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

An analysis of the population dynamics of *Nephrops norvegicus* (L.) in the Mediterranean Sea*

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SUMMARY: The state of exploitation of the *Nephrops norvegicus* fisheries in different areas in the Mediterranean Sea is examined for the first time. Length cohort analysis (LCA) by sex has been applied for each area, and Y/R curves are presented to show the current status of the stocks under the steady-state assumption. A simulation of short and long-term effects of changes in fishing effort levels is presented. Norway lobster populations in the Mediterranean share the same biological features, but different exploitation patterns have been observed in several areas. Considering current exploitation levels, certain of the stocks analysed appear to be slightly growth-overexploited, while others seem to be placed near the optimum level of exploitation. For comparison purposes, the study areas can be classified as follows: fully exploited: Catalan Sea (Spain), Adriatic Sea and Tyrrhenian Sea (Italy); moderately exploited: Ligurian Sea (Italy) and Euboikos Gulf (Greece); and lightly exploited: Atlantic (Portugal). The stock in the Alboran Sea (Spain) is a special case and is therefore discussed separately.

Key words: Population dynamics, LCA, Y/R, Mediterranean, *Nephrops norvegicus*, fishery.

RESUMEN: ANÁLISIS DE LA DINÁMICA DE LAS POBLACIONES DE *NEPHROPS NORVEGICUS* (L.) EN EL MEDITERRÁNEO. – Se analiza, por primera vez en el Mediterráneo, el estado de explotación de la pesquería de cigala (*Nephrops norvegicus*) en siete áreas distintas. Para ello se ha aplicado un LCA (análisis de cohortes por tallas) para cada sexo y área Se presentan las curvas de producción por recluta (Y/R) para comparar el estado actual de las poblaciones estudiadas asumiendo su estado de equilibrio. También se realiza un estudio simulado de los efectos del cambio de esfuerzo a largo plazo. La cigala en el Mediterráneo presenta unas características biológicas similares pero con diferentes estados de explotación en las diversas áreas. Considerando los actuales estados de explotación, algunos de las poblaciones estudiadas presentan cierta sobreexplotación de crecimiento, mientras que otras se sitúan alrededor del nivel óptimo de explotación. A modo comparativo, las áreas estudiadas pueden situarse en el siguiente gradiente: plenamente explotadas: el mar Catalán (España), el Adriático y el mar Tirreno (Italia); medianamente explotados: el mar Ligur (Italia) y el golfo de Euboikos (Grecia); y poco explotada, la costa de Atlántica (Algarve, Portugal). La población del Mar de Alborán es un caso especial y se discute separadamente.

Palabras clave: *Nephrops norvegicus*, dinámica de poblaciones, LCA, Y/R, Mediterráneo, pesquería.

INTRODUCTION

Management of the Norway lobster (*Nephrops norvegicus*) fisheries in the North Atlantic has been common for many years now (Anon. 1997), with varying levels of success. However, despite the relative importance of fisheries on this species in the Mediterranean Sea, there have been no studies on population dynamics capable of serving as a basis for providing conservation advice. Although many studies on the species biology in the Mediterranean have been published (Karlovac, 1952; Orsi Relini and Relini, 1989; Froglia, 1972; Froglia and Gramitto, 1981; Sardà, 1991; Sardà, 1995; Passamonti *et al*., 1997 and Ferruccio *et al*., 1998), there have been few attempts at in-depth assessment of the resource (Froglia, 1972; Sardà and Lleonart, 1993) or at determining selectivity factors (Sardà *et al,*. 1993; Mytilineou *et al*., 1998 a).

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The objective of this paper is to present a comparative analysis of the exploitation pattern on the Norway lobster (*Nephrops norvegicus*) in a series of different study areas in the Mediterranean. In the Mediterranean (as in the North Atlantic) many difficulties are encountered in trying to compile true and exact information on actual landings (Sardà, 1998). Analytic methods have been employed in the present assessment. The strength of such methods lies in their robustness when biological data and size frequencies are accurate. Therefore, one of the underpinnings of this study has been to put great care and effort into collecting accurate data on the biology of the species in each of the study areas considered.

