5	0,0	16,7	1,5	1,5	3,0	10,6	15,2	56,1	0,0	1,5	34,8	27,3	18,2	22,7
A	SUMMER	28,6	0,0	0,0	0,0	0,0	28,6	7,1	0,0	0,0	42,9	42,9	71,4	7,1	0,0	0,0	0,0	28,6	71,4
	AUTUMN	12,5	0,0	6,3	0,0	0,0	25,0	6,3	0,0	0,0	25,0	12,5	87,5	0,0	0,0	6,3	0,0	12,5	31,3
	WINTER	0,0	0,0	0,0	0,0	0,0	6,7	13,3	0,0	6,7	6,7	33,3	73,3	6,7	0,0	0,0	0,0	53,3	46,7
	ANNUAL	12,1	0,0	1,7	0,0	0,0	22,4	6,9	0,0	3,4	22,4	27,6	74,1	5,2	0,0	1,7	0,0	27,6	51,7
G	SPRING	37,5	0,0	0,0	0,0	0,0	62,5	43,8	6,3	12,5	0,0	25,0	50,0	0,0	0,0	31,3	6,3	25,0	50,0
	SUMMER	23,5	5,9	0,0	0,0	0,0	0,0	41,2	0,0	5,9	5,9	17,6	76,5	0,0	0,0	0,0	0,0	11,8	47,1
	AUTUMN	0,0	5,0	0,0	0,0	0,0	30,0	15,0	0,0	10,0	5,0	65,0	20,0	0,0	0,0	15,0	5,0	25,0	85,0
	WINTER																		
	ANNUAL	18,9	3,8	0,0	0,0	0,0	30,2	32,1	1,9	9,4	3,8	37,7	47,2	0,0	0,0	15,1	3,8	20,8	62,3

Table 6.2: Principal Component Analysis; Vector matrix

VARIABLE	PRINCIPAL COMPONENTS		
	1ª	2ª	3ª
Foraminifera - FORAM	0.538	0.470	0.159
Porifera - PORIF	-0.311	-0.069	-0.203
Cnidaria - CNID	0.109	-0.542	-0.229
Sipuncula - SIPUNC	-0.142	-0.665	-0.238
Polyplacophora - POLIP	-0.355	-0.092	0.406
Gastropoda - GASTROP	0.551	-0.206	0.034
Bivalvia - BIVALV	0.743	0.186	-0.061
Scaphopoda - SCAPH	0.351	-0.008	-0.269
Cephalopoda - CEPHAL	0.305	0.673	-0.053
Polichaeta - POLICH	-0.012	-0.564	0.493
Crustac. not Decap.- CRUST-O	0.388	-0.623	0.158
Decapoda - DECAP	-0.179	-0.056	0.268
Bryozoa - BRYOZ	-0.249	0.179	0.784
Chaetognatha - CHAET	-0.332	-0.039	-0.346
Echinodermata - ECHINO	0.400	-0.156	-0.591
Tunicata - TUNIC	-0.569	0.124	-0.616
FISH	0.495	-0.363	0.167
EIGENVALUES	2.703	2.416	2.252
PROPORTION	15.90	14.21	13.25
CUMULATIVE PROPORTION	15.90	30.11	43.36

Assessment of the spatial structure and biomass evaluation by Geostatistics

INTRODUCTION

Norway lobster (Nephrops norvegicus) is the most important species in the European crustacean fishery (in terms of catch and economically, FAO, 1992). The biology of the species is now well known and a summary can be found in Sardà (1995). Fisheries data are continuously evaluated by the ICES Nephrops Working Group (Anon., 1992). Uncertainties on growth and mortality coefficients of Nephrops norvegicus generate difficulties for assessing stocks from data on landings and cohort analysis (see Sardà and Lleonart, 1993 for an application). Alternative methods, such as direct assessments, have been recommended (Conan, 1985; Anon., 1989).

Norway lobster populations show highly complex aggregated patterns of spatial distribution. Fishermen and researchers indicate that sex-ratio, size composition, presence of berried females and overall abundance of the catch may vary between localities in close proximity, as well as seasonally (Sardà, 1991).

Nephrops is found between 100 and 700 m depth on the Catalan Sea slope off Ebro Delta (Spain, NW Mediterranean), which is deeper than for Bay of Biscay and higher latitude NE Atlantic stocks, but published information on the depth and geographic distribution of the species in the area surveyed is still limited (Sardà 1991, Sardà and Abelló, 1984).

It is important for the purpose of stock conservation and profit optimization, to map and accurately forecast the location and the spatial characteristics of the resource (Conan, 1985). Only a portion of the stock can be harvested with profit: at locations and times at which the density of commercial quality Norway lobster is too low, harvesting costs may be higher than the value of the catch. It may be also worthwhile to protect certain fishing areas by setting annual or seasonal closures to protect certain biological categories, such as berried females or immature individuals.

The presence of spatial patterns has not, until recently, been taken into account for calculating biomasses and setting confidence limits on these estimates, other than by using stratified random sampling. Conan (1985), Conan *et al.* (1988a, 1988b, 1992) and Conan and Wade (1989) have introduced techniques derived from the geostatistical methodology, initially developed in Mining Geology (Matheron, 1971; Journel and Huijbregts, 1978), which are at present routinely employed for the assessment and management of snow crab stocks in the Gulf of St Lawrence (Canada) and which are gaining interest in other species and areas (Simard *et al.*, 1992; Petitgas, 1993; Fariña *et al.*, 1994).

In order to map and assess the harvestable biomass of Norway lobster on the fishing grounds, experimental trawl surveys and spatial statistics (Geostatistics) were employed to optimize the evaluation of this spatially structured resource. We investigated the applicability of the statistical methodology to directly assess Nephrops stocks on commercial fishing grounds located off Tarragona, Spain (NW Mediterranean) based on data from a experimental cruise (GEODELTA) carried out during the spring of 1994. The sampling scheme was specifically designed for the geostatistical application. The technology available (Global Positioning System and an acoustic measuring device for the trawl, SCANMAR) allowed for highly accurate positioning and measuring of the area swept by trawl.

The application of geostatistics for mapping and estimating marine benthic harvestable resources is also reviewed and analysed. The need to adapt existing geostatistical models to actual case-studies (species) is stressed and a critical study of their use and scope is presented, together with an application of the methodology to the commercial fishery of Nephrops norvegicus in the NW Mediterranean area.

MATERIAL AND METHODS

The sampling routine

The GEODELTA survey (6 to 16 May 1994) was specifically designed for the mapping and assessment of harvestable Nephrops resources off NE Spain. The sampling area is shown in fig. 1, covering 939.5 km^2. A total of 72 trawl stations were sampled.

The experimental fishing gear was a specially designed otter trawl ("Maireta System", Sardà *et al.*, 1994) drawn by a single warp, to reach up to 2 000 m depth. The cod-end stretched mesh was 12 mm in order to retain small individuals, not normally available to the commercial fishing gear.

The actual opening of the trawl was measured using a SCANMAR acoustic system and stabilized at 14.0 m width by 2.0 m height. During the survey, tows were made parallel to the depth contours. The duration of each tow varied between 15 and 30 min (time of effective trawling). The towing speed varied between 2.3-2.6 knots (mean 2.5 knots). Start and end locations for each tow were measured by GPS. The actual surface covered by each tow was computed from the GPS and SCANMAR readings.

The total catch of Nephrops was counted, weighed and measured and the presence of berried females was noted. The catch was sorted into biological categories for each tow: juvenile males, juvenile females, adult males, adult females and berried females. A carapace length (CL) of 26 mm was used as a knife-edge approximation to first presence of gonadal maturity for segregating juvenile from adult individuals, 32 mm (CL) size at 50% maturity to determine the percentage of ovigerous females (Sardà, 1991).

Geostatistical methods

Basic to the linear geostatistical methodology is the assumption of second order stationarity, analogous to the same concept in time series analysis. Let the density of Norway lobster be a spatially referenced variable, $Z(\mathbf{x})$, where $\mathbf{x}$ is the position of a sampling point in R^n, n=2 for our purposes, then

Z(**x**) is called a *regionalized variable* (Matheron, 1971) if the value taken by Z at **x** only depends on its geographical position.

Under the second order stationary hypothesis, the mathematical expectation of the first moment (mean) of Z(**x**) is assumed to be constant over the field of study, as well as the variance. This strong stationarity hypothesis can be relaxed to the intrinsic hypothesis (Matheron, 1971) by the use of the semivariogram. The intrinsic hypothesis requires only that the mean and variance of the increments Z(**x**)-Z(**x**+**h**) be constant over the field but not Z(**x**) itself, which is more realistic when dealing with fisheries data.

The experimental semivariogram, which is a form of computing the variance of a population taking into account the spatial position of the samples, is employed as a descriptor of the spatial structure of the density of Norway lobster. The experimental semivariogram is given by (Matheron 1971):

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{N(h)} (Z(x_i) - Z(x_j))^2$$

where N(h) is the number of pairs used to compute the experimental semivariogram at distance h, is a vector of distances ± tolerance, $Z(x_i)$ is the density of Nephrops at location x_i and $Z(x_j)$ is the density of Nephrops at locations x_j within a distance h ± tolerance of location x_i. The spatial structure of the Z(**x**) of interest is represented by a plot of $\hat{\gamma}(h)$ vs h from which the parameters that summarize the structure of spatial dependence can be obtained.

Most semivariograms show a regular increase of $\hat{\gamma}(h)$ with h up to a certain distance *a* (range of the semivariogram) where $\hat{\gamma}(h)$ stabilizes around $c'+c_0$ (sill of the semivariogram). The range of the semivariogram can be interpreted as the distance beyond which no effects of spatial covariance among samples exists. In the absence of spatial autocorrelation, the mathematical expectation of the semivariogram is the sample variance and the variogram appears flat (pure nugget effect).

Many experimental semivariograms show a discontinuity at the origin, c_0, called the *nugget* component of the variance, which represents the microscale variability of Z(**x**) at distances shorter than the smallest distance among samples. It may include also sampling error or white noise. The variability introduced by the nugget effect can considerably increase the variance of the kriging estimates, thus a correct modeling of c_0 and a careful design of the sampling plan are central to geostatistics in order to produce precise estimates.

In mining geostatistics the proportional effect has been described (David, 1977; Isaaks and Srivastava, 1989) and modeled by a relative semivariogram, which re-scales the local semivariance by the local mean:

$$\hat{\gamma}_R(h) = \frac{\hat{\gamma}(h)}{m(h)^2}$$

We used experimental semivariograms (Matheron, 1971), relative experimental semivariograms (Isaaks and Srivastava, 1989) and their theoretical equivalent (Cressie, 1991), experimental semivariograms on log-transformed data, to describe the spatial autocorrelation structure of Nephrops densities in the area surveyed, for the biological categories established and for the two surveys.

For the purpose of mapping the resource we employed the spatial estimation technique known as point kriging (Matheron, 1971) within the boundaries defined by the presence of samples. In order to implement the kriging technique, the experimental semivariograms need to be fitted to a theoretical model. Models which comply with certain mathematical conditions (Matheron, 1971) and suitable for kriging are well described in the literature (Journel and Huijbregts, 1978; Cressie, 1991).

To produce precise maps of the density of Nephrops in the study area we used biological information and catch data to restrict the area by means of an irregular polygon bounded by the 100 and 600 m depth contours and by adjacent submarine canyons. We estimated the density at the nodes (Z*) of a 276 x 249 regular grid (internodal distance 1/6 km) within the boundaries of the polygon using the linear estimator (Matheron, 1971):

$$Z^* = \sum_{i=1}^{n} w_i Z(\mathbf{x}_i)$$

Where the $Z(\mathbf{x}_i)$ are the observed densities and w_i are weights obtained by the solution of the kriging system of equations using the fitted semivariogram. The kriging variance (σ^2_k) obtained when solving the kriging system was used as a precision index to help establish the area within which reliable global estimates could be produced. When kriging with relative semivariograms, as will be the case here, the kriging variance needs to be re-scaled by the local mean in order to obtain a variance which is at the same scale than the data (Conan *et al.*, 1992).

Block kriging (Matheron, 1971) was used to produce global estimates of average density and total (available to the fishing gear) biomass over the surveyed area and to give confidence intervals for the biomass estimates. The global estimate of the quantity Z_V over the (irregular) polygon V for point samples defined on v is:

$$Z_V = \frac{1}{V}\int_V Z(\mathbf{x})\,dx$$

Its estimation variance (σ^2_e)is given by:

$$\sigma_e^2 = 2\bar{\gamma}(V,v) - \bar{\gamma}(V,V) - \bar{\gamma}(v,v)$$

Where $\bar{\gamma}(\bullet,\bullet)$ is the average of the fitted semivariogram over the areas or volumes in parentheses.

Computing average semivariograms on two dimensions requires the computation of double integrals (see Journel and Huijbregts, 1978, for details). The computation of the average semivariogram can be achieved analytically only when the polygon V is a simple geometric shape and must be appoximated by numerical integration in the general case (Journel and Huijbregts, 1978). A numerical approximation was developed to integrate the semivariogram over an irregular contour and to obtain estimates of the mean and global densities and their associated confidence intervals on the area sampled. For ease of comparison of the global estimates and their standard deviations produced by kriging, global estimates and standard deviation of the mean were also produced by the swept area method (Cochran, 1977; Sparre *et al.*, 1989).

RESULTS

Biological assessment of the data showed that the populations under study have similar biological characteristics to other Mediterranean and Atlantic populations. Depth distribution of the species in the area ranged between 103 and 114 m on the shelf 216 and 584 m on the slope, with peak abundance at about 400-450 m depth (fig. 2a).

An exploratory data analysis was conducted in order to check for inconsistencies with the assumptions of the geostatistical model: dispersion diagrams of Nephrops density vs depth did not show any obvious depth-related trend (fig. 2a). The catch was not related to the time of day (fig. 2b) and no geographical trend was observed in Nephrops density (figs. 2c and 2d) in a northern or eastern direction. Hence, the basic assumptions of the linear geostatistical method were not invalidated.

For the spring cruise, experimental semivariograms computed for Nephrops categories are shown in fig. 3. Relative semivariograms described the structure of spatial dependence better than traditional (Matheron's) semivariograms. Relative semivariograms for all categories were fitted to a spherical model (model and parameters shown in fig. 3) yielding a range of 6.1 to 6.9 km. This was consitent for all the biological categories in which Nephrops catch was subdivided and closely fits the value of 7 km obtained for *Nephrops* in the Catalan Sea in a previous study (Conan *et al.*, 1992).

The variance unexplained by the spatial model (c_0) to total variance (c_0+c') ratio was 40.8% in juvenile males and 40.1% in juvenile females, while it was much lower for adults (13.4% in adult males and 21.9% in adult females). This results suggests a higher degree of spatial structuration in adults than in juveniles. Presence of anisotropy (differential spatial continuity in a given geographical direction) could not be demonstrated for any biological category or season (see also Conan *et al.*, 1992). Hence, in the absence of anisotropy, the spatial structure of Nephrops populations in the NW Mediterranean can be regarded as high-density patches ~ 7 km in diameter.

Density maps were generated by point kriging for all categories and both cruises. The locations of high-density patches extensively overlapped for all biological categories and only total number is shown in fig. 4, along with the precision index of the estimate.

Global biomass and average density were computed by block kriging within the polygon over which Norway lobster density was mapped. Table 1 shows the mean density, the global estimate and their kriging standard deviations. For comparison, table 1 includes also mean density, global estimates and standard deviation of the mean computed by the swept area method. Estimates produced by the kriging technique had lower standard deviations and hence were more precise.

DISCUSSION

One of the aims of fisheries biology is the study of spatial and temporal distribution patterns in relation to abundance. Within the ICES Working Group on Nephrops, studies in this direction have been recomended (Anon., 1992). The geostatistical model built here has been shown to be a useful step on that direction, as it directly revealed the spatial structure of Nephrops populations at a finer resolution than in the past.

High-resolution mapping may be worthwhile in order to optimize profit and to forecast accurately the location and the spatial charactersitics of the resource (Conan, 1985). Also, density maps are useful for assessing the economical potential of the catch as well as for fisheries management.

Nephrops norvegicus is a benthic species of low mobility at the scale of study, due in part to its burrowing behaviour (Chapman, 1980). This makes the application of linear geostatistics ideal to this species, as well as to other crustaceans and molluscs which can be considered sessile at the spatial and temporal scales of study.

The applicability of geostatistical techniques was enhanced by the availability of accurate technology (GPS, SCANMAR) and a careful design of the sampling scheme. A preliminary data analysis was necessary to check the validity of the geostatistical technique and to build a spatial model for our data sets.

Average abundances obtained in this study (Table 1) were similar to those found by authors working in the same area (Sardà and Abelló, 1984; Sardà and Lleonart, 1993) and slightly lower than those reported for the Atlantic (Briggs, 1987; Hillis and Geary, 1990; Fariña *et al.*, 1994). Population biology characteristics (seasonal variations in abundance and sex-ratio) of Catalan Sea Nephrops populations show no marked differences with other areas (Sardà, 1995).

The geostatistical analysis of the harvestable fraction of the Nephrops populations over the slope off Tarragona showed that these populations were spatially structured in pacthes about 7 km in diameter. It also showed that the spatial dependence effects remained stable within biological categories (cf. Conan *et al.*, 1988a for snow crab in the Gulf of Saint Lawrence (Canada) where an important spatial segregation by size and sex was demonstrated). Analysis of Nephrops stocks in NW Spain Atlantic waters (Fariña *et al.*, 1994) at larger spatial scales revealed a spatial structure in larger (around 100 km) patches, but our results are not directly comparable to theirs due to the fact that the distance among stations in Fariña *et al.* (1994) was larger than the range obtained here.

In summary, a pattern of spatial structuration of NW Mediterranean lobster populations has been shown. This spatial pattern remained fairly stable between spring and fall. Further research is needed in order to ascertain the underlying causes of spatial patterning in Nephrops norvegicus, although sedimentological factors certainly require attention. It would be also interesting to further investigate the generality of this pattern to Atlantic Nephrops fishing grounds, by means of appropriate experimental surveys and the geostatistical methodology laid out in this work.

REFERENCES

ANONYMOUS. 1989. Report of the Worshop on Spatial Statistics Techniques. *ICES CM* 1989/K:38, 42 pp.

ANONYMOUS. 1992. Working Group on Nephrops and Pandalus Stocks. *ICES CM 1992/Assess:8*, 275 pp.

BRIGGS, R.P. 1987. A review of the factors influencing landing size in the Northern Ireland Nephrops fishery. *ICES CM* 1987/K:34, 24 pp.

CHAPMAN, C.J. 1980. Ecology of juvenile and adult Nephrops. *In*: The biology and management of lobsters, pp. 143-178. *Ed. by J.S. Cobb and B.F. Phillips. Academic Press, NY.*

CONAN, G.Y. 1985. Assessment of shellfish stocks by geostatistical techniques. *ICES CM* 1985/K:30, 24 pp.

CONAN, G.Y. AND WADE, E. 1989. Geostatistical analysis, mapping and global estimation of harvestable resources in a fishery of the northern shrimp (Pandalus borealis). ICES CM 1989/D:1, 29 pp.

CONAN, G.Y., MAYNOU, F. AND SARDÀ, F. 1992. Direct assessment of the harvestable biomass from a stock of Nephrops norvegicus, seasonal and spatial variations. *ICES CM* 1992/K:22, 24 pp.

CONAN, G.Y., MORIYASU, M., WADE, E. AND COMEAU, M. 1988a. Abundance and spatial distribution surveys of snow crab stocks by geostatistics. ICES CM 1988/K: 10, 23 pp.

CONAN, G.Y., BUERKLE, E., WADE, E., CHADWICK, M. AND COMEAU, M. 1988b. Geostatistical analysis of spatial distribution in a school of herring. ICES CM 1988/D:25, 18 p.

CRESSIE, N. 1991. Statistics for spatial data. Wiley Interscience, NY. 900 pp.

DAVID, M. 1977. Geostatistical ore reserve estimation. Elsevier, Amsterdam. 364 pp.

FAO, 1992. FAO Yearbook 1990. Fishery Statistics. Vol. 70. Rome.

FARIÑA, A.C., FREIRE, J., GONZÁLEZ-GURRIARÁN, E. 1994. Nephrops norvegcius in the Galician continental shelf (NW Spain): abundance and distribution. *Fisheries Research*, 19: 333-347

HILLIS, J.P. AND GEARY, M. 1990. The Irish fishery for Nephrops on the Porcupine Bank. *ICES CM* 1990/K:22, 15 pp.

ISAAKS, E.H. AND SRIVASTAVA, M.R. 1989. Applied geostatistics. *Oxford University Press, NY.* 561 pp.

JOURNEL, A. AND HUIJBREGTS, CH. 1978. Mining geostatistics. *Academic Press, London.*

MATHERON, G. 1971. The theory of regionalized variables and its applications. *Les Cahiers du Centre de Morphologie Mathématique, fasc. 5. Ecole Nationale Supérieure de Mines de Paris, Paris.*

PETITGAS, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. *ICES Journal of marine Science.* 50: 285-298.

SARDÀ, F. 1991. Reproduction and moult synchronism in Nephrops norvegicus (L.)(Decapoda, Nephropidae) in the Western Mediterranean: Is spawning annual or biennial ?. *Crustaceana,* 60(2): 186-199.

SARDÀ, F. 1995. A review (1967-1990) of some aspects of the life history of Nephrops norvegicus. *ICES marine Science Symposium,* 199:78-88.

SARDÀ, F. AND ABELLÓ. P. 1984. Distribución y abundancia de Nephrops norvegicus (L.) en el mar Catalán. Seguimiento de una población. *Actas do IV° simpósio Ibérico de Estudos do Benthos Marinho. Lisboa.* III, 235-243.

SARDÀ, F., LLEONART, J. 1993. Evaluation of the Norway lobster (Nephrops norvegcius, L.) resource off the "Serola" bank off Barcelona (western Mediterranean). *Scientia Marina,* 57 (2-3):191-197.

SARDÀ, F., CARTES, J.E., NORBIS, W. 1994. Spatio-temporal structure of the deep-sea shrimp Aristeus antennatus (Decapoda: Aristeidae) population in the western Mediterranean. *Fishery Bulletin,* 92: 599-607.

SIMARD, Y., LEGENDRE, P., LAVOIE, G. AND MARCOTTE, D. 1992. Mapping, estimating biomass, and optimizing sampling programs for spatially autocorrelated data: case study of the northern shrimp (Pandalus borealis). *Canadian Journal of Fisheries and Aquatuc Science.* 49(1):32-45.

SPARRE, P., URSIN, E. AND VENEMA, S.C. 1989. Introduction to tropical fish stock assessment. Part 1-Manual. FAO *Fisheries technical papers.* 306/1: 1-337.

Table 1. Global kriging and swept area computations of mean and global abundances for Norway lobster categories, along with their standard deviations.

Key: Z(B) is the mean density computed by global kriging, σ_K its standard deviation; $Z_G(B)$ is the total abundance computed by global kriging, σ_{KG} its standard deviation; X_a is the mean density computed by the area swept method, s_a is the standard error of the mean; and X_G is the total abundance computed by the area swept method, s_G is its standard error.

Z(B) and X_a in ind./km^2, except for weight, in kg/km^2. $Z_G(B)$ and X_G in individuals, except for weight, in kg.

	Global kriging				Swept area			
	Z(B)	σ_K	$Z_G(B)$	σ_{KG}	X_a	s_a	X_G	s_G
GEODELTA								
Juvenile males	26.80	9.26	35,672.1	12,320.8	30.04	73.58	28,242.1	69,162.0
Juvenile females	33.74	10.76	44,948.2	14,324.3	40.11	89.53	37,700.1	84,154.8
Adult males	63.67	18.09	84,737.9	24,070.1	77.75	150.55	73,079.9	141,513.0
Adult females	76.10	22.06	101,271.0	29,363.4	94.45	178.95	88,781.1	168,216.1
Number	197.56	51.99	262,915.7	69,192.1	242.40	454.18	227,854.4	426,925.0

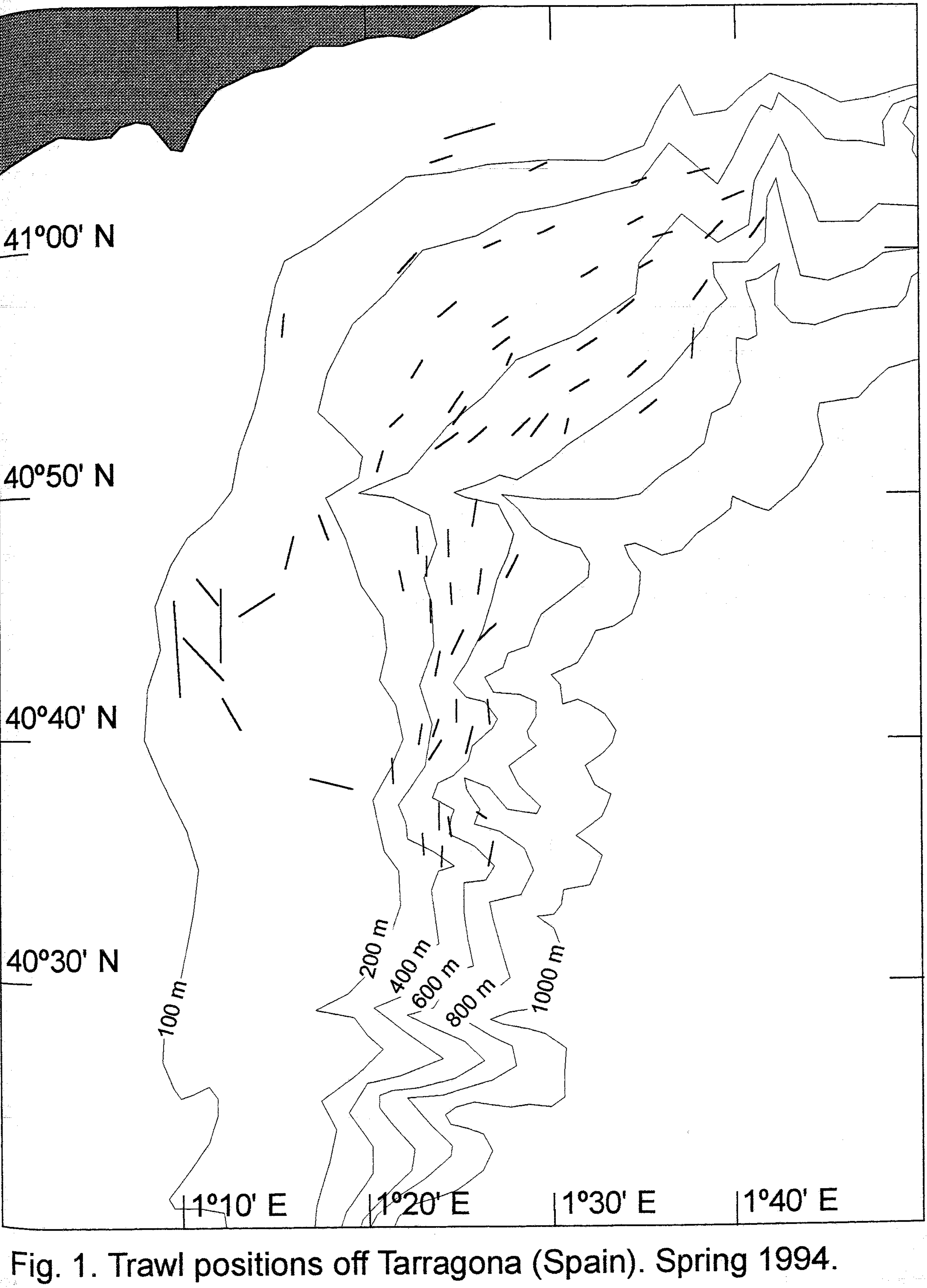


Fig. 1. Trawl positions off Tarragona (Spain). Spring 1994.

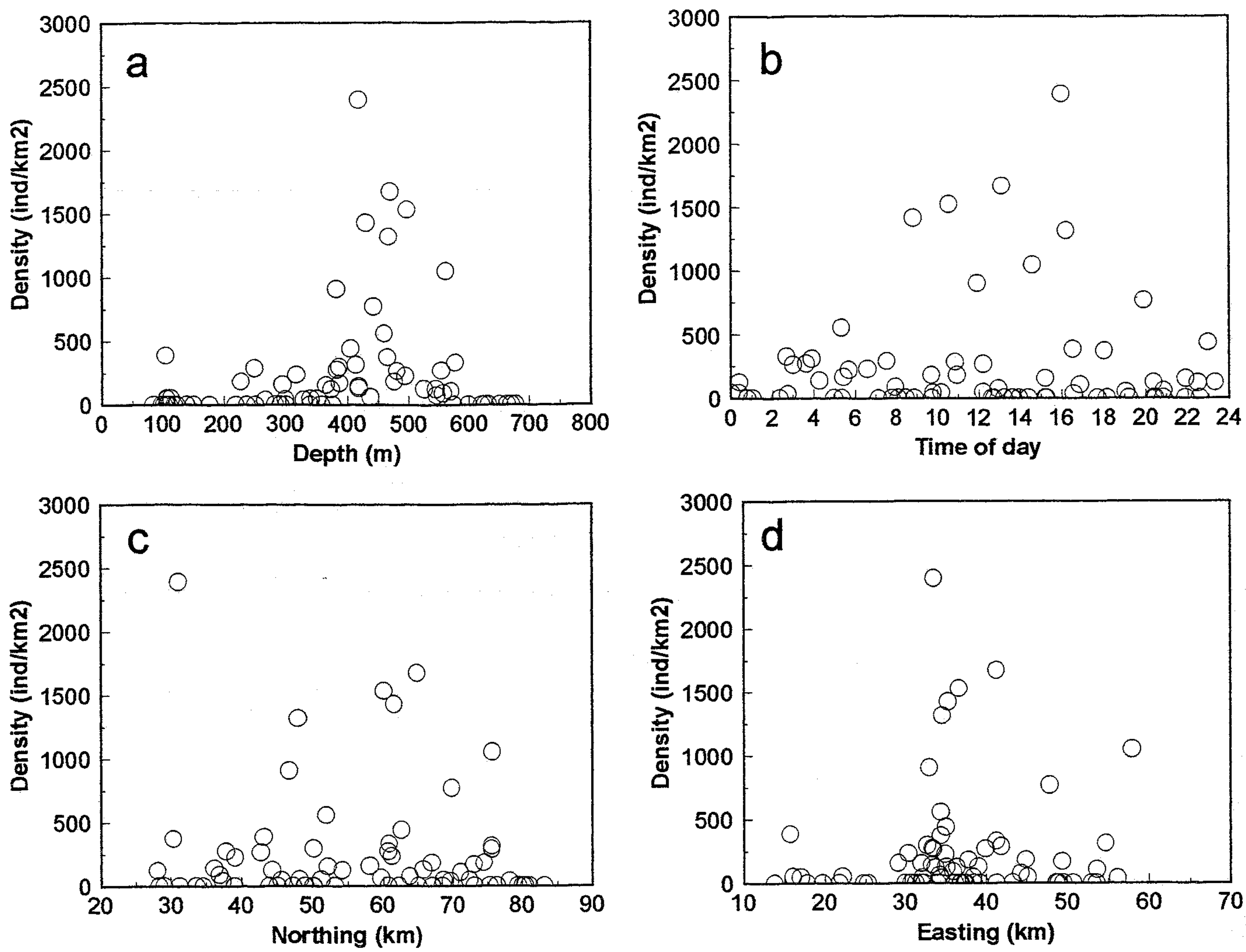
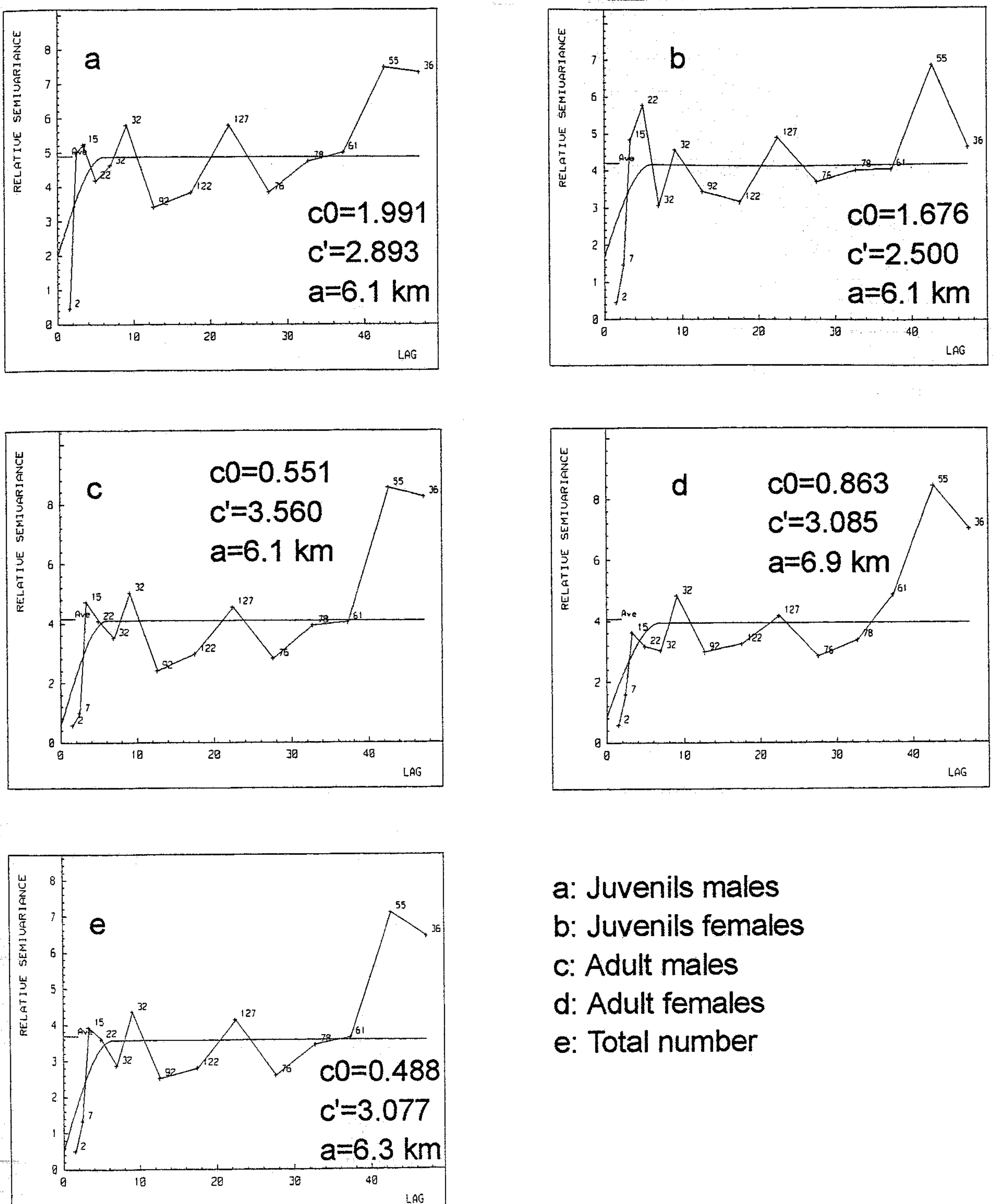


Fig. 2: Exploratory data analysis of *Nephrops* density vs. environmental variables.

Fig. 3: Relative semivariograms and spherical models fitted to biological categories.



a: Juvenils males
b: Juvenils females
c: Adult males
d: Adult females
e: Total number

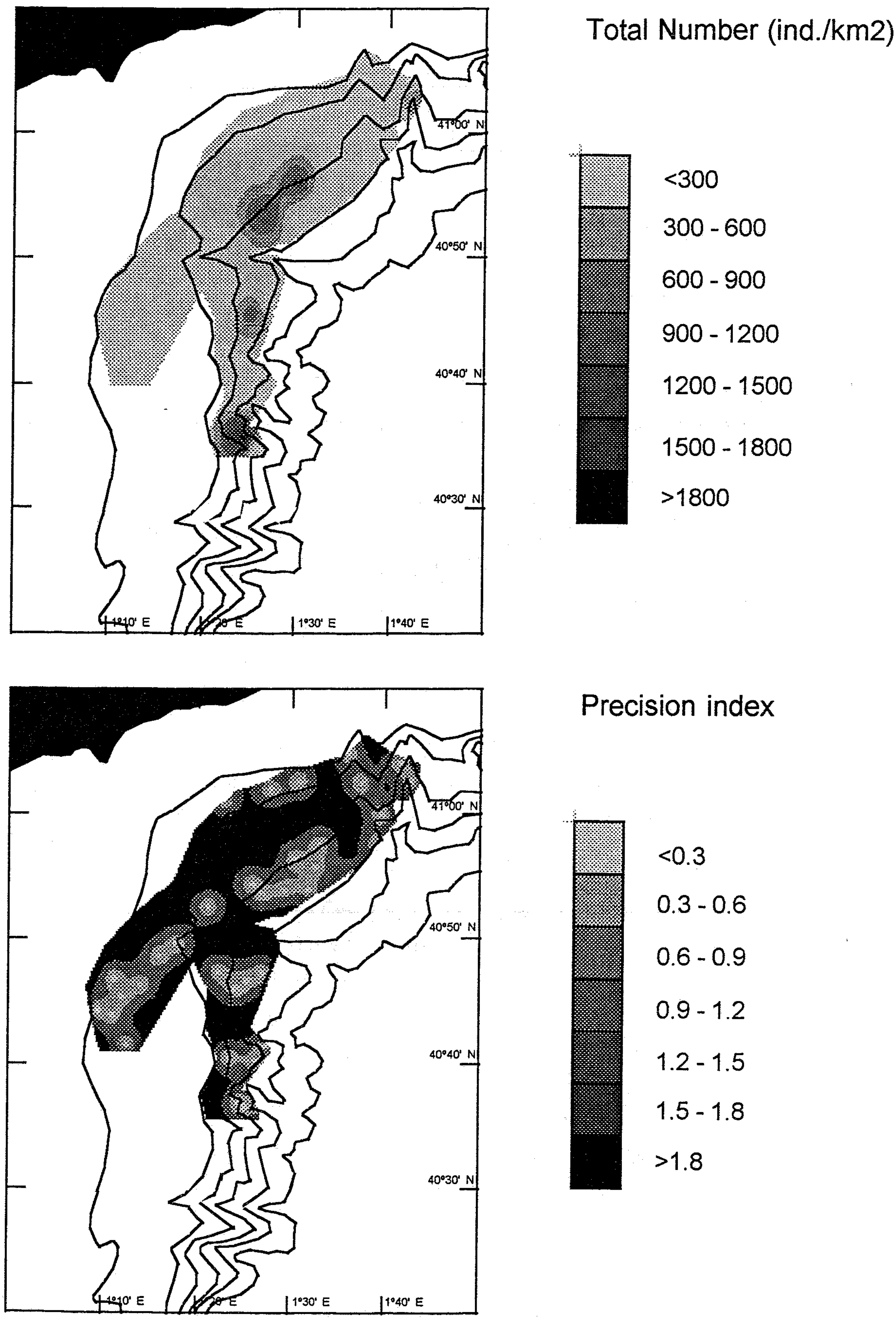


Fig. 4: Norway lobster density estimated by kriging (top) and precision index of the estimate (bottom)

INFLUENCE OF THE SUBSTRATE

INTRODUCTION

Nephrops norvegicus (L.) is a burrowing decapod crustacean whose area of distribution comprises the NE Atlantic and the Mediterranean (Farmer, 1975). It is an important commercial species in its area of distribution (Anon., 1992). The overall Nephrops depth range extends from 15 to 800 m, but NE Atlantic populations are mainly found on the continental shelf. In NW Mediterranean waters it has been reported between 200 and 800 m depth, with peak abundance at 400-450 m, although Abelló et al. (1988) found Nephrops at very low densities (1 - 2 individuals h^{-1} trawling) at shelf depths in the southern margin of the Catalan Sea.

Nephrops population spatial structure in the Catalan Sea comprises high-density patches of ~ 7 km diameter, alternating with areas of low density (Maynou *et al.*, unpublished). In our area of study (shelf and slope off NE Spain), the low-density patches of Nephrops detected on the shelf were spatially disjointed from the immediate slope populations.

The heterogeneous nature of the sediment may be expected to affect the population characteristics of a burrowing sedentary species like Nephrops norvegicus. These influences may be revealed as differences in biological characteristics (such as growth rate, natural mortality or density) among populations (Tully and Hillis, 1995). Chapman and Howard (1988) and Tully and Hillis (1995) showed that some characteristics of the sediment were correlated with some population and biological parameters of Irish Sea Nephrops populations, viz. population density, morphometry, and catch composition.

Although no studies on the influence of environmental factors on the population characteristics of Norway lobster have been undertaken in the Mediterranean until now, local fishermen working on fishing grounds over our study area have noticed morphological (size and colour) and density differences between slope and shelf populations.

In this paper we study in detail the entire depth range (between 100 and 700 m, approximately) of Nephrops in the Catalan Sea, analysing the biological and ecological characteristics of Nephrops in relation to environmental variables.

MATERIAL AND METHODS

Study area:

This study sampled outer shelf and slope depths (between 85 and 713 m) off the Ebro River delta (40°20' to 41°00', NE Spain, Fig. 1). The main geomorphological features of the northern part of the study area are a narrow shelf (8-10 km width) and a gentle slope cut by deep submarine canyons. In the southern part of the study area (south of ~ 40°50'N) the shelf becomes progressively wider (38-40 km) due to sediment outflow from the Ebro river and the slope is steeper, and submarine canyons crossing it become less important.

