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Stock Assessment of the Deep-Water Spiny Lobster *Palinurus delagoae*, off Mozambique

by

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ABSTRACT

Preliminary estimates of growth parameters and mortality are presented for the deep-water spiny lobster *Palinurus delagoae* fished off Mozambique.The length-converted catch curve shows three levels of total mortality (year^{-1}): Z = 2.9 for the smaller sizes; Z = 1.4 for intermediate, and Z = 0.6 for the larger lobsters. These results are confirmed by a length-structured virtual population analysis.Yield-per-recruit analysis suggests that a long-term yield, at least 50% higher than the present one, could be obtained by increasing the mean size at first capture from about 6 cm (carapace length) to about 10 cm.

RESUMO

Estimativas preliminares dos parâmetros de crescimento e mortalidade são apresentadas para a lagosta de profundidade, *Palinurus delagoae,* capturada em Moçambique. A curva de captura mostra três níveis de mortalidade total (ano^{-1}): Z = 2,9 para os tamanhos mais pequenos; Z = 1,4 para os intermédios, e Z = 0,6 para as lagostas maiores. Estes resultados são confirmados pela análise da população virtual. A análise do rendimento por recruta sugere que um rendimento a longo prazo, de pelo menos 50% superior ao presente, pode ser obtido aumentando o tamanho médio da primeira captura de cerca de 6 cm (comprimento de carapaça) para cerca de 10 cm.

INTRODUCTION

Palinurus delagoae (Barnard, 1926) is a deep-water spiny lobster which occurs south of 17°00'S in Mozambican and South African waters at depths below 200 m.

The species is caught by trawling and with traps, the main concentrations occurring south of 22°00'S at depths between 200 and 400 m. The main fishing grounds off Mozambique (Fig. 1) are Barra Falsa, Boa Paz Bank (east and southwest) and Inhaca (Brinca & Palha de Sousa, 1984).

At the end of the 1960s, a South African trawler fleet started to exploit this resource but no further information on this fishery is available. This operation stopped when Mozambique declared an EEZ of 200 miles in 1978. During the period from 1980 to 1984, the most important fishery on the Mozambican stock of *P. delagoae* was conducted by a licensed Japanese vessel, fishing with arrays of traps. In 1986, one vessel from a joint venture started fishing with the same gear.

In South Africa, this species supports a commercial trawl fishery, based in the port of Durban. Studies on the distribution, biology and ecology of *P. delagoae* were reported by Berry (1971, 1973).

The aim of this report is to present preliminary growth parameters and

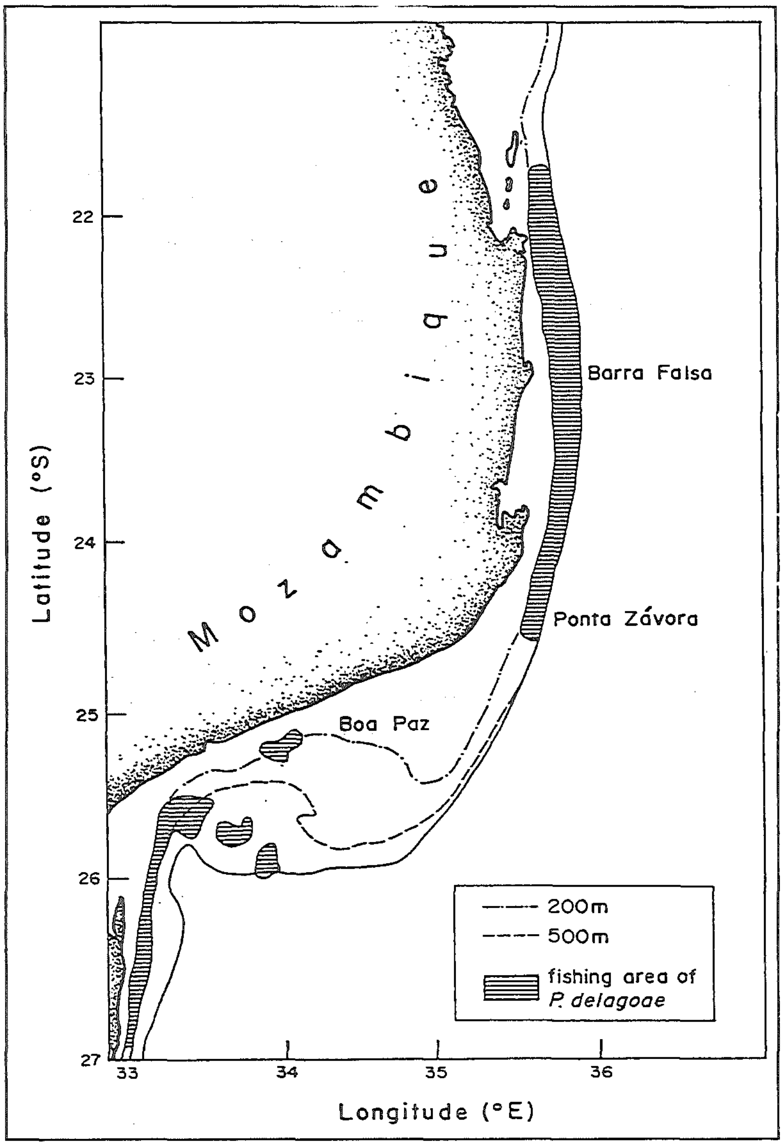

Fig. 1. Distribution of the main fishing areas of P. delagoae *off Mozambique.*

mortality estimates from data collected by traps, and a preliminary assessment of the state of these resources.

MATERIALS AND METHODS

Selection and Preprocessing of Data

Two sets of length-frequency distributions of males and females are available. One refers to the Mozambican part of the stock and was taken onboard the trap fishing vessel, from August 1980 to December 1984. From each long-line a sample of 100 individuals was taken from the catch. After sorting by sex, the lobsters were measured (carapace length), and the numbers and weight per 0.5 cm class were recorded.

The second set of data taken from Berry (1973) consists of the length-frequency samples collected by a research trawler operating off Durban, covering the period 1968-1970.

All data were processed using the Compleat ELEFAN software package (Pauly, this