Seven Mediterranean stocks of Norway lobster were analysed by means of LCA (length cohort analysis) and yield-per-recruit methods. The basic data were length-frequency distributions for monthly catches, collected in each area over two years.

Fisheries management policies in the Mediterranean are non-adaptive. Effort limitation (fishing time and power limits), mesh size, legal length regulations, and closed areas are the main measures currently in use, though they are not regularly revised according to the state of the stocks and are not always enforced.

The objective is to examine, for the first time in the Mediterranean Sea, the state of exploitation in the *Nephrops norvegicus* fishery, to assess qualitatively how management measures should be applied rather than to present results or data for use in quantitative management decisions. In this paper, LCA by sex is applied for each area, and yield-per-recruit (Y/R) studies are presented. An analysis of the projection to a new equilibrium state on the basis of an assumed 20 % reduction or increase in fishing effort has also been performed and is likewise presented.

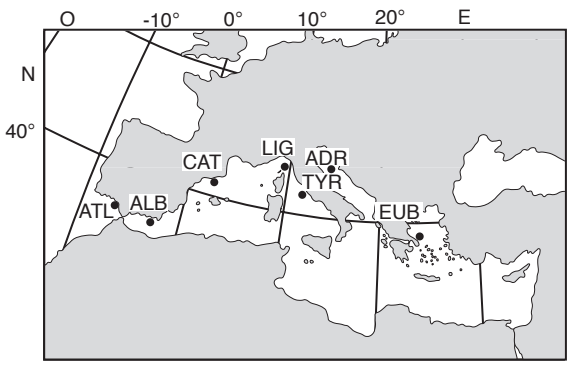

FIG. 1. – General view of the Mediterranean studied areas.

MATERIALS AND METHODS

Length frequency distributions have been obtained by means of monthly samples collected over a two-year period (1994-95) in seven areas (the Algarve coast in southern Portugal; the Alboran and Catalan seas off Spain; the Ligurian, Tyrrhenian, and Adriatic seas off Italy, and the Euboikos Gulf off Greece) (Fig. 1). There are no data on stock definition, but all the areas have been taken to correspond to separate stocks because of the large geographical distances separating them. Table 1 summarizes the sampling strategy and number of individuals measured. Annual length-frequency distributions were prepared by area, and the weighted averages of the monthly samples were raised to the total catch. Sizes ranged from 10 to 50 mm *CL* for females and 10 to 60 mm *CL* for males. Due to difficulties in ascertaining real annual catch levels, a preliminary investigation into the value of landings by port was carried out, and landings were found to average around 20,000 tonnes/year (Sardà, 1998). The sex ratio was taken to be 1:1 (Table 1). Therefore, the values obtained, and the behaviour of the Y/R curves, may only be interpreted comparatively, not as absolute quantitative values.

TABLE 1. – Number of individuals measured in each area by sex and year.

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Year	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
No. of samples	12	7	12	9	12	10	8	9	12	10	12	7	12	9
Individuals measured	6320	2929	10485	5119	15461	10748	4809	7960	17159	11922	18952	8789	29762	10980
Females	2844	1595	5813	2476	7574	4942	2259	3939	8061	5751	9584	4586	14941	6317
Males	3476	1334	4672	2643	7887	5806	2550	4021	9098	6171	9368	4203	14821	4663

LCA was applied to the data using the classic catch equation. The growth and length-weight relationship parameters used in the analyses (Table 2) were estimated by sex for each area and year using the information published by Mytilineou *et al.,* (1998 b) and Sardà (1996). Because the size at first maturity may vary between successive years depending on population density and environmental conditions (Orsi Relini and Relini, 1989; Sardà, 1991,1995), a mean size value was used for all populations to establish the proportion of mature individuals by size class. The same value was employed for both males and females. The size at first maturity has been considered to span the sizes ranging from 21 to 30 mm *CL*, with an estimated increase of 10 % in the proportion of mature individuals with each additional mm in *CL*.

Following ICES recommendation (Anon. 1996), the analyses have been carried out separately by sex, since the two sexes have different parameter values. The analysis covers two consecutive years and three different natural mortality levels (0.1, 0.2, and 0.3). Accordingly, a total of 84 analyses were performed to cover seven areas, two sexes, two years, and three natural mortality levels.