The hydrological features of the area comprise a permanent southward flowing shelf/slope current (Liguro-Provençal-Catalan current, Castellón et al., 1990). This current affects mainly the superficial water mass (North Atlantic Water, NAW) and its effects become negligible deeper than ~ 250 m. The superficial NAW mass (~ 0-200 m) has important seasonal temperature and salinity fluctuations, due to evaporation and freshwater run-off (Font et al., 1988; Hopkins, 1985). The underlaying Levantine Intermediate Water mass (LIW), is found between ~ 200-600 m and has minor temperature and salinity seasonal oscillations (13.0 ± 0.5°C and 38.55 ± 0.05 ppt; Hopkins, 1985). The Mediterranean Deep Water (DW) is found deeper than ~ 600 m, where temperature and salinity are nearly constant throughout the year (12.8 °C and 38.4 ppt; Hopkins, 1985).

Sea sampling:

Forty-four sediment samples and 72 trawl hauls were taken in spring 1994 (cruise GEODELTA 6-16 April 1994, aboard the R/V "García del Cid", Fig. 1). Sediment samples were collected using a Van Veen grab (Gray, 1981). Sediment samples were collected every second trawl haul, except in the shelf area, where sediment heterogeneity was presumably higher and the collection of one sediment sample per tow was attempted.

Biological samples were obtained by short (15-30 min) trawl hauls (Fig. 1). The sampling gear used was the Maireta system single-warp bottom trawl (MST, Sardà et al., unpublished; Maynou et al., 1996). The cod-end stretched mesh size was 12 mm. Trawl start and end positions were measured by satellite positioning (GPS). Tow length varied between 0.8 and 2.0 km. Trawl opening was monitored by an acoustic measuring device (SCANMAR) and stabilized at 2.0 m height and 14.0 m width. Tow length and tow width measures allowed for a precise computation of the area swept by each trawl haul.

Sediment analysis:

Sediment temperature and redox potential (Eh, at 1 and 6 cm depth) were measured on board, using a pH-Eh-temperature meter (double joint electrode, Model 231, Orion Research). Immediately afterwards, sediment samples were stored at -20 °C for later laboratory analyses.

Laboratory analyses comprised grain size analysis, determination of carbonate content, and organic matter analysis. The granulometric analysis was carried out using a SEDIGRAPH 5000D for the fine fraction (<0.05 mm) and sedimentation tube analysis for the coarse fraction, following the methodology by Giró and Maldonado (1985). At each station, the fraction (%) of sand (0.0625 to 1 mm), silt (2 to 62.5 μm) and clay (0.06 to 2 μm) was computed. The grain size distribution of each sample was summarized by its median, $\phi = -\log_2$ [median grain size in mm] (Gray, 1981), and its sorting coefficient IGSD (Inclusive Graphic Standard Deviation; Gray, 1981). Small values of IGSD indicate a well-classified sediment in low-energy environments and large values of IGSD indicate poorly sorted sediments, in high-energy environments.

Laboratory analyses comprised also determination of carbonate content (% in volume, Giró, 1985) and organic matter content by ignition loss (% in weight, modified from Giró, 1985).

Analysis of biological data:

All Nephrops caught were sexed, measured and weighed. Nephrops catch was sorted into biological categories: adult males, juvenile males, adult females, juvenile females and berried females. Morphometric measures were taken to the nearest 0.1 mm. Morphometric variables and their abreviations used throughout this article are as follows: CL: Carapace Length, CW: Carapace Width, AW: Abdomen Width, ChL: Chela Length, ChW: Chela Width, SPL: Small Pincer (II Pereiopod) Length, SPW: Small Pincer Width, 2PCL: II Pereiopod Carpal Length, see Fig. 2. Chela measurements refer always to the crusher chela. A CL of 26 mm was taken, as a jacknife approximation, to segregate adult from juvenile categories, as this is the size at which first instances of gonadal maturity are generally recorded in the Catalan Sea (Sardà, 1991).

Biological samples were also obtained from two commercial trawlers, one operating over the shelf (28 August 1995) and the other over the slope (31 August 1995) in the study area. Commercial trawlers in the study area perform 2-3 hour hauls following the depth contours, which in our case represents a constant NE-SW direction. Commercial catch was sorted and measured in the same fashion as the experimental biological samples.

Statistical analysis:

Sediment samples were classified by cluster analysis (UPGMA) using the Pearson's correlation coefficient (Legendre and Legendre, 1984).

Catch at each experimental station was standardised to individuals / km^2 for the following biological categories: juvenile males, juvenile females, adult males, adult females, and total number; and kg / km^2 for total weight. Analysis of Variance (ANOVA) was used to compare the densities by categories and differences in morphometrical variables, between clusters of stations as classified by the cluster analysis of sediment data. Comparison of linear regressions was used to establish the possible differences in relative growth in individuals from separate clusters of stations. The relationship between CL and the other morphological variables was linearized by log transformation and the resulting regression lines were compared by means of the t-test of parallelism of slopes for two populations, once the equality of the two population variances had not been rejected by means of the F-test (Berenson et al., 1983). The alpha probability level for rejection of the null hypothesis of parallelism was taken as 5%.

Canonical analysis of populations (Legendre and Legendre, 1984) was used to test for the contribution of the measured morphometrical variables, standardized by CL (Senar et al., 1994), in separating the lobster populations established by cluster analysis of sediment data.

Canonical correlation analysis (Gittins, 1979) was used to relate sediment variables to biological characteristics of Nephrops populations.

RESULTS

Analysis of sediment data showed important substrate spatial heterogeneity over Nephrops fishing grounds. The clusters of stations based on sediment properties are shown in the inset of Fig. 3, together with their spatial positions (Fig. 3). Based on sediment properties and cluster analysis, three main zones could be defined: Ebro delta shelf and upper slope (from 102 to 383 m), shelf north of 40°50' N (from 190 to 290 m) and slope (from 270 to 660 m). Median, minimum and maximum values of the sedimentological parameters are summarized in Table 1.

The first cluster delimited areas of shelf and upper slope depths south of 40°50'N, and comprised muddy sands of high carbonate content, with heterogeneous grain size (phi ranging form 2.2 to 8.1) and poorly sorted (sorting coefficient, IGSD, between 2.5 and 3.5 phi) indicating a highly energetic environment. This is clearly related to the outflow of the Ebro river. Sediment temperature ranged from 12.4 to 13.1 °C, corresponding to the surface water mass in the NW Mediterranean in winter (Hopkins, 1985). It must be noted that the temperature of the surface water mass shows important annual variations and that in summer, it can reach values of over 20°C (Hopkins, 1985). Organic content was very low, from 3.8 to 9.2%, being higher at the shelf / slope transition.

The second cluster comprised shelf and shelf-break depths north of ~ 40°50' N where sediment was homogeneous, well-sorted sandy muds with a low carbonate content. Sediment temperature ranged from 12.2 to 12.9°C, corresponding to the surface water mass. Organic content of the sediment was high, ranging from 7.4 to 9.3% from the shallowest locations to the deepest.

The third cluster included stations at slope depths and comprised fine muds with a low carbonate content. Sediment was well-sorted and homogeneous. Temperature was high, from 12.4 to 13.6 °C, corresponding to the Levantine Intermediate Water mass (Hopkins, 1985), where temperature and salinity are relatively stable throughout the year (13 ± 0.5 °C, Hopkins, 1985). Organic content of the sediment was high, ranging from 6.4 to 12.5 %.

Of the 72 stations where trawl samples were taken, 14 were located in the first cluster as established by the sediment statistical analysis, 10 in the second cluster and the remaining (48) in the third cluster (Fig. 3). Of the 10 stations lying in the second cluster lobsters were present at only 5. Thus, those 10 stations were not taken into account for further analyses. There were 57 individuals in cluster 1, and 350 in cluster 3.

In the commercial data set a total of 306 individuals was sampled from the commercial boat operating over the shelf (corresponding to cluster 1) and 496 individuals were sampled from the commercial boat operating over the slope (corresponding to cluster 3).

Under the hypothesis that substrate variability could affect Nephrops population characteristics or its morphometry, biological samples from the commercial data set taken at the stations corresponding to clusters 1 (referred to shelf in the tables) and 3 (referred to slope) were analysed by an ANOVA. Table 2 summarizes the results of ANOVA tests carried out between pairs of morphological variables between Nephrops populations of cluster 1 and 3, for males and females separately. Nephrops individuals dwelling in shelf sediments were larger and weighed more than individuals from the slope, both for males and females. The mean of the remaining morphological variables was also significantly larger in shelf individuals than in slope individuals. As expected, the mean of all morphometrical variables in males was larger than in females.

Comparison of linearized regressions between standardized CL and morphological variables is summarized in Table 3. Weight, carapace width and abdomen width relative growth was significantly larger in shelf populations than in slope populations. On the other hand, chela length and chela width grew proportionately larger in slope individuals than in shelf individuals, as well as the II pereiopod carpal length. Small pincer length and width growth were not significantly different.

The results of the ANOVA comparing densities of shelf individuals and slope individuals are summarized in Table 4 for the experimental data set. Although densities for all biological categories in shelf sediments were consistently lower than in slope sediments, in no case were density differences between slope and shelf significant at the 95 % level.

Canonical analysis of populations using morphometrical variables standardized to CL showed that populations of cluster 1 (shelf) and 3 (slope) were significantly different ($F=5.2746$, $p= 0.000019$). For the commercial data set, this analysis also gave significant results ($F=4.858$, $P=0.000029$).

Individuals from the first commercial data set (shelf) ranged from 21 to 53 mm CL and those from the second commercial data set (slope) from 20 to 42 mm CL. Females from the shelf data set were in a more advanced stage of the reproductive cycle (36.6% berried females) than those from the slope data set (1.3%), Table 5. Gonadal maturity in females (stages I to VI, from Sardà 1991) is summarized in Table 5. Gonadal maturity (developmental stages) is more advanced in females belonging to the shelf population than in females from the slope.

In the Canonical Correlation Analysis, the environmental variables used were a subset of the available variables, as it was found that some were highly correlated (and thus, redundant) for the analysis. Thus, phi was used as a varible summarizing the grain size distribution. Carbonate and organic matter contents were highly correlated with phi and were not, as such, included in the analysis. For the biological variables, CL was used as a summary variable for the morphological variables. Two other biological variables were used in each analysis: density of males and females and percentage of juvenile males and females, to evaluate the effect of substrate heterogeneity in relation to population density and composition.

The results of the Canonical Correlation Analysis showed that the canonical variable resulting fom a linear combination of biological variables was significantly dependent on the canonical variable constructed from a linear combination of sediment variables, both for males and females (canonical correlations of 0.998 and 0.999, respectively, Table 6). Overall significance of the two analyses is given by the chi-square Bartlett's approximate test (Gittins, 1979): as shown in Table 6 both analyses were highly significant (p=0.007 for males and p=0.001 for females) for a model of rank 1. Both for males and females, a similar amount of variance was extracted by the biological canonical variables, around 28 %, but the variance extracted by the sediment canonical variable was higher for males (32.1 %) than for females (14.7 %).

Table 7 shows the canonical correlation coefficients between each of the biological variables and the sediment variables. Depth, temperature of the sediment, phi, and redox potential at 1 cm show a positive correlation with adult male density, % juvenile males, adult female density and % juvenile females. Depth, temperature and phi show a negative correlation with CL in males and females.

Both for juvenile males and females, their correlation with phi was higher than for their respective adult categories, indicating a higher affinity of juveniles for finer and organic matter enriched sediments. In males and females, CL was not related to redox potential at 1 cm indicating that grain size (and related organic content) may be more important in Nephrops environmental ecology than oxygen levels (cf. Baden et al. 1990).

DISCUSSION

Biological characteristics (morphometry and population density) of Nephrops norvegicus were shown to be related, in our study area, to sediment variables. This result corresponds to similar findings by Chapman and Howard (1988) and Tully and Hillis (1995) for North Atlantic Nephrops stocks. Tully and Hillis (1995), analysing Irish Sea Nephrops populations, further indicate that patch size in Nephrops populations may be a result of patchiness in sediment characteristics, although other studies (White et al. 1988, Hill and White, 1990) suggest that patch size in Irish Sea Nephrops populations is related to larval dispersal determined by hydrological factors. Maynou et al. (unpublished) attributed Nephrops populations patchiness to substrate heterogeneity and topography (steepness of the slope, presence of submarine canyons) in a spatial study of slope Nephrops populations located in an area farther north than the present study area.

We found that depth, temperature of the sediment, grain size (as summarized by the median of its distribution, phi) and redox potential at 1 cm were the main factors determining adult and juvenile density of Norway lobster. The effect of temperature is probably misleading as temperature was higher in slope sediments during our survey (April 1994). Temperature of the slope water mass is approximately constant throughout the year (around 13°C, Hopkins, 1985), while temperature of shelf waters has important year fluctuations (being as low as 12°C during our sampling and reaching over 20°C in summer, Hopkins, 1985). Depth is considered here only as an indirect explanatory variable, as direct effects of depth on Nephrops distribution are not documented. It is rather the relation between depth and other sediment variables, such as organic content, and grain size, which determines the distribution of Norway lobster, and that of other species of decapod crustaceans.

Norway lobster was found at higher densities in finer sediments (silt and clay fraction between 50 and 90 %) although individuals were comparatively smaller (CL) than in coarser sediments, where lobster density was low (cf. results Tully and Hillis 1995). Redox potential was shown to be also an important factor determining lobster distribution. Redox potential at 1 cm correlated positively with Nephrops densities for all biological categories, showing a preference for well-oxygenated sediments. Thus, Nephrops populations in our study area showed a trade-off between finer, less well-oxygenated sediments and coarser, well-oxygenated sediments, favoring the former (cf. Baden et al. 1990).

The effects of redox potential, grain size and organic content on Nephrops individuals could be direct (enhanced survival at high oxygen levels, or enhanced survival in fine cohesive sediments, where unlined burrows would be easier to construct) or indirect (higher food availability in organic-rich sediments). In view of what is known of Nephrops ecology (Chapman, 1980) the hypothesis of enhanced survival at higher oxygen levels and in finer sediments seems more likely. Nephrops is a macrophage predator, and to a lesser extent, scavenger in the area of study (Lagardère, 1977; Sardà and Valladares, 1990; Cartes pers. comm.) which feeds on small benthic invertebrates (mainly polychaetes and small burrowing decapod crustaceans). Thus, higher food availability in organic-rich sediments does not seem to be an important factor in the distribution of Nephrops.

As discussed by Tully and Hillis (1995), high density in populations dwelling on finer sediments could be linked to slower growth in individuals of those areas, but the exact mechanisms are unclear. Effects of differential growth related to temperature variability, as suggested for Irish Sea populations (Tully and Hillis, 1995), may not hold here, as temperature during the principal or fixed period of molt in the NW Mediterranean, December to April (Sardà, 1991), is essentially the same for our shelf and slope populations, as the thermocline weakens in winter. We conclude instead that a more suitable substrate for burrowing in finer sediments allows for higher density in slope populations, and that density dependent factors inhibit growth in these populations. Although densities were considerably higher on the slope, they were not significantly different from shelf densities, but this may be accounted for by fishing pressure, which would keep density at lower levels than otherwise attainable.

It is in the reproductive cycle of Norway lobster that temperature does play a role in our study area, as higher temperatures of the shelf water mass in summer can be related to the more advanced stages of sexual maturity and the higher proportion of berried females present in the shelf samples. The fraction of females which were in reproductive state was about 2/3 on the shelf as well as on the slope, in accordance with results from other studies (Sardà, 1991) which show that during the reproductive season not all the adult females in a population actually reproduce.

Morphometrical growth was also found to differ in shelf and slope populations. Shelf individuals were found to grow larger in weight and width than slope individuals, but the latter had a higher chela relative growth. This can be related to the agonistic mating behaviour observed for Nephrops, where males are selected for larger chelae, as known in other clawed lobsters and crabs (Atema and Cobb, 1980; Abelló et al., 1994). As Nephrops males actively compete for territory and females, Nephrops individuals could be selected for disproportionately bigger claws in slope sediments. Variables related to the second pereiopod morphometry had also larger values in slope individuals than in shelf individuals (although only second pereiopod carpal length was significant), suggesting that although body measures and relative growth are smaller in slope individuals, relative first and second pereiopod measures and growth need to be relatively larger for efficient burrow digging.

REFERENCES

ABELLÓ, P., VALLADARES, F. J. AND CASTELLÓN, A., 1988. Analysis of the structure of decapod crustacean assemblages off the Catalan coast (North-West Mediterranean). *Mar. Biol.*, 98: 39-49.

ABELLÓ, P., WARMAN, C. G., REID, D. G. AND NAYLOR, E., 1994. Chela loss in the shore crab Carcinus maenas (Crustacea: Brachyura) and its effects on mating success. *Mar. Biol.* 121:247-252.

ANONYMOUS, 1992. Working Group on Nephrops and Pandalus stocks. *ICES CM 1992/Assess:8, 275 pp.*

ATEMA, J. AND COBB, J. S., 1980. Social behaviour. In: J. S. Cobb and B. F. Phillips (Editors), The Biology and Management of Lobsters, vol. I. *Academic Press, New York*. pp. 409-450.

BADEN, S. P., PIHL, L. AND ROSENBERG, R., 1990. Effects of oxygen depletion on the ecology, blood physiology and fishery of the Norway lobster Nephrops norvegicus. *Mar. Ecol. Prog. Ser.* 67(2): 141-155.

BERENSON, M. L., LEVINE, D. M. AND GOLDSTEIN, M., 1983. Intermediate statistical methods and applications. *Prentice-Hall, Englewood Cliffs, N. J.,* 568 pp.

CASTELLÓN, A., FONT, J. AND GARCÍA, E., 1990. The Liguro-Provençal-Catalan current (Northwestern Mediterranean) observed by Doppler profiling in the Balearic Sea. *Sci. Mar.* 54(3): 269-276.

CHAPMAN, C. J., 1980. Ecology of juvenile and adult Nephrops. In: J. S. Cobb and B. F. Phillips (Editors), The biology and management of lobsters, Vol. II. *Academic Press, New York,* pp. 142-178.

CHAPMAN, C. J. AND HOWARD, F. G., 1988. Environmental influences on Norway lobster (Nephrops norvegicus) populations and their implications for fishery management. In: A. A. Fincham and P. S. Rainbow (Editors), *Aspects of decapod crustacean biology. Symposia of the Zoological Society of London,* 59: 343-353.

FARMER, A. S. D., 1975. Synopsis of biological data on the Norway lobster Nephrops norvegicus (Linnaeus, 1758). *FAO Fisheries Sysnopsis* 112: 1-97.

FONT, J., SALAT, J. AND TINTORÉ, J., 1988. Permanent features of the circulation in the Catalan Sea. *Oceanologica Acta,* 9: 51-57.

GIRÓ, S., 1985. La plataforma continental del Golfo de Valencia: facies y procesos durante el Cuaternario superior. M.Sc. *Thesis. Faculty of Geology, University of Barcelona,* 157 pp.

GIRÓ, S. and Maldonado, A., 1985. Análisis granulométrico por medios automáticos: tubo de sedimentación y SEDIGRAPH. *Acta Geológica Hispánica,* 20(1): 95-102.

GITTINS, R., 1979. Ecological applications of Canonical Analysis. In: L. Orlóci, C. R. Rao and W. M. Stiteler (Editors), Multivariate methods in ecological work, vol. 7. *International Co-operative Publishing House, Fairland, Maryland,* pp. 309-535.

GRAY, J. S., 1981. The ecology of marine sediments. Cambridge Studies in Modern Biology, 2. *Cambridge University Press,* Cambridge, 185 pp.

HILL, A. E. AND WHITE, R. G., 1990. The dynamics of Norway lobster (Nephrops norvegicus, L.) populations on isolated mud patches. *J. Cons. int. Explor. Mer.* 46(2): 167-174.

HOPKINS, T. S., 1985. Physics of the Sea. In: R. Margalef (Editor) Key environments: Western Mediterranean. *Pergamon Press, New York,* pp. 100-125.

LAGARDÈRE, J. P. 1977. Recherches sur le régime alimentaire des décapodes benthiques de la pente continentale de l'Atlantique (Golfe de Gascogne et Maroc). In: B. F. Keegan, P. O. Ceidigh and P. S. J. Boaden (Editors), Biology of benthic organisms. Pergamon Press, New York, pp. 397-408.

LEGENDRE, L. AND LEGENDRE, P., 1984. Ecologie numérique, 2nd edition. 2 vols. *Presses Universitaires du Québec, Québec,* 260 and 335 pp.

MAYNOU, F., CONAN, G.Y., CARTES, J. E., COMPANY, J. B. AND SARDÀ, F., 1996. Spatial structure and seasonality of decapod crustacean populations on the northwestern Mediterranean slope. *Limno. Oceanogr.* 41(1): 113-125.

SARDÀ, F., 1991. Reproduction and moult synchronism in Nephrops norvegicus (L.) (Decapoda, Nephropidae) in the Western Mediterranean: is spawning annual or biennial? *Crustaceana* 60(2): 186-199.

SARDÀ, F. AND VALLADARES, F. J., 1990. Gastric evacuation of different foods by Nephrops norvegicus (Crustacea: Decapoda) and estimation of soft tissue ingested, maximum food intake and cannibalism in captivity. *Mar. Biol.* 104: 25-30.

SENAR, J.C., LLEONART, J. AND METCALFE, N. B., 1994. Wing-shape variation between resident and transient wintering siskins (Carduelis spinus). *J. Avian Biol.* 25: 50-54.

TULLY, O. AND HILLIS, J. P., 1995. Causes and spatial scales of variability in population structure of Nephrops norvegicus (L.) in the *Irish Sea. Fish. Res.* 21: 329-347.

WHITE, R. G., HILL, A. E. AND JONES, D. A., 1988. Distribution of Nephrops norvegicus (L.) larvae in the western Irish Sea: an example of advective control on recruitment. *J. Plankton Res.* 10(4): 735-747.

Table 1. Summary statistics of environmental variables at each cluster. Cluster results are shown in Fig. 3.

	depth	temp	Eh1	Eh6	%CO3	Phi	IGSD	%MO	%sand	%silt	%clay
Cluster1											
Median	119	12.5	-133	-190	37.0	7.119	3.200	6.627	29.72	32.30	38.18
Minimum	102	12.4	-174	-215	29.3	2.213	2.546	3.817	9.67	14.70	15.54
Maximum	383	13.1	-8	-105	41.1	8.080	3.452	9.201	69.76	39.60	51.82
Cluster2											
Median	230	12.5	-70	-135	26.1	7.881	1.875	7.874	1.32	52.62	47.24
Minimum	190	12.2	-170	-220	25.9	7.355	1.748	7.446	0.00	49.91	38.34
Maximum	290	12.9	147	204	35.0	7.948	1.890	9.314	1.72	59.93	48.92
Cluster3											
Median	437	13.0	-148	-194	25.8	8.288	1.862	8.764	1.36	41.12	56.04
Minimum	270	12.4	-310	-370	23.0	7.969	1.661	6.372	0.80	33.87	49.36
Maximum	660	13.6	-18	-128	30.5	8.654	2.451	12.51	8.53	49.54	64.87

Table 2. ANOVA Results for the commercial data set. See text for abbreviations of names of morphological variables.

	Males				Females			
Variable	two-tailed t	p-level	mean - cluster 1	mean - cluster 3	two-tailed t	p-level	mean - cluster 1	mean - cluster 3
CL	-4.371	0.000	35.22	31.64	-3.602	0.000	32.16	29.22
Weight	-5.683	0.000	39.51	23.54	-5.100	0.000	29.12	17.96
CW	-3.972	0.000	19.20	17.20	-3.261	0.001	17.85	16.13
AW	-4.972	0.000	18.23	15.98	-3.805	0.000	17.75	15.49
ChL	-3.890	0.000	52.05	46.29	-3.320	0.001	45.64	41.70
ChW	-4.215	0.000	13.06	11.39	-4.070	0.000	11.41	10.00
SPL	-4.200	0.000	13.81	12.27	-4.217	0.000	12.56	11.07
SPW	-4.440	0.000	3.07	2.73	-4.501	0.000	2.79	2.45
2PCL	-3.559	0.000	8.63	7.72	-3.278	0.001	7.60	6.81

Table 3. Comparison of linear regressions between pairs of morphological variables (log-transformed data) for the commercial data set; pooled male and female data. In each case, the equality of the slopes of the regression: log (morphological variable) = a + b · log (CL) is being tested, standardized to CL. For all pairs of morphological variables, r was higher than 0.85.

Variable	b -- shelf	b -- slope	t-value	p-level
Weight	3.209	3.120	-1.79	0.074
CW	1.128	0.961	-5.10	0.000
AW	1.150	1.035	-2.99	0.003
ChL	1.099	1.188	2.77	0.006
ChW	1.203	1.383	4.65	0.000
SPL	1.025	1.034	0.21	0.833
SPW	0.975	1.012	0.68	0.496
2PCL	1.086	1.213	2.25	0.025

Table 4. Comparison of <u>Nephrops</u> densities by biological categories between shelf and slope populations, experimental data set. (Densities in number/ km^2, except total weight in kg/km^2)

Category	p-level	mean - cluster 1	mean - cluster 3
Juvenile males	0.219	4.587	45.199
Juvenile females	0.249	21.783	72.730
Adult males	0.091	22.059	148.642
Adults females	0.153	36.117	149.031
Total number	0.132	84.546	414.054
Total weight	0.195	2.868	9.077

Table 5. Sexual maturity and berried females in commercial catch, for females >= 32 mm

	shelf		slope	
	number	%	number	%
II			2	3
III	4	5.6	36	48
IV	16	22.5	12	16
V	1	1.4		
ovigerous	26	36.6	1	1.3
total in repr. state	47	66.2	51	66.7

Table 6. Results of Canonical Correlation Analysis for the experimental biological and environmental variables.

	Males	Females
Biological data set		
Variance extracted (%)	28.6	27.7
Redundancy (%)	28.5	27.6
Environmental data set		
Variance extracted (%)	32.1	14.7
Redundancy (%)	31.9	14.6
Canonical correlation	0.998	0.999
Chi-square	31.97	36.62
Probability	0.007	0.001

Table 7. Results of Canonical Correlation Analysis between biological variables of the experimental data set and substrate variables; model of rank 1. Correlation coefficients larger than 0.3 (in absolute value) are marked in bold face.

	adult males	% juvenile males	CL males	adult females	% juvenile females	CL females
Depth	**0.582**	**0.468**	**-0.354**	**0.313**	**0.456**	**-0.668**
Temperature	**0.658**	**0.525**	**-0.324**	**0.368**	**0.477**	**-0.545**
Eh1	**0.614**	**0.312**	-0.011	**0.640**	**0.542**	-0.031
Eh6	0.264	0.283	0.081	0.208	**0.321**	0.155
Phi	**0.418**	**0.505**	**-0.491**	**0.370**	**0.456**	**-0.417**

Fig. 1. Map of the study area. Trawl positions are marked by lines indicating tow length; Van Veen grab hauls are marked by circles.

Fig. 2. Morphometrical measurements taken on Nephrops norvegicus specimens. See text for abbreviations of morphological variables. Second left pereiopod has been removed to accomodate lettering.

Fig. 3. Locations of samples used in the cluster analysis of sediment variables. *Inset*: Results of cluster analysis of sediment variables using Pearson's correlation coefficient and UPGMA linking algorithm. Figures at the bottom of the dendrogram refer to depths (m) of the sampling station. ●: cluster 1 (shelf south of 40°50' N); ▲: cluster 2 (slope); ◆: cluster 3 (shelf north of 40°50'N).

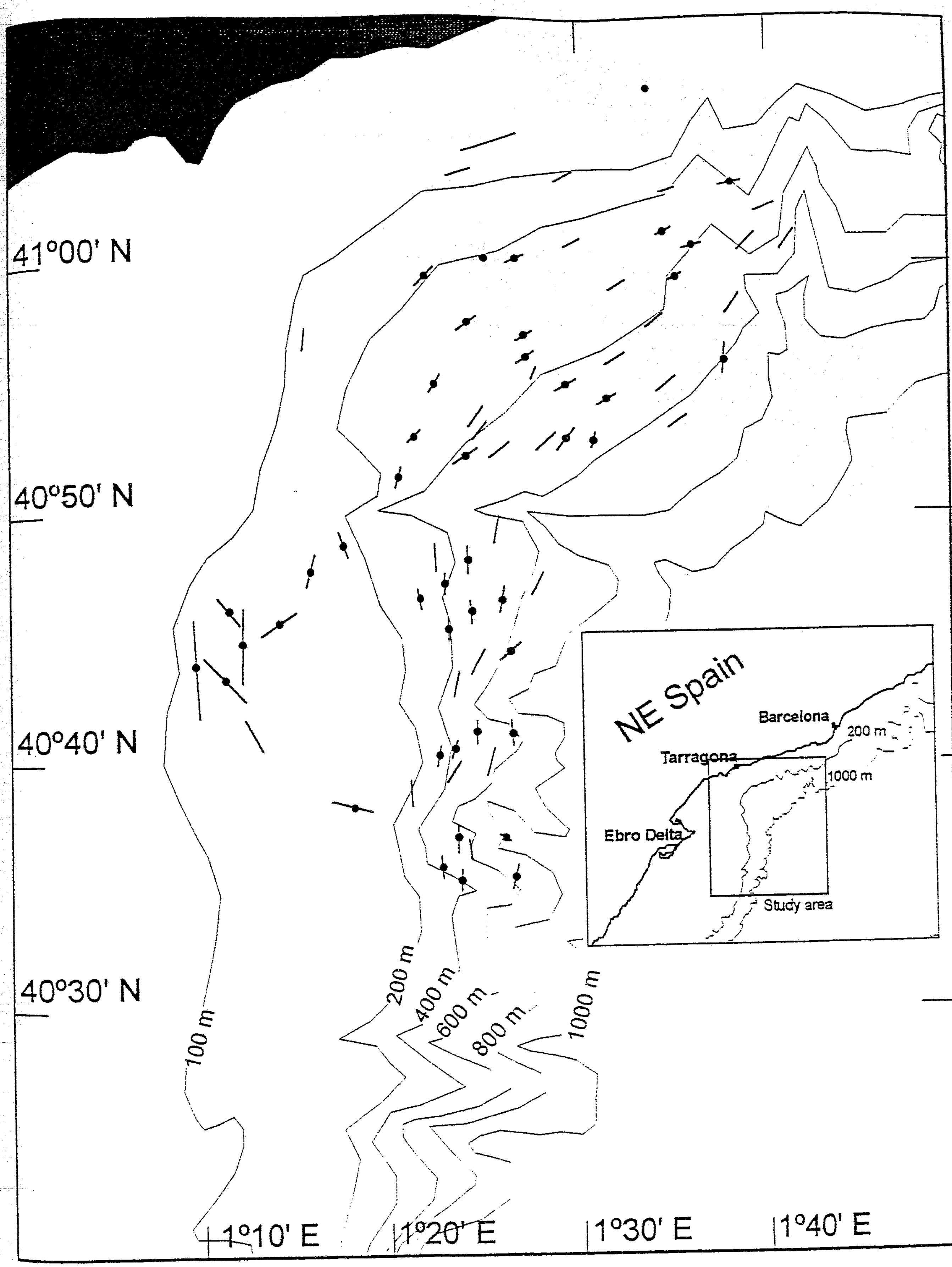

41°00' N
40°50' N
40°40' N
40°30' N
1°10' E
1°20' E
1°30' E
1°40' E
100 m
200 m
400 m
600 m
800 m
1000 m
NE Spain
Barcelona
Tarragona
Ebro Delta
200 m
1000 m
Study area

FIG. 1

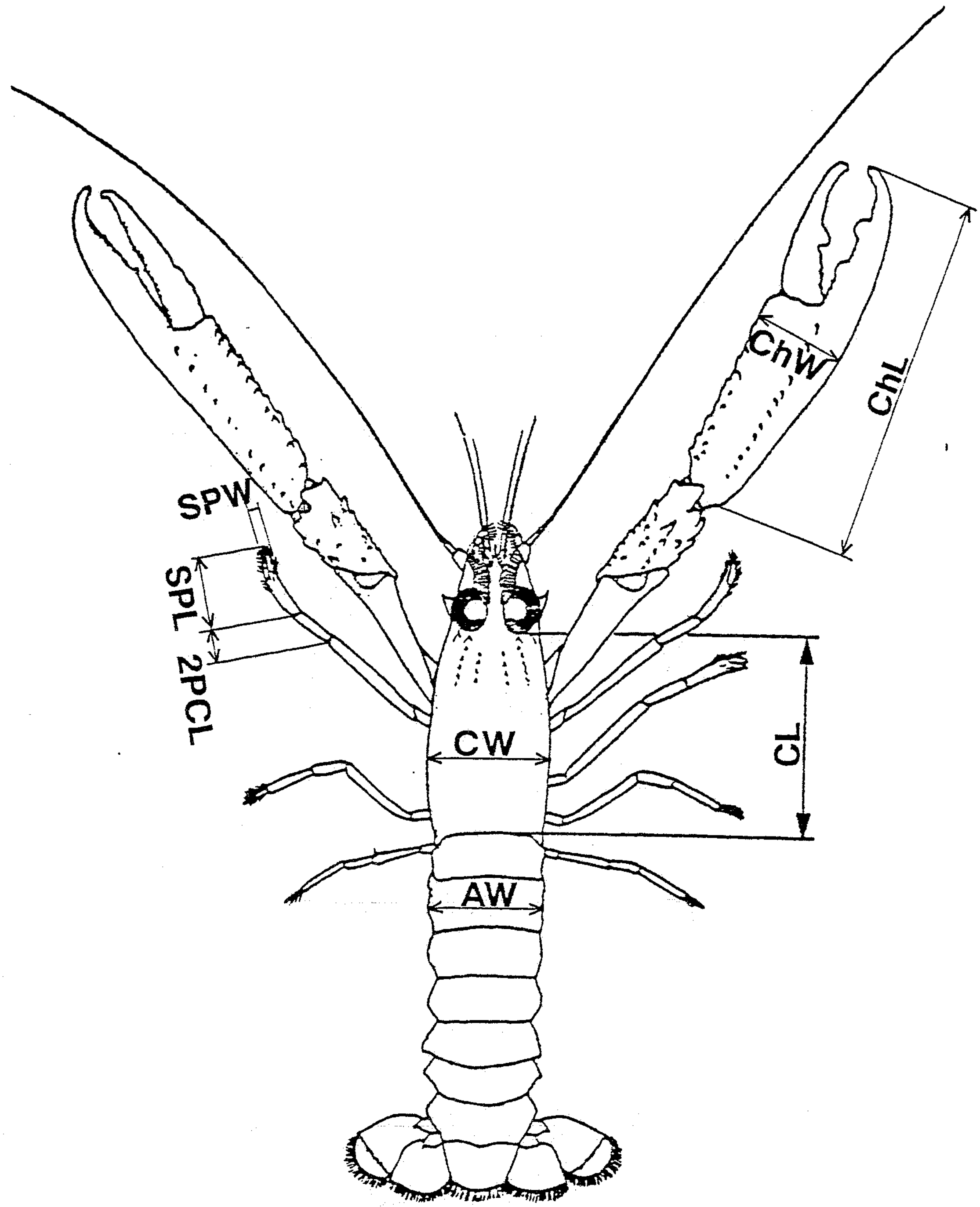


FIG. 2

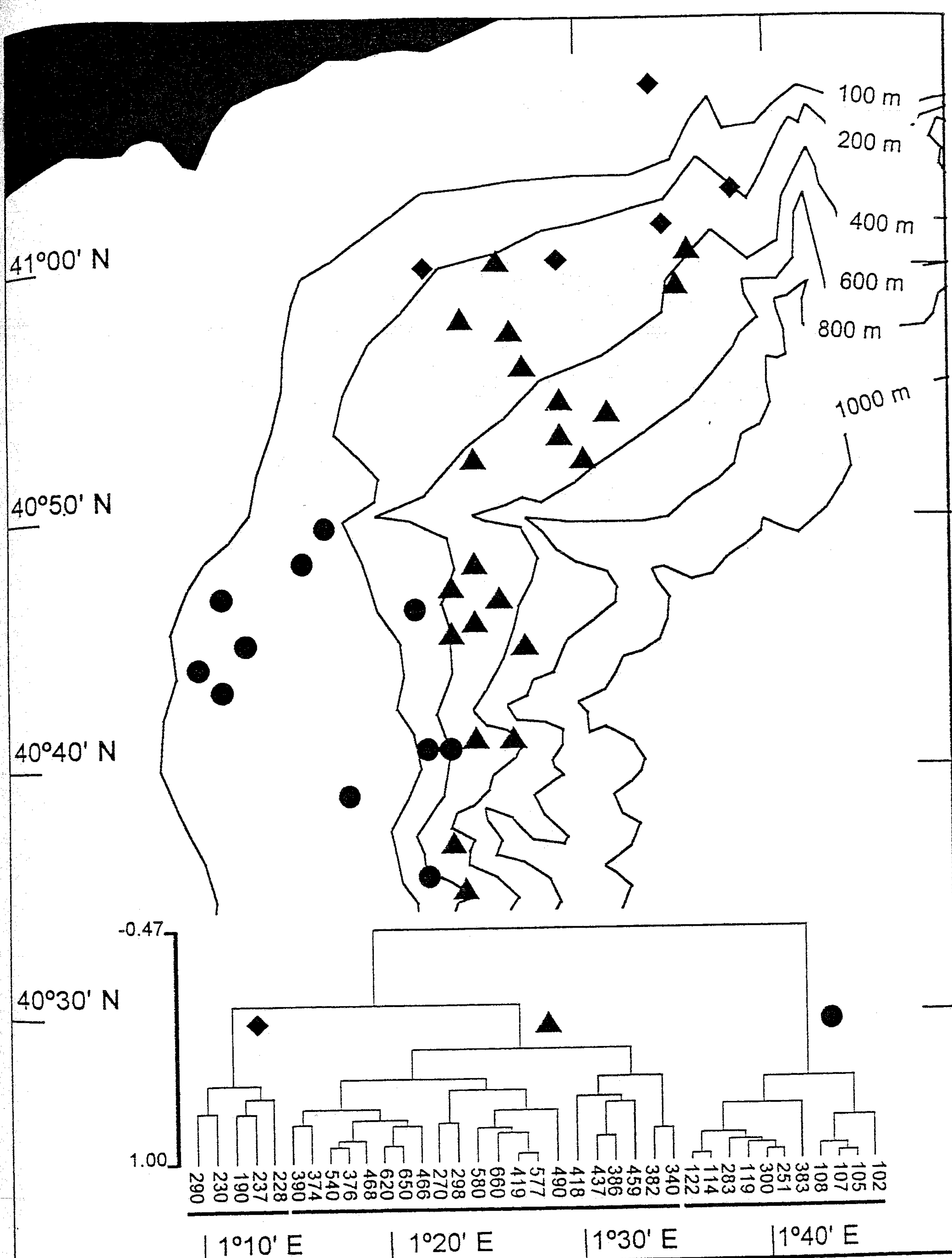
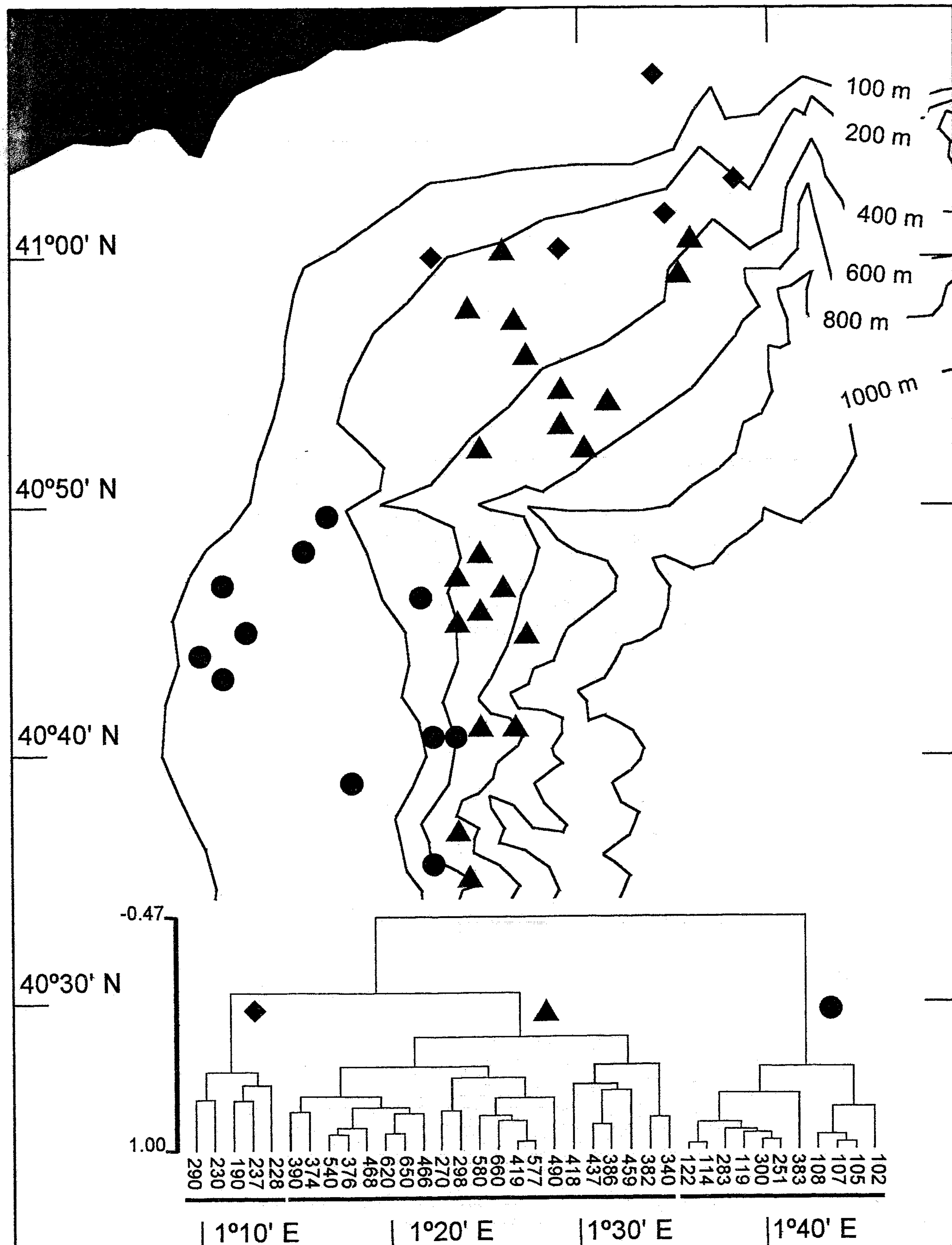

100 m
200 m
400 m
600 m
800 m
1000 m
41°00' N
40°50' N
40°40' N
40°30' N
-0.47
1.00
290 230 190 237 228 390 374 540 376 468 620 650 466 270 298 580 660 419 577 490 418 437 386 459 382 340 122 114 283 119 300 251 383 108 107 105 102
1°10' E
1°20' E
1°30' E
1°40' E

FIG. 3



100 m
200 m
400 m
600 m
800 m
1000 m
41º00' N
40º50' N
40º40' N
40º30' N
-0.47
1.00
290 230 190 237 228 390 374 540 376 468 620 650 466 270 298 580 660 419 577 490 418 437 386 459 382 340 122 114 283 119 300 251 383 108 107 105 102
1º10' E
1º20' E
1º30' E
1º40' E

FISHERIES: GENERAL ASPECTS

INTRODUCTION

Fishing practices and techniques primarily directed to *Nephrops* differ in the Mediterranean to a large degree. These differences have an influence in the quality and type of the data, which in turn may limit the reliability of scientific comparisons and interpretations.