The method used (LCA) assumes that the stock is in a steady state. Obviously, this is not the case of the stocks analysed. Nevertheless, in the absence of long enough historical time series of catch-at-age data to run VPA, and since the sampling programme ceased on termination of the project, this assumption is the only one that allows us to say anything about the stock.

The results of the LCA, in particular the *F*-at-length values, have been used as input for yield per recruit analysis.

A predictive analysis of the short-term transition for a projected reduction of the level of effort expended to 0.8 of the actual value was also performed. Catch-at-age data obtained by slicing the length-frequency distribution were used in that analysis.

All analyses were performed using VIT software (Lleonart and Salat, 1992).

The following are the most significant output variables presented in the results:

Age (in years): Mean age in the catches. Current mean age of the stock. Current critical age (the age at which a cohort exploited at current levels reaches maximum biomass) of the stock. Mean age of the virgin stock.

Carapace length measurements (in mm): Mean length in the catches. Current mean length of the stock. Current critical length of the stock. Mean length of the virgin stock. All these values correspond to the respective ages.

Fishing mortality, F (in years^{-1}): Mean *F* and global *F*. Both are overall fishing mortalities computed on the basis of different weighting criteria. Mean *F* is the average of all *F* values weighted by the time period considered (mortality on each size class varies over time). Global *F* is the average of all *F* values weighted by the number of affected individuals.

Biomass (in %): Several percentage annual biomass-based ratios have been presented. Natural

TABLE 2. – von Bertalanffy growth parameters (L_∞, K, t_0) and constants (a,b) for the size-weight relationship.

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Year	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
FEMALES														
L_∞ (mm)	70.7		72.6		67.0		63.2		65.0		67.0		73.9	
K (year^{-1})	0.12		0.16		0.15		0.15		0.15		0.14		0.14	
t_0 (year)	-1.36		-0.87		-0.33		-0.89		-0.76		-0.88		-0.47	
a (g·10^{-3})	0.398	0.433	0.633	0.485	0.859	0.552	0.680	0.250	0.317	0.459	0.434	0.464	0.543	0.603
b	3.151	3.110	3.020	3.102	2.914	3.075	2.979	3.254	3.214	3.113	3.120	3.110	3.043	3.018
MALES														
L_∞ (mm)	83.4		86.8		86.8		83.2		81.6		81.5		82.7	
K (year^{-1})	0.13		0.14		0.10		0.12		0.13		0.11		0.12	
t_0 (year)	-0.33		-0.84		-0.30		-0.87		-0.89		-0.95		-0.95	
a (g·10^{-3})	0.336	0.332	0.420	0.402	0.562	0.479	0.270	0.364	0.235	0.277	0.279	0.359	0.467	0.436
b	3.202	3.199	3.137	3.163	3.052	3.118	3.239	3.157	3.295	3.258	3.255	3.185	3.100	3.123

deaths, expresses the percentage of biomass lost to the stock due to natural causes, The catches represent the proportion of biomass removed by fishing (caught). B:VB is the proportion of current biomass to the virgin biomass. Turnover is production per biomass.

Yield per recruit: Current Y/R *(ϕ=1)* (in g), the value of yield per recruit at current exploitation levels (expressed as the *F* factor *ϕ=1*). Y/R max (in g), the maximum yield per recruit obtained at the level of ϕ_{MAX}. If ϕ_{MAX} is lower than 1, growth overfishing exists.

RESULTS AND DISCUSSION

Tables 3 and 4 present the output variables from the VPA and Y/R analyses by sex and natural mortality for each area and year.

The results of the analyses must be interpreted with caution because of the steady-state assumption that has had to be made. Under these conditions, it is advisable to take the results as representing qualitative features of the stocks rather than as truly accurate quantitative estimates. Furthermore, most of output variables presented are relative (percentages, etc.) because they have been considered to be more reliable than the absolute values (e.g., the actual biomass estimates).

Our main comments will basically focus on Tables 3 to 5, presenting the analysis results for *M*=0.2, which has been taken as the most realistic natural mortality estimate for *Nephrops* (Anon. 1996).

The Tables show that the highest mean age in the catches were basically for the Atlantic, Alboran, and Ligurian stocks, whereas the mean age for the virgin stock was similar for most of the populations considered. The results for length were comparable, with very few differences in the mean length of the virgin stocks of each sex. For instance, for the virgin female populations, age varied between 7.1 and 7.6 years among the study areas, with only the Catalan and Alboran seas

TABLE 3. – Results of the VPA and Y/R analysis for females for *M*=0.2 (explanation in the text); * indicates an asymptotic value.

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Year	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
Age values (year)														
Mean age of catch	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
Current mean age of stock	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
Current critical age of stock	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
Mean age of virgin stock	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
Length values (mm)														
Mean length of catch	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
Current mean length of stock	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
Current critical length of stock	31	30	36	34	27	25	39	31	28	27	27	27	26	31
Mean length of virgin stock	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
F values (year^{-1})														
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
Biomass values (%)														
Natural deaths	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
Caught	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
B:VB	31.3	30.6	16.5	10.5	16.1	12.7	40.9	34.2	18.1	17.9	17.7	17.5	22.3	32.2
Turnover	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
Yield per recruit														
Current Y/R (ϕ=1) (g)	11.8	11.1	19.8	17.5	9.3	9.5	17.2	11.1	10.6	10.6	10.0	10.1	10.4	13.0
Y/R max (g)	11.9	11.3	20.9	20.7	11.1	12.0	17.9	11.3	11.7	11.9	11.6	11.7	11.0	13.2
ϕ_{MAX}	0.77	0.70	0.45	0.30	0.33	0.35	*	0.70	0.47	0.42	0.40	0.42	0.64	0.81

TABLE 4. – Results of the VPA and Y/R analysis for males for M=0.2.

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Year	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
Age values (years)														
Mean age of catch	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
Current mean age of stock	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
Current critical age of stock	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
mean age virgin stock	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
Length values (mm)														
Mean length of catch	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
Current mean length of stock	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
Current critical length of stock	36	35	40	36	28	28	34	30	33	32	30	32	36	36
Mean length of virgin stock	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
F values (years^{-1})														
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
Biomass values (%)														
Natural death	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
Caught	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
B:VB	29.4	29.9	15.5	12.4	16.2	14.0	29.6	16.9	20.8	19.3	18.2	31.8	32.2	34.3
Turnover	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
Yield per recruit														
Current Y/R (ϕ=1) (g)	20.0	19.7	26.9	25.3	11.6	12.0	16.0	11.8	16.5	16.0	13.1	12.0	14.4	16.2
Y/R max (g)	20.2	20.6	29.6	29.9	13.7	15.5	16.1	13.3	18.6	17.9	14.3	12.3	14.5	16.2
ϕ_{MAX}	1.58	0.64	0.41	0.35	0.41	0.32	0.85	0.53	0.49	0.51	0.55	0.77	0.90	0.93

TABLE 5. – Y/R results and transition analysis for females for M=0.2 (variation factor ± 20 %).

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variable	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
Y/R initial (g)	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
% increase	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
% increase	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
Years to stability	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
% decrease	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
% decrease	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
Years to stability	5	4	4	5	5	5	8	6	5	6	6	6	6	5

falling outside this range in 1994. The age of the reconstructed male population ranged between 7.2 and 8.7 years in all areas. The maximum length of the virgin stocks in the different study areas was between 44.1 and 51.3 mm *CL* for females and from 51.1 to 58.8 mm *CL* for males. The results of length analyses are considered to be more reliable than age-based analysis results, since age is computed indirectly from length-age keys. The variations observed among the areas are attributable to environmental conditions or to differing states of exploitation (Sardà, 1998).

TABLE 6. – Y/R results and transition analysis for males for M=0.2 (variation factor ± 20 %).

Area	Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Variable	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
Y/R initial (g)	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
% increase	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
% increase	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
Years to 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
% decrease	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
% decrease	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 to stability	6	5	5	6	8	7	7	7	6	6	8	6	10	7

TABLE 7. – Comparison of main VPA and Y/R parameter values at different mortalities.