We believe that the quantitative information provided by Government agencies and Fishermen's Associations are of uncertain reliability. However, the compilation of field information by the scientist directly from the fishermen can offer a valuable insight into the bias resulting from data collecting processes and in other fishery related information.

For this reason, we only can present a qualitative study of the fishing techniques (vessels, gear and markets) employed in the harvesting and capture of Norway lobster. The technical characteristics of Norway lobster fishing are also described and compared among the different areas considered. We set forth the basics for an understanding of the main structural phenomena which difficult the compilation of accurate and exact data. All these aspects will help clarify the major problems encountered when attempting to establish a global management strategy for Norway lobster in the Mediterranean.

METHODOLOGY

The methodology employed is qualitative. Its purpose has been to find out where the information is inaccurate and as such, is a major factor in the inconsistency of quantitative data.

This information has been gathered directly from fishermen, complementing the information requested in specific questionnaires designed in the FIR, and also from the experience of the scientists involved. The information has been collated according to the following process:

* Manoeuver, fishing technology and vessel characteristics.
* Landings, sale and data recording
* Fishing gear structure

Data and information treatment:

1. Precise and specific information request (see FIR).
2. Comparison and standardization of the information, eliminating non-relevant or inexact information which might induce to errors.
3. Data layout in standard table format.
4. Data integration and data comparison.
5. Global discussion and conclusions.

RESULTS AND DISCUSSION

Results based on the filtered information are presented in tables 1, 2 and 3. From these tables the following aspects are to be emphasized:

General aspects

Norway lobster (*Nephrops norvegicus*) fisheries in the Mediterranean follow the general patterns of trawl fisheries (see Introduction), due to their multispecific characteristic. Although trawling on Norway lobster grounds is an activity directed primarily to the Norway lobster itself, hake (*Merluccius merluccius*), monkfish (*Lophius sp.*), conger eel (*Conger conger*), blue whiting (*Micromesistius poutassou*), and megrim (*Lepidorhombus boscii*) are also important target species.

Norway lobster has a strictly benthic behaviour, mostly restricted to burrows and lacking migratory activity (Farmer, 1975) and accordingly fishing techniques are fairly similar for this species in the Mediterranean. The use of creels or trammel nets is rare in the Mediterranean.

Norway lobster catch is highly variable on a temporal scale (THOMAS and FIGUEIREDO, 1965; BAILEY, 1986 or TULLY and HILLIS, 1995) also in the Mediterranean Sea (seasonally, weekly and daily: FROGLIA, 1972; ARTEGIANI et al, 1979; SARDÀ, 1995). This variability excludes the possibility of carrying a directed fishery targeting only this species, hence the fishing gear is not totally modified or adapted to its capture. In order to catch other valuable species, the height of the quarter and top wings are increased, the trawl is hauled at a higher speed and the bellies are fitted with larger mesh sizes. However, on Norway lobster grounds and at times of peak abundance, the danlenos are usually fitted with chains extending across the trawl opening. During trawling, these chains are positioned at about 1 m in front of the ground wire, thus facilitating the "lifting" of the Norway lobster and its entrance in the trawl (MAIN AND SANGSTER, 1985; NEWLAND AND CHAPMAN, 1989).

Yields for different areas vary between 15-20 kg/km^2 annually, suggesting fairly constant densities in all areas. Density studies carried out in N. Atlantic countries (CHAPMAN and BAILEY, 1987; BRIGGS, 1987;) indicate density dependence between number of individuals and individual size throughout its distribution range includiong sedimentary relationship. Stocks in three localized areas differ significantly from the rest: shallow-water populations off the Ebro Delta (see chapter VIII), Alboran and Adriatic stocks, specially the stock in the Pomo trough (see introduction). Individuals in these populations are considerably larger and found at lower densities than individuals from the remaining Mediterranean stocks.

Technical aspects

Vessel size and equipment (Table. 1 and Annex)

Average Gross Register Tonnage (GRT) is similar in all the study areas, (excepting Ligurian) suggesting a tendency towards boat size optimization in relation to

	Atlantic	Alborán	Catalonian	Ligurian	Thyrrenian	Adriatic	Euboikos
Port	Faro	Málaga	Barcelona	St. Margarita	St.Stefano	Ancona	Chalkis
Boats nº	31	20	20	5-12	6	120	13
Working time (h)	24	16	12	12-16	12-18	96	14
Catch time (h)	18	12	8	8-10	8-10	12 to 24	10
Mean depth (m)	450	400	450	400	400	80-110	150-200
GRT medium (t) (min-max)	50	43 (47-53)	52 (45-125)	33 (10-54)	56 (33-120)	41 (12-109)	56 (56-116)
HP medium (HP) (min-max)	280	250 (190-400)	500 (400-1200)	290 (220-420)	470 (220-800)	300 (200-1000)	400 (275-500)
Warp Ø mm	16	16	16	11**	14	12	11-26
Warp whinch	+	+	+	+	+	+	+
Gear whinch	+	+	+	-	-	+	+
GPS	+	+	+	+	+	+	+
Echo sounder	+	+	+	+	+	+	+
Plotter	+	+	+	-	+	+	-
Rem. G. Control	-	±	±	-	-	-	-
Door size (m)	18 x 1.1	2.5 x 1.25	2.3 x 1.4	1.6 x 1.09	1.8 x 1.15	0.9 x 1.0	2.2 x 1.3
Door weigth (k)	340	450	450	100	350	200	180
Mouth spread (m)	22-25	20-22	22-24	12	18-20	17	14
Bridles length (m)	250	250	250	250	260	250	230
Strech mesh size	45	55	38-40	40	40	38-40	32
Codend close	swed	swed	swed	swed	knoted	swed	knoted
Chains	+	+	±	+	+	+	+
Trawling speed (k)	3	2.8-3.5	3.5-4	2.5	3-3.5	3.5	2.7-3
Hauls/day	3	2-3	2	2-3	2-3	6.8	2-7
Stern	+	+	+	+	+	+	+
Total landing ports in the area	5	5	3	7	3	2	1

Table, 1.- Vessel size, equipment and technical characteristics of differents areas studied the trawl used and the working expenses. Smaller boats would not permit to place two winches (cable and net), to have proper engine aeration, to have fridge or fishing aft deck. Larger boats would require higher fuel expenses. However, this is not an impediment for larger engines, which have actual powers much higher than described in Tables 1 and 2 (as much as 25-40% higher than registered). Summarizing, in the Mediterranean boats of small to medium GRT are found, but with high engine power which sometimes can surpasse 1000 HP (registered up to 700-800 HP).

Given the low catch obtained in the Mediterranean and the high price fetched by accompanying species, an increase in engine power is reflected in manoeuver speed and higher trawling time due to:

- Shorter time from port to fishing grounds
- Shorter heaving time
- Larger gear with larger otter doors and wider mouth openings

In relation to this, new technological improvements in boat construction are continuously implemented:

- Reinforced stern
- More resistant bridge masts
- Larger otter doors
- New engines
- Hydraulic-powered otter doors

New technologies are also incorporated to the fishing process: Global Satellite Positioning (GPS) aids in the accurate positioning of trawl hauls by means of electronic plotters and in locating reefs, rocks or wrecks; depth sounders; and acoustic remote devices for gear control. All this represents increasing fishing effort which is difficult to quantify. Summarising, in the last five years fishing effort has increased considerably over Norway lobster stocks, without a proper recording or assessment of these changes having been made.

Thus, the main problem in Norway lobster management is the increased and non-recorded fishing effort, with a concomitant increase in effective trawling time, due to the following reasons:

- Increased engine power (although the total power per port does not vary) is directed towards boats working over deeper Norway lobster and shrimp fishing grounds.

- Increased catchability due to the higher capability of gear to adhere to the sea bottom, due to remote telemetric control of the trawling operation. A reminding of the low movement capabilities of Norway lobster is relevant here.

- From the two previous points, a general increasing fishing effort is applied to *Neprhops* stocks resulting in an increased manoeuver ability and speed and more accurate ship positioning.

Working time and catch time (table 1)

Fishing time is established on a daily basis, with local modifications which may amount to differences in 2-4 hours depending on the distance from port to fishing grounds. The difference in relation to actual working time amounts to 2 hours on average. Working time can be taken as homogeneous for each area, except for the Adriatic region, where the continental shelf is wide and boats work on 2-3 day shifts. In the Euboikos Gulf area there exists a 6 month close season, and during the open season fishing boats work for 10-14 hours or more a day. This and the proximity of the fishing grounds to the ports result in an increased effective trawling effort. The Adriatic and Euboikos Gulf stocks are shallow water stocks, with marked population differences with the remaining Mediterranean stocks (with the exception of the Ebro Delta stock).

Gear structure (Table 2 and annex)

Three different structures of the trawl gear have been observed: Atlantic and western Mediterranean trawls (Portugal and Spain), central Mediterranean trawls (Italy), and eastern Mediterranean trawls (Greece). The main characteristics of each type are summarised in table 2.

The following is a list of the possible reasons which may account for the differences observed:

1.- Spanish and Portuguese trawls have wider mouth openings and are longer. The low yield in these areas and the narrow continental shelves compel to maximize efficiency by using high-powered engines and larger trawls. As a result to this, the mesh size of the wings is relatively larger than the mesh size of the codend and drag on trawl netting is concentrated on the wings. Trawling speed and water filtering are higher, and accordingly the trawl is fitted with longer codends.

2. Italian trawls are comparatively smaller, with smaller mouth openings and relatively lower wings to codend mesh size ratios.

3. Greek trawls are longer than the others due to its smaller codend mesh size.

Summarising, Italian trawls seem to be better adapted and more specific to Norway losbter fishing. They are also more adequate in relation to vessel power and to smaller otter doors.

As shown in table 2 the trawl size is not in close agreement with the engine power, as most boats have fairly similar engine power. Instead there is a close agreement between trawl size and otter door size (larger trawls and otter doors in Portugal, Spain and Greece, while smaller in Italy). The diameter of the warps shows the same relationship. From this, we conclude that engine power is not a reliable measure of the effort, but an assessment by the expert of the warp diameter and otter door size can give an accurate idea of the trawl used.

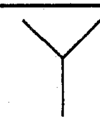
	Atlantic	Alborán	Catalan	Ligur	Tyrrheno	Adriatic	Euboikos
Mouth							
Headline (m)	59	53	47	32	42	34	30
Footrope (m)	69	66.5	64	40	55	43	37.2
Wings							
Length (m)	28	25	25	15	20	16	25
Width (n° of meshes)	275	180	210	200	380	188	240
Strech mesh (mm)	110	110	150	80	72	120	72
Body funnel							
Length (m)	18	18	47	21.6	22	24	20
Initial width (n° meshes)	550	600	468	450	400	406	500
Final width (n° meshes)	120	200	170	350	300	170	350
Strech mesh (mm, mean)	56	60	65	40	44	48	36
Codend							
Length (m)	7-13	11	13	5	5	5	6.5
Width (n° of meshes)	60-80	200	170	350	300	140	350
Strech mesh (mm)	56	40	38	40	40	40	32
General shape							
Total length (m)	59	54	82	41.6	47	44.7	62
Opening among wings (m)	25	22	24	12	18	17	14
Schema of the gear							

Table .2.- Technical characteristics of different gears used in Mediterranean *Nephrops* fishery

Catch recording (table 3)

Table 3, is a compilation of the administrative structure surrounding catches by trawling and issues related to it.

In all countries there exist official agencies and administrative bodies which compile and analyse landings data by species, but in many cases it is not compulsory that fish sales are made always at the same port. Boats fishing over a specific fishing ground may sell their catch at different ports (including other countries' ports), and the converse is also true, boats from different ports may fish on the same location. The various possibilities of marketing fish make catch estimates very approximative due to:

1. The existence of more than one place of sale at each port (for instance fish market and central market).

2. Catch directly sold to trucks which deliver it to cities or international markets.

3. Catch directly sold to fishmonger's, restaurants, etc.

4. Sales recording can be very exact in some instances, through computerized sales by auction with official invoices delivered to sellers (as in some ports of Spain and Portugal), but not reliable in other places.

5. Sale of mixed crates is not itemized. Mixed crates often comprise small individuals which, if recorded, would constitute an important source of information on recruitement.

Thus, the monitoring of landings and fishing boats in the different markets is very difficult. In a small fishery like the Mediterranean Norway lobster fishery, non-recorded catch may amount to 30 % of what is officially recorded, specially in Greece and at some ports in Italy and Portugal.

There is a further complication in the nomenclature of species and classification by size: many species which are important commercially and ecological are mixed when marketed and are not recorded, or they are recorded under generic names comprising different species. This is specially important in juvenile Norway lobster (marketed under the category "small fry" mixed with other species), but also in other species, given that in the Mediterranean fishing is applied on rather small species.

Population dynamics studies based on these very approximate data must be taken with caution and only used on a comparative basis. This conclusion would invalidate the use of fisheries models in quantitative management of the Norway lobster fishery. The seasonal variability demonstrated in the behaviour of Norway lobster stocks must also be taken into account here.

Area	Atlantic	Alborán	Catalonia	Ligurian	Tyrrhenian	Adriatic	Euboikos
Landings official record administration	SNLV	IEO AG	IEO AG	ISTAT	ISTAT	ISTAT	NSS, ETANAL
Reliable records of landings	NO	NO	NO	NO	NO	NO	NO
Reliable records of effort	NO	NO	NO	NO	NO	NO	NO
Places of sale	FP-LM-C	FP-IM-LM	FP-IM-LM	FP-LM	FP-LM	FP-IM-LM	FP-LM-C
Fishermen associations	YES	YES	YES	YES	YES	YES	NO
Landings change of ports	YES	NO	NO	NO	YES	YES	YES (?)
Langing/year, estimation and error (T/%)*	40.000 (30)	20.000 (20)	15.000 (10)	8.000 (20)	20.000 (20)	150.000 (50)	30.000 (50-70 ?)
Share stock among ports	YES	YES	YES	YES	YES	YES	YES
Multiespecies fishery	YES	YES	YES	YES	YES	YES	YES

Table, 3.- Catch recording of different localities studied

SNLV, Servicio Nacional de Lotas e Vendages
IEO, Ins. Español de Oceanografía. Ministerio de Agricultura, Pesca y Alimentación
AG, Authonomic local administrations
ISTAT, Ist. Office for statistics Collected data from Gross Markets
NSS, National Statistic Service, Ministry of Agriculture
ETANAL, Company of Fisheries Development
FP, Fishing port
LM, IM, Local and International Markets
C, Directly to consumers

Accompanying species

In the Mediterranean Sea and in the nearby Portuguese waters also if *Nephrops norvegicus* is an important component of the multispecies trawl fishery, other finfish and crustacean species make a remarkable proportion of the trawler income.

Due to the wide geographical range covered by this project and to the range of depths where Norway lobster can be found in different mediterranean regions, the by catch recorded by the different research units differs considerably. A simplest agreed protocol was used point-scale to record the 10 commonest species (see the FIR). A detailed analysis of the accompaning species in the *Nephrops* oriented fishery is not a main objective of this project and is not feasible with the available data recorded. Then only some general remarks for the different geographic areas are presented here.

Algarve (Atlantic)

The trawl fishery oriented to *Nephrops,* off the Algarve coast is carried out on mesobathyal grounds in depths of 400 m, or more, where *Nephrops norvegicus* was caught together with the high valued red-shrimp *Aristeus antennatus*. These two species made the bulk of the catch. Another shrimp (*Parapenaeus longirostris*) was caught sometimes in large quantities, but its commercial fishery is carried out on epibathyal grounds (200 - 300 m) where *N. norvegicus* is rare. The more common commercial fish species, in order of abundance and value, were *Lophius spp.*, *Merluccius merluccius* (large specimens), *Lepidopus* caudatus and *Galeus melanostomus. Micromesistius poutassou* was by far the most abundant species, but it is considered of no commercial value on local market and is usually discarded at sea. Discard included also large number of Macrurid fish (*Himenocephalus italicus*, *Coelorhynchus coelorhynchus* and *Nezumia* spp.)

Alboran

Also in the Alboran Sea *Nephrops* fishery is restricted to bathyal grounds. The year round *Nephrops* made only 5% of the total catch. Also Pandalid shrimps (*Plesionika* sp.) never exceeded 5% of the total catch. Like in the nearby Atlantic grounds the finfish comunity was characterized by *Micromesistius poutassou* and *Galeus melanostomus*. These two species together accounted for 20 - 45 % of the whole catch, with maximum in spring. Each of the other, more valuable, commercial fish species (*M. merluccius, C. conger, Lophius* spp. and *Phycis blennoides*) made 5% of the total catch on average.

Catalan

On bathyal grounds off Barcelona *M. poutassou* was the more abundant species. It made up to 40% of the total catch in spring month when also *N. norvegicus* reached its maximum of 20%. Two other fish very common in the area are *Scilliorhinus canicula* and *Phycis blennoides* that on average made 20% of the whole catch. Fish of higher commercial values (*Merluccius merluccius, Lophius budegassa* and *Conger conger*) were caught in less quantities, rarely exceeding 5% of the total catch.

Pandalid shrimps (*Plesionika edwardsii* and *P. martia*) were the only other crustaceans caught in significant quantities. The cephalopod *Eledone cirrhosa* was caught in large quantities (up to 20% of the whole catch) only in winter months.

Ligurian

Two different depths were sampled in the Ligurian Sea during the project. On epibathyal grounds in all, but winter, season *M. poutassou* was the commonest fish. Other commercial fish common in the catch were: *Trachurus trachurus, Phycis blennoides, Galeus melastomus, Scyliorhinus canicula* and *Lepidorhombus boscii*. The high valued shrimp *Aristeus antennatus* was caught only in winter, when it ranked first in number and weight.

Catches obtained on mesobathyal grounds were characterized by non commercial Macrurid fish (*Coelorhynchus coelorhynchus, Hymenocephalus italicus*). On these trawling grounds the catch of commercial fish was rather poor with *Phycis blennoides*, few *Merluccius merluccius, Lepidorhombus boscii* and *Helicolenus dactylopterus. M. poutassou* was abundant only in summer, together with Galeus melastomus.The contribution of cephalopods (*Todarodes* sagittatus and different species of Octopodidae) to the commercial catch was marginal.

Tyrrhenian

On the *Nephrops* grounds of the Northern Tyrrhenean sea *Galeus melastomus, Phycis blennoides* and *Micromesistius poutassou* are the commonest fish associated with *Nephrops norvegicus*. These 3 species alone made 50% of thetrawl bycatch. The more valuable *Merluccius merluccius* made about 10% and the other commercial species: *Lophius piscatorius, Lepidorhombus boscii, Conger conger, Helycolenus dactylopterus* made another 10%. *Eledone cirrhosa* was by far the most abundant cephalopod and made 10 % of the bycatch. Macrurid fish dominated the discards.

Adriatic

In the Adriatic Sea *Nephrops* fishing grounds extend to the circalitoral zone. The *Nephrops fishing* ground investigated during the project is located off Ancona and has an average depth of 70 m. In these shallow grounds *N. norvegicus* is more active out of the burrow in the hours between sunset and sunrise. Therefore in the Adriatic sea all experimental fishing was carried out at night, whereas in all other investigated areas fishing was carried out at daytime. For the above reasons catch composition recorded off Ancona differs significantly from the other investigated areas and showed more marked seasonal differences. Proportion of *Nephrops* in the experimental catches ranged from a minimum of 6% in winter (low vulnerability of prawns) to a maximum of 70% in spring (mating season of prawns).

On an annual basis *Merluccius merluccius* ranked second by quantity and by value. Seasonal Maximum and minimum registered for hake are opposite to those obtained for Norway lobster. Other demersal finfish as *Trisopterus minutus capelanus*, *Mullus barbatus, Trigla lucerna, Lophius* spp. were caught in much smaller quantities and all together rarely reached 20% of the catch of commercial species. *Sepia officinalis*, that overwinters on this circalitoral nephrops ground, made up to 30% of the whole catch of commercial species in winter months, but was totally absent in summer catches.

Discards of "low priced" or "non commercial" species were characterized by the swimming crab *Liocarcinus depurator* and small pelagic fish, mostly *Sardina pilchardus*. Amount of swimming crabs frequently exceeded amount of Norway lobster.

Euboikos

In the Euboikos gulf trawling for *Nephrops norvegicus* was carried out mostly on epibathial grounds, but some tows were done also on the continental shelf in depths of 100 m. Catch composition was recorded on a semi-quantitative basis using a points scale. All the year round *Nephrops norvegicus* and *Merluccius merluccius* were the dominant species in the catch, both in terms of abundance and value. Other finfish of commercial interest were *Micromesistius poutassou, Lepidorhombus boscii, Lophius spp., Trisopterus minutus capelanus* and *Galeus melastomus*. But their importance may be considered marginal in consequence of their lower abundance and especially their low price on local markets. The discard of non commercial species was characterized by large quantities of *Gadiculus argenteus* and *Munida* spp. (Crustacea Decapoda).

In summary, in *Nephrops* grounds, the most important species for the entire Mediterranean, economically and in terms of target species, are *Merluccius merluccius* and *Nephrops norvegicus*, obviously. These two species combined maximize the economic yield of the catch, and frequently, they are the most abundant species landed by trawlers. In terms of economic importance they are followed by *Lophius spp* and *Lepidorhombus boscii*. Abundant species in number but of lesser economic importance are *Micromesistius poutassou* and *Phycis blennoides*. The by-catch in the Adriatic Sea differs somewhat in composition, except for *M. merluccius*, from the general pattern observed in the Mediterranean. This is attributed to the fact that fishing is conducted at shallower depths in this area. The by-catch of shrimps (mainly *Plesionika spp*) of the *Nephrops* fishery is of economic importance, due to its market value.

The by-catch of the *Nephrops* fishery yields high economic profits (combining abundance-weight and price). The fishery must be considered a multi-species fishery and regulatory management based solely on *Nephrops*, without properly considering the remaining species, cannot be recommended.

CONCLUSIONS

* Fishing effort over Norway lobster fishing grounds has increased to a large amount in recent years due to an increase in engine power and improvements in mechanical and electronical (positioning, detection and control of the catch) technologies.

* Official records are deficient and inaccurate in some countries, and disperse in others, invalidating a good quantitative fisheries management.

* Three well differentiated areas appear in the Mediterranean (by fishing and exploitation practices): a) the western and central Mediterranean, including the Atlantic Iberian stocks, the Mediterranean Spanish coast, and the western Italian coast, b) the Adriatic area, and c) the Greek area which can be made extensive to the whole Egean sea.

* Engine power data can be misleading. Spain, Portugal and Greece have larger trawls and higher engine power when compared to Italy.

* A fisheries management system established to monitor and regulate Norway lobster fisheries in the Mediterranean would have to take into account the three types of structures encountered and the multiespecific character of this fishery.

REFERENCES

ARTEGIANI, A., P. CURZI, C. FROGLIA, R. LENAZ, L. TOMADIN. (1979). Primi resultati delle indagini sui fattori bilogici, oceanografici e sedimentologici che condicionano la distribuzione degli scampi in Adriatico. Conv. Scien. Naz. P.F. Oceanogr. e Fondi Mar.: 229-241

BAILEY, N. (1986). Why does the size of *Nephrops* vary ?. Scotish Fisheries Bulletin, 49:31-36

BRIGGS, R.P. 1987. A review of the factors influencing landing size in the northern *Nephrops* fishery. ICES. CM/K:34, 24 pp

CHAPMAN, C.J. AND N. BAILEY. 1987. Biological research on fish and shellfish stocks. Recent progress in Norway lobster research. . Fishing New Books. London.: 99-111.

FROGLIA, C. 1972.- Osservazioni sulle variazioni di cattura dello scampo, *Nephrops norvegcius* (l.) in riferimento all'etologia de alla biologia della specie. Quad. Lab. Technol della Pesca.1(4):83-99

MAIN, J and G.L. SANGSTER. (1985). The behaviour of the Norway lobster, *Nephrops norvegcicus* (L.) during trawling. Scottish fisheries Research, Rep. 34: 1-23

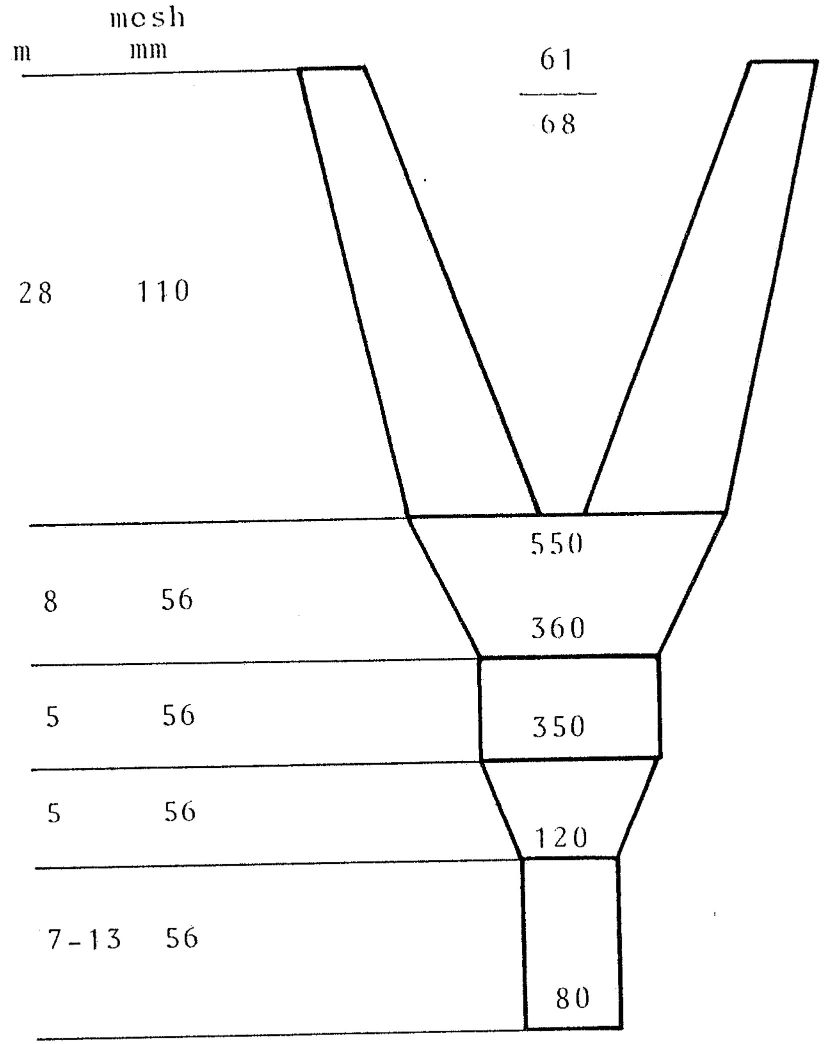
NEWLAND, P.L. and C.J. Chapman (1989). The swimming and orientation behaviour of the Norway lobster, *Nephrops norvegcicus* (L.), in relation to trawling. fisheries Research, 8: 63-80

SARDÀ, F. (1995). A review (1967-1990) of some aspects of the life history of *Nephrops norvegcius.* ICES. Sci. Symp. 199: 78-88.

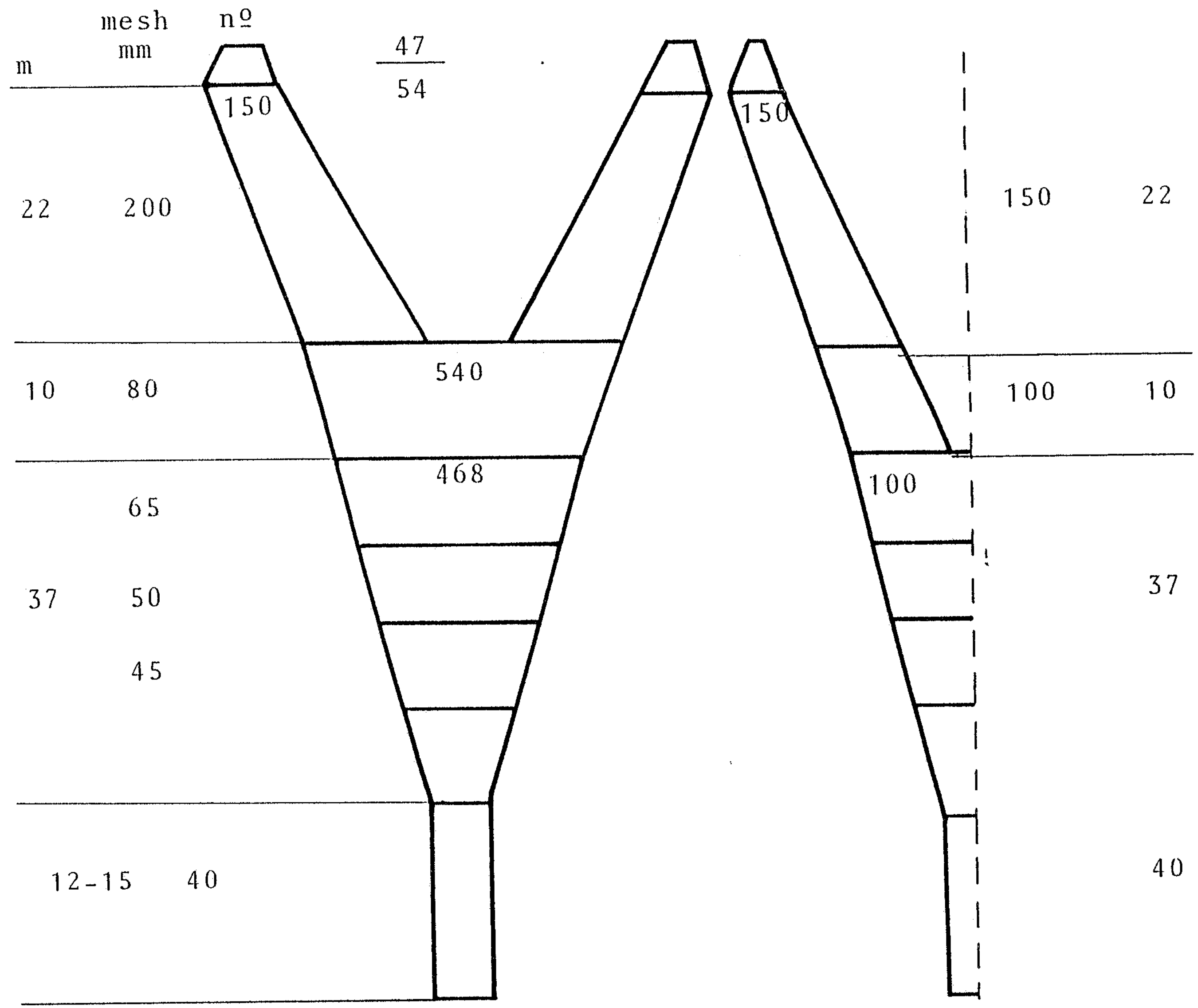
THOMAS, H.J. and J.M. FIGUEIREDO (1965). Seasonal variations in the catch composition of the Norway lobster,*Nephrops norvegicus* (L.) around Scotland. J. Cons. perm. Explor. Mer, 30(1):75-85.

TULLY, O. AND J.P. HILLIS. 1995. Causes and spatial scales of variability in population structure of *Nephrops norvegicus* (L.) in the Irish Sea. Fisheries Research, 21: 329-347

Annex



ALGARVE



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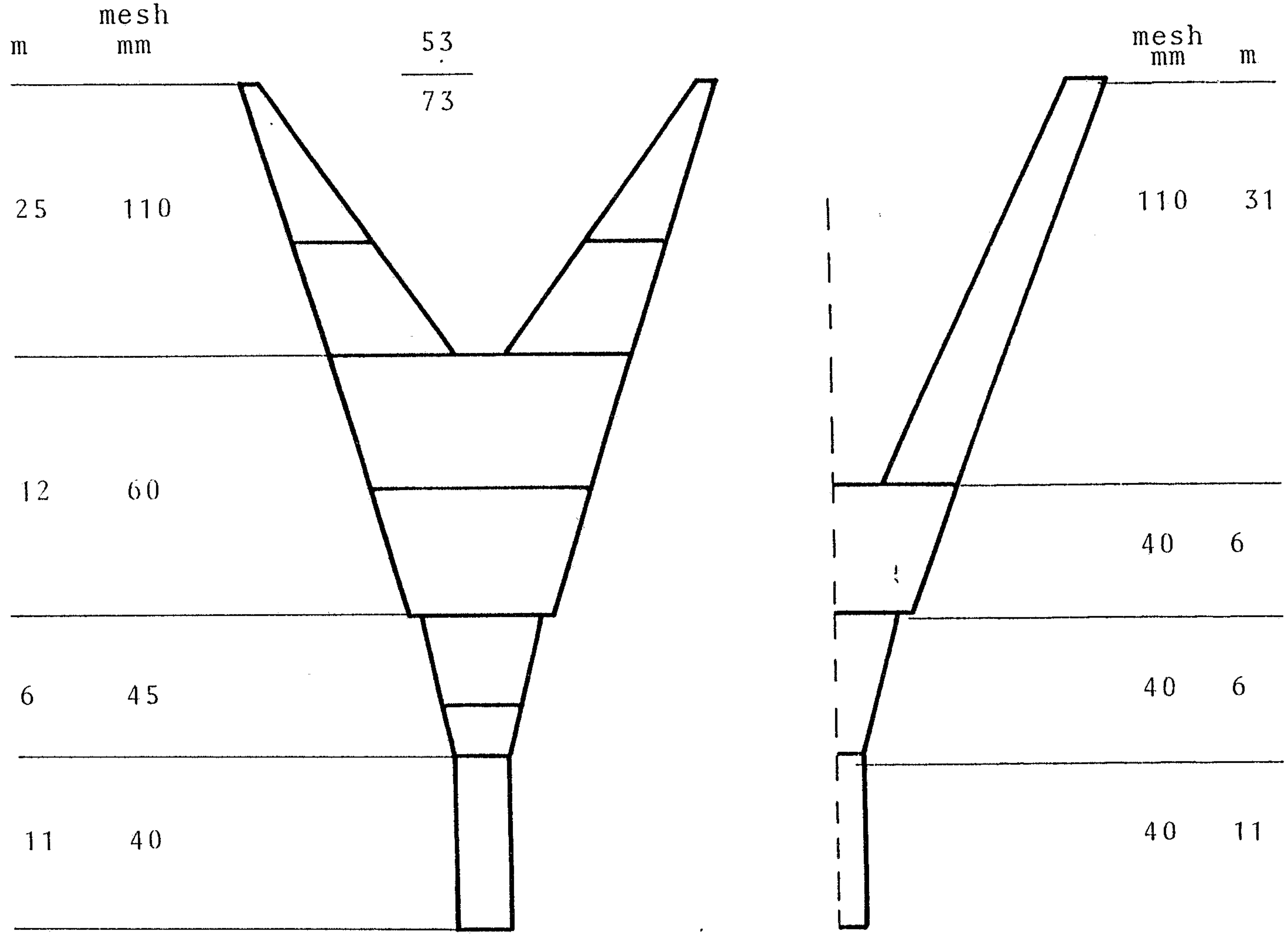
CATALAN



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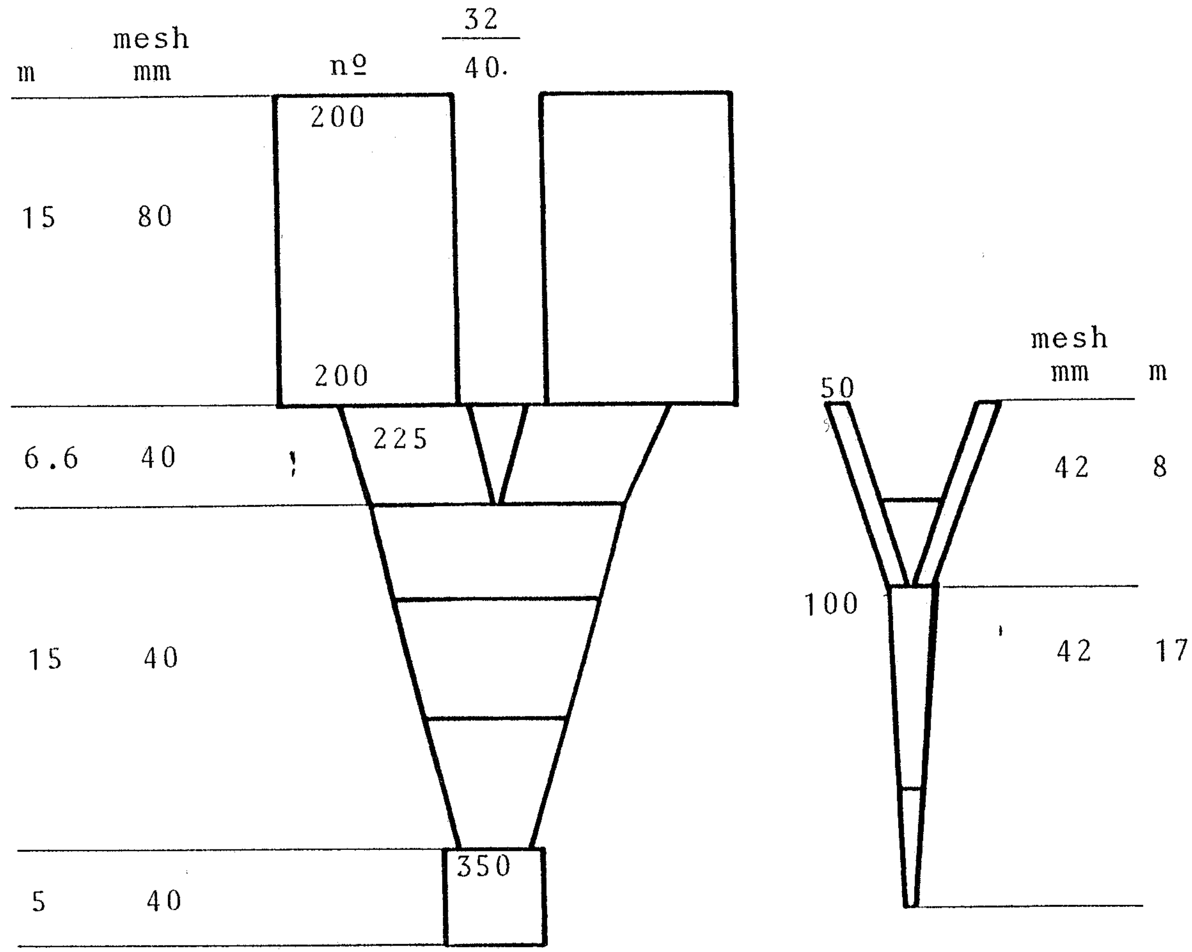
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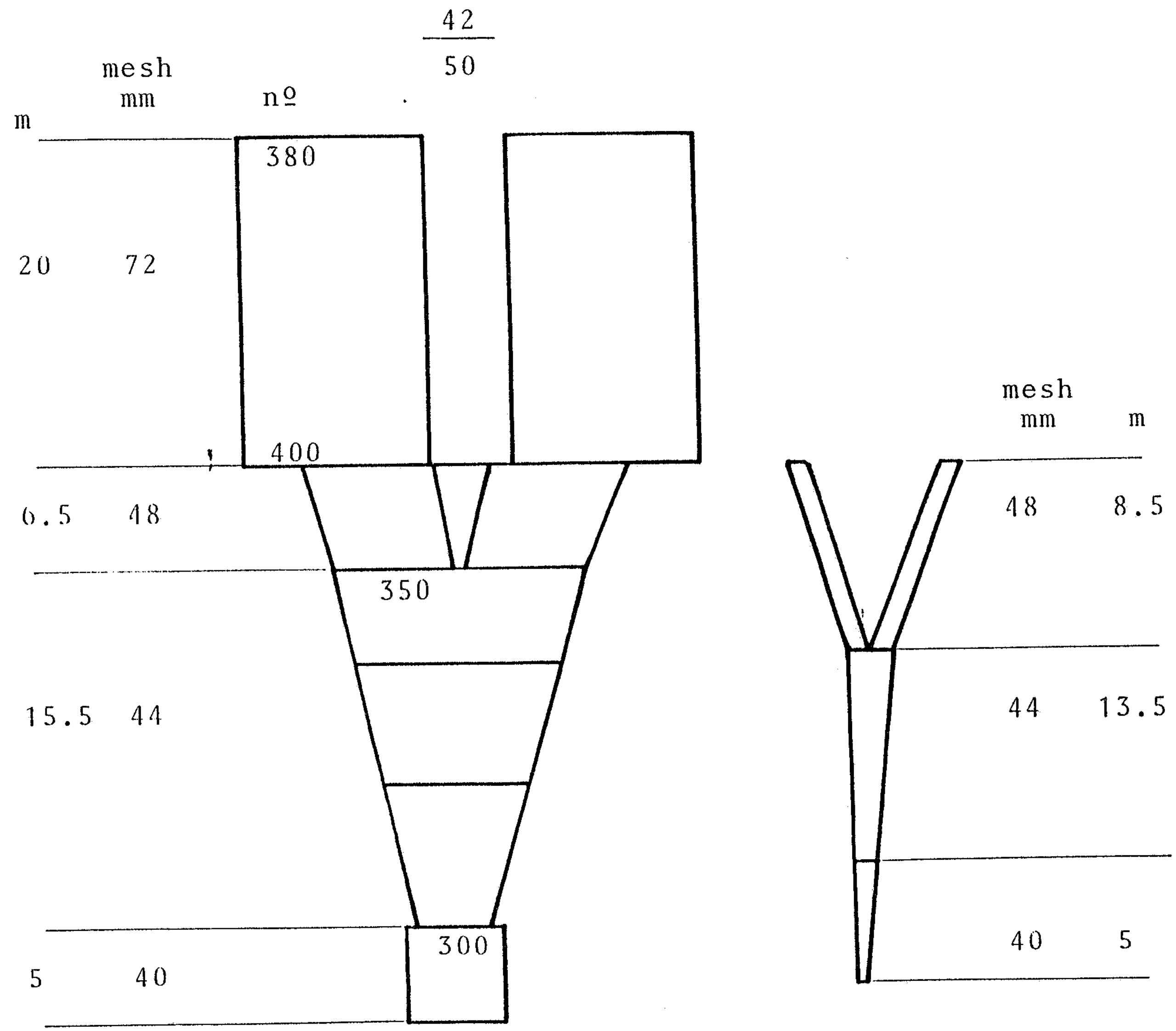