Area		Atlantic		Alboran		Catalan		Ligurian		Tyrrhenian		Adriatic		Euboikos	
Year		1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
MORTALITY															
Males															
M=0.1	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
	B:VB	20.8	20.6	5.2	3.9	9.9	8.5	19.9	10.3	13.6	12.4	10.9	23.3	20.6	28.0
	ϕ *max*	0.57	0.46	0.17	0.16	0.30	0.23	0.58	0.60	0.36	0.38	0.49	0.58	0.60	0.63
M=0.2	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
	B:VB	29.4	29.9	15.5	12.4	16.2	14.0	29.6	16.9	20.8	19.3	18.2	31.8	32.2	34.3
	ϕ *max*	1.58	0.64	0.41	0.35	0.41	0.32	0.85	0.53	0.49	0.51	0.55	0.77	0.90	0.93
M=0.3	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
	B:VB	39.6	39.3	29.5	24.8	25.1	21.8	41.5	26.3	30.2	28.4	28.4	41.6	46.4	49.9
	ϕ *max*	1.16	0.96	0.95	0.72	0.65	0.48	1.38	0.79	0.72	0.76	0.86	1.10	1.49	1.57
Females															
M =0.1	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
	B:VB	22.6	22.0	5.9	3.5	11.0	8.5	22.6	23.6	12.7	12.1	12.0	11.8	16.0	24.6
	ϕ *max*	0.55	0.51	0.19	0.14	0.25	0.24	0.64	0.67	0.36	0.35	0.29	0.33	0.50	0.63
M=0.2	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
	B:VB	31.3	30.6	16.5	10.5	16.1	12.7	40.9	34.2	18.1	17.9	17.7	17.5	22.3	32.2
	ϕ *max*	0.77	0.70	0.45	0.30	0.33	0.35	*	0.70	0.47	0.42	0.40	0.42	0.64	0.81
M=0.3	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
	B:VB	41.5	40.6	29.8	20.2	22.6	18.3	60.8	46.5	25.5	25.3	24.8	24.7	30.0	40.7
	ϕ *max*	1.23	1.10	1.01	0.55	0.46	0.42	*	1.61	0.66	0.59	0.57	0.58	0.87	1.11

For males global F was lower in the Atlantic, Alboran Sea, and Euboikos Gulf, higher in the other areas. For females, the Ligurian Sea population can be said to have low mortality levels. In general, the smallest sizes were recorded in the Catalan Sea, where mean F values were highest, probably a reflection of intensity of exploitation in the biological parameters.

Natural mortality values were more stable for males than for females, and the B:VB ratio was around 30 % except for males in the Alboran, Catalan, and Tyrrhenian seas and for females in the Alboran, Catalan, Tyrrhenian, and Adriatic seas. Based on stock-recruitment relationships, an unfished biomass value of 20 % has been considered a limit reference point not to be surpassed if a stock's rebuilding capabilities are to be maintained (Caddy and Mahon, 1996). However, those same authors suggested that this value of 30 % has been taken into account for few studied stocks. The values obtained here would appear to indicate that the fishery may be situated in a dangerous region of recruitment overfishing.

The differences in the results for the two sexes do not seem to show any particular trends, though the values for the females exhibited greater variability than the values for males. The explanation put forward for this is that females are less active during the period of berry (autumn-winter), and thanks to this behaviour their capturability levels decline, making sampling of females less representative and thus the size-frequency data less reliable.

Variability among areas was higher for females than for males. However, the possibility that this result may be caused by bias arising from poorer sampling due to unavailability of females to the sampling gear in autumn cannot be ruled out. Overall, males displayed a more uniform response to exploitation.

The mean lengths in the catches decreased from 1994 to 1995 for both sexes in all areas except Euboikos. This may represent a drop in selectivity or an increase in recruitment. Because absolute catch data are not available, no clear explanation for this question can be given. Nevertheless, a virtually generalized trend (with few exceptions) towards increased exploitation levels is observable.

The analyses carried out at the other natural mortalities considered (M=0.1 and M=0.3, Table 7) show that values obtained at M=0.1 are the most pessimistic, depicting stocks with lower current biomass to virgin biomass values, higher F values, etc., and hence these analyses should be chosen if the precautionary approach is to be employed (Anon. 1992). The picture provided by the analyses run using an assumed value of M=0.1 shows stocks subject to both growth overfishing and recruitment overfishing. The analyses performed using M=0.3 provide a more optimistic picture, although several stocks still appear to have a current biomass of less than 30 % of the virgin biomass.

The overall analysis shows the Catalan and Adriatic stocks as the most heavily exploited on the basis of most output variables, the Atlantic and, particularly, the Ligurian stocks are being the most healthy. The Alboran stock seems to be heavily depleted on the basis of the remaining fraction of virgin biomass, although the mean age in the catch, mean length in the catch, are among the highest. The Alboran Sea population combines large individuals with low relative biomass levels, yielding the highest yield per recruit. This is probably related to higher growth rates caused by local seasonal upwelling in this area. The size range for the Alboran Sea stock is relatively small and encompasses only large sizes, and this may lead to errors in interpreting certain parameters. For example, the virgin biomass calculation made on the basis of the range of size classes in the samples is very different from those for the other areas. Nevertheless, on the basis of the set of all parameter values, the Alboran Sea stock can be considered lightly exploited.

In the Ligurian Sea, a comparison of the results for 1994 and 1995 reveal notable differences, sometimes even suggestive of contradictory conclusions. The reason can be attributed to low sampling in the Ligurian Sea in 1994, yielding size frequencies that were not representative for the population indicating low exploitation of the stock. On the other hand, in 1995 sampling was considerably more comprehensive, and for that reason the results for this latter year have been considered more reliable for comparison with those for other areas.

The highest yield per recruit values, by a large difference, were for males in the Atlantic and Alboran Sea, whereas the values for females are similar in all the areas studied.

Yield per recruit curves have been plotted in Figures 2 and 3 by sex and area for the different natural mortalities, and therefore the figures show the curves only for the areas with the most and least optimistic results, by way of example. The curves calculated at M=0.2 fall in between the curves for the higher and lower natural mortality estimates, as expected. Taking M=0.1 suggests an overexploited resource; taking M=0.2 places most populations near the optimum exploitation level; and taking M=0.3 indicates that those same populations are underexploited. This means that the fishery is inefficient, and yields would be higher if effort were to decrease or if selectivity were to be improved (increasing the mesh size). However, selectivity improvement measures have been considered unsuitable for the Mediterranean by Sardà *et al*. (1993) and Mytilineou *et al*. (1998). Therefore, M=0.2 has been used as the basis for our commentary on the results, as in the North Atlantic (Anon., 1996). Integrating the results for our VPA and Y/R analyses leads to the conclusion that on the whole Mediterranean Norway lobster populations are fully exploited, following the scheme already set out above:

Highly (fully) exploited: 1. Catalan Sea; 2. Adriatic Sea; 3. Tyrrhenian Sea; moderately exploited: 4. Ligurian Sea; 5. Euboikos Gulf; and lightly exploited: 6. Alboran Sea; 7. Atlantic (Algarve).