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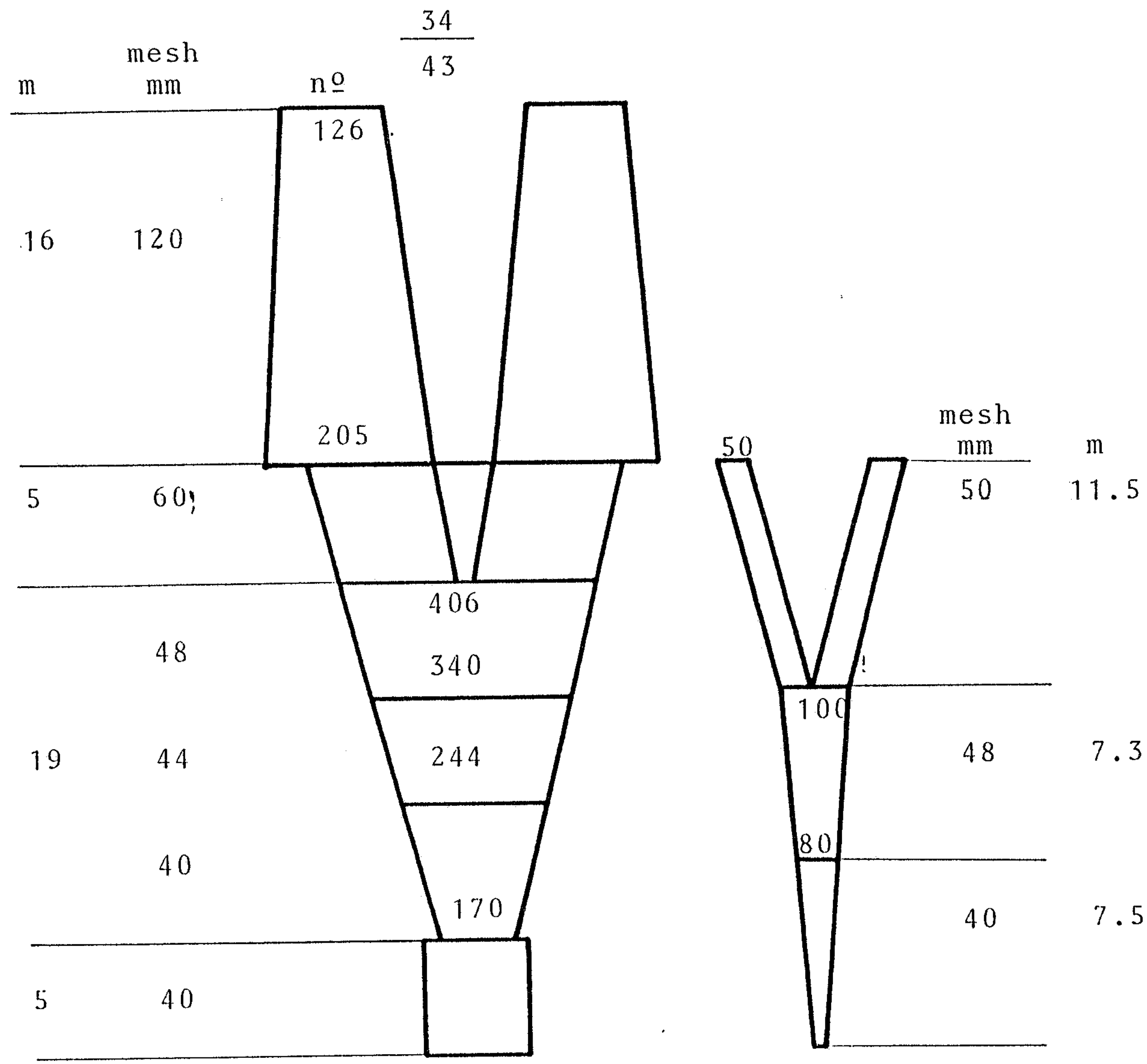
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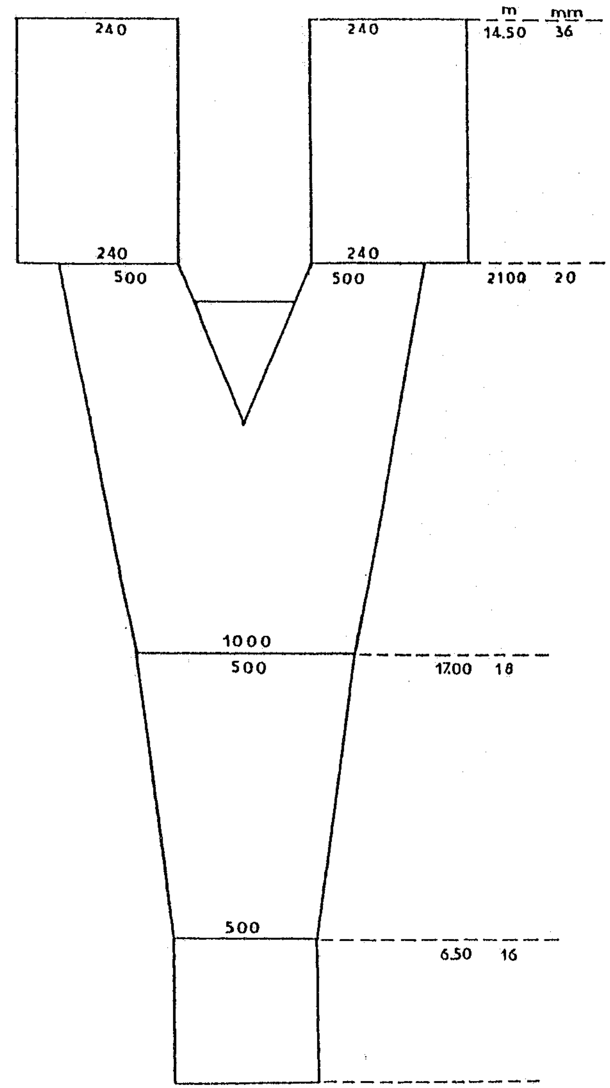
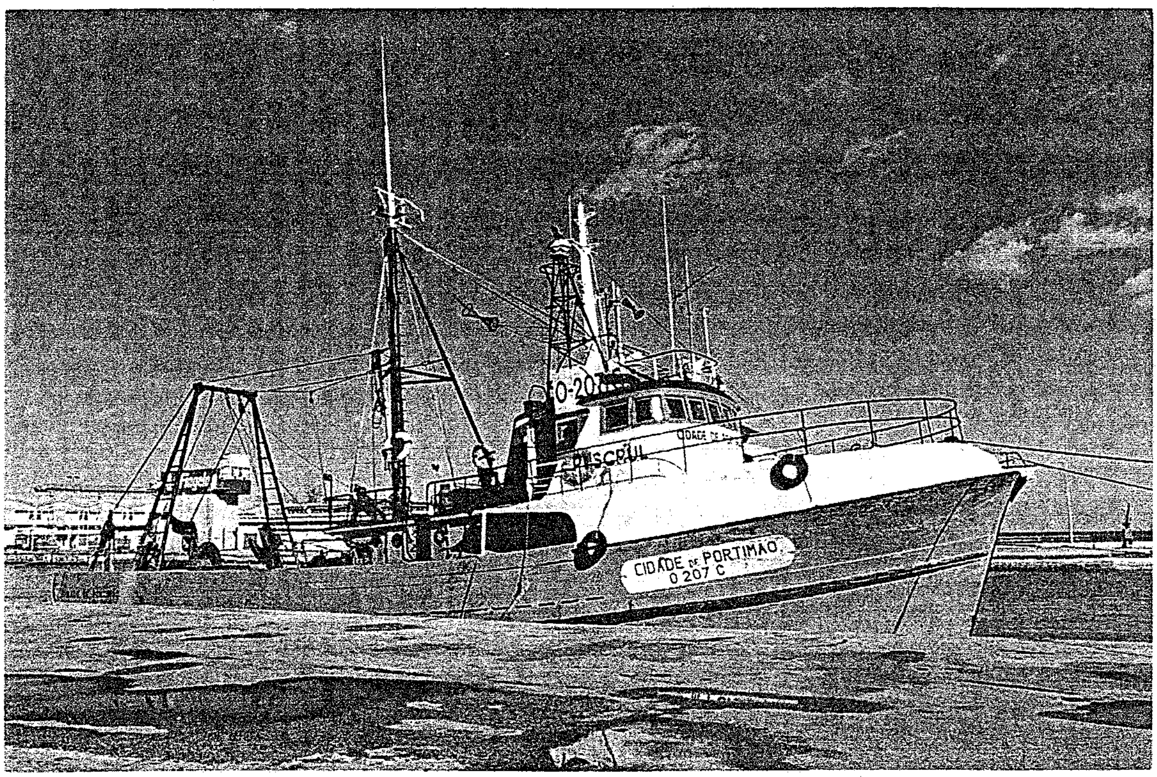
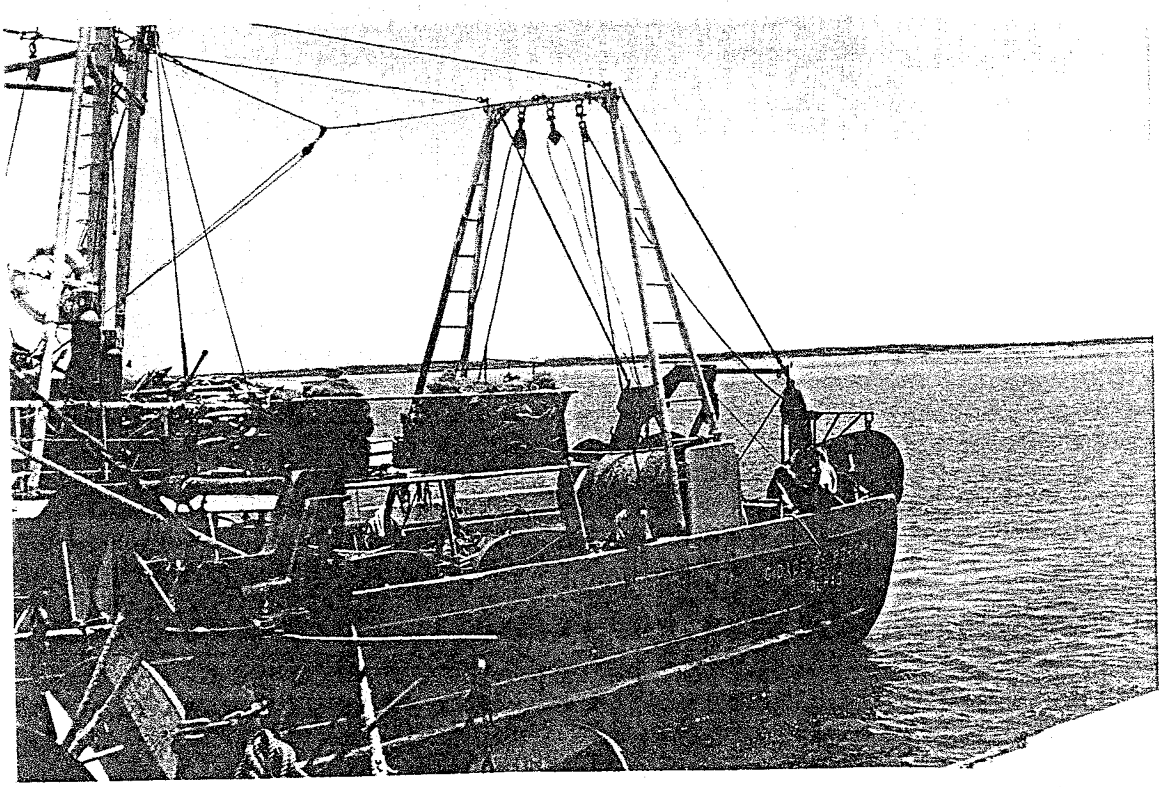


EUBOIKOS

Figure - Picture of the trawler 'Cidade de Portimão' where the fishing for this project was done. Courtesy of the fishing company 'PESCRUL', Olhão, Algarve, Portugal.



ALGARVE



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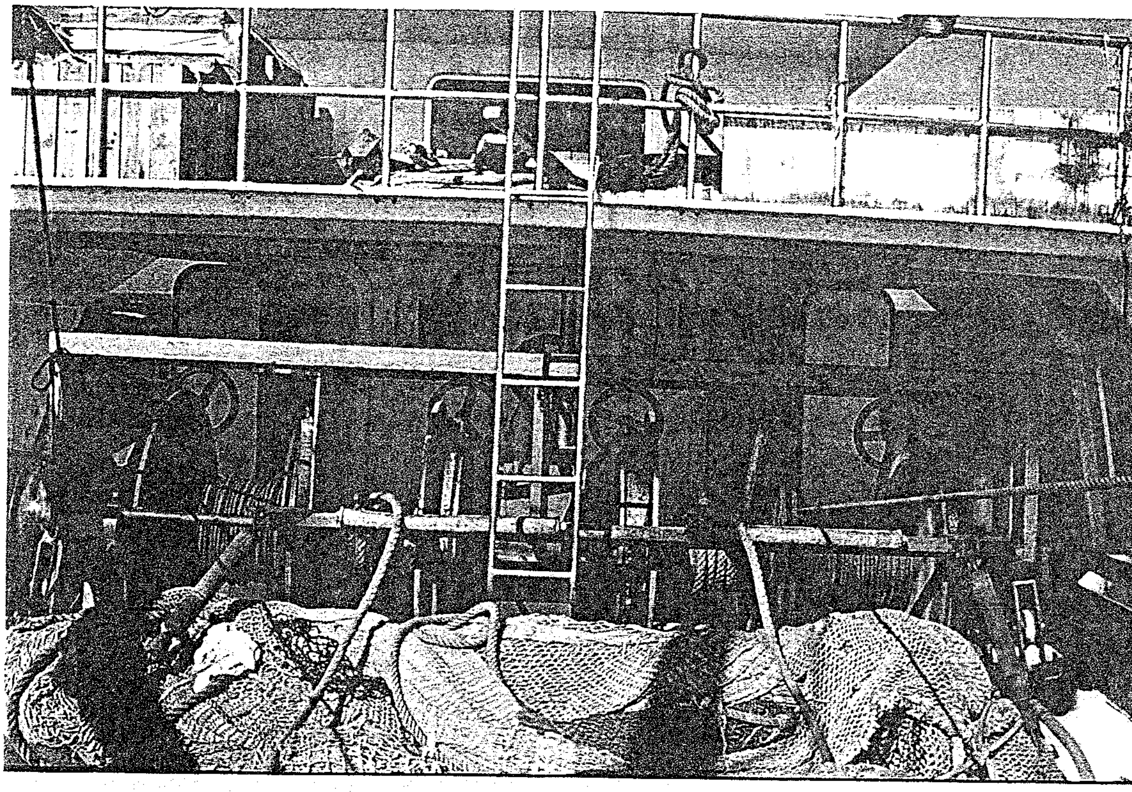

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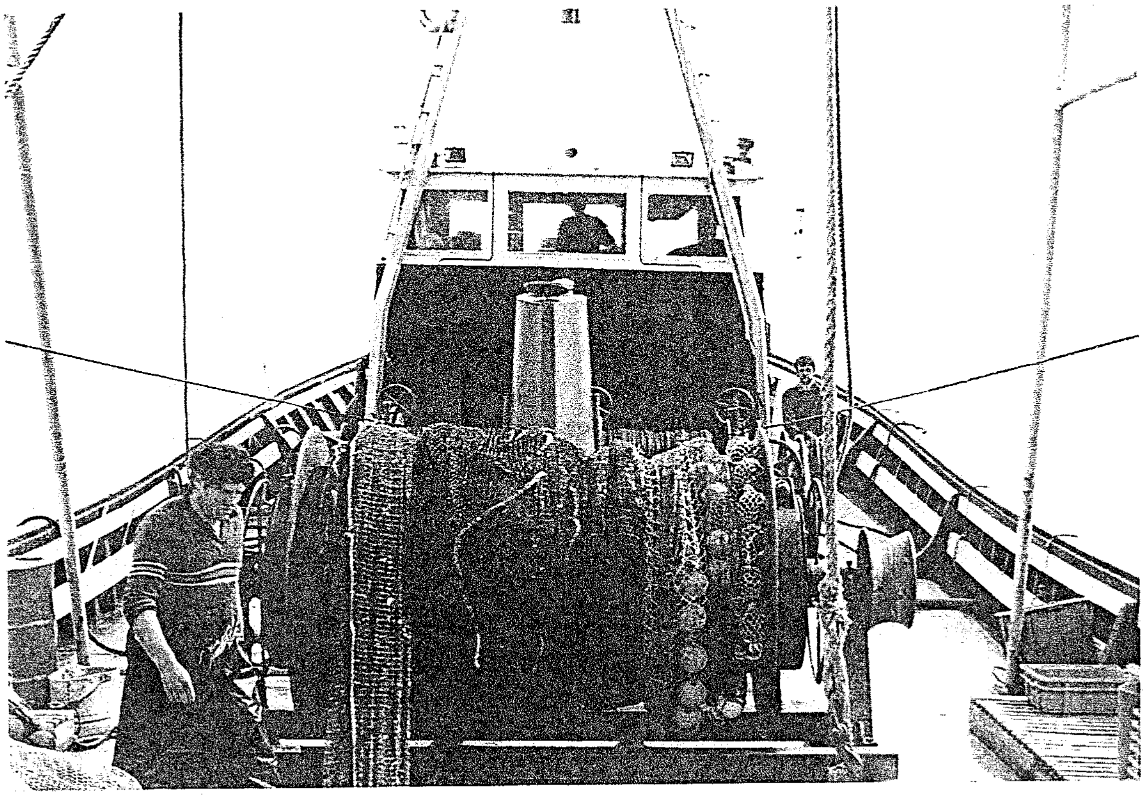

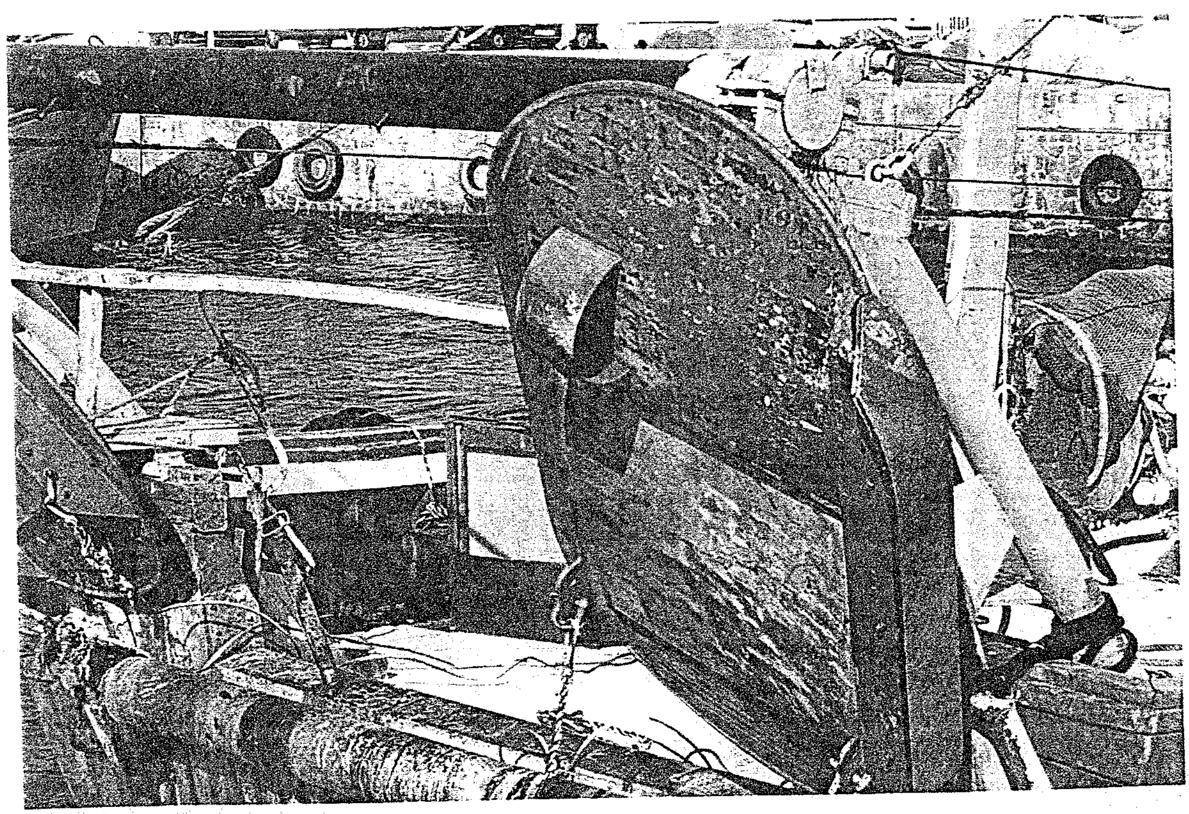

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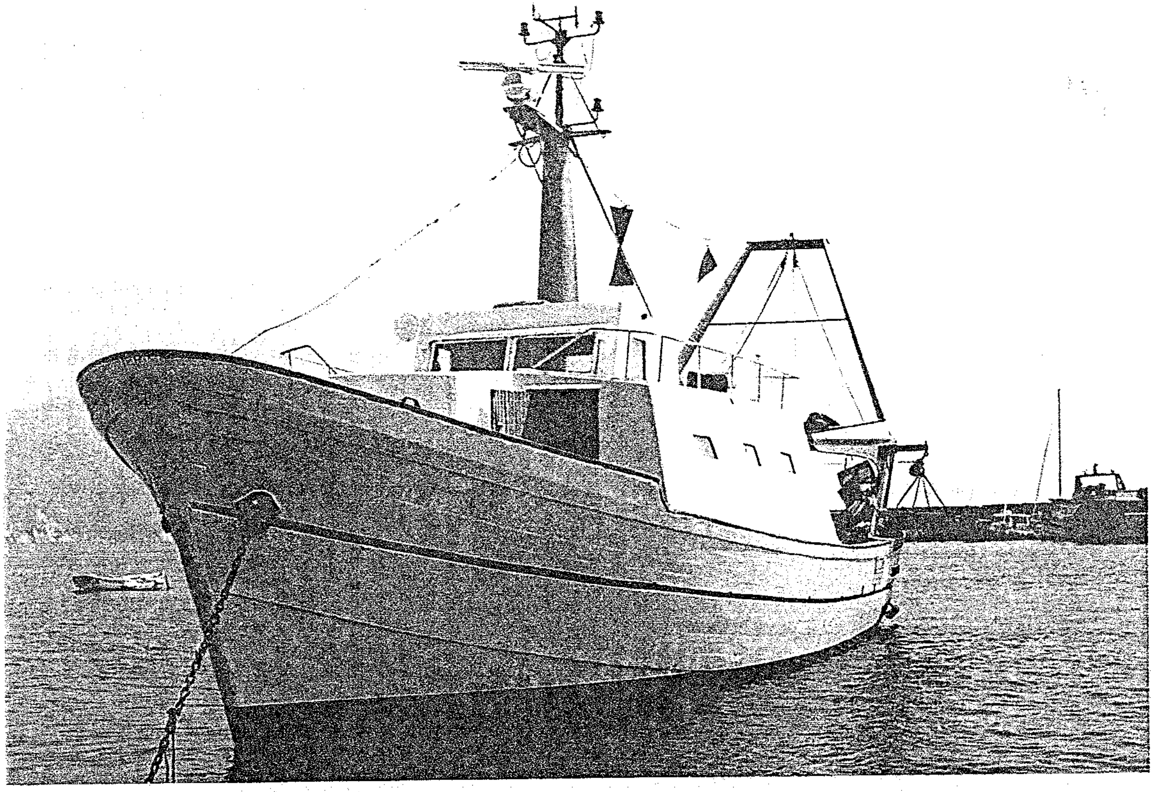

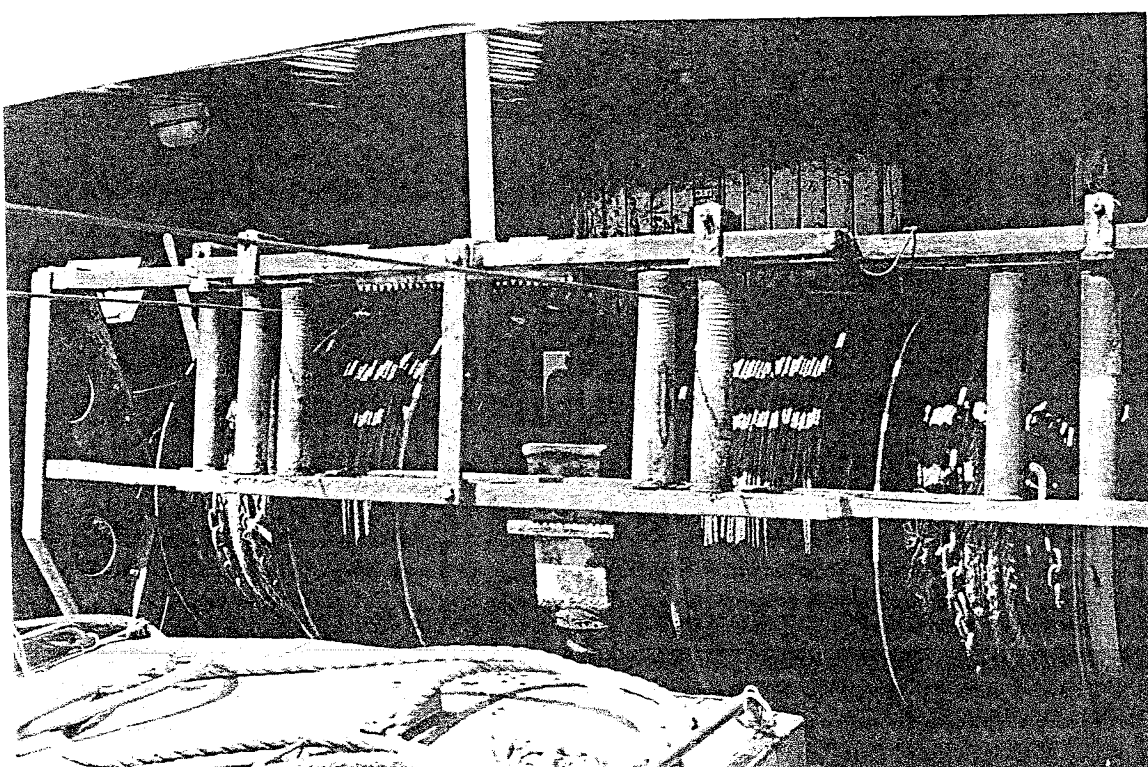

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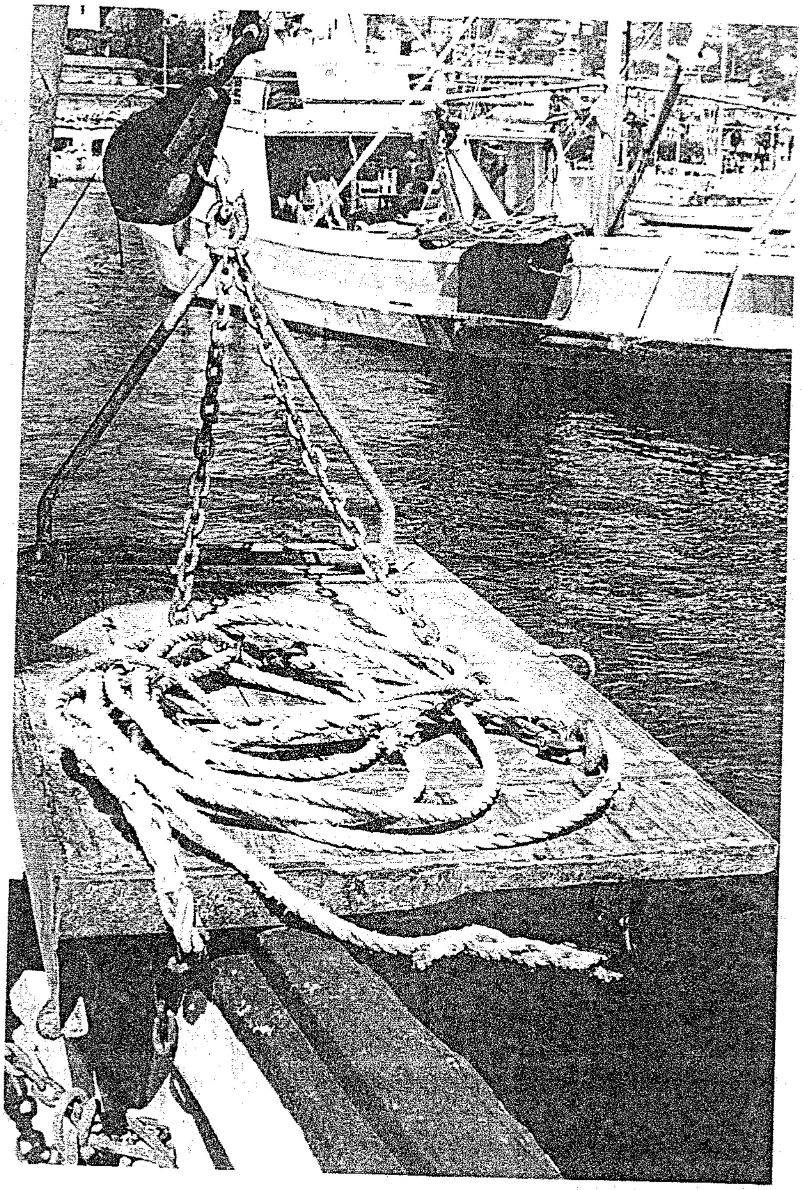

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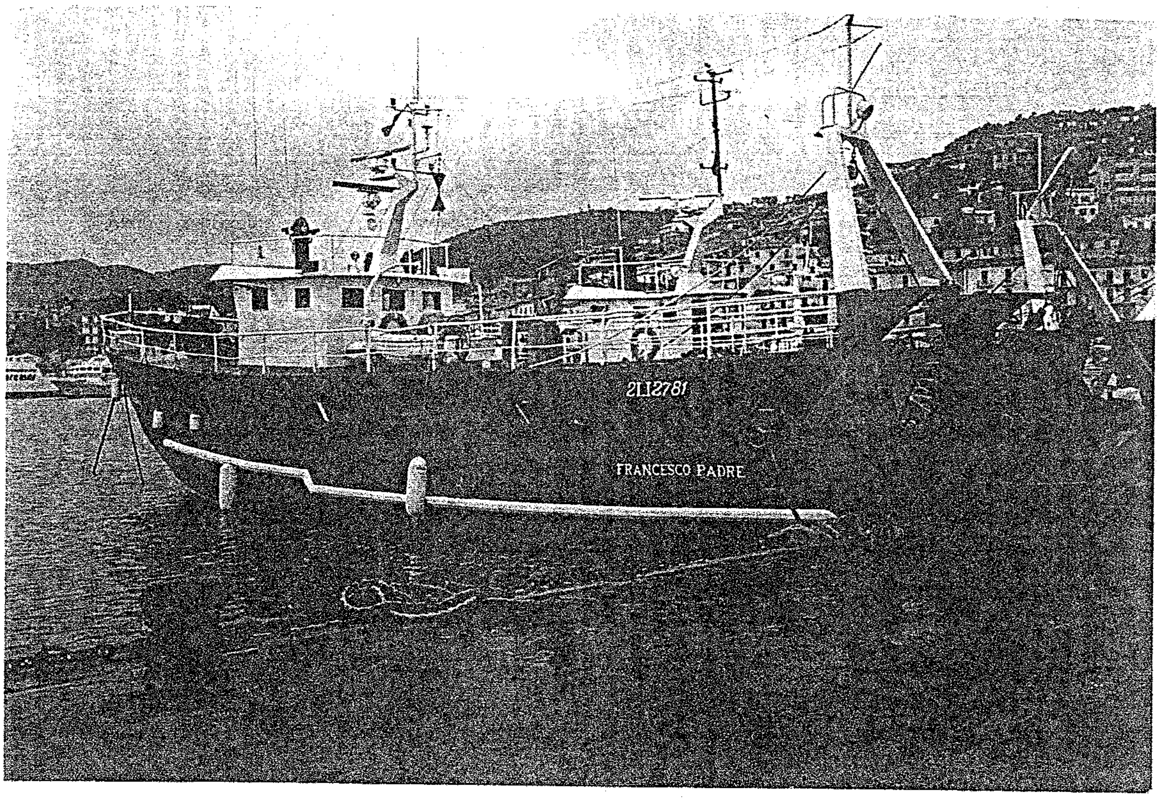

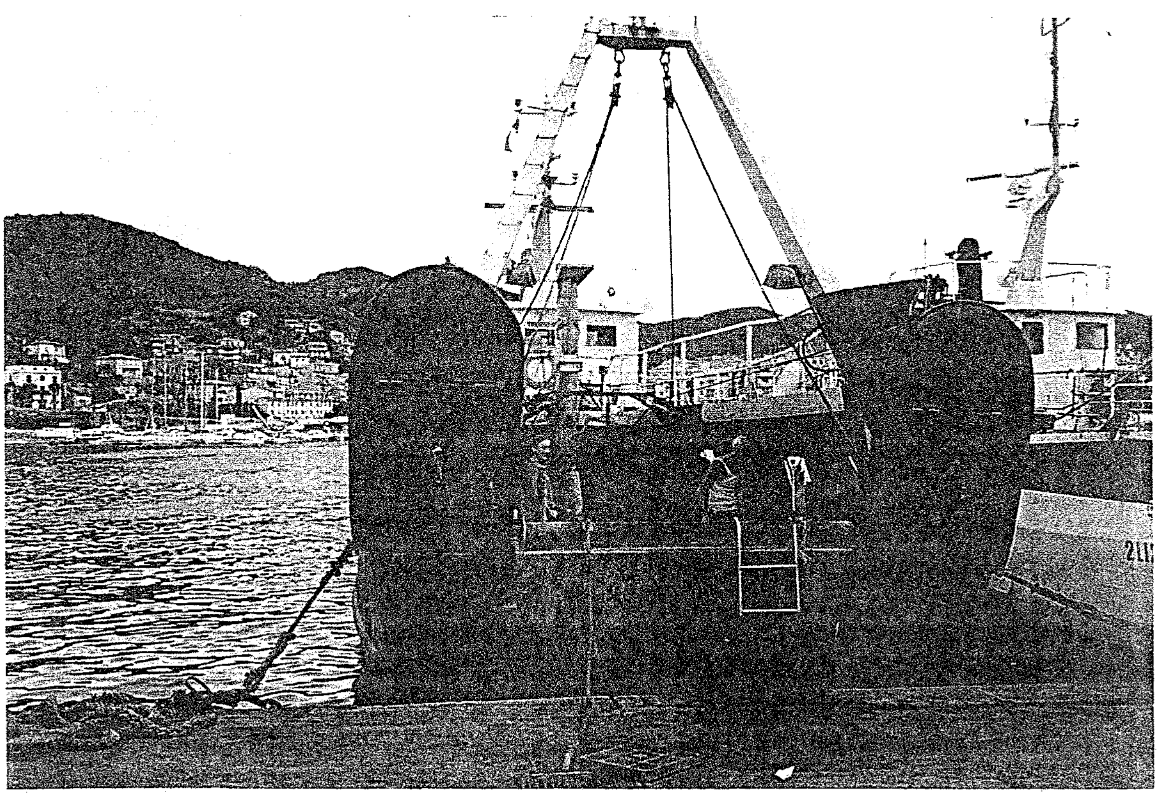

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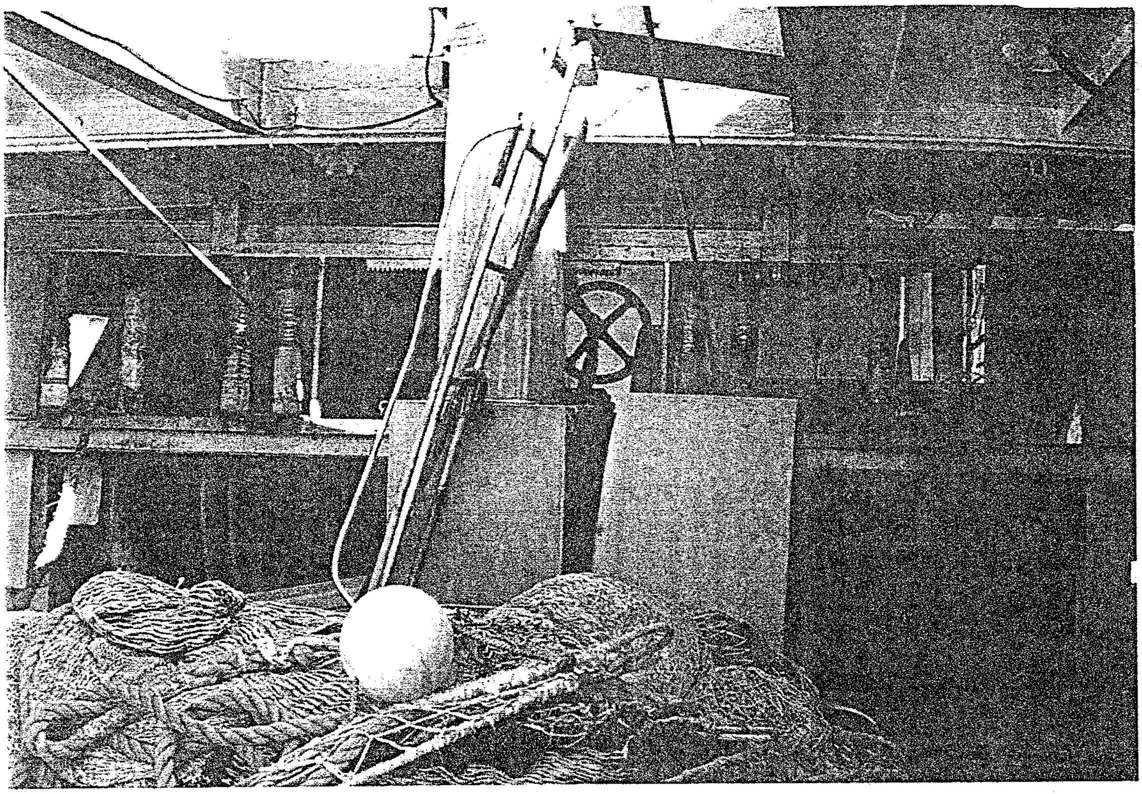

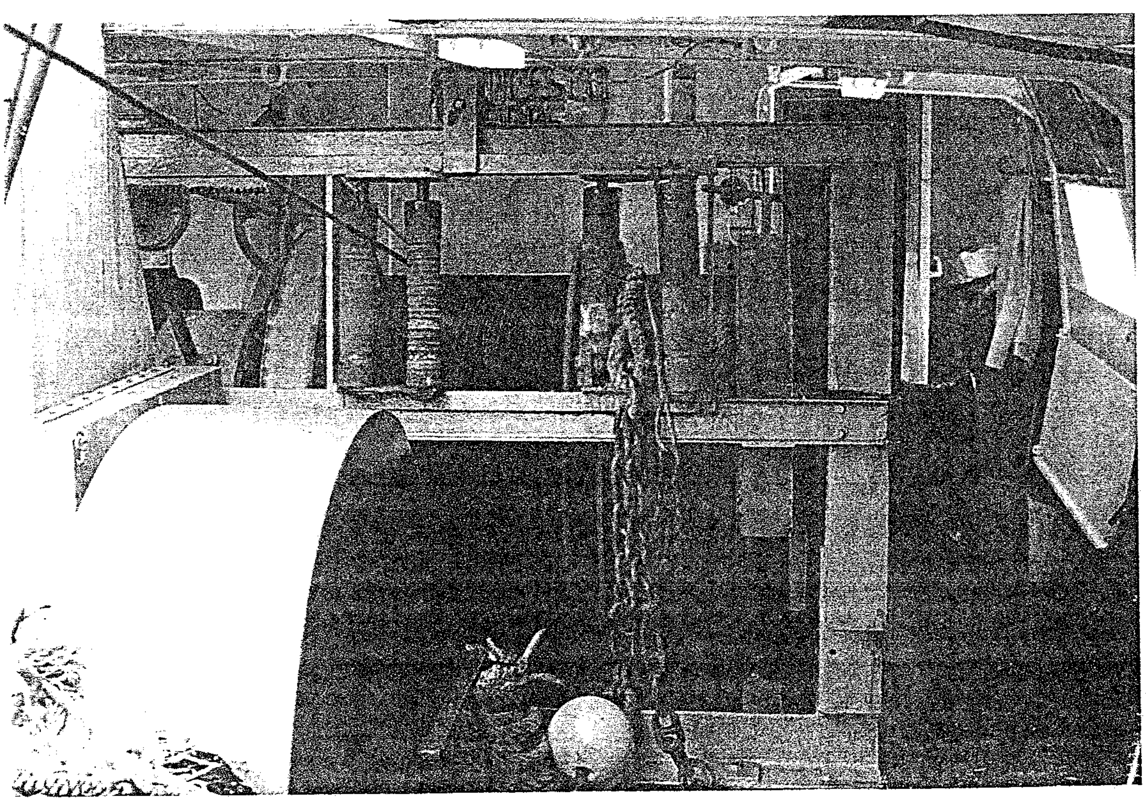

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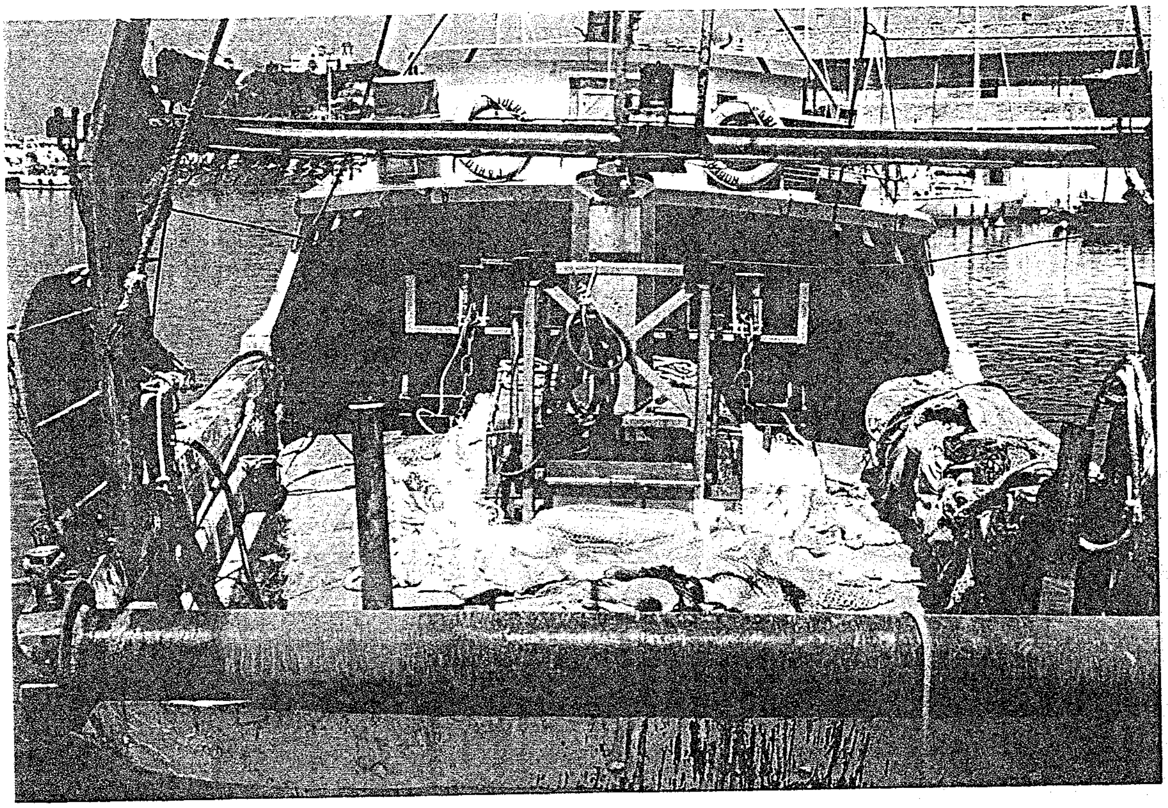

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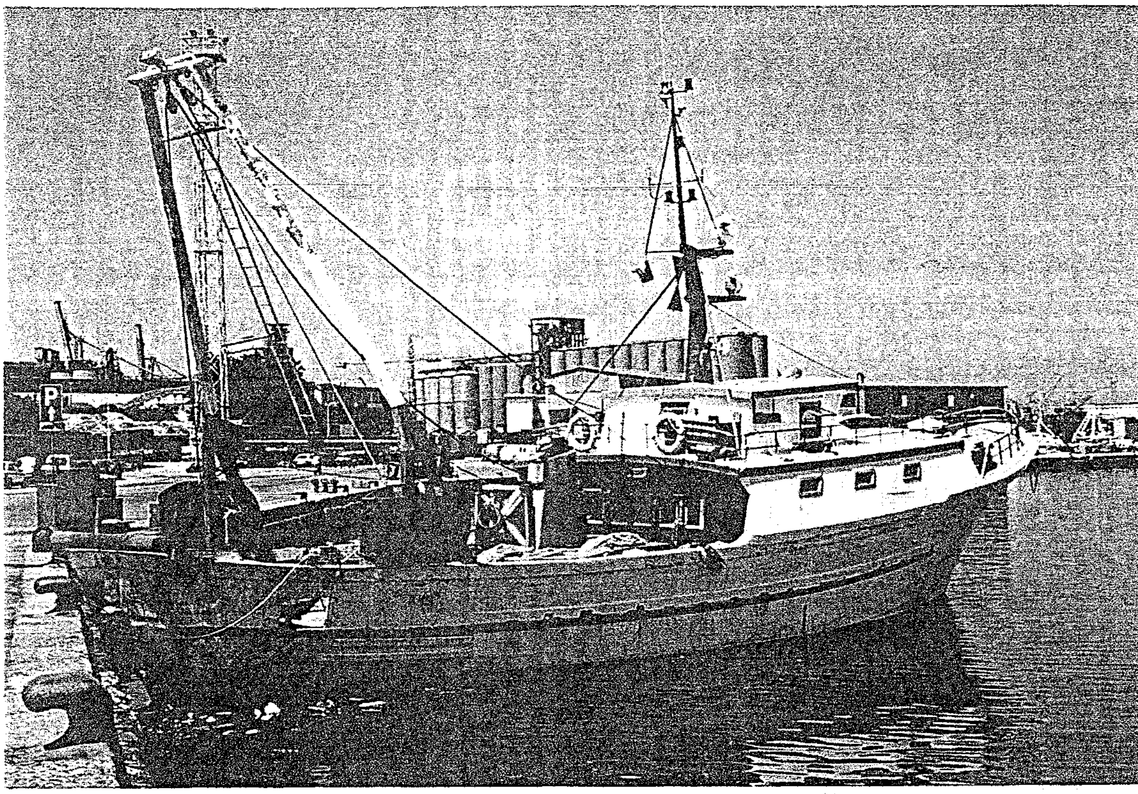

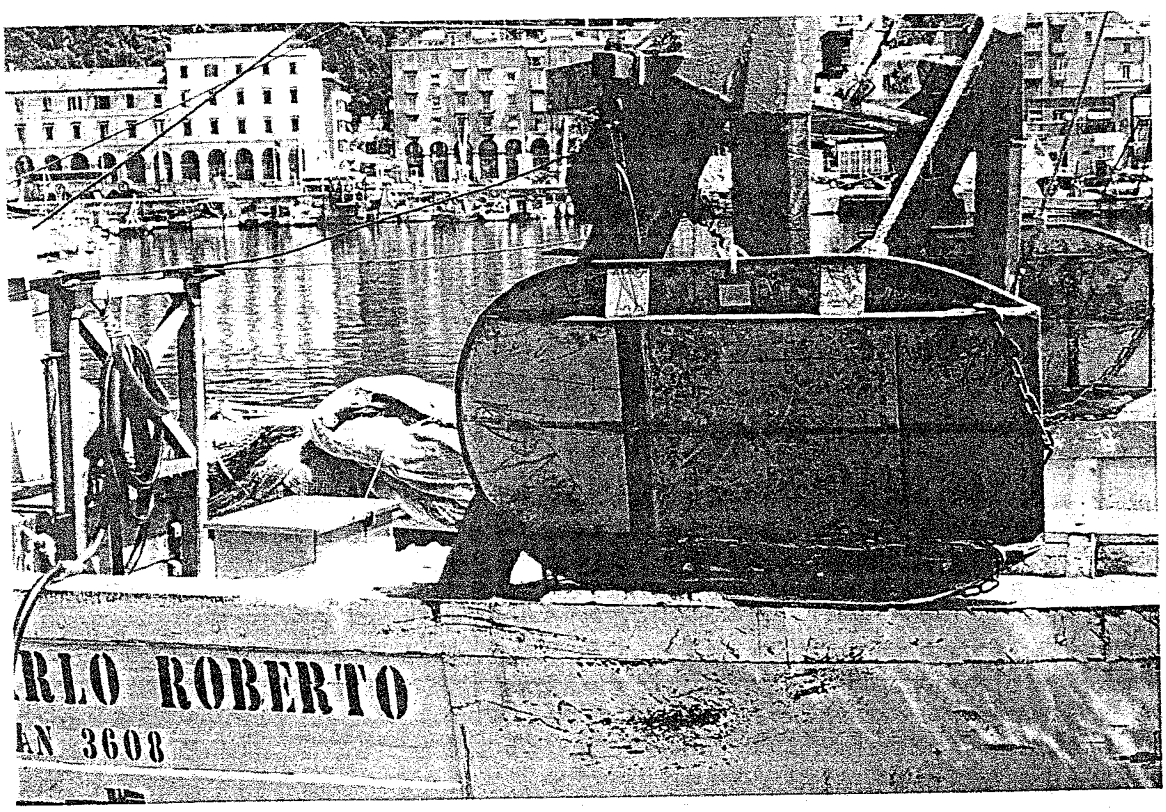

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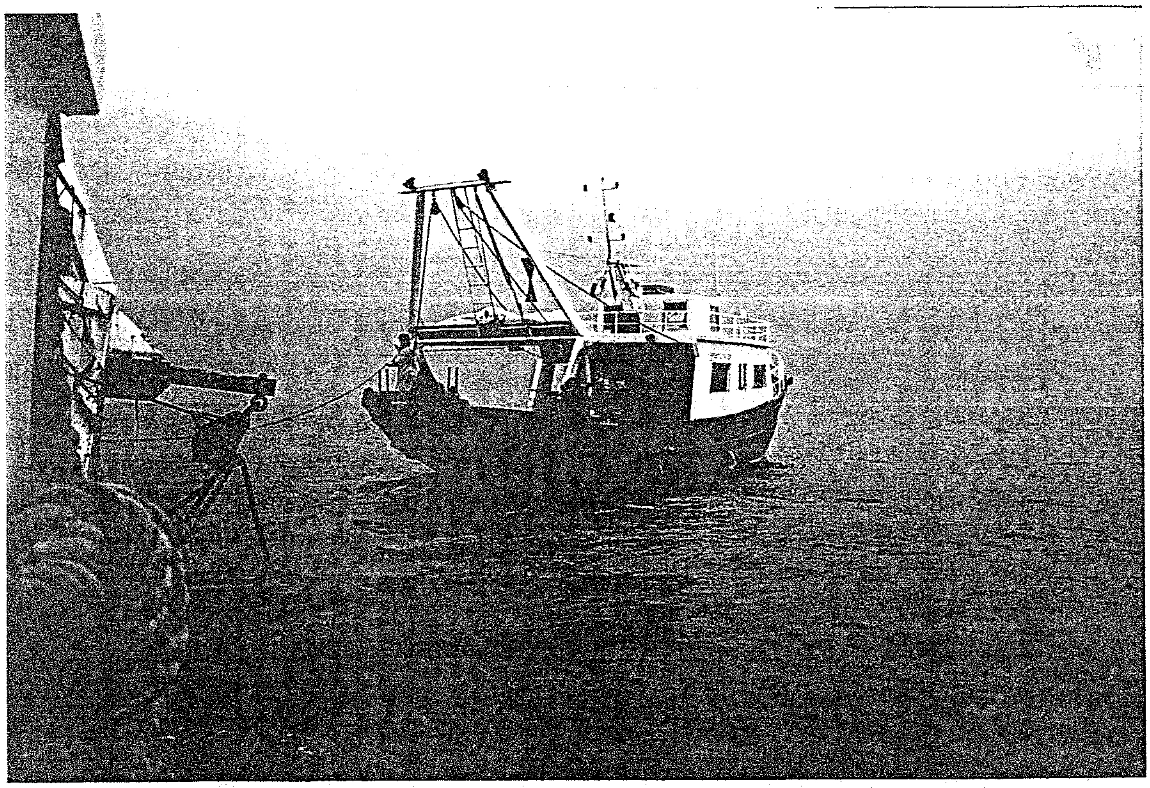
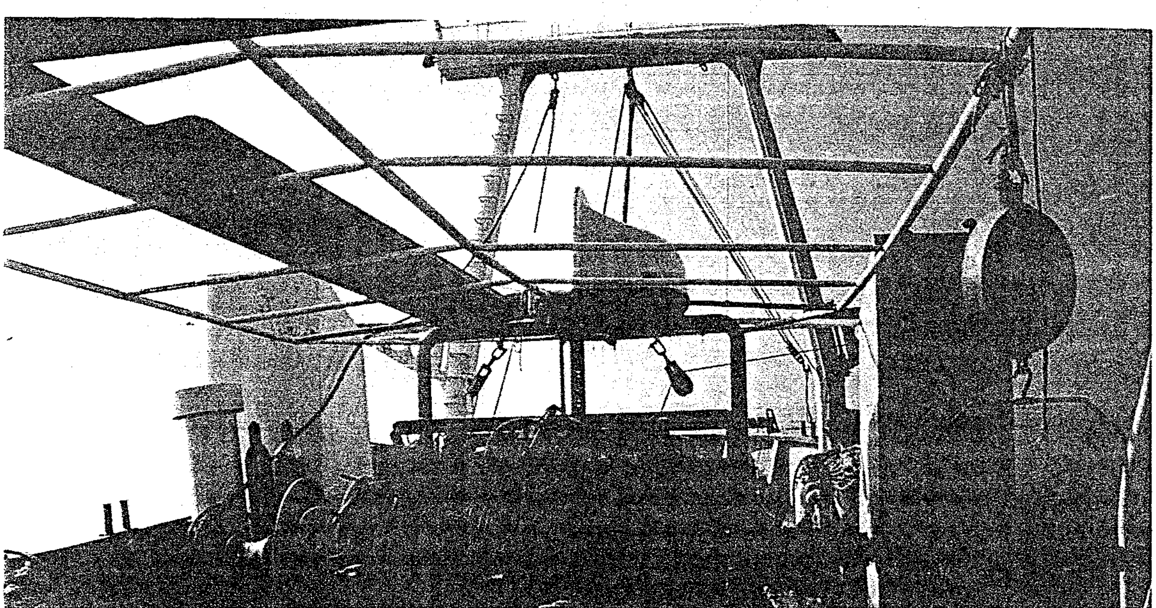
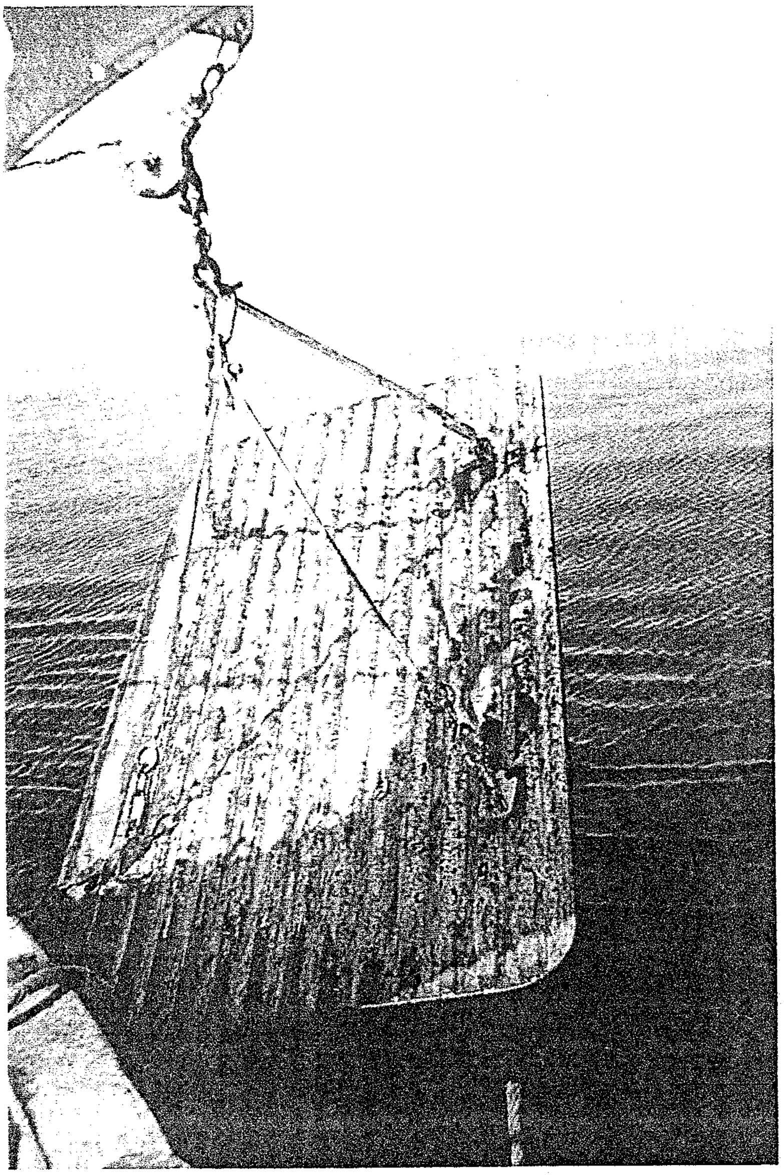
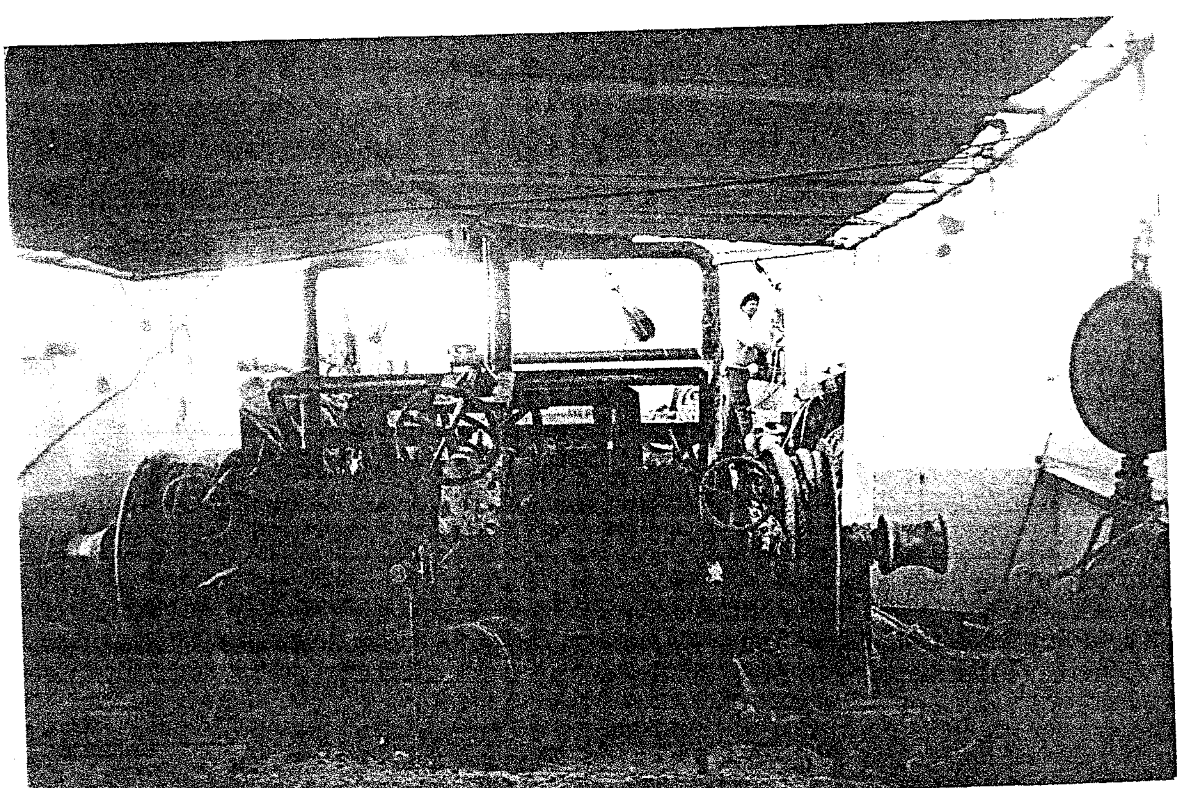




EUBOIKOS





EUBOIKOS

SELECTIVITY

INTRODUCTION

Nephrops norvegicus is one of the most commercially important product of the multi-species fisheries exercised in the Mediterranean waters. This species is mainly fished by trawlers. In the framework of this project, trawl cod-end selectivity was studied for *N. norvegicus* using diamond meshes of 16 mm, 20 mm, 24 mm and 26 mm. In the North Euboikos Gulf (Greece), the selected study area, about 30 t of *N. norvegicus* are fished by the trawlers every year (ETANAL data, 1990-1994) during a strict fishing period of only five months (January-March and November-December); this quantity corresponds to about 3.8% of the total trawl landings in the area.

Studies on the trawl selectivity of *N. norvegicus* in the Atlantic ocean are numerous and every year the I.C.E.S. presents comparative data from the different countries (e.g. ANON., 1991). Although some studies on the biology of this species in the Greek waters exist (MYTILINEOU et al., 1992; MYTILINEOU et al., 1993), only one work (STERGIOU et al., 1996) on the trawl selectivity of the species is available.

The legal mesh size for the Greek trawl fisheries is until now 14 mm. However, the 16 mm one is often used in *Nephrops* fisheries and for hauls on sandy and maddy bottoms. The 20 mm mesh size was used in the present study because it is actually legislated by the E.U. as the minimum size for the trawl cod-end. Two larger mesh sizes (24 mm and 26 mm) have been also used for reasons of comparison.

MATERIAL AND METHODS

The sampling was conducted in the North Euboikos Gulf (eastern continental Greece) during May 1995 (Fig.1, see chapter INTRODUCTION) using a commercial trawler (26 m length) equipped with two engines (250 HP each one).

The cover cod-end method (POPE et al., 1975) was applied in order to study trawl cod-end selectivity for *N. norvegicus*. The following sizes of diamond mesh (measured from knot to knot) were used for the cod end: 16 mm, 20 mm, 24 mm and 26 mm (corresponding to the stretched mesh sizes: 32 mm, 40 mm, 48 mm and 52 mm respectively). The cover net was made of 10 mm diamond meshes. The material of the four cod-ends was braided polyethilene with knots, whereas that of the cover was monofilament nylon without knots. The different cod-ends were attached to the same trawl net. The cover was attached to the cod-end and it was 2 m wider and 2 m longer in order to permit good water circulation and avoid overlapping of the nets. Three experimental stations considered as *Nephrops* grounds have been selected for the study. Their depth ranged from 100 to 350 m of depth. Two hauls were carried out in each station; the duration of each one lasted 1 hour. The towing speed was 2.9 knots (standard in the commercial trawl fisheries) for all cruises.

The carapace length (CL) was measured to the nearest mm for all specimens caught. For the analysis, length data from all hauls and stations were combined and a mean selectivity was estimated from the total of the data (SPARRE & VENENA, 1992). For the selectivity study, L_{50}, L_{25}, and L_{75}, corresponding to the length at which 50%, 25% and 75% of individuals entering the gear are retained, were estimated. The Selection range (Sr) = $L_{75} - L_{25}$ and the Selection factor (Sf) = L_{50} / mesh size were also determined.

FRYER's (1991) logistic function for a simple haul was used in order to estimate the selectivity parameters of the different cod-ends. Selectivity of a net is determined by the relationship between the probability p of a fish entering the cod-end and the fish length L (HOLDEN, 1971). This is described by the relationship:

$$p = \frac{\exp(v_1+v_2*L)}{1+\exp(v_1+v_2*L)}$$

which can be transformed to a linear logistic function by a log transformation: log (p/1-p) = v_1+v_2*L (FRYER, 1991). The parameters v_1 (representing the intercept) and v_2 (representing the slope of the curve) were estimated by the maximum likelihood method, assuming that the retained in the cod-end fish have a binomial distribution. For the estimation of the selectivity parameters based on this model, a DOS algorithm for PC developed in our laboratory by G. Petrakis, has been used.

RESULTS

The length frequency distributions of the retained individuals presented one mode between 34-36 mm (Fig. 2.b). The proportions of those individuals retained by the 16 mm, 20 mm, 24 mm and 26 mm cod-ends were 99.6%, 97.5%, 95.6% and 94.3%, respectively; this indicated a decrease with the mesh size, although no remarkable differences were found. On the other hand, the distributions of individuals which escaped did not show clear modes; however their length and number increased with the mesh size (Fig. 2.c). The main bulk of escapes was found until 24 mm for the mesh of 16 mm, 27 mm for the mesh of 20 mm, 29 mm for the mesh of 24 mm and 32 mm for the mesh of 26 mm.

The estimation of the selectivity parameters gave the values presented in Fig. 3 and in Table 1. The L_{50} values increased with the mesh size (17.8 mm, 20.1 mm and 20.5 mm for the 20 mm, 24 mm and 26 mm cod-ends respectively), although for the two biggest meshes they were found very close. In contrast with the other nets, the selectivity parameters of the 16mm cod-end could not be estimated because of the low proportion of specimens escaping from this net. The deviance statistic Ä and x^2 values indicated that the data were not overdispersed (Table 1).

The Selection factor and the Selection range estimates are also presented in Table 1. It is evident that the selection factor was decreasing, whereas the Selection range was increasing with mesh size. Using the selection factor of the 20 mm mesh size, an approximate estimation for the L_{50} value of the 16 mm mesh size was done and this was found to be 14.2 mm.

DISCUSSION AND CONCLUSIONS

The results of the present work showed that the proportions of the retained individuals by the different cod-ends did not present great differences between them. However, it was obvious that the greater the mesh size was the lower was the proportion of the retained individuals. Moreover, differences existed in the structure of the length distribution of the escapes.

The 16 mm mesh size was not selective since almost all individuals were retained. Furthermore, visual analysis of the by-catch, showed that for the most commercially important species (i.e. *Merluccius merluccius,, Eutrigla gurnardus, Lepidorhombus bosci, Lophius piscatorius, Lophius budegassa etc)* the 16 mm mesh was not selective. It is very clear that the use of this mesh size should be prohibited as well as that of the 14mm actually used in the Greek fishery.

Comparing the L_{50} estimates for the different nets, the 24 mm and 26 mm mesh sizes were found to be more selective than the 20 mm. STERGIOU et al. (1996) found for the same area a higher value (L_{50} = 22.82mm) for the 20 mm mesh size than the one found in the present work; however, the authors pointed out that this value may be overestimated. The L_{50} values for *N. norvegicus,* mentioned in the bibliography, (e.g. BRIGGS, 1986; SARDA et al., 1993) are found to be from 16 mm to 50 mm CL for streched mesh sizes of 40 mm to 80 mm. Our results lie within this range of values. This is also valid for the estimated values of the Selection factor of the present work in comparison to those reported in the bibliography.

In all cases the estimated L_{50} values were considerably lower than the length at first maturity of the species in the study area (33 mm, see chapter 3). Furthermore, the estimated values of L_{25} were also considerably lower than the minimum landing size (20 mm), legislated by the E.U. for *N. norvegicus.* From our work it was obvious that none of the used mesh sizes gave results adequate to the *N. norvegicus* biology and morphology. It is known that *Nephrops* has a shallow ogive and a wide selection range (BRIGGS, 1986); that implies a research for a special gear taking in account the *Nephrops* characteristics as well as the by-catch composition. However, it could be suggested for the time being that a net of more than 20mm mesh size should be applied in *Nephrops* fisheries.

In conclusion, according to the results of the present work:

- A net of more than 20 mm mesh size should be applied in *Nephrops* fishery
- A new gear should be found for *Nephrops* multispecies fishery, selective not only for the *Nephrops* specimens but also for the commercial by-catch species.

REFERENCES

ANONYMUS.-1991. Working group on *Nephrops* stocks. ICES. C.M. 1991/Assess: II, 132pp.

FRYER, R.J.-1991. A model of between-haul variation in selectivity. ICES J. Mar. Sci., 48: 281-290.

HOLDEN, M. (ed.)-1971. Report of the ICES/ICNAF working groups on selectivity analysis. Coop. Res. Rep. Cons. Int. Explor. Mer. A, 25.

MYTILINEOU, CH., A. FOURTOUNI and C. PAPACONSTANTINOU.-1992. Stomach content analysis of norway lobster, *Nephrops norvegicus*, in the North Aegean Sea (Greece). Rapp. Comm. Int. Mer Medit., 33: 46.

MYTILINEOU, CH., C. PAPACONSTANTINOU and A. FOURTOUNI.-1993. Preliminary study on the biology of Norway lobster (*Nephrops norvegicus)* in the N. Euboikos Gulf (Greece). BIOS, vol. 1(1): 115-126.

SPARRE, P. and S.C. VENENA.-1992. Introduction to tropical fish stock assessment. Part 1. Manual FAO Fisheries Technical Paper No 306, Rev. 1. Rome, FAO, 376p.

STERGIOU, K.I., G. PETRAKIS and C-Y. POLITOU.-1996. Size selectivity of diamond and square mesh cod-ends for *Nephrops norvegicus* in the Aegean Sea. Fish. Res. (in press).

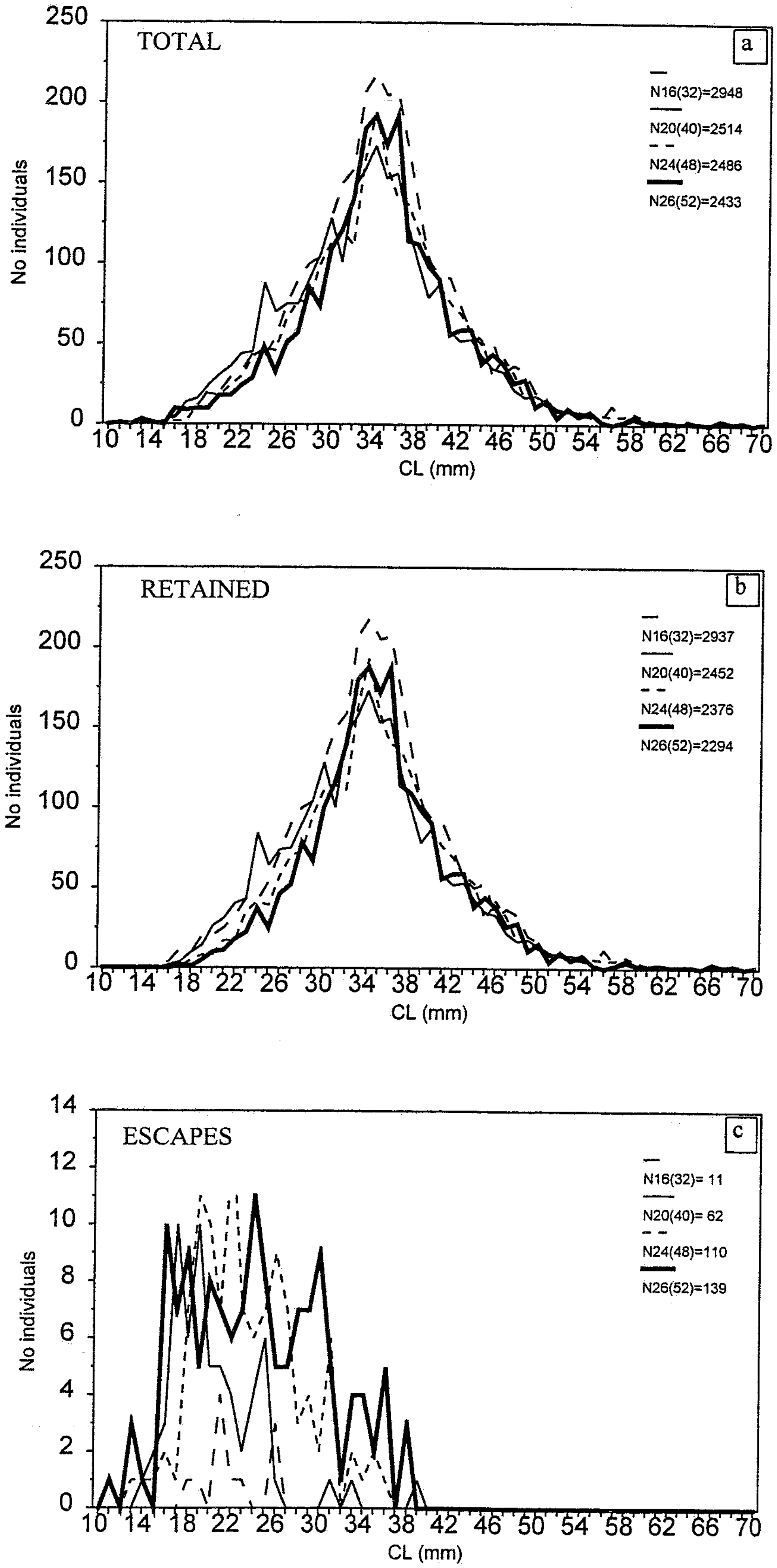


Figure 2. Length distribution of the total number of entered individuals (a), the retained (b) and the escapes (c) of *Nephrops norvegicus* in the N. Euboikos Gulf for different mesh sizes (16 mm, 20 mm, 24 mm, 26 mm from knot to knot).

Table 1. Selectivity parameters of Nephrops norvegicus in the N. Euboikos Gulf for different mesh sizes (20 mm, 24 mm, 26 mm from knot to knot).

Selectivity estimates/Mesh size	20(40)	24(48)	26(52)
Proportion of population retained	97.53	95.58	94.29
v1	-7.81	-6.7	-5.91
v2	0.44	0.33	0.29
Standard error of v1	0.92	0.63	0.52
Standard error of v2	0.04	0.02	0.02
L25	15.32	16.77	16.71
L50	17.83	20.06	20.53
L75	20.34	23.35	24.35
Confidence interval of L50	16.63-18.76	18.92-20.98	19.33-21.52
Deviance statistic Δ	30.01	21.72	33.67
Degrees of freedom	48	50	53
Selection factor	0.89 (0.045)	0.84 (0.035)	0.79 (0.030)
Selection range	5.02	6.58	7.64

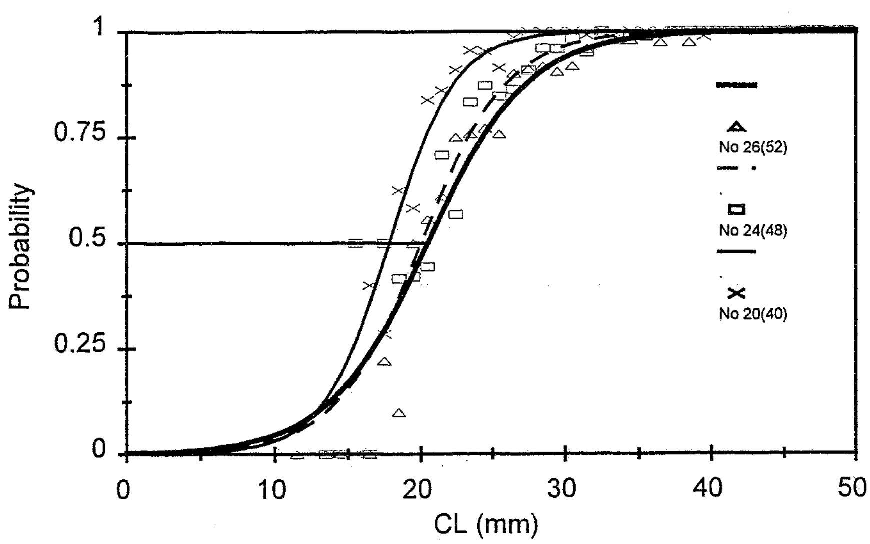


Figure 3. Selectivity curves of *Nephrops norvegicus* in the N. Euboikos Gulf for different mesh sizes (20 mm, 24 mm, 26 mm from knot to knot).

EXPLOITATION STATE

INTRODUCTION

One of the objectives of the project is to establish the exploitation state of *Nephrops* in each study area. However, in the Mediterranean (as well as in the North Atlantic) difficulties are encountered when trying to obtain real and exact information on the exploitation state. Given the general difficulties to obtain reliable data of CPUE, the ICES (Anon., 1995) advises the use of VPA methods. The strength of these methods lies in their robustness when biological data and size frequencies are accurate. Thus, one of the underlying principles of the project has been to put great care and effort in collecting accurate data on the biology of the species in each of the study areas.

On the other hand, Y/R curves can be understand to show trends in the exploitation state of the stock. In this chapter, LCA (Length Cohort Analysis) by sex is applied to each area and Y/R curves are presented, together with a analysis of the transition to a new equilibrium, assuming a 20 % reduction or increase in fishing effort

Our aim is to examine the general state of the fishery, rather than present quantitative results or data for use in management decisions, in order to give sound advice on the situation of the fishery.

METHODOLOGY

Population dynamics

Length Cohort Analysis (LCA) has been performed using the VIT package (Lleonart and Salat, 1992). This program carries an analysis of the dynamics of a population subject to fishing effort by means of pseudo-cohort analysis techniques. Input parameters required are: size (or age) frequency data and biological parameters of the species. It outputs information containing the exploitation level of the stock, and the reaction of the stock to changes in fishing procedures, complemented with a Yield by Recruit analysis.

The LCA is carried under the assumption of stationarity, and a reconstruction of the population is made. Among pseudo-cohort analyses two basic methods are employed, depending on the equation used to relate catch and fishing mortality with the number of individuals. Thus the user can make the choice of using Gulland's catch equation (1965).

Starting with the reconstructed population, Y/R and transition analyses are performed. The transition analysis is performed by changing the fishing procedures. A sensitivity analysis of the parameters is also included.

Following ICES recommendations and our own opinion, the analyses have been carried out separately by sexes. We have analysed two consecutive years and three different natural mortalities.

Input parameters for LCA:

von Bertalanffy's growth parameters (L_{inf}, k, t_0) have been obtained using the FISHPARM programme, which produces the best fit of the growth curve (see method and justification in chapter IV)

Length/weight relationship parameters (a, b) obtained by fitting the potential curve yearly by sex (see tables ...)

Natural Mortality (M) start value has been the generally accepted M=0.2 (ICES), and values of M=0.1 and 0.3, have been introduced for comparative purposes.

Terminal Fishing Mortality (F) has been assigned a value of F=1*.

Ratio of mature individuals by size class. From the results obtained in the Chapter "Reproduction" and previous studies (Sardà, Relini, ... others), a similar criterion has been employed for males and females. The reproductive period has been extended between the classes 21 and 30 mm CL and an increase of 10% maturity for each mm of CL has been employed.

Size frequency. Monthly mm-class size frequencies have been employed (see Chapter "Growth"), for each year of study. Size ranged from 10 to 50 mm CL in females and 10 to 60 mm CL in males. In all cases, the existence of a "plus-class" has been considered.

Catch. Due to the previously mentioned difficulties, a preliminary exploration of the value of landings by port has been carried out. Landings average around 20,000 tonnes/year. A realistic value of 10,000 tonnes/year for each sex has been assumed, following our objectives of studying the relative values and behaviour of Y/R curves, rather than providing quantitative information.

LCA. Gulland's catch equation (1965) and the survival equation have been used:

Survival $$N_{i+1} = N_i e^{-Z_i \Delta t_i}$$ *Catch* $$C_i = \frac{F_i}{Z_i} N_i (1 - e^{-Z_i \Delta t_i})$$

where:
N_i, number of individuals at the start of class i
t_i, Mean age of individuals in class i
Z_i, F_i, Total and fishing mortalities of class i
C_i, Catch in number of individuals of class i

Y/R. For Yield by Recruit computations

Using the reconstructed population in number by the VPA, the conversion to biomass is made from the mean abundances and weights measured by class:

$$\overline{B_i = N_i w_i}$$ where $$\overline{N}_i = N_i \frac{1 - e^{-z_i \Delta t_i}}{z_i}$$

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* Exploratory simulations with different F (=0.1, 1 and 2) has been made without considerable differences observed (Table F in annex), then a F = 1 has been used in all analyses

Output parameters (by year):
mean Z
mean F
global F
mean age (and critical age, at which the cohort reaches its maximum biomass)
mean length (and critical)
mean individuals in the population
mean biomass (B(mean))
recruitment (number): number of individuals in the first class
Y/R (*R* in biomass)
B/R
General Biomass Equation (stock in equilibrium)
total biomass balance (D)

Inputs,	Recruitment	(biomass and %)
	Growth	(" ")
Outputs, M		(" ")
	Biomass caught	(" ")

R/B (mean)
B(max)/B(mean); B(max) is the biomass corresponding to critical age
D/B(mean) turnover
B(max)/D
F(0.1) and F(max.)

Sensitivity analysis. This analysis is performed to assess how variations or precision errors in the estimation of parameters may affect results. This procedure outputs an interval of variation for each of the parameters and an estimate of the yields at the extremes of the interval.

Input parameters:
L_{inf}, k, t_o, a, b, M and F
Factor: 0.1 (10%)
Applied to all parameters

Output parameters:
Indication of the parameter affected by the factor (in the same order that for input: o, not modified; +, increase; -, decrease)
Total *Y/R*
Biomass by recruit

Y/R. The following equation allows to introduce the variation in effort using an effort factor Φ:

$$Y/R(\Phi) = \frac{1}{N_1}\sum_{i=1}^{n} \overline{N_i w_i} F_i \Phi = \frac{1}{N_1}\sum_{i=1}^{n} N_1 \frac{1-e^{-(F_i\Phi+M)\Delta t_i}}{F\Phi + M} \overline{w_i} F_i \Phi$$

Output parameters:
Slope of the *Y/R* curve at the origin (effort, 0 and virgin biomass)
Total *Y/R*
Biomass by recruit

Simulation of effort (Φ) change to a new equilibrium situation ("transition analysis") by age has been performed under the assumption of a reduction in effort to simulate the effect of the fishery on the population during a certain number of years. An effort increase has not been considered for it is not relevant in the current situation.

Previously, a conversion of sizes to ages has been accomplished by the method of "slicing"

Input parameters:
VPA (LCA) output results
Number of years: 10
Transition factor: 0.2 (20%) of effort reduction

Output parameters:
Start, Final and Total *Y/R* by year
Biomass by recruit

RESULTS

Length Cohort Analysis (tables 12.1 to 12.6 and annex)

The main output parameters of the virtual population analysis are represented in tables 12.1 to 12.6 by different natural mortalities and sexes by each area. The amount of variability in these parameters is relatively small, females being more variable than males. To avoid extensive repetition of results based on each table, we will comment on the results for M=0.2 for both sexes as an example.

The values observed are more similar to those of virgin populations than to those of exploited populations. This suggests that in case of no exploitation, the populations would converge towards similar population parameters.

For instance, for the virgin female populations reconstructed with M=0.2 (Tables 12.3 and 12.4) the age varies among areas between 7.1 and 7.6 years, only the Catalan and the Alboran Seas being off this range for 1964 (the age of the reconstructed male population lies between 7.2 and 8.7 for all areas). The virgin stock length is between 44.1 and 51.3 mm CL for females (ranging from 51.1 to 58.8 mm CL for males). Assuming that variation in length for females is greater than for males, we conclude that non-exploited virgin stocks show a similar population structure among areas. The results from length analyses are considered to be more reliable than the age results as age is computed indirectly from length-to-age keys. The variations observed among areas are attributed to environmental conditions or to differing exploitation state, as reflected in the size frequencies sampled.

In general, the smallest size values are found in the Catalan Sea, where mean *Z* and *F* are highest, showing that the intensity of the exploitation is reflected in the biological parameters.

Table, 12.1.- VPA RESULTS FEMALES (M=0.1)

Zones	**Atlantic**		**Alboran**		**Catalan**		**Ligurian**		**Tyrrhenian**		**Adriatic**		**Euboikos**	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean age catches (y)	4.2	4.2	4.2	3.4	4.2	3.3	7.8	4.9	3.5	3.4	3.2	3.2	3.1	3.8
Stock mean age	2.1	2.1	2.2	1.8	2.9	2.1	5.1	3.3	2.0	2.0	1.9	1.8	2.1	2.3
Stock critical age	3.6	3.4	3.5	3.0	3.9	2.9	6.4	4.5	3.0	3.0	2.9	2.9	2.7	3.3
Virgin stock age	11.4	11.4	10.1	10.8	11.8	11.2	11.1	11.1	10.6	10.6	10.8	10.8	11.1	11.1
Mean length (mm)	34.4	34.2	40.2	35.9	28.9	27.6	43.9	33.4	30.5	30.1	29.7	29.1	29.3	33.3
Stock mean length	23.2	23.1	26.9	24.6	20.5	18.9	33.7	24.4	21.5	21.3	21.2	21.1	21.9	23.8
Stock crit. length	32	31	37	34	27	25	40	32	28	28	28	28	27	31
Virgin stock length	55.3	55.3	60.1	60.2	54.5	54.5	51.9	51.9	53.1	53.1	54.4	54.4	60.0	60.0
Mean *F*	0.52	0.57	0.32	0.56	1.14	1.10	0.40	0.37	0.75	0.84	0.89	0.83	0.58	0.52
Global *F*	0.18	0.18	0.19	0.24	0.30	0.33	0.13	0.19	0.26	0.27	0.28	0.28	0.32	0.24
R recruitmren (%)	2.5	2.6	1.8	2.1	4.9	4.7	11.7	2.1	3.0	3.5	3.6	3.7	3.7	2.8
G growth (%)	97.5	97.4	98.2	97.9	95.1	95.3	88.3	97.9	97.0	96.5	96.4	96.3	96.3	97.2
M (%)	18.1	17.8	17.8	14.6	12.7	11.6	28.0	20.6	13.8	13.8	13.6	13.7	14.3	16.2
C captured (%)	81.9	82.2	82.2	85.4	87.3	88.4	72.0	79.4	86.2	86.2	86.4	86.3	85.7	83.8
Bmax/Bmean	27.3	24.2	27.1	33.8	38.6	40.4	19.4	21.0	34.1	33.4	34.1	31.7	27.5	27.9
D/Bmean tourn.(%)	55.3	56.2	56.2	68.7	78.6	85.9	35.7	48.5	72.3	72.4	73.7	73.2	69.9	61.8
Y/R max (gr)	20.20	19.11	42.5	41.6	17.33	18.93	31.99	17.63	18.53	18.99	18.8	18.6	16.2	19.8

Table 12.2.- VPA RESULTS MALES (M=0.1)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean catches age (y)	4.7	4.7	4.3	3.7	3.9	3.8	4.3	3.0	3.6	3.4	3.7	3.5	3.6	4.0
Stock mean age	2.8	2.8	2.3	2.1	2.4	2.4	2.4	1.9	2.0	2.0	2.2	2.2	2.4	2.5
Stock critical age	4.0	3.9	3.7	3.0	3.3	3.3	3.5	2.9	3.1	3.0	3.3	3.5	3.9	3.8
Virgin stock age	11.9	11.9	10.9	10.9	13.5	13.5	11.8	11.8	11.4	11.4	12.2	12.2	11.7	11.7
Mean length (mm)	39.3	39.1	43.8	40.0	31.0	30.5	37.7	30.5	34.9	33.9	32.3	31.2	34.0	36.5
Stock mean length	26.6	26.6	29.4	27.9	22.1	21.6	26.2	23.0	24.8	24.3	23.3	23.2	26.3	26.8
Stock crit. length	36	35	41	36	28	28	34	30	33	32	31	32	37	36
Virgin stock length	66.2	66.2	70.1	70.1	66.5	66.5	65.1	65.1	64.9	64.9	62.8	62.8	64.8	64.8
Mean *F*	0.46	0.56	0.31	0.37	0.69	0.88	0.39	0.51	0.63	0.58	0.50	0.46	0.34	0.34
Global *F*	0.19	0.19	0.18	0.25	2.51	0.26	0.18	0.29	0.23	0.25	0.23	0.24	0.28	0.18
R recruitmren (%)	1.4	1.4	1.1	1.3	3.2	3.2	1.5	2.7	1.6	1.8	2.2	2.6	2.0	1.7
G growth (%)	98.6	98.6	98.9	98.7	96.8	96.8	98.5	97.3	98.4	98.2	97.8	97.4	98.0	98.3
M (%)	17.8	17.5	18.4	17.1	15.3	14.3	19.4	15.9	15.9	15.6	16.6	17.6	22.3	21.9
C captured (%)	82.2	82.5	81.6	82.9	84.7	85.7	80.6	84.1	84.1	84.4	83.4	82.4	77.7	78.1
Bmax/Bmean	24.7	24.1	23.0	23.1	26.7	28.7	21.9	20.9	23.4	24.3	22.7	21.4	15.2	17.3
D/Bmean tour. (%)	56.3	57.3	54.3	58.4	65.3	69.7	51.6	63.0	62.9	64.1	60.1	56.9	44.0	45.7
Y/R max (gr)	33.8	35.7	66.2	67.9	24.8	28.9	27.6	22.5	31.9	30.6	25.5	19.3	24.6	27.8

Table 12.3.- VPA RESULTS MALES (M=0.2)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean catch age (y)	4.7	4.7	4.3	3.7	3.9	3.8	4.3	3.0	3.6	3.4	3.7	3.5	3.6	4.0
Stock mean age	2.7	2.6	2.1	2.0	2.3	2.3	2.3	1.9	1.9	1.9	2.1	2.1	2.3	2.3
Stock critical age	4.0	3.9	3.6	3.0	3.3	3.3	3.5	2.9	3.1	3.0	3.1	3.5	3.8	3.8
Virgin stock age	8.0	8.0	7.2	7.2	8.7	8.7	7.7	7.7	7.5	7.5	7.9	7.9	7.6	7.6
Mean length (mm)	39.3	39.1	43.8	40.0	31.0	30.5	37.7	30.5	34.9	33.9	32.3	31.2	34.0	35.6
Stock mean length	25.6	25.6	28.1	27.0	21.5	21.0	25.3	22.6	24.1	23.6	22.7	22.6	25.5	25.9
Stock crit. length	36	35	40	36	28	28	34	30	33	32	30	32	36	36
Virgin stock length	55.0	55.0	58.8	58.8	52.8	52.8	53.5	53.5	53.8	53.8	51.1	51.1	53.3	53.3
Mean *F*	0.41	0.51	0.28	0.32	0.62	0.82	0.34	0.45	0.57	0.52	0.44	0.42	0.28	0.29
Global *F*	0.14	0.15	0.13	0.16	0.20	0.21	0.14	0.23	0.18	0.20	0.18	0.19	0.15	0.13
R recruitmren (%)	1.8	1.8	1.4	1.6	3.8	3.8	1.8	3.1	1.9	2.2	2.6	3.0	2.4	2.1
G growth (%)	98.2	98.2	98.6	98.4	96.2	96.2	98.2	96.9	98.1	97.8	97.4	97.0	97.6	97.9
M (%)	33.9	33.5	35.1	32.9	29.7	27.9	36.9	30.9	30.8	30.2	32.2	33.5	42.0	41.2
C captured (%)	66.1	66.5	64.9	67.1	70.3	72.1	63.1	69.1	69.2	69.8	67.8	66.5	58.0	58.8
R/Bmean	1.0	1.1	0.8	0.9	2.6	2.7	1.0	2.0	1.3	1.4	1.6	1.8	1.1	1.0
D/Bmean tour. (%).	59.0	59.8	57.0	60.8	67.3	71.8	54.2	64.7	65.0	66.2	62.0	59.8	47.6	48.5
Y/R max (gr)	20.2	20.6	29.6	29.9	13.7	15.5	16.1	13.3	18.6	17.9	14.3	12.3	14.4	16.1
F (0.1)	0.69	0.39	*	0.19	0.27	0.20	0.63	0.36	0.32	0.34	0.43	0.51	0.78	0.19
F (max.)	1.58	0.64	*	0.35	0.43	0.32	1.19	0.53	0.49	0.56	0.72	0.77	1.16	0.38

Table 12.4.- VPA RESULTS FEMALES (M=0.2)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean age catch (y)	4.3	4.2	4.2	3.5	4.3	3.4	7.8	5.0	3.5	3.5	3.3	3.2	3.1	3.8
Stock mean age	1.9	1.9	2.0	1.7	2.8	2.1	4.9	3.1	1.9	1.9	1.8	1.8	2.0	2.2
Stock critical age	3.4	3.2	3.4	3.0	3.9	2.9	6.1	4.3	3.0	2.8	2.7	2.7	2.5	3.3
Virgin stock age	7.2	7.2	6.7	6.7	8.3	7.6	7.7	7.7	7.1	7.1	7.1	7.1	7.5	7.5
Mean length (mm)	34.4	34.2	40.2	35.9	28.9	27.6	43.9	33.4	30.5	30.1	29.7	29.1	29.3	33.3
Stock mean length	22.4	22.2	25.9	23.9	20.0	19.4	32.7	23.6	20.9	20.8	20.6	20.6	21.6	23.1
Stock crit. length	31	30	36	34	27	25	39	31	28	27	27	27	26	31
Virgin stock length	45.5	45.5	51.3	51.3	46.0	46.0	44.1	44.1	44.9	44.9	45.7	45.7	50.5	50.5
Mean *F*	0.47	0.52	0.29	0.51	1.08	1.03	0.35	0.32	0.69	0.78	0.83	0.76	0.52	0.47
Global *F*	0.13	0.14	0.14	0.19	0.25	0.29	0.10	0.14	0.21	0.22	0.23	0.23	0.26	0.19
R recruitmren (%)	3.1	3.3	2.2	2.5	5.7	5.3	14.5	2.6	3.6	4.1	4.2	4.3	4.2	3.3
G growth (%)	96.9	96.7	97.8	97.5	94.3	94.7	85.5	97.4	96.4	95.9	95.8	95.7	95.8	96.7
M (%)	34.4	33.9	33.8	28.0	24.6	22.6	51.1	39.0	26.7	26.7	26.2	26.4	27.7	30.9
C captured (%)	65.6	66.1	66.2	72.0	75.4	77.4	48.9	61.0	73.3	73.3	73.8	73.6	72.3	69.1
Bmax/Bmean	26.3	26.5	26.6	32.8	37.8	39.8	18.2	20.9	33.5	32.8	33.6	31.3	27.4	27.7
D/Bmean tour. (%).	58.1	59.1	59.2	71.3	81.3	88.4	39.1	51.3	74.8	75.0	76.2	75.7	72.1	64.7
Y/R max (gr)	11.9	11.3	20.9	20.7	11.1	12.0	17.9	10.7	11.6	11.9	11.6	11.7	11.0	13.2
F (0.1)	0.45	0.40	0.29	0.16	0.22	0.19	0.56	0.61	0.30	0.26	0.25	0.26	0.16	0.18
F (max.)	0.83	0.70	1.02	0.30	0.41	0.32	0.93	1.00	0.49	0.43	0.40	0.42	0.28	0.35

Table 12.5.- VPA RESULTS FEMALES (M=0.3)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean catch age (y)	4.3	4.2	4.2	3.5	4.3	3.4	7.8	5.0	3.5	3.5	3.3	3.2	3.1	3.8
Stock mean age	1.8	1.7	1.9	1.6	2.8	2.0	4.7	3.0	1.8	1.8	1.7	1.7	1.9	2.1
Stock critical age	3.2	3.2	3.2	2.7	3.7	2.9	5.6	4.3	3.0	2.8	2.7	2.7	2.5	3.3
Virgin stock age	5.2	5.2	5.1	5.1	6.5	5.8	5.9	5.9	5.4	5.4	5.3	5.3	5.7	5.7
Mean length (mm)	34.4	34.2	40.2	35.9	29.0	27.6	43.9	33.4	30.5	30.1	29.7	29.4	29.3	33.3
Stock mean length	21.5	21.3	34.8	23.1	19.6	19.0	31.6	22.7	20.4	20.2	20.1	20.1	21.1	22.5
Stock crit. length	30	30	35	32	26	25	37	31	28	27	27	27	26	31
Virgin stock length	38.5	38.5	44.8	44.8	39.7	39.7	38.3	38.3	38.9	38.9	39.4	39.4	43.6	43.6
Mean *F*	0.42	0.47	0.26	0.47	1.01	0.97	0.29	0.27	0.63	0.72	0.77	0.74	0.47	0.43
Global *F*	0.10	0.10	0.11	0.15	0.21	0.24	0.06	0.10	0.17	0.18	0.18	0.19	0.21	0.15
R recruitmren (%)	3.9	4.2	2.8	3.0	6.6	6.1	17.7	3.1	4.3	4.9	4.9	5.0	4.7	3.9
G growth (%)	96.1	95.8	97.2	97.0	93.4	93.9	82.3	96.9	95.7	95.1	95.1	95.0	95.3	96.1
M (%)	48.8	48.1	47.8	40.4	35.6	32.9	69.5	54.8	38.6	38.5	37.9	38.2	40.2	44.2
C captured (%)	51.2	51.9	52.2	59.6	64.4	67.1	30.5	45.2	61.4	61.5	62.1	61.8	59.8	55.8
Bmax/Bmean	25.5	25.8	26.3	31.9	37.1	39.1	17.6	20.8	32.8	32.5	33.1	31.0	27.4	27.4
D/Bmean tournov.	61.5	62.4	32.7	74.3	84.3	91.1	43.2	54.7	77.7	78	79.1	78.5	74.7	67.9
Y/R max (gr)	7.4	6.9	12.5	12.4	7.3	8.0	10.4	6.8	7.6	5.5	7.6	7.7	7.6	8.9

Table 12.6.- VPA RESULTS MALES (M=0.3)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Mean catch age (y)	4.7	4.7	4.3	3.7	3.9	3.8	4.3	3.0	3.6	3.4	3.7	3.5	3.6	4.0
Stock mean age	2.5	2.5	2.0	1.8	2.2	2.2	2.1	1.8	1.8	1.8	2.0	1.9	2.1	2.2
Stock critical age	4.0	3.9	3.6	3.0	3.3	3.1	3.3	2.7	3.1	3.0	3.1	3.1	3.6	3.6
Virgin stock age	6.1	6.1	5.4	5.4	6.4	6.4	5.7	5.7	5.5	5.5	5.8	5.8	5.6	5.6
Mean length (mm)	39.2	39.1	43.8	40.0	31.0	30.5	37.7	30.5	34.9	33.9	32.3	31.1	34	36.5
Stock mean length	24.6	24.6	26.9	26.0	20.9	20.5	24.3	22.1	23.3	23.0	22.0	21.9	24.6	24.8
Stock crit. length	36	35	40	36	28	27	33	29	33	32	30	30	35	35
Virgin stock length	47.0	47.0	50.6	50.6	43.9	43.9	45.4	45.4	46.0	46.0	43.1	43.1	45.2	45.2
Mean *F*	0.36	0.47	0.23	0.28	0.56	0.75	0.29	0.39	0.52	0.47	0.38	0.37	0.23	0.25
Global *F*	0.11	0.11	0.10	0.12	0.16	0.17	0.10	0.18	0.14	0.15	0.14	0.14	0.10	0.09
R recruitmren (%)	2.2	2.2	1.8	1.9	4.5	4.5	2.3	3.5	2.3	2.6	3.1	3.6	2.8	2.6
G growth (%)	97.8	97.8	98.2	98.1	95.5	95.5	97.7	96.5	97.7	97.4	96.9	96.4	97.2	97.4
M (%)	48.3	47.8	49.8	47.2	43.1	40.5	52.5	45.0	44.4	43.8	46.6	47.6	58.8	57.8
Bmax/Bmean	24.0	23.8	22.7	23.2	25.9	27.8	21.4	21.1	23.6	24.1	22.4	21.8	16.4	17.9
D/Bmean tour. (%)	62.1	62.8	60.2	63.6	69.6	74.1	57.1	66.7	67.6	68.6	64.3	63.0	51.0	51.9
Y/R max (gr)	12.6	12.4	16.4	16.5	8.1	9.0	9.9	8.3	11.2	11.0	8.7	8.0	9.0	9.9

Sorted by exploitation state the study areas would rank as follows:

High exploitation:	1. Catalan Sea
	2. Adriatic Sea
	3. Tyrrhenian Sea
Intermediate exploitation:	4. Ligurian Sea
	5. Euboikos Gulf
Low exploitation:	6. Alboran Sea
	7. Atlantic

The most heavily exploited stocks are maintained by good levels of recruitment. The recruitment percentages are higher than 2% in males and 3% in females. Turnover values are higher in these areas, being larger than 60% for both sexes. Turnover values vary with M but maintain their differences in proportion to it.

The Alboran Sea population comprises large individuals and is exploited at a low level, yielding the highest production per recruit. This is probably related to higher growth rates due to local seasonal upwelling in this area.

Females are more sensitive to exploitation than males, as seen by the more variable values found for females. Variability among areas is higher for females than for males. However it cannot be ruled out that this result is a bias arising from poorer sampling due to the unavailability of females to the sampling gear in autumn. In all, males show a more uniform response to exploitation (cf. tables by sexes).

Sensitivity analysis (annex)

The sensitivity analysis on each of the parameters considered (L_{inf}; k, t_o in the growth equation; a and b, in the size-weight relationship; and terminal M and F), is conducted by varying each parameter individually and progressively by 10%, keeping other parameters constant

The results of the sensitivity analysis are shown in the corresponding annex. Variations regarding the parameters analysed are indicated as 0, + and -. The first 3 items correspond to L_{inf}, k, t_o, the next two are a and b of the length-weight relationship and M and F_t, finally the 3 items to the right belong to analysis using different gear types and are not used in this analysis.

This analysis is conducted by varying each parameter individually and progressively by 10%, keeping other parameters constant. The parameter more heavily affecting yield per recruit is b and, to a lesser extent, *Linf* and k. Therefore, the differences observed between years for a given area are probably due to the estimates of b, which in some cases differ (table Annex).

Yield per recruit (tables 12.7 and 12.8, and figures 12.1 to 12.7) and Transition Analysis (tables 12.7 and 12.8)

Yield per recruit curves are represented in figures 12.1 to 12.7, by different mortalities, sexes and areas. Curves corresponding to M=0.2 fall between higher and lower mortality curves, as expected. Taking M=0.1 would suggest an overexploited resource. Taking M=0.2 most populations are near the optimum exploitation level, while taking M=0.3 would lead to interpret those populations as underexploited. Therefore regarding our comments on the results, M=0.2 will be used, as in the North Atlantic ICES community. Integrating our results of VPA and Y/R we are led to conclude that Mediterranean Norway lobster populations are slightly overexploited, following the gradient shown earlier.

These results have been repeated for VPA and Y/R using M=0.2, employing the growth parameters obtained by the MIX package, in order to examine the possible variations which could arise (table 12.9 and figures 12.8 to 12.10) when using different fitting methods. Although these differences may be significant in mean size and age computations for the virgin stock and for computations of absolute yield per recruit, the differences observed in Y/R curves have been minimal. However, regarding the values of the parameters given by MIX, values of L_{inf} lower than the maximum size can be obtained and thus some curves could not be computed.

The transition analysis (tables 12.7 and 12.8) is based upon an effort reduction of 20%, i.e. a 1-day reduction per week, or a 2-hour reduction per day, or a 2-month close season per year. The results of this analysis show that, as expected, the stocks which would more easily recover their Y/R levels would be precisely those most heavily exploited, increasing between 4.8 and 6.9% for females and between 0.9 and 5.0% for males.

As females are more sensitive to exploitation than males, they also show a speedier recovery. Taking males and females together, the estimated percentages of recovery by a 20% effort reduction in the most heavily exploited stocks would be:

Catalan Sea:	12-15 %
Tyrrhenian Sea:	10-12 %
Adriatic Sea:	8-10 %

The highest levels of recovery would be obtained in 4 to 6 years, depending on the area. However these are probably underestimates as recruitment is assumed to be constant throughout the recovery process. The female stock would stabilise 6 years after the effort reduction and the male stock 7 years after that.

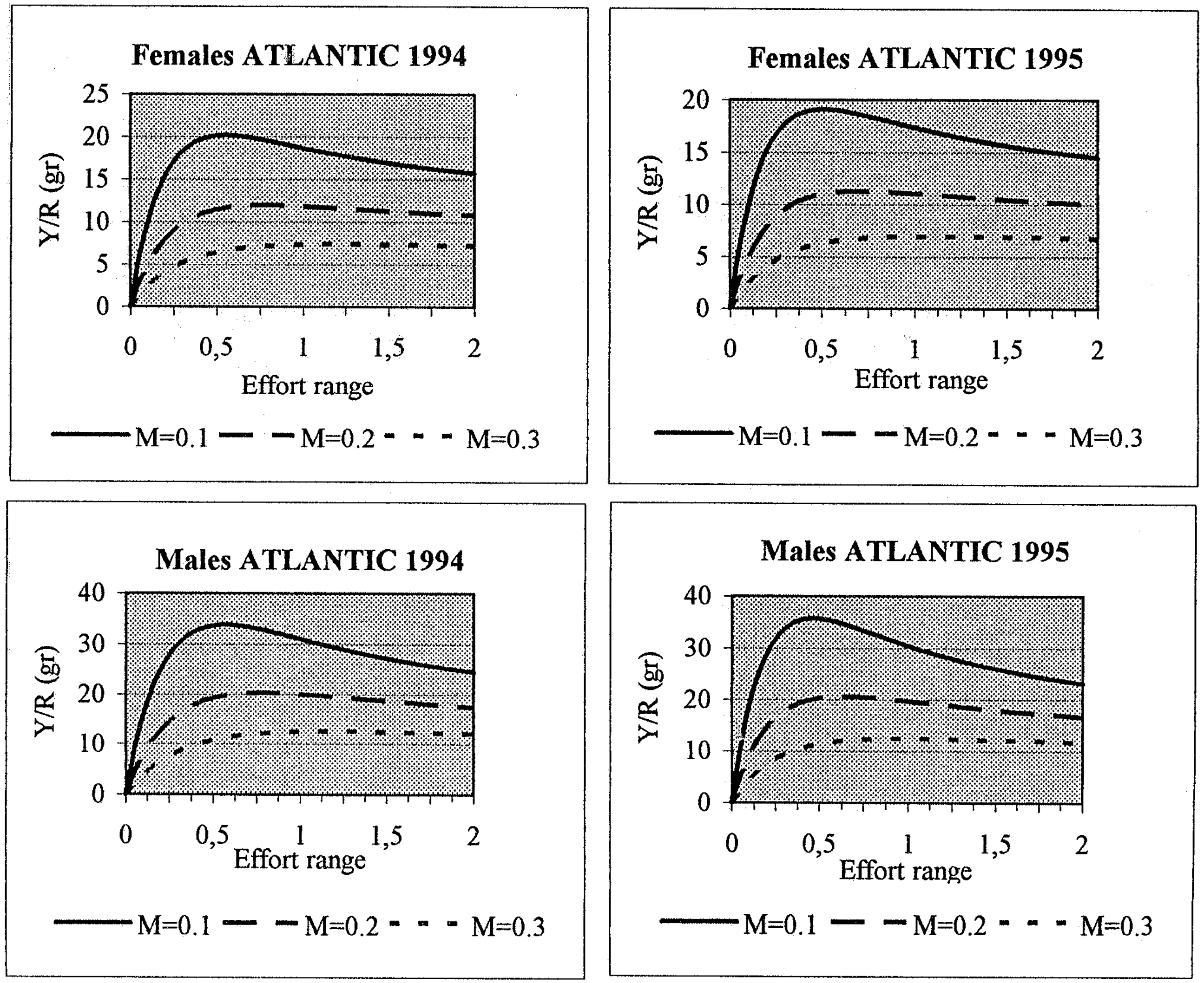
Conversely, if effort is increased by 20%, the losses in 7 to 8 years would be around 10% in Y/R. As in the effort reduction scenario, this is probably an underestimate as recruitment is assumed constant.

Table 12. 7.- Y/R Results and transition analysis. FEMALES (M=0.2). Variation factor ± 20%

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Y/R max (gr)	12.0	11.3	21.0	20.7	11.1	12.0	17.9	10.7	11.7	11.9	11.6	11.7	11.0	13.2
F (max)	0.8	0.7	0.4	0.3	0.3	0.3	2.0	1.0	0.5	0.4	0.4	0.4	0.6	0.8
Y/R initial (gr)	11.9	11.1	19.2	17.1	8.3	7.9	15.8	10.6	9.6	9.6	9.4	9.5	9.2	11.6
Y/R (5 years) + 20%	12.0	11.3	19.8	17.9	8.8	6.9	14.9	10.2	10.1	10.1	9.9	10.1	9.6	11.7
% increased	0.8	1.8	3.1	4.7	5.4	6.9	-5.7	-3.8	5.2	4.8	5.5	6.3	4.3	0.8
Y/R (10 years)	12.0	11.3	19.8	17.9	8.8	8.5	15.2	10.4	10.1	10.1	10.0	10.1	9.7	11.7
% increased	0.8	1.8	3.1	4.7	5.5	7.0	-3.8	-1.9	5.2	5.8	5.9	6.3	5.4	0.8
Stability year	5	5	8	5	6	6	9	7	4	6	7	5	7	5
Y/R (5 years) - 20%	11.7	10.9	18.4	16.3	8.0	7.5	16.4	10.6	9.23	9.0	8.9	9.0	8.8	11.3
% decreased	1.7	1.8	2.6	4.7	4.4	5.7	+3.8	0.0	4.4	6.5	4.9	5.4	9.8	2.6
Y/R (10 years)	11.7	10.9	18.7	16.3	8.0	7.5	16.2	10.5	9.23	9.0	8.9	9.0	8.8	11.3
% decreased	1.7	1.8	2.6	4.7	4.4	5.7	+2.5	0.9	4.4	6.6	5.0	5.5	9.8	2.6
Stability year	5	4	4	5	5	5	8	6	5	6	6	6	6	5

Table 12. 8.- Y/R Results and Transition analysis. MALES (M=0.2). Variation factor ± 20%

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
Y/R max (gr)	20.2	20.6	21.0	20.7	13.8	15.5	16.1	13.3	18.6	17.9	14.3	12.3	14.4	16.2
F (max)	0.8	0.7	0.5	0.4	0.4	0.3	0.9	0.5	0.5	0.5	0.5	0.8	0.9	0.9
Y/R initial (gr)	17.4	17.1	26.4	24.7	10.1	10.4	15.2	11.3	15.9	15.4	12.4	11.4	14.1	15.5
Y/R (5 years) + 20%	17.5	17.5	27.4	26.0	10.6	11.0	14.9	11.6	16.7	16.1	12.8	11.5	13.4	14.8
% increased	0.6	2.3	3.8	5.2	4.9	5.8	-2.0	2.6	5.0	4.5	3.2	0.9	-4.9	-4.5
Y/R (10 years)	17.6	17.7	27.5	26.3	10.8	11.2	15.2	12.0	17.0	16.4	13.1	11.7	14.0	15.3
% increased	1.1	3.5	4.1	6.5	6.9	7.7	0.0	6.2	6.9	6.5	5.6	2.6	-0.7	-1.3
Year of stability	6	7	6	8	7	6	8	7	8	7	8	7	9	8
Y/R (5 years) - 20%	17.0	16.5	25.4	23.5	9.6	9.8	15.1	10.7	15.1	14.6	11.9	11.1	14.3	15.7
% decreased	2.3	3.5	3.8	4.8	5.2	6.0	0.6	5.3	5.0	5.2	4.0	2.6	-1.4	-1.3
Y/R (10 years)	16.9	16.5	25.4	23.4	9.5	9.7	14.9	10.5	15.0	14.5	11.7	11.0	13.8	15.4
% decreased	2.9	3.5	3.8	5.2	5.9	6.4	2.0	7.1	5.6	5.8	5.6	3.5	2.1	0.6
Year of stability	6	5	5	6	8	7	7	7	6	6	8	6	10	7


Females ATLANTIC 1994
Y/R (gr)
25
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females ATLANTIC 1995
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ATLANTIC 1994
Y/R (gr)
40
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ATLANTIC 1995
Y/R (gr)
40
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fis. 12.1

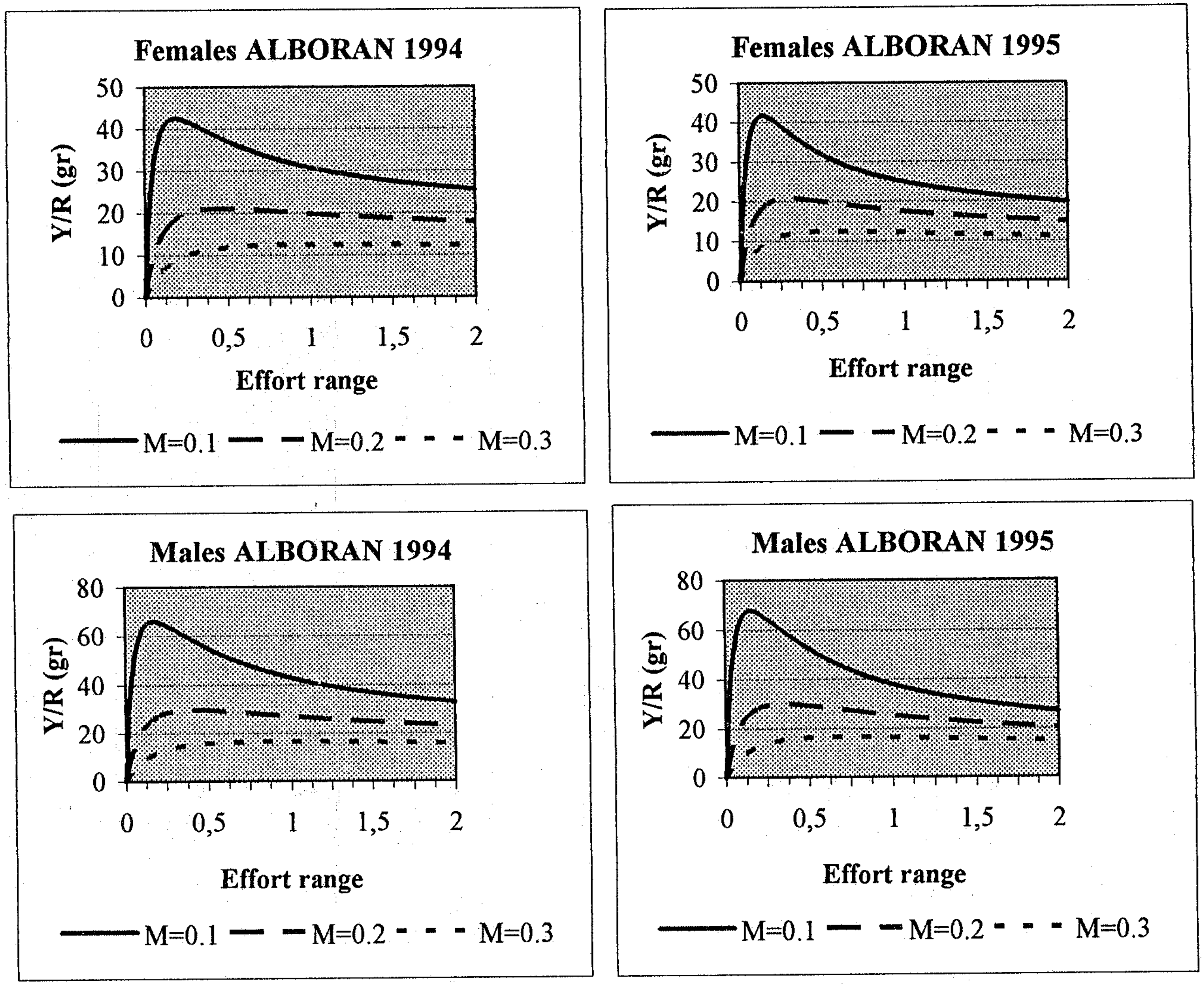

Females ALBORAN 1994
Y/R (gr)
50
40
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females ALBORAN 1995
Y/R (gr)
50
40
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ALBORAN 1994
Y/R (gr)
80
60
40
20
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ALBORAN 1995
Y/R (gr)
80
60
40
20
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.2

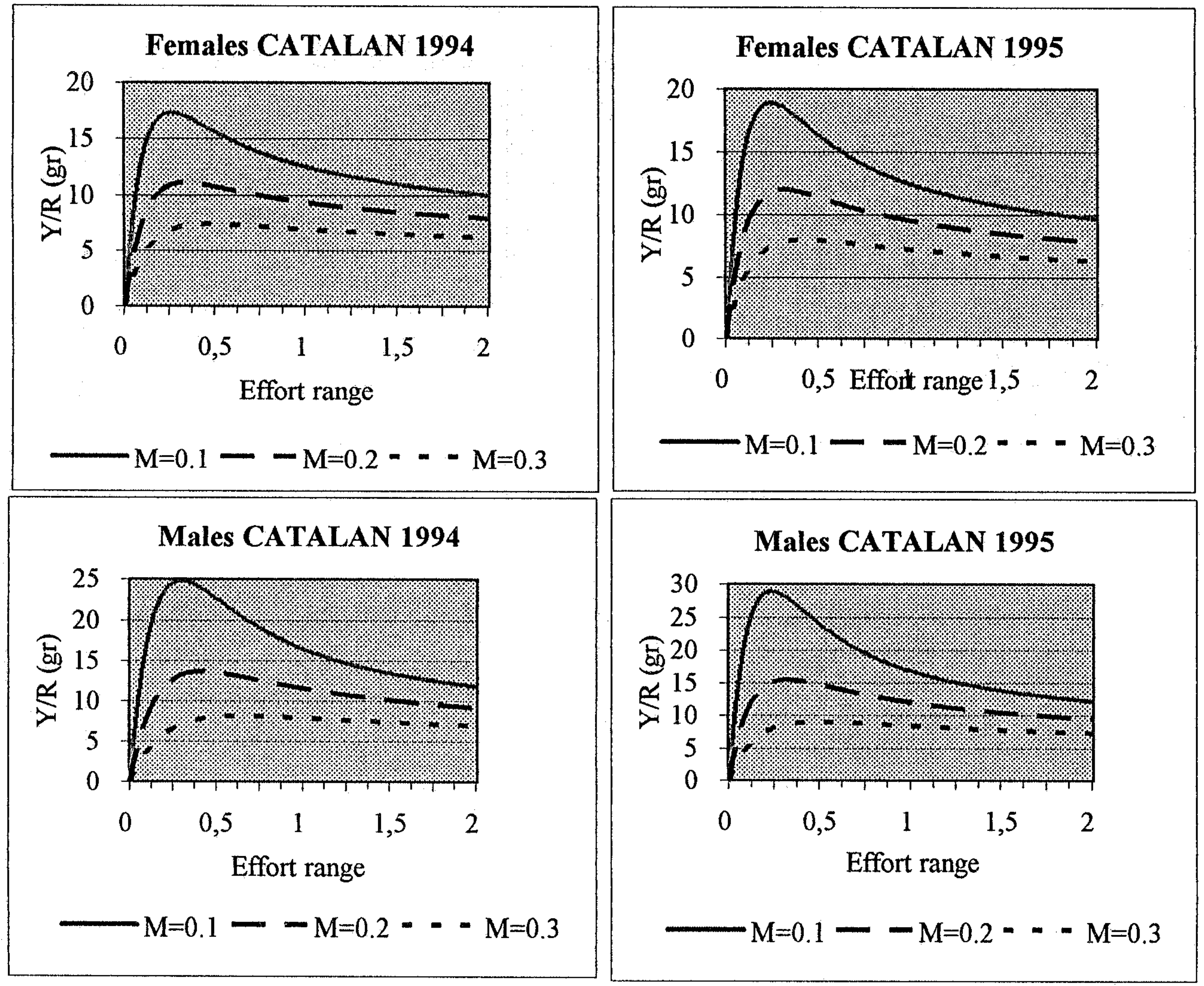

Females CATALAN 1994
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females CATALAN 1995
Y/R (gr)
20
15
10
5
0
0
0,5
Effort range
1,5
2
M=0.1
M=0.2
M=0.3
Males CATALAN 1994
Y/R (gr)
25
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males CATALAN 1995
Y/R (gr)
30
25
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.3

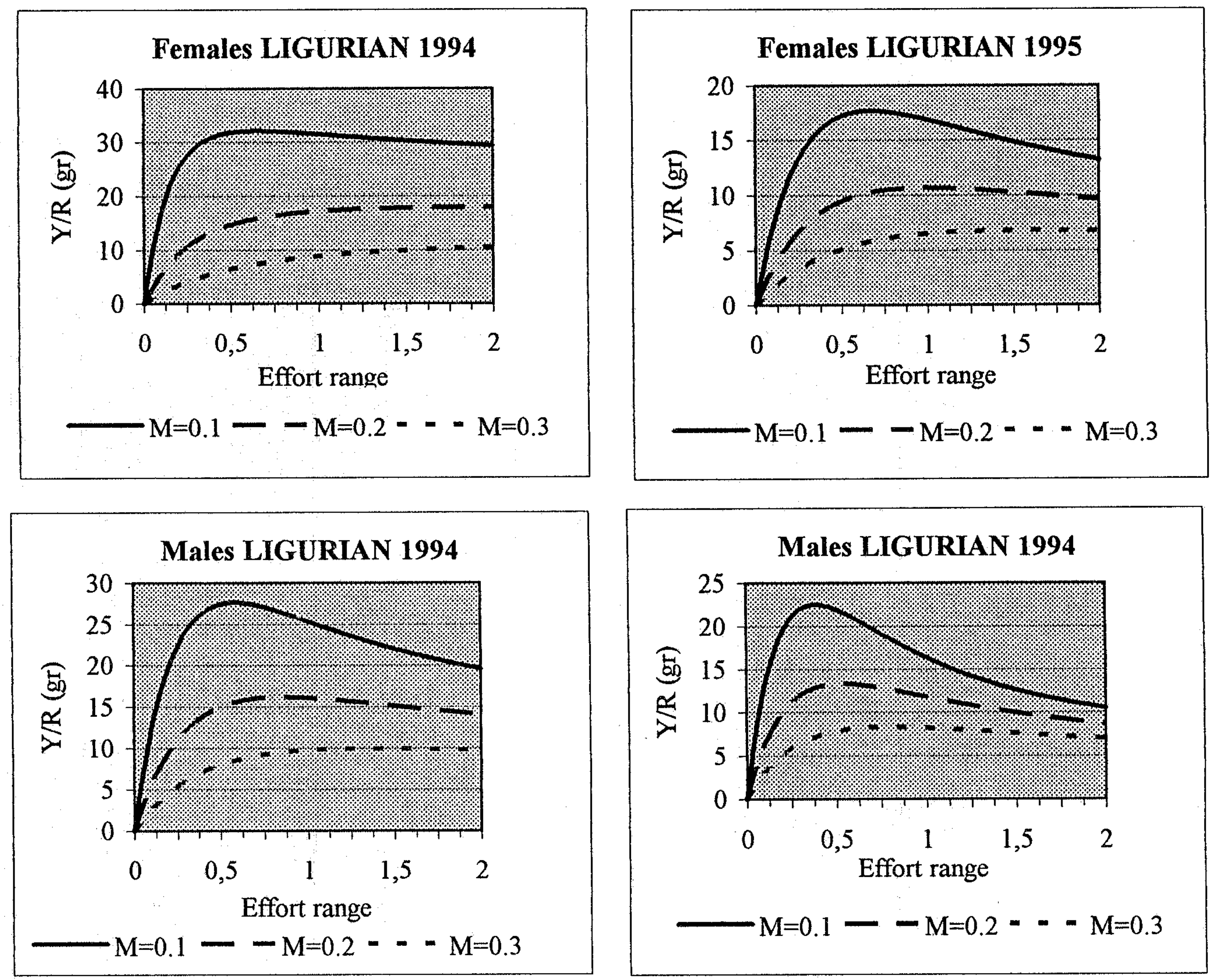
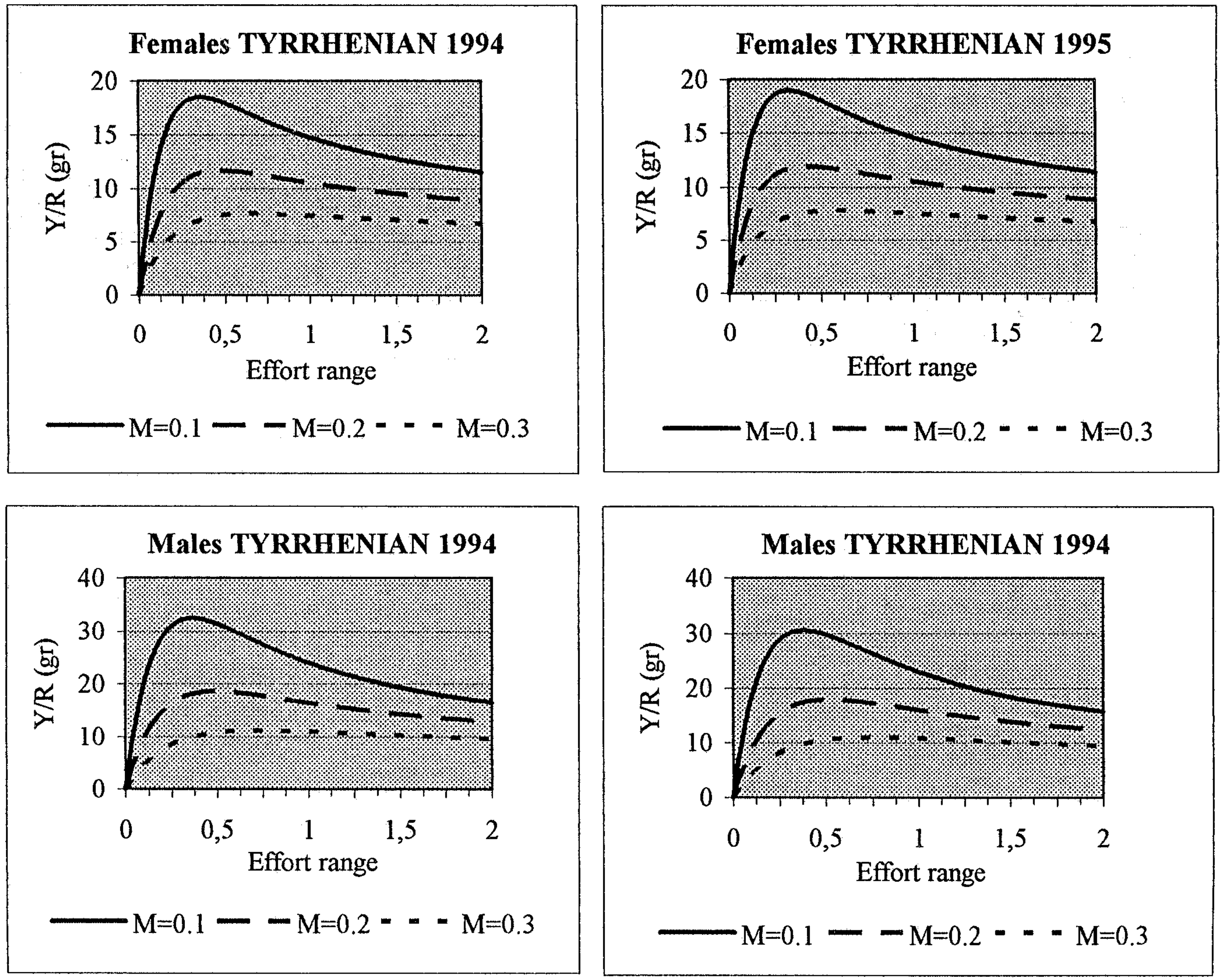

Females LIGURIAN 1994
Y/R (gr)
40
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females LIGURIAN 1995
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males LIGURIAN 1994
Y/R (gr)
30
25
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males LIGURIAN 1994
Y/R (gr)
25
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.4



Females TYRRHENIAN 1994
Y/R (gr)
Effort range
M=0.1
M=0.2
M=0.3
Females TYRRHENIAN 1995
Y/R (gr)
Effort range
M=0.1
M=0.2
M=0.3
Males TYRRHENIAN 1994
Y/R (gr)
Effort range
M=0.1
M=0.2
M=0.3
Males TYRRHENIAN 1994
Y/R (gr)
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.5

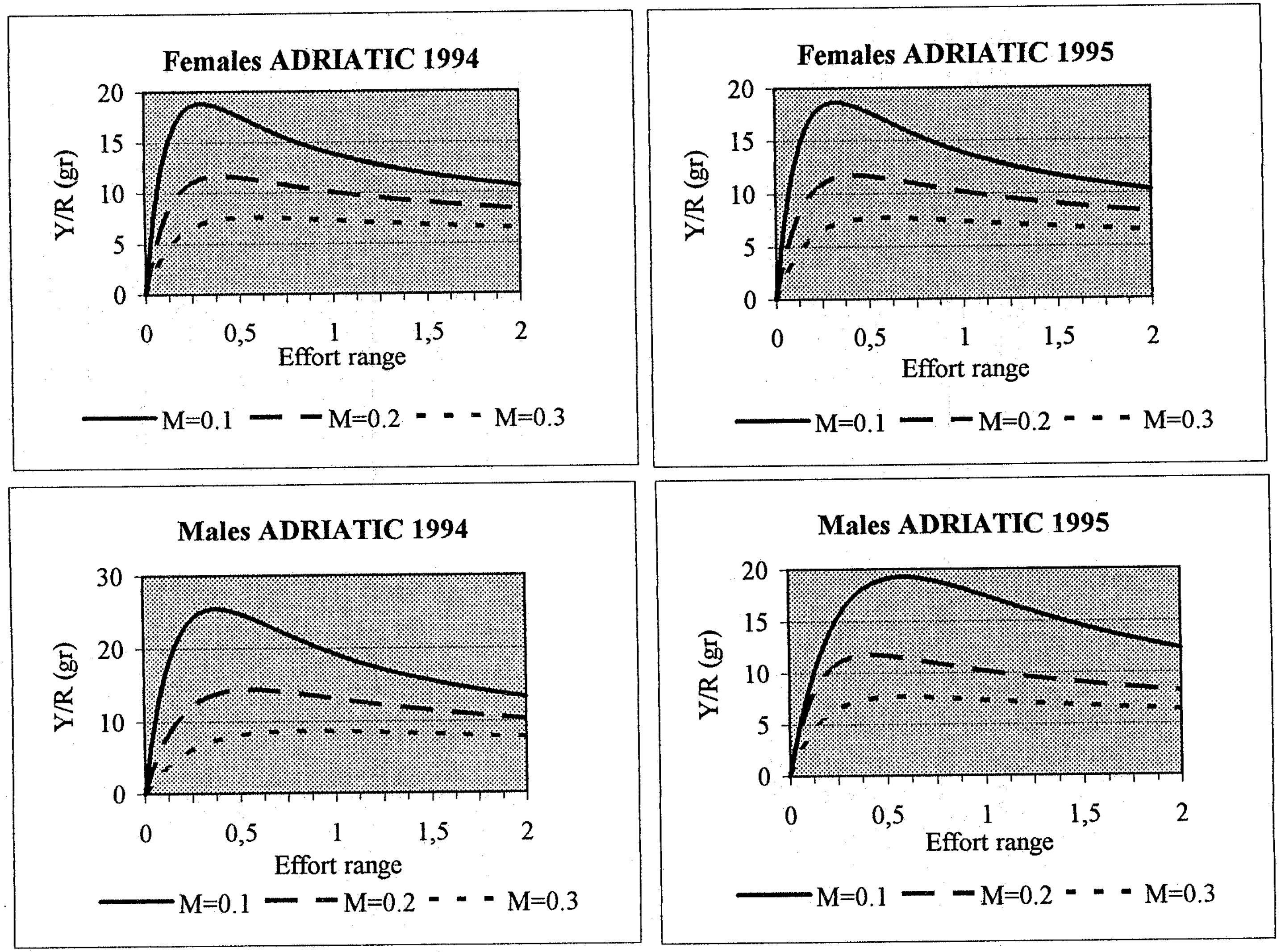

Females ADRIATIC 1994
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females ADRIATIC 1995
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ADRIATIC 1994
Y/R (gr)
30
20
10
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males ADRIATIC 1995
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.6

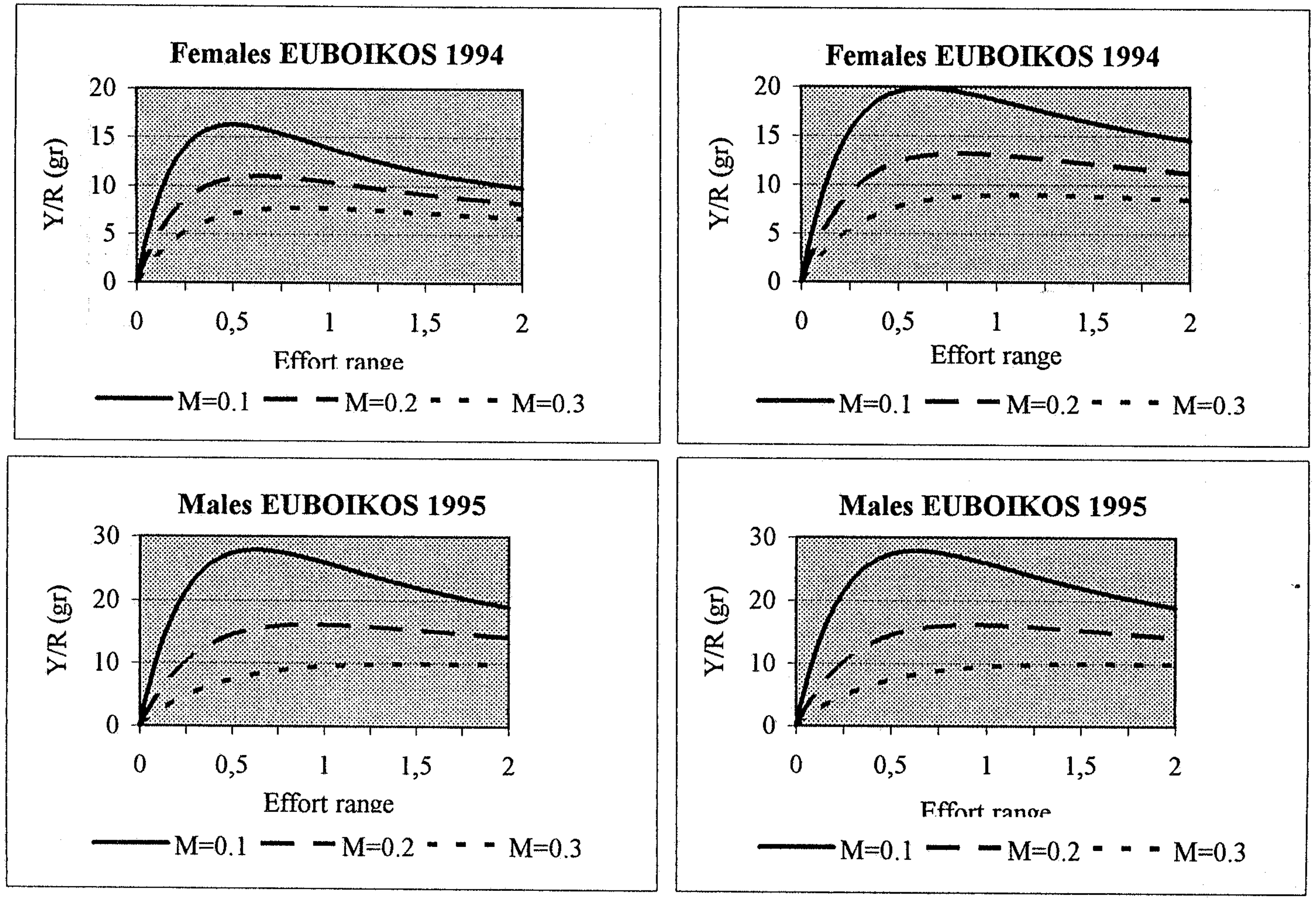

Females EUBOIKOS 1994
Y/R (gr)
0
5
10
15
20
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Females EUBOIKOS 1994
Y/R (gr)
0
5
10
15
20
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males EUBOIKOS 1995
Y/R (gr)
0
10
20
30
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3
Males EUBOIKOS 1995
Y/R (gr)
0
10
20
30
0
0,5
1
1,5
2
Effort range
M=0.1
M=0.2
M=0.3

Fig. 12.7

Table 12.9.- VPA RESULTS, MALES AND FEMALES, 1994 (M=0.2)

Zones	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variables	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Mean catch age (y)	5.8	4.6	4.6	5.0	2.6	2.9	4.7	-	4.5	4.2	4.5	3.9	4.6	4.1
Stock mean age	2.1	2.2	2.5	2.3	1.2	1.3	2.6	-	2.9	2.4	2.5	2.4	3.4	2.7
Stock critical age	4.3	3.7	3.8	3.5	2.0	2.2	3.6	-	4.1	3.7	3.8	3.4	5.1	3.4
Virgin stock age	6.7	6.9	7.0	6.0	6.6	5.9	6.7	-	8.4	7.9	7.7	7.9	8.6	8.5
Mean length (mm)	39.3	34.4	43.8	40.1	31.0	28.9	37.7	-	34.9	30.5	32.3	29.7	34.2	29.3
Stock mean length	24.8	22.6	28.8	26.6	22.1	20.3	26.5	-	24.1	20.7	22.8	20.6	26.3	21.2
Stock crit. length	35.0	31.0	40.0	35.0	28.0	26.0	34.0	-	33.0	28.0	30.0	27	38.0	26.0
Virgin stock length	42.8	42.3	56.3	44.5	49.4	40.0	46.0	-	53.4	44.6	44.5	46.0	53.0	48.7
Mean *F*	0.23	0.42	0.25	0.19	0.59	0.75	0.26	-	0.57	0.64	0.31	0.84	0.20	0.22
Global *F*	0.06	0.12	0.13	0.10	0.22	0.22	0.1	-	0.18	0.18	0.12	0.23	0.13	0.04
R recruitmren (%)	2.3	3.2	1.4	2.3	3.7	5.8	1.8	-	2.0	3.8	2.8	4.2	2.3	4.3
G growth (%)	97.7	96.8	98.6	97.7	96.3	94.2	98.2	-	98.0	96.2	97.2	95.8	97.7	95.7
M (%)	54.8	37.2	36.0	42.6	29.3	28.3	47.3	-	31.1	29.3	41.4	26.1	47.8	29.8
C captured (%)	45.2	62.8	64.0	57.4	70.7	71.7	52.7	-	68.9	70.7	58.6	73.9	52.2	70.2
Bmax/Bmean	13.8	24.1	22.4	20.9	26.8	32.5	16.3	-	23.3	30.1	17.2	33.7	14.3	24.9
D/Bmean tour. (%)	36.5	53.8	55.5	46.9	68.2	70.6	42.2	-	64.3	68.2	48.3	76.5	41.8	67.2
Y/R max (gr)	10.8	11.3	28.8	16.3	14.1	9.6	13.6	-	18.4	10.6	10.8	11.7	13.5	12.7

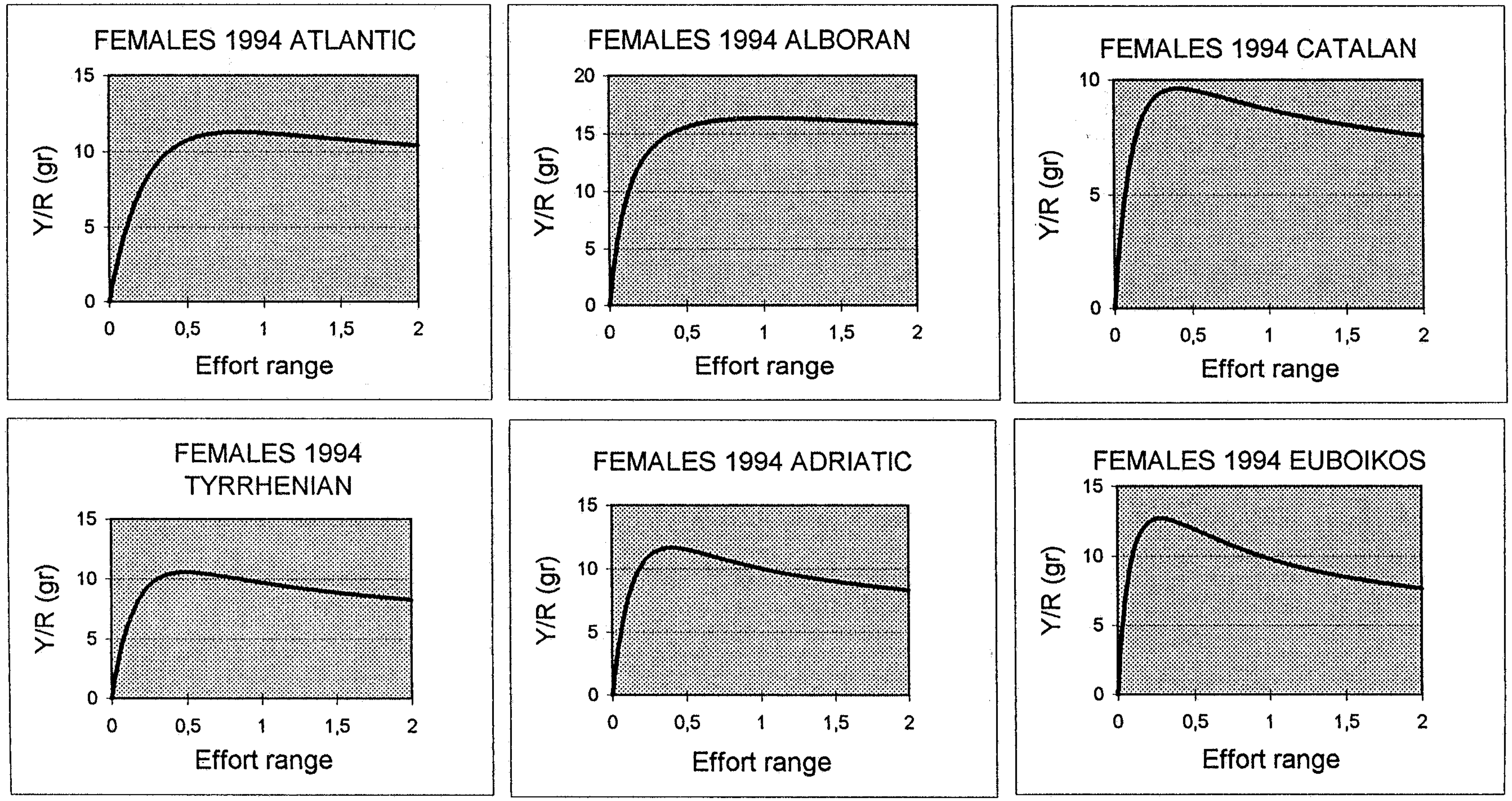

FEMALES 1994 ATLANTIC
Y/R (gr)
Effort range
FEMALES 1994 ALBORAN
Y/R (gr)
Effort range
FEMALES 1994 CATALAN
Y/R (gr)
Effort range
FEMALES 1994 TYRRHENIAN
Y/R (gr)
Effort range
FEMALES 1994 ADRIATIC
Y/R (gr)
Effort range
FEMALES 1994 EUBOIKOS
Y/R (gr)
Effort range

Fig 12.8

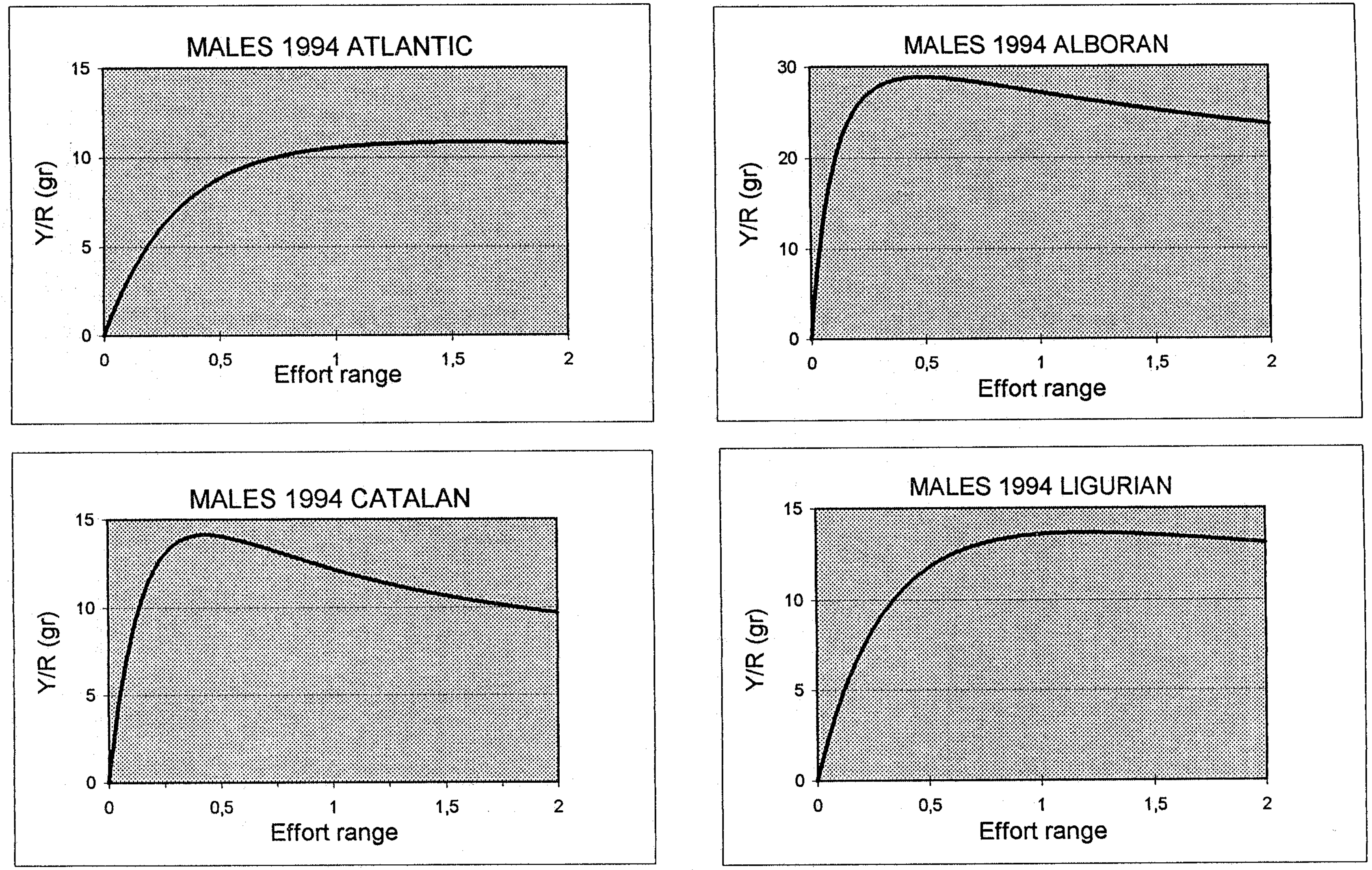

MALES 1994 ATLANTIC
Y/R (gr)
15
10
5
0
0
0,5
1
1,5
2
Effort range
MALES 1994 ALBORAN
Y/R (gr)
30
20
10
0
0
0,5
1
1,5
2
Effort range
MALES 1994 CATALAN
Y/R (gr)
15
10
5
0
0
0,5
1
1,5
2
Effort range
MALES 1994 LIGURIAN
Y/R (gr)
15
10
5
0
0
0,5
1
1,5
2
Effort range

Fig. 12.9

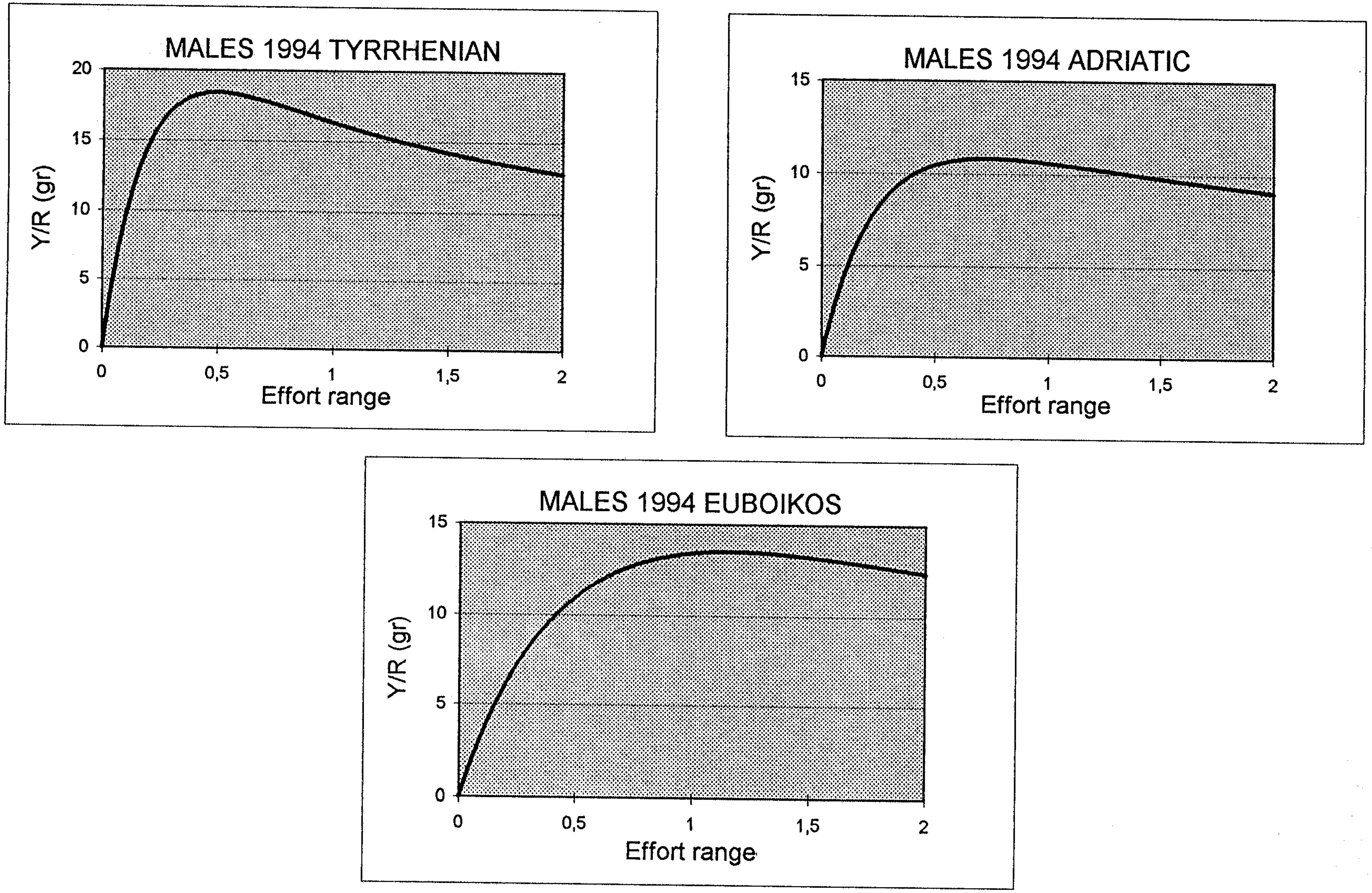

MALES 1994 TYRRHENIAN
Y/R (gr)
20
15
10
5
0
0
0,5
1
1,5
2
Effort range
MALES 1994 ADRIATIC
Y/R (gr)
15
10
5
0
0
0,5
1
1,5
2
Effort range
MALES 1994 EUBOIKOS
Y/R (gr)
15
10
5
0
0
0,5
1
1,5
2
Effort range

Fig. 12.10

CONCLUSIONS

Norway lobster populations in the Mediterranean share the same biological and fisheries features. Similar results are observed in all study areas in the reconstructed virgin stock by age or size: size is comparable among areas within a few millimetres and the current average age differs by a year at most. Norway lobster population show a considerable uniformity.

None of the stocks studied show signs of heavy overexploitation. Some are slightly overexploited and others are near the optimum level of exploitation. For comparative purposes, the study areas can be sorted as follows:

High exploitation:	1. Catalan Sea
	2. Adriatic Sea
	3. Tyrrhenian Sea
Intermediate exploitation:	4. Ligurian Sea
	5. Euboikos Gulf
Low exploitation:	6. Alboran Sea
	7. Algarve

Taking together the population parameters analysed we conclude that the Atlantic (Algarve) is the area where the exploitation state nears its optimum level, while the Euboikos Gulf and the Alboran sea suffer a lower fishing pressure.

Females are more sensitive to exploitation than males, as seen by the more variable values found for females. Variability among areas is higher for females than for males. However it cannot be ruled out that this result is a bias arising from poorer sampling due to the unavailability of females to the sampling gear in autumn. In all, males show a more uniform response to exploitation (cf. tables by sexes).

We have evidence that Norway lobster populations present a high degree of self-protection against trawl exploitation for the following reasons:

1.- In the Mediterranean multi-species fishery the trawling gear is not specifically modified and adapted for an exclusive fishery of Norway lobster.

2.- The burrowing behaviour of the species lowers its catchability by the trawl.

3.- The ratio of recruitment rate to turnover is relatively high in the population.

The application of effort reduction measures should be based on the knowledge on the life-cycle of the species. Specifically, such measures should follow one or more of the following criteria:

- In stocks where a clear size segregation is present, the depths where the smallest individuals are found should be protected from exploitation, as recuitment is a major input to the population (e.g. the Catalan and Adriatic Seas).

- In stocks where females are heavily exploited, the effort reduction should be concentrated on the maturity period previous to egg-carrying, as females are naturally protected during the egg-carrying period by their burrowing habits.

- When considering an effort reduction based on reducing the daily working time, fishing during the maximum daily activity period of the species should be avoided. Specifically, maximum activity periods for Norway lobster are noon in deep-water stocks and dusk and dawn shallow-water stocks (e.g. Adriatic Sea and Euboikos Gulf).

- If a working day per week is to be reduced, the day should be chosen after weekends or holidays, to avoid continuous disturbance of the habitat.

REFERENCES

ANONYMOUS (1995). Report of the Working Group on *Nephrops* stocks. *ICES. Assess: 12, Part 1 and 2.*

GULLAND, J.A. (1965). Estimation of mortality rates. Annex to Rep. *Arctic Fish. Working Group, Int. Counc. Explor. Sea* C.M. 3: 9 pp.

LLEONART, J., AND J. SALAT (1992). VIT, Programa de análisis de pesquerías. *Informes Técnicos de Scientia Marina.* CSIC. Barcelona, 168-169:116 pp.

Table F. -Results of different values of *F* (i.e. Catalan, Males; M=0.2 from 1993), from LCA and Y/R analyses

	F =0.1	*F=1.0*	*F=2.0*
Stock mean age	1.31	1.26	1.26
Stock mean length	22.32	22.09	22.08
Rrecruitment (%)	3.6	3.7	3.7
Growth (%)	96.4	96.3	96.3
Mortality (%)	30.9	29.3	29.2
R/B	2.3	2.5	2.5
B/B	25.2	26.8	26.9
D/B	64.7	68.2	68.4
B/D	39.0	39.3	39.3
Y/Rm	12.8	14.1	14.4
Φ	0.6	0.4	0.4

Annex

- ***Size-wegiht relationship***
- ***Outputs of VIT program for Analysis of Virtual Populations***

H0: b = 3

MALES

$y=a\,x^b$	year	a	b	r	n	s	S_{94-95}
Faro (Atl)	94	.000336	3.202	.996	46	***	
	95	.000332	3.199	.989	94	***	ns
Malaga (Alb)	94	.000420	3.137	.981	207	**	
	95	.000402	3.163	.970	190	**	ns
Barna (Cat)	94	.000562	3.052	.979	469	ns	
	95	.000479	3.118	.990	263	***	ns
Genova (Lig)	94	.000270	3.239	.986	152	***	
	95	.000364	3.157	.985	95	***	ns
Pisa (Tyr)	94	.000235	3.295	.992	200	***	
	95	.000277	3.258	.994	231	***	ns
Ancona (Adr)	94	.000279	3.255	.998	390	***	
	95	.000359	3.185	.998	378	***	***
Atenas (Eub)	94	.000467	3.100	.991	306	***	
	95	.000436	3.123	.995	133	***	ns

FEMALES

Faro (Atl)	94	.000398	3.151	.990	14	ns	
	95	.000433	3.110	.985	46	ns	ns
Malaga (Alb)	94	.000633	3.020	.989	235	ns	
	95	.000485	3.102	.972	191	ns	ns
Barna (Cat)	94	.000859	2.914	.968	238	ns	
	95	.000552	3.075	.992	235	**	**
Genova (Lig)	94	.000680	2.979	.960	139	ns	
	95	.000250	3.254	.939	81	ns	ns
Pisa (Tyr)	94	.000317	3.214	.988	200	***	
	95	.000459	3.113	.989	206	***	*
Ancona (Adr)	94	.000434	3.120	.996	336	***	
	95	.000464	3.110	.996	368	***	ns
Atenas (Eub)	94	.000543	3.043	.985	239	ns	
	95	.000603	3.018	.987	159	ns	ns

Size-weigth relationship by sexes and different areas

BC93MV2

```
***********
*         *
*   VIT   *
*         *
***********
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" Institut de Ciencies del Mar (C.S.I.C.). Barcelona

" Date " 27/05/96 "Initial time:" 10:55:02

" GENERAL INFORMATION

" barm93

" Num. of Classes:" 51 " Num. of Gears:" 1

" Data arranged by LENGTHS VPA Method: STANDARD

" Lower Limits: First class =" 10.00 " Last class =" 60.00

" Incr. per Class:" 1.00 " Class + ? NO

" Input File: bcn93m.prn
" Output File: bc93mv2
" Parameter File: bcn93mp.prn

"L(inf)=" 89.55 "K=" .9600E-01 "t(0)="-.5890

"a=" .5620E-03 "b=" 3.052

"M=" .2000 "Fterm=" 1.000

"Proportion factors:" 58.2

"Rates of matures:"

```
 1  .00  2  .00  3  .00  4  .00  5  .00  6  .00  7  .00  8  .00  9  .00
10  .00 11  .00 12  .00 13  .00 14  .10 15  .20 16  .30 17  .40 18  .50
19  .60 20  .70 21  .80 22  .90 23 1.00 24 1.00 25 1.00 26 1.00 27 1.00
28 1.00 29 1.00 30 1.00 31 1.00 32 1.00 33 1.00 34 1.00 35 1.00 36 1.00
37 1.00 38 1.00 39 1.00 40 1.00 41 1.00 42 1.00 43 1.00 44 1.00 45 1.00
46 1.00 47 1.00 48 1.00 49 1.00 50 1.00 51 1.00
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"Global data:"

"	" "Ages"	"	" "Lengths"	"	" "Weights"	
"Class"	"Lower"	"Mean"	"Lower"	"Mean"	"Lower"	"Mean"
1	.644	.710	10.000	10.499	.633	.737
2	.776	.843	11.000	11.499	.847	.972
3	.910	.977	12.000	12.499	1.11	1.25
4	1.045	1.113	13.000	13.499	1.41	1.58
5	1.182	1.251	14.000	14.499	1.77	1.97
6	1.321	1.391	15.000	15.499	2.18	2.42
7	1.461	1.532	16.000	16.499	2.66	2.92

8	1.604	1.676	17.000	17.499	3.20	3.50
9	1.749	1.821	18.000	18.498	3.81	4.14
10	1.895	1.969	19.000	19.498	4.49	4.86
11	2.044	2.119	20.000	20.498	5.25	5.67
12	2.195	2.271	21.000	21.497	6.10	6.55
13	2.348	2.425	22.000	22.497	7.03	7.53
14	2.503	2.581	23.000	23.496	8.05	8.59
15	2.661	2.740	24.000	24.496	9.17	9.76
16	2.821	2.901	25.000	25.495	10.4	11.0
17	2.984	3.065	26.000	26.494	11.7	12.4
18	3.149	3.231	27.000	27.494	13.1	13.9
19	3.317	3.400	28.000	28.491	14.7	15.5
20	3.487	3.572	29.000	29.491	16.3	17.2
21	3.661	3.747	30.000	30.490	18.1	19.0
22	3.837	3.925	31.000	31.488	20.0	21.0
23	4.017	4.105	32.000	32.486	22.1	23.1
24	4.199	4.289	33.000	33.485	24.2	25.3
25	4.385	4.477	34.000	34.488	26.5	27.7
26	4.574	4.668	35.000	35.487	29.0	30.2
27	4.767	4.863	36.000	36.488	31.6	32.9
28	4.963	5.061	37.000	37.487	34.3	35.8
29	5.164	5.262	38.000	38.486	37.3	38.7
30	5.368	5.469	39.000	39.487	40.3	41.9
31	5.576	5.679	40.000	40.488	43.6	45.2
32	5.788	5.893	41.000	41.488	47.0	48.7
33	6.005	6.112	42.000	42.485	50.6	52.4
34	6.226	6.336	43.000	43.485	54.3	56.2
35	6.453	6.563	44.000	44.480	58.3	60.3
36	6.684	6.797	45.000	45.481	62.4	64.5
37	6.920	7.037	46.000	46.484	66.8	68.9
38	7.162	7.280	47.000	47.479	71.3	73.5
39	7.410	7.532	48.000	48.483	76.0	78.4
40	7.664	7.789	49.000	49.483	80.9	83.4
41	7.924	8.050	50.000	50.477	86.1	88.6
42	8.191	8.322	51.000	51.483	91.5	94.1
43	8.464	8.600	52.000	52.484	97.0	99.8
44	8.746	8.882	53.000	53.475	103.	106.
45	9.035	9.178	54.000	54.484	109.	112.
46	9.332	9.475	55.000	55.472	115.	118.
47	9.638	9.783	56.000	56.465	122.	125.
48	9.953	10.113	57.000	57.496	128.	132.
49	10.278	10.427	58.000	58.447	135.	139.
50	10.613	10.772	59.000	59.460	143.	146.
51	10.960	11.127	60.000	60.467	150.	154.
""	11.319	""	61.000	""	158.	

"Catch in numbers:"

"Class"	"Total catch"	"Catch per gear"
1	5.82	5.82
2	5.82	5.82
3	5.82	5.82
4	5.82	5.82
5	174.46	174.46
6	232.61	232.61
7	174.46	174.46
8	1279.36	1279.36
9	3547.32	3547.32
10	6862.02	6862.02
11	8083.23	8083.23
12	9304.44	9304.44
13	12968.06	12968.06

14	16224.62	16224.62
15	17736.59	17736.59
16	20469.77	20469.77
17	21981.74	21981.74
18	23551.86	23551.86
19	32623.69	32623.69
20	27855.17	27855.17
21	27971.47	27971.47
22	29483.44	29483.44
23	29367.14	29367.14
24	26924.72	26924.72
25	16573.53	16573.53
26	15992.01	15992.01
27	11921.31	11921.31
28	11339.79	11339.79
29	10176.73	10176.73
30	7734.32	7734.32
31	6280.50	6280.50
32	5291.90	5291.90
33	5291.90	5291.90
34	4477.76	4477.76
35	4826.68	4826.68
36	3605.47	3605.47
37	2326.11	2326.11
38	2500.57	2500.57
39	1511.97	1511.97
40	1221.21	1221.21
41	1279.36	1279.36
42	697.83	697.83
43	523.37	523.37
44	639.68	639.68
45	290.76	290.76
46	407.07	407.07
47	348.92	348.92
48	5.82	5.82
49	290.76	290.76
50	116.31	116.31
51	58.15	58.15
"Sum:"	432569.20	432569.20
"Mean Age:"	3.91	3.91
"Mean Length:"	31.03	31.03

"Catch in weight:"

"Class"	"Total catch"	"Catch per gear"
1	4.28	4.28
2	5.65	5.65
3	7.29	7.29
4	9.22	9.22
5	343.83	343.83
6	561.85	561.85
7	509.92	509.92
8	4474.50	4474.50
9	14697.83	14697.83
10	33382.98	33382.98
11	45804.68	45804.68
12	60969.47	60969.47
13	97612.48	97612.48
14	139442.90	139442.90

15	173099.80	173099.80
16	225695.20	225695.20
17	272535.70	272535.70
18	326923.80	326923.80
19	504861.00	504861.00
20	478927.80	478927.80
21	532382.30	532382.30
22	619118.10	619118.10
23	678284.90	678284.90
24	682067.10	682067.10
25	459436.50	459436.50
26	483660.80	483660.80
27	392499.70	392499.70
28	405422.40	405422.40
29	394250.10	394250.10
30	324053.90	324053.90
31	284018.50	284018.50
32	257810.30	257810.30
33	277204.20	277204.20
34	251807.80	251807.80
35	290837.60	290837.60
36	232513.20	232513.20
37	160335.40	160335.40
38	183865.90	183865.90
39	118507.00	118507.00
40	101868.50	101868.50
41	113399.90	113399.90
42	65693.56	65693.56
43	52251.80	52251.80
44	67616.88	67616.88
45	32539.11	32539.11
46	48123.56	48123.56
47	43543.23	43543.23
48	766.95	766.95
49	40314.50	40314.50
50	16994.31	16994.31
51	8944.05	8944.05
"Sum:"	.10000E+08	.10000E+08
"Percentages:"		100.00

"VPA RESULTS"

'Numbers & Mortalities:"

'Class"	"Initial no."	"Mean no.""	Z"	"F(tot)"	"F per gear"
1	863194.30	112261.10	.200	.000	.000
2	840736.30	110722.70	.200	.000	.000
3	818585.90	109185.90	.200	.000	.000
4	796742.90	107650.80	.200	.000	.000
5	775206.90	106105.80	.202	.002	.002
6	753811.30	104546.60	.202	.002	.002
7	732669.30	102989.50	.202	.002	.002
8	711896.90	101358.60	.213	.013	.013
9	690345.90	99485.00	.236	.036	.036
10	666901.60	97203.28	.271	.071	.071
11	640598.90	94589.19	.285	.085	.085
12	613597.80	91793.78	.301	.101	.101
13	585934.60	88624.91	.346	.146	.146

14	555241.60	84922.59	.391	.191	.191
15	522032.40	80851.06	.419	.219	.219
16	488125.60	76442.49	.468	.268	.268
17	452367.30	71696.16	.507	.307	.307
18	416046.30	66700.87	.553	.353	.353
19	379154.30	60794.04	.737	.537	.537
20	334371.80	54571.98	.710	.510	.510
21	295602.30	48743.93	.774	.574	.574
22	257882.00	42772.61	.889	.689	.689
23	219844.00	36688.96	1.000	.800	.800
24	183139.10	30858.98	1.073	.873	.873
25	150042.60	26272.80	.831	.631	.631
26	128214.50	22674.97	.905	.705	.705
27	107687.50	19550.17	.810	.610	.610
28	91856.13	16868.41	.872	.672	.672
29	77142.66	14368.72	.908	.708	.708
30	64092.19	12249.28	.831	.631	.631
31	53908.02	10533.05	.796	.596	.596
32	45520.91	9076.55	.783	.583	.583
33	38413.70	7723.42	.885	.685	.685
34	31577.12	6468.39	.892	.692	.692
35	25805.68	5258.27	1.118	.918	.918
36	19927.34	4165.65	1.066	.866	.866
37	15488.74	3371.88	.890	.690	.690
38	12488.26	2699.64	1.126	.926	.926
39	9447.76	2141.92	.906	.706	.706
40	7507.40	1740.65	.902	.702	.702
41	5938.07	1366.53	1.136	.936	.936
42	4385.40	1070.93	.852	.652	.652
43	3473.38	874.76	.798	.598	.598
44	2775.05	683.60	1.136	.936	.936
45	1998.65	532.80	.746	.546	.546
46	1601.33	410.55	1.192	.992	.992
47	1112.15	281.87	1.438	1.238	1.238
48	706.86	221.51	.226	.026	.026
49	656.74	160.14	2.016	1.816	1.816
50	333.95	90.48	1.485	1.285	1.285
51	199.55	58.15	1.200	1.000	1.000

"Tot:" "" .21525E+07

"Mean mortalities:" "" "" .825 .625 .625
"Global Fishing mortalities:" "" "" "" .201 .201

"Stock:" "Mean age=" 2.35 "Mean length=" 21.51

"Weights:"

'Class"	"Initial"	"Mean"
1	546820.70	82702.38
2	712404.40	107633.10
3	904610.80	136858.80
4	1124112.00	170622.80
5	1371314.00	209120.90
6	1645999.00	252524.70
7	1948133.00	301027.00
8	2277632.00	354497.20
9	2629631.00	412202.80
10	2996085.00	472883.10
11	3365628.00	536001.80
12	3741394.00	601499.80
13	4117746.00	667092.50

14	4469014.00	729869.40
15	4784522.00	789064.00
16	5067350.00	842838.20
17	5293297.00	888908.90
18	5462611.00	925876.00
19	5562611.00	940805.10
20	5460152.00	938283.40
21	5353258.00	927745.40
22	5161707.00	898175.30
23	4848069.00	847394.90
24	4436311.00	781731.30
25	3981297.00	728310.70
26	3716800.00	685779.90
27	3402020.00	643673.60
28	3154977.00	603082.90
29	2874290.00	556649.40
30	2585060.00	513222.60
31	2348967.00	476328.90
32	2138768.00	442190.80
33	1942582.00	404573.90
34	1715752.00	363751.40
35	1504074.00	316843.60
36	1243914.00	268638.80
37	1033926.00	232418.80
38	890186.20	198503.80
39	718147.20	167881.70
40	607721.50	145198.00
41	511255.40	121126.80
42	401097.30	100817.00
43	337078.40	87333.10
44	285428.70	72259.53
45	217640.30	59625.60
46	184418.10	48535.06
47	135322.20	35176.06
48	90781.77	29214.13
49	88943.12	22202.82
50	47649.41	13221.45
51	29970.87	8944.04
"Tot:"	""	.21161E+08

"	"Critical age"	"Critical length"
"Actual Stock"	3.32	28.00
"Virgin Stock"	8.70	52.85

"General Biomass Equation" "Total Biomass Balance (D) = " .1423E+08

		"Biomass"	"Percent"
"Inputs"	"Recruitment"	.5468E+06	3.8 "%"
" "	"Growth"	.1369E+08	96.2 "%"
"Outputs"	"Natural dead"	.4232E+07	29.7 "%"
" "	"Biomass caught"	.1000E+08	70.3 "%"

"R/B(mean) =" 2.6 "%" "D/B(mean) =" 67.3 "% (turnover)

"B(max)/B(mean) =" 26.3 "%" "B(max)/D =" 39.1 "%"

"YIELD PER RECRUIT"

"Slope at origin=" 115.655 "Virgin biomass=" .129938E+09

"Method: * Calculated Mean Weights "

"Number of points=" 200 "Maximum Factor for effort=" 2.0
" Resolution=" .010

"Factor"	"Y/R"	"Biomass"	"S.S.B."	"Y/R per gear"
.00	.00000	150.53	139.88	.00
.01	1.1151	145.83	135.19	1.12
.02	2.1508	141.32	130.70	2.15
.03	3.1124	137.00	126.39	3.11
.04	4.0048	132.85	122.26	4.00
.05	4.8326	128.88	118.30	4.83
.06	5.5999	125.07	114.50	5.60
.07	6.3109	121.41	110.85	6.31
.08	6.9692	117.89	107.35	6.97
.09	7.5783	114.52	103.99	7.58
.10	8.1416	111.28	100.77	8.14
.11	8.6620	108.17	97.673	8.66
.12	9.1424	105.18	94.698	9.14
.13	9.5854	102.31	91.840	9.59
.14	9.9937	99.548	89.093	9.99
.15	10.369	96.893	86.452	10.37
.16	10.715	94.341	83.913	10.71
.17	11.032	91.885	81.472	11.03
.18	11.323	89.523	79.123	11.32
.19	11.589	87.249	76.863	11.59
.20	11.833	85.061	74.688	11.83
.21	12.055	82.953	72.595	12.05
.22	12.257	80.924	70.579	12.26
.23	12.441	78.969	68.638	12.44
.24	12.607	77.085	66.767	12.61
.25	12.757	75.270	64.965	12.76
.26	12.893	73.519	63.229	12.89
.27	13.014	71.832	61.554	13.01
.28	13.123	70.204	59.940	13.12
.29	13.219	68.634	58.383	13.22
.30	13.304	67.119	56.881	13.30
.31	13.379	65.656	55.432	13.38
.32	13.445	64.244	54.033	13.44
.33	13.501	62.881	52.683	13.50
.34	13.549	61.563	51.379	13.55
.35	13.589	60.291	50.120	13.59
.36	13.622	59.061	48.903	13.62
.37	13.648	57.873	47.727	13.65
.38	13.669	56.723	46.591	13.67
.39	13.683	55.612	45.492	13.68
.40	13.693	54.537	44.430	13.69
.41	13.697	53.496	43.403	13.70
.42	13.697	52.490	42.409	13.70
.43	13.693	51.515	41.447	13.69
.44	13.685	50.571	40.516	13.69
.45	13.674	49.658	39.615	13.67
.46	13.659	48.772	38.742	13.66
.47	13.641	47.914	37.897	13.64
.48	13.621	47.083	37.078	13.62

.49	13.598	46.277	36.285	13.60
.50	13.573	45.495	35.516	13.57
.51	13.545	44.737	34.770	13.55
.52	13.516	44.002	34.047	13.52
.53	13.485	43.288	33.346	13.49
.54	13.453	42.596	32.666	13.45
.55	13.419	41.923	32.006	13.42
.56	13.384	41.270	31.365	13.38
.57	13.347	40.636	30.743	13.35
.58	13.310	40.020	30.140	13.31
.59	13.271	39.422	29.553	13.27
.60	13.232	38.840	28.984	13.23
.61	13.192	38.275	28.430	13.19
.62	13.152	37.725	27.893	13.15
.63	13.111	37.190	27.370	13.11
.64	13.069	36.670	26.862	13.07
.65	13.027	36.164	26.368	13.03
.66	12.984	35.671	25.887	12.98
.67	12.942	35.192	25.420	12.94
.68	12.899	34.725	24.965	12.90
.69	12.856	34.270	24.522	12.86
.70	12.812	33.828	24.091	12.81
.71	12.769	33.396	23.671	12.77
.72	12.726	32.976	23.263	12.73
.73	12.682	32.566	22.865	12.68
.74	12.639	32.167	22.477	12.64
.75	12.596	31.778	22.100	12.60
.76	12.553	31.398	21.731	12.55
.77	12.509	31.028	21.373	12.51
.78	12.466	30.666	21.023	12.47
.79	12.424	30.314	20.682	12.42
.80	12.381	29.970	20.349	12.38
.81	12.339	29.634	20.025	12.34
.82	12.296	29.306	19.708	12.30
.83	12.254	28.985	19.399	12.25
.84	12.213	28.673	19.097	12.21
.85	12.171	28.367	18.803	12.17
.86	12.130	28.068	18.516	12.13
.87	12.089	27.776	18.235	12.09
.88	12.048	27.491	17.961	12.05
.89	12.008	27.212	17.693	12.01
.90	11.968	26.939	17.432	11.97
.91	11.928	26.673	17.176	11.93
.92	11.889	26.412	16.926	11.89
.93	11.850	26.156	16.682	11.85
.94	11.811	25.907	16.443	11.81
.95	11.772	25.662	16.210	11.77
.96	11.734	25.423	15.981	11.73
.97	11.696	25.189	15.758	11.70
.98	11.659	24.959	15.540	11.66
.99	11.622	24.735	15.326	11.62
1.00	11.585	24.515	15.117	11.58
1.01	11.548	24.299	14.912	11.55
1.02	11.512	24.088	14.711	11.51
1.03	11.476	23.881	14.515	11.48
1.04	11.441	23.678	14.323	11.44
1.05	11.406	23.479	14.135	11.41
1.06	11.371	23.284	13.951	11.37
1.07	11.337	23.093	13.770	11.34
1.08	11.302	22.906	13.593	11.30
1.09	11.269	22.722	13.420	11.27
1.10	11.235	22.541	13.250	11.24
1.11	11.202	22.364	13.083	11.20
1.12	11.169	22.191	12.920	11.17

1.13	11.136	22.020	12.760	11.14
1.14	11.104	21.853	12.603	11.10
1.15	11.072	21.689	12.449	11.07
1.16	11.041	21.527	12.299	11.04
1.17	11.009	21.369	12.150	11.01
1.18	10.978	21.213	12.005	10.98
1.19	10.948	21.061	11.863	10.95
1.20	10.917	20.910	11.723	10.92
1.21	10.887	20.763	11.586	10.89
1.22	10.858	20.618	11.451	10.86
1.23	10.828	20.476	11.319	10.83
1.24	10.799	20.336	11.189	10.80
1.25	10.770	20.198	11.061	10.77
1.26	10.741	20.063	10.936	10.74
1.27	10.713	19.930	10.813	10.71
1.28	10.685	19.799	10.692	10.68
1.29	10.657	19.671	10.574	10.66
1.30	10.629	19.544	10.457	10.63
1.31	10.602	19.420	10.343	10.60
1.32	10.575	19.297	10.230	10.57
1.33	10.548	19.177	10.120	10.55
1.34	10.522	19.058	10.011	10.52
1.35	10.495	18.941	9.9041	10.50
1.36	10.469	18.827	9.7991	10.47
1.37	10.444	18.713	9.6958	10.44
1.38	10.418	18.602	9.5942	10.42
1.39	10.393	18.493	9.4943	10.39
1.40	10.368	18.385	9.3961	10.37
1.41	10.343	18.278	9.2995	10.34
1.42	10.318	18.174	9.2045	10.32
1.43	10.294	18.071	9.1110	10.29
1.44	10.270	17.969	9.0190	10.27
1.45	10.246	17.869	8.9285	10.25
1.46	10.222	17.770	8.8394	10.22
1.47	10.199	17.673	8.7518	10.20
1.48	10.175	17.577	8.6655	10.18
1.49	10.152	17.483	8.5806	10.15
1.50	10.129	17.390	8.4970	10.13
1.51	10.107	17.298	8.4147	10.11
1.52	10.084	17.208	8.3336	10.08
1.53	10.062	17.119	8.2538	10.06
1.54	10.040	17.031	8.1753	10.04
1.55	10.018	16.944	8.0979	10.02
1.56	9.9964	16.859	8.0216	10.00
1.57	9.9750	16.774	7.9466	9.97
1.58	9.9537	16.691	7.8726	9.95
1.59	9.9326	16.609	7.7997	9.93
1.60	9.9116	16.528	7.7279	9.91
1.61	9.8909	16.448	7.6572	9.89
1.62	9.8703	16.369	7.5875	9.87
1.63	9.8499	16.291	7.5188	9.85
1.64	9.8297	16.215	7.4511	9.83
1.65	9.8097	16.139	7.3843	9.81
1.66	9.7898	16.064	7.3185	9.79
1.67	9.7701	15.990	7.2537	9.77
1.68	9.7505	15.917	7.1897	9.75
1.69	9.7311	15.845	7.1267	9.73
1.70	9.7119	15.774	7.0646	9.71
1.71	9.6928	15.704	7.0033	9.69
1.72	9.6739	15.634	6.9428	9.67
1.73	9.6552	15.566	6.8832	9.66
1.74	9.6366	15.498	6.8244	9.64
1.75	9.6181	15.431	6.7664	9.62
1.76	9.5998	15.365	6.7092	9.60

1.77	9.5816	15.300	6.6528	9.58
1.78	9.5636	15.236	6.5971	9.56
1.79	9.5458	15.172	6.5421	9.55
1.80	9.5280	15.109	6.4879	9.53
1.81	9.5104	15.047	6.4344	9.51
1.82	9.4930	14.986	6.3816	9.49
1.83	9.4757	14.925	6.3295	9.48
1.84	9.4585	14.865	6.2781	9.46
1.85	9.4414	14.805	6.2274	9.44
1.86	9.4245	14.747	6.1773	9.42
1.87	9.4077	14.689	6.1278	9.41
1.88	9.3911	14.631	6.0790	9.39
1.89	9.3745	14.575	6.0308	9.37
1.90	9.3581	14.519	5.9832	9.36
1.91	9.3419	14.463	5.9362	9.34
1.92	9.3257	14.408	5.8898	9.33
1.93	9.3096	14.354	5.8440	9.31
1.94	9.2937	14.300	5.7987	9.29
1.95	9.2779	14.247	5.7540	9.28
1.96	9.2622	14.195	5.7099	9.26
1.97	9.2467	14.143	5.6663	9.25
1.98	9.2312	14.091	5.6232	9.23
1.99	9.2159	14.041	5.5806	9.22
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'o-o oo oo oooo"	5.31	32.55	18.74	5.31
'o+o oo oo oooo"	14.70	18.73	11.78	14.70
'oo- oo oo oooo"	11.58	24.51	15.12	11.58
'oo+ oo oo oooo"	11.58	24.51	15.12	11.58
'ooo -o oo oooo"	5.79	12.26	7.56	5.79
'ooo +o oo oooo"	17.38	36.77	22.68	17.38
'ooo o- oo oooo"	.05	.16	.07	.05
ooo o+ oo oooo"	2754.18	4767.71	3679.02	2754.18
ooo oo -o oooo"	16.52	29.90	18.92	16.52
ooo oo +o oooo"	7.94	20.05	12.00	7.94
ooo oo o- oooo"	11.57	24.71	15.31	11.57
ooo oo o+ oooo"	11.59	24.45	15.05	11.59
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"Elapsed time:" 1.30 "minutes"

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"                                   *         *
"                                   *   VIT   *
"                                   *         *
"                                   ***********

"     Institut de Ciencies del Mar (C.S.I.C.).          Barcelona

" Date "  27/05/96                       "Initial time:" 11:21:14

" GENERAL INFORMATION

" barm93

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" Data arranged by LENGTHS   VPA Method: STANDARD

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" Incr. per Class:" 1.00     " Class + ?  NO

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      "M=" .2000       "Fterm=" 1.000

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10   .00 11   .00 12   .00 13   .00 14   .10 15   .20 16   .30 17   .40 18   .50
19   .60 20   .70 21   .80 22   .90 23 1.00 24 1.00 25 1.00 26 1.00 27 1.00
28 1.00 29 1.00 30 1.00 31 1.00 32 1.00 33 1.00 34 1.00 35 1.00 36 1.00
37 1.00 38 1.00 39 1.00 40 1.00 41 1.00 42 1.00 43 1.00 44 1.00 45 1.00
46 1.00 47 1.00 48 1.00 49 1.00 50 1.00 51 1.00
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+oo oo oo oooo"	12.65	22.12	13.55	12.65
o-o oo oo oooo"	10.68	26.03	15.94	10.68
o+o oo oo oooo"	12.37	23.13	14.34	12.37

"oo- oo oo oooo"	11.58	24.51	15.12	11.58
"oo+ oo oo oooo"	11.58	24.51	15.12	11.58
"ooo -o oo oooo"	10.43	22.06	13.61	10.43
"ooo +o oo oooo"	12.74	26.97	16.63	12.74
"ooo o- oo oooo"	3.93	8.77	5.09	3.93
"ooo o+ oo oooo"	34.31	69.14	45.05	34.31
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"ooo oo +o oooo"	10.76	23.55	14.44	10.76
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" ***********
" * VIT *
" ***********

B.V93MYRT

" Institut de Ciencies del Mar (C.S.I.C.). Barcelona

" Date " 13/06/96 "Initial time:" 12:17:38

" GENERAL INFORMATION

" barm93

" Num. of Classes:" 12 " Num. of Gears:" 1

" Data arranged by AGES VPA Method: STANDARD

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" Incr. per Class:" 1.00 " Class + ? NO

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" Parameter File: bcn93mcp

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"a=" .5620E-03 "b=" 3.052

"M=" .2000 "Fterm=" .3187

"Proportion factors:" 58.2

"Rates of matures:"

1 .00 2 .00 3 .10 4 .65 5 1.00 6 1.00 7 1.00 8 1.00 9 1.00
10 1.00 11 1.00 12 1.00

"TRANSITION ANALYSIS"

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1	8.57	22.7	14.1	8.57
2	9.40	24.2	15.6	9.40
3	9.99	25.2	16.6	9.99
4	10.4	25.8	17.2	10.4
5	10.6	26.2	17.6	10.6
6	10.7	26.4	17.8	10.7
7	10.8	26.5	17.9	10.8
8	10.8	26.5	17.9	10.8

9	10.8	26.6	17.9	10.8
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"End time:" 12:18:13

"Elapsed time:" .58 "minutes"

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"                                  *         *
"                                  *   VIT   *
"                                  *         *
"                                  ***********

"     Institut de Ciencies del Mar (C.S.I.C.).          Barcelona

" Date "  13/06/96                        "Initial time:" 13:42:09

" GENERAL INFORMATION

" barm93

" Num. of Classes:"   12   " Num. of Gears:"   1

" Data arranged by AGES       VPA Method: STANDARD

" Lower Limits:  First class ="        .00  " Last class ="    11.00

" Incr. per Class:" 1.00      " Class + ?  NO

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"     Output File: bn93myr1
" Parameter File: bcn93mcp
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10 1.00 11 1.00 12 1.00
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"TRANSITION ANALYSIS"

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1	11.5	20.8	12.5	11.5
2	10.5	19.6	11.4	10.5
3	9.94	18.9	10.8	9.94
4	9.68	18.7	10.5	9.68
5	9.57	18.5	10.4	9.57
6	9.52	18.5	10.3	9.52
7	9.51	18.5	10.3	9.51
8	9.50	18.5	10.3	9.50

9	9.50	18.5	10.3	9.50
10	9.50	18.5	10.3	9.50
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"End time:" 13:42:36

"Elapsed time:" .45 "minutes"

"

" * *
" * VIT *
" * *
" ***********

" Institut de Ciencies del Mar (C.S.I.C.). Barcelona

" Date " 11/11/96 "Initial time:" 13:59:23

" GENERAL INFORMATION

" barm93

" Num. of Classes:" 51 " Num. of Gears:" 1

" Data arranged by LENGTHS VPA Method: STANDARD

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" Incr. per Class:" 1.00 " Class + ? NO

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" Parameter File: bcn93mp.prn

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"a=" .5620E-03 "b=" 3.052

"M=" .2000 "Fterm=" 1.000

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10	.00	11	.00	12	.00	13	.00	14	.10	15	.20	16	.30	17	.40	18	.50
19	.60	20	.70	21	.80	22	.90	23	1.00	24	1.00	25	1.00	26	1.00	27	1.00
28	1.00	29	1.00	30	1.00	31	1.00	32	1.00	33	1.00	34	1.00	35	1.00	36	1.00
37	1.00	38	1.00	39	1.00	40	1.00	41	1.00	42	1.00	43	1.00	44	1.00	45	1.00
46	1.00	47	1.00	48	1.00	49	1.00	50	1.00	51	1.00						

"YIELD PER RECRUIT"

"Slope at origin=" 117.143 "Virgin biomass=" .143562E+09

"Method: * Calculated Mean Weights "

"Number of points=" 200 "Maximum Factor for effort=" 2.0
" Resolution=" .010

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.00	.00000	175.05	164.90	.00
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.27	13.441	78.845	69.079	13.44
"*** Max(1):"				
.43	14.140	56.703	47.132	14.14
"*** Max:"				
.44	14.139	55.590	46.031	14.14
1.00	12.194	25.284	16.379	12.19
2.00	9.7050	13.676	5.7072	9.70

"End time:" 14:00:14

"Elapsed time:" .85 "minutes"

CONCLUSIONS AND RECOMMENDATIONS

There exists an extensive bibliographic record on the Norway lobster, *Nephrops norvegicus*, in the Mediterranean and the European Atlantic. The biology and the population dynamics of this species in northern countries is well known. Hence in these conclusions only those results directly pertaining to the comparative studies undertaken during this project will be presented. Biological or fisheries concepts that can be found in the literature are considered as known. A complete review of the literature can be found in Sardà (1995), referred to in the Introduction.

Partial conclusions are discussed in detail in every chapter. In these final conclusions only the most relevant ones are reviewed, in the same order as the corresponding chapters:

- Overall, young specimens do not show differences in molt periodicity between sexes, confirming a common growth pattern between males and females in the juvenile phase. There are two or three moulting periods per year, as results from Euboikos Gulf and Tyrrhenian Sea data show: a "winter" moult (December-March), a "late summer" moult (August-September) and, eventually, a "spring" moult (April-May). In some areas (Catalan Sea, Adriatic Sea) moult peaks are less evident, hidden by an asynchronous moulting of part of the young population (see Sardà, 1991 for the Catalan Sea). Differences in moulting periodicity between males and females are evident in adult specimens. Mature females present only one moulting period per year between December and March, except for the Ligurian Sea and the Atlantic, where it seems slightly moved to spring (March-May). This period is situated immediately after egg hatching, and in the literature it is reported that adult females undergo moult before mating. Males present two distinct moulting periods: the first common to females, the second in late Summer to Autumn (August-October). In some areas (Euboikos Gulf, Adriatic Sea, Catalan Sea) this second period seems to be more important than the first one. Again, in the Ligurian Sea and the Atlantic there is a single moult period in late Spring. The existence of a common seasonal pattern of moult can be confirmed in almost all the studied areas. Results obtained for the Ligurian Sea and the Atlantic could be due to the paucity of samples or to a different response of *Nephrops* to different environmental conditions. The study on presence of gastroliths as indicators of moult frequency confirms the results obtained with other techniques as percentage of occurrence of "soft" specimens in size frequency distributions or studies in aquaria.

- The Norway lobster is characterized by a growth in which laying occurs in each postpuberty instar. The timing of the basic processes of reproduction, i.e. maturation and laying of embryos on pleopods are closely synchronised in the study areas; however at lower latitudes or in shallow waters the timing is slightly advanced. Light and temperature are the factors possibly involved: as temperature is lower in winter in shallow waters (Adriatic, Euboikos).

The sizes at maturity (50%) ranged between 29.4 and 36.0 mm CL with three patterns: a) Algarve, Catalan and Adriatic are very close to each other with the smallest size; b) the intermediate size was found in Ligurian, Tyrrhenian and Euboikos Gulf ; and finally c) Alboran has a population composed by large females, with the larger maturity size. This complex picture suggest that local factors are involved, for instance the density of population, the food availability and so on. The study of fecundity seems to present only one important difference: Algarve in respect of other areas, an Atlantic versus Mediterranean trends.

- The visual comparison of growth parameters following two approaches (MIX and BHATTACHARYA's) used in the present work showed no significant differences between them. In all the analyses it was obvious that the main problem in the length-based methods is not the method chosen, but rather the sample structure and to a lesser extent, the way in which this method is applied (criteria used). The comparison of the results of the length frequency analyses among sexes and areas was difficult, but it was obvious that a difference exists between the two sexes in all the areas. The females always presented fewer age groups and lower increments than the males. This could be attributed to the effect of maturation of the females on their growth pattern. Furthermore, among the different areas, Alboran and Catalan presented the largest and smallest mean lengths-at-age, respectively. The mean lengths-at-age of Ligurian, Tyrrhenian, Adriatic and Euboikos seemed to be closer to each other, although higher differences existed among the females. This could be attributed to the differences in the reproductive cycle of females in these areas. For male lobsters (and excluding the Ligurian Sea which had much less information available), all estimates of L_∞ obtained by the two approaches (Gauss-Newton and FISHPARM) are between 71 and 87 mm, which is a narrow range considering the differences in population structure shown in the study areas. For K the range of estimated parameters was 0.10 to 0.17. Females show a high variability in the estimated parameters, a sign of poor results for this sex. Some of the facts that contribute to this may include behavioural aspects, and difficulty in separating ages during the moulting season. Behavioural patterns affect the population structure since the availability to the gear decreases for ovigerous females. For age classes that do not reach 100% maturity, this could result in bias in the estimation of mean lengths-at-age during the ovigerous season. After larval hatching, mature females are well represented in the catch, but this is also the period when moulting occurs. We believe that these difficulties are shown in the wide confidence limits both for L and K of females. If growth parameters are used for stock assessment and management purposes, perhaps ranges of values should be taken into consideration. The results of this work generally let us to suggest that more consideration should be given to: *a*) the use of length frequency analysis in the absence of information on individual growth in wild populations. and *b*) the research of alternative models that could express the growth of decapods.

- Biometric analyses show very small separation between the different populations compared. However, the number of spines of Alboran lobsters are on average lower than that for the other areas studied. These differences do not seem to be biologically significant. In general, the results of the biometric study were comparable to the results of the genetic analysis presented in this report, with no strong evidence for segregated populations of *Nephrops norvegicus* among the areas studied.

- Despite the low genetic heterogeneity, there are signs of a certain Nephrops population substructuring. Therefore Mediterranean Norway lobster population should not be seen necessarily as a pure single genetic unit. This last image is in partial agreement with the variability of vital parameters estimates as well as reproductive, growth and morphometric features recorded in several sites of the Mediterranean and in this study. Therefore there is evidence that local differences could be based on small genetic diversity and not only due to ecological and/or habitat differences.

- Biological characteristics (morphometry and population density) of Nephrops norvegicus were shown to be related, in the Catalan Sea, to sediment variables. In grounds off the Ebro Delta, Norway lobster was found at higher densities in finer sediments (silt and clay fraction between 50 and 90 %) although individuals were comparatively smaller than in coarser sediments, where lobster density was low. Redox potential was shown to be also an important factor determining lobster distribution. Redox potential at 1 cm correlated positively with Nephrops densities for all biological categories, showing a preference for well-oxygenated sediments. Morphometrical growth was also found to differ in shelf and slope populations. Shelf individuals were found to grow larger in weight and width than slope individuals, but the latter had a higher chela relative growth. In a spatial study of slope Nephrops populations located in an area farther north than the present study area, Nephrops populations showed patches of high abundance (about 7 km diameter) in relation to substrate heterogeneity and topography (steepness of the slope, presence of submarine canyons). This pattern of spatial distribution is also substantiated in this study.

- The results of the present work showed that the proportions of the individuals retained by the different cod-end mesh sizes did not present great differences among them. However, it was obvious that the greater the mesh size the lower was the proportion of individuals retained. Moreover, differences existed in the structure of the length distribution of the escapees. The 16 mm mesh size (32 mm strech mesh size)was not selective since almost all individuals were retained.. It is very clear that the use of this mesh size should be prohibited as well as that of the 14mm actually used in the Greek fishery. In all cases the estimated L_{50} values were considerably lower than the length at first maturity of the species in the study area. Futhermore, the estimated values of L_{25} were also considerably lower than the minimum landing size (20 mm), legislated by the E.U. for *N. norvegicus.*

From our work it was obvious that none of the mesh sizes employed gave results adequate to the *N. norvegicus* biology and morphology. These results coincide with previous results obtained in the Catalan Sea, allowing to extend these considerations to the entire Mediterranean.

- Stomach contents are composed mainly of small pieces of crustacean carapace, bivalve and gastropod shells, fish vertebrae and otoliths , and other hard and soft prey items, since as carnivores/scavengers they break apart the animals they feed on. This stomach contents composition, makes identification a long and difficult task that cannot be completed in the framework of a research project involving a two-year sampling period and one-year data analysis. Currently the identification of stomach contents at a fine taxonomic scale are the object of a Ph.D. The results of the latter will be send in due time to the D.G. XIV.

- Technically trawlers and trawl machinery are fairly similar in the Mediterranean, although some variations are apparent in shape and size. The trawls with larger mouth width are found in the Catalan, Alboran and Tyrrhenian Sea, indicating a higher exploitation state in the first two areas. Alboran is not exploited at a high level due probably to lower fishing activity. Trawls in western Mediterranean have wider mouths and a better hydrodynamic shape, probably due to the influence of technology originating in the Northern Atlantic. Technological aspects are also better developed in this area, probably because fishing is conducted at greater depths. Remote acoustic control of the gear, SCANMAR or FURUNO (plotter), precise positioning by GPS, double winch, larger otter doors and high-powered engines are also more common in these areas. In general fishing effort over Norway lobster fishing grounds has increased to a high degree in recent years due to an increase in engine power and improvements in mechanical and electronical (positioning, detection and control of the catch) technologies. So, three well differentiated areas appear in the Mediterranean (by fishing and exploitation practices): *a*) the western and central Mediterranean, including the Atlantic Iberian stocks, the Mediterranean Spanish coast, and the western Italian coast, *b*) the Adriatic area, and *c*) the Greek area which can be made extensive to the whole Aegean Sea. A fisheries management system established to monitor and regulate Norway lobster fisheries in the Mediterranean would have to take into account the three types of structures encountered and the fishery multispecific character.

- Norway lobster populations in the Mediterranean share the same biological and fisheries features agree with the used methodologies . This results are observed in all study areas in the reconstructed virgin stock by age or size: size is comparable among areas within a few millimetres and the current average age differs by a year at most. Taking in consideration the methodological restrictions assumed (equilibrium state, LCA analysis, etc.). Norway lobster population show a high uniformity. For instance, for the virgin female populations reconstructed with M=0.2 the age varies among areas between 7.1 and 7.6 years, only the Catalan and the Alboran Seas being off this range.The virgin stock length is between 44.1 and 51.3 mm CL for females (ranging from 51.1 to 58.8 mm CL for males).

- Assuming that variation in length for females is greater than for males, we conclude that non-exploited virgin stocks show a similar population structure among areas. The CL results are considered to be more reliable than the age results as age is computed indirectly from length-to-age keys. In general, the smallest CL values are found in the Catalan Sea, where Z and F are highest, showing that the intensity of the exploitation is reflected in the biological parameters.

Sorted by exploitation status the study areas would rank as follows:

Full exploitation:	1. Catalan Sea
	2. Adriatic Sea
	3. Tyrrhenian Sea
Intermediate exploitation:	4. Ligurian Sea
	5. Euboikos Gulf
Low exploitation:	6. Algarve
	7. Alboran

- Taking together the population parameters analysed we conclude that the Algarve is the area where the exploitation state nears its maximum level of exploitation, while the Euboikos Gulf and the Alboran sea suffer a lower fishing pressure. The most full exploited stocks are maintained by good levels of recruitment or catch selectivity. Annual renovate biomas values (turnover) are higher in these areas, being larger than 60% for both sexes. Turnover values vary with M but maintain their differences in proportion to it. Females are more sensitive to exploitation than males, as seen by the more variable values found for females. Variability among areas is higher for females than for males. However it cannot be ruled out that this result is a bias arising from poorer sampling due to the unavailability of females to the sampling gear in autumn. In all, males show a more uniform response to exploitation.

- The simulation based upon an effort reduction of 20%, (i.e. a 1-day reduction per week, or a 2-hour reduction per day, or a 2-month close season per year), show that, as expected, the stocks which would more easily recover their Y/R levels would be precisely those most heavily exploited, increasing between 4.8 and 6.9% for females and between 0.9 and 5.0% for males. As females are more sensitive to exploitation than males, they also show a speedier recovery. Taking males and females together, the estimated percentages of recovery by a 20% effort reduction in the most heavily exploited stocks would be:

Catalan Sea:	12-15 %
Tyrrhenian Sea:	10-12 %
Adriatic Sea:	8-10 %

The highest levels of recovery would be obtained in 4 to 6 years, depending on the area. However these are probably underestimates as recruitment is assumed to be constant throughout the recovery process. The female stock would stabilise 6 years after the effort reduction and the male stock 7 years after that. Conversely, if effort is increased by 20%, the losses in 7 to 8 years would be around 10% in Y/R. As in the effort reduction scenario, this is probably an underestimate as recruitment is assumed constant. The application of effort reduction measures should be based on the knowledge on the life-cycle of the species.

- The sensitivity analysis on each of the parameters considered (L_{inf}, k, t_o in the growth equation; a and b, in the size-weight relationship; and terminal M and F), is conducted by varying each parameter individually and progressively by 10%, keeping other parameters constant. The parameter more heavily affecting Y/R is b and, to a lesser extent, *Linf* and k. (excluding natural mortality). Therefore, the differences observed between years for a given area are probably due to the estimates of b, which in some cases differ.

GENERAL CONCLUSIONS

- In the populations of the Mediterranean and adjoining Atlantic areas (Portugal) there is no evidence of significant differences in the life-cycle patterns of Norway lobster. The differences observed are attributed to environmental variations among the study areas and the fishing pressure applied on each of the stocks.

- Natural mortality is the most important factor that affect the stock productions. Considering M=0.2, all stocks would be slightly underexploited, following a gradient (more to less) as Catalan, Adriatic, Tyrrhenian, Ligurian, Euboikos, Atlantic and Alboran. For M=0.1, most stocks would be near its explotation optimum or underexploited. For M=0.3, all stocks would be clearly overexploited but not near collapse.

- Shape and gear structure presents important differences among areas, including different level of technologies applied.

- A reduction of 20% in the fishing effort would increase the *Y/R* by 10 to 15% and stocks would be in an optimal exploitation state 6 years after implementing the reduction measure. On the other hand, a fishing effort increase would amount to heavier exploitation, with overexploitation in 7 to 8 years and a decrease in *Y/R* of 10%.

- All this indicates that the current exploitation state is near full exploitation and not excessive, according to the specific area. The stock would respond slowly to a progressive effort increase, however this measure is not recommended for such stocks as the Catalan Sea which could fall into overexploitation rapidly.

- Populations have a good capability of recovery and protection against fishing: percentage recruitment is satisfactory, and the burrowing behaviour represents added protection against fishing. The preservation of the substrate condition and a decrease in disturbance are accompanying measures in a strategy of effort reduction.

- Females show indications of higher exploitation than males, which is to be considered when attempting to reduce effort by closed seasons.

RECOMMENDATIONS

- Every state should have a centralised administration able to record and integrate real catch data from different markets.

- At a management level, measures of effort reduction are recommended in general and moderately over the entire Mediterranean, except where they are already applied (e.g. Euboikos Gulf). Management measures are clearly needed in the Catalan, Adriatic and Tyrrhenian Seas.

- Any management measure should be appropriate to the multi-species nature of the fishery. Any reduction measure beneficial to other species should be equally beneficial to *Nephrops* and *viceversa* (*Merluccius, Lophius, Phycis, Lepidorhombus*).

- An important effort increase has been noted in the study area, corresponding to items difficult to quantify: technological improvements regarding positioning, mechanical and manoeuver improvements, and remote control of the fishing gear. These difficulties should be addressed with priority.

- Fishing regulations concerning the selectivity of the trawl are to be disregarded for *Nephrops* as they are not very efficient.

- Specifically, the management measures adopted should follow one or more of the following criteria:

  - *a*) In stocks where a clear size segregation is present, the depths where the smallest individuals are found should be protected from exploitation, as recuitment is a major input to the population (e.g. the Catalan and Adriatic Seas).

  - *b*) In stocks where females are heavily exploited, the effort reduction should be concentrated on the maturity period previous to egg-carrying, as females are naturally protected during the egg-carrying period by their burrowing habits.

  - *c*) When considering an effort reduction based on reducing the daily working time, fishing during the maximum daily activity period of the species should be avoided. Specifically, maximum activity periods for Norway lobster are noon in deep-water stocks and dusk and dawn shallow-water stocks (e.g. Adriatic Sea and Euboikos Gulf).

  - *d*) If a working day per week is to be reduced, the day should be chosen after weekends or holidays, to avoid continuous disturbance of the habitat.