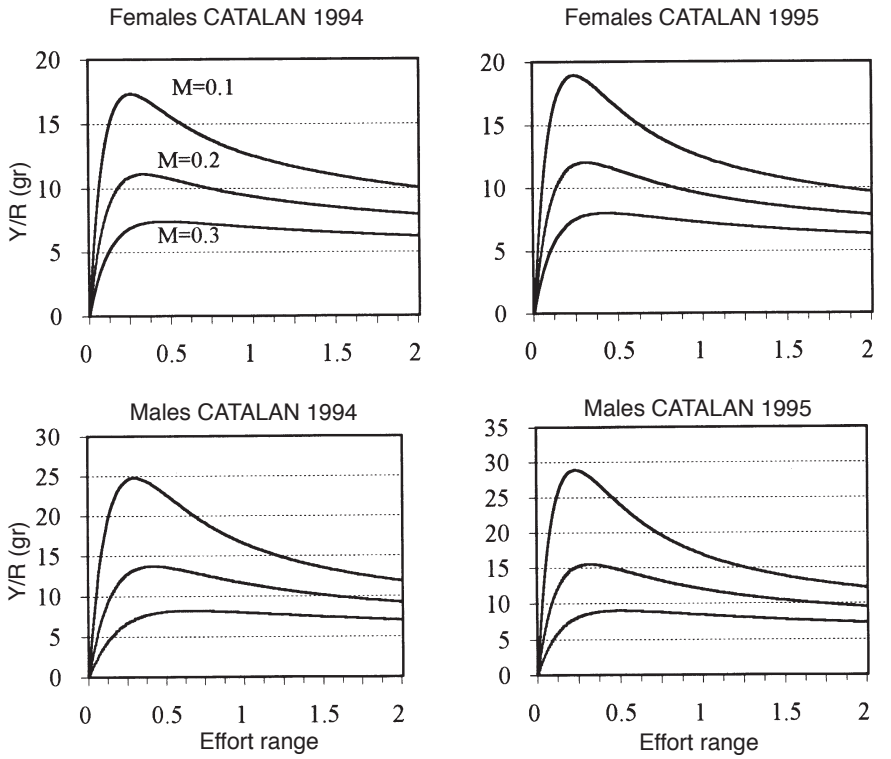

FIG. 2. – Catalan yield per recruit curves.

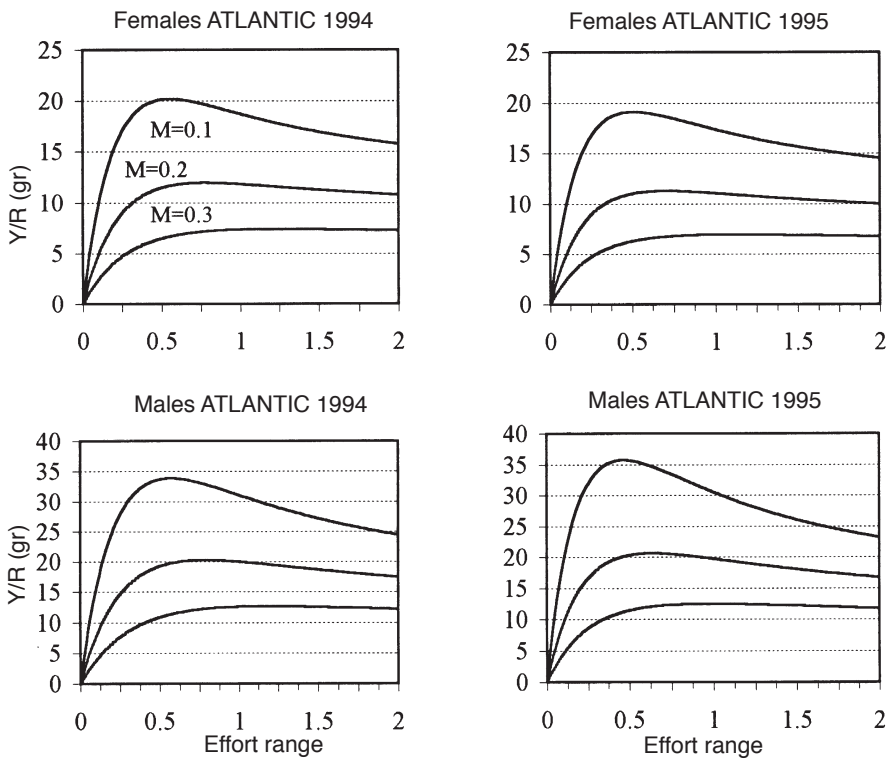

FIG. 3. - Atlantic yield per recruit curves.

The transition analysis (Tables 5 and 6) was based on a projected effort reduction of 20 %, i.e., a reduction of one day per week, two hours a day, or a two-month closed season every year. The results of this analysis show that, as expected, the stocks that would more readily recover to higher Y/R levels would be precisely the ones that are most heavily exploited, with Y/R 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 would also undergo a speedier recovery. Taking males and females together, the estimated percentage recovery values for a 20% effort reduction on the most heavily exploited stocks would be: Catalan Sea: 12-15 %; Tyrrhenian Sea: 10-12 %; Adriatic Sea: 8-10 %.

Maximum recovery would be achieved in four to six years, depending on the area. However, these are probably underestimates, because recruitment has been assumed to be constant throughout the recovery process. The female stock would stabilize six years after effort reduction came into effect, and the male stock after seven years. Conversely, if effort were to be increased by 20 %, the losses in seven to eight years would be around 10 % of Y/R.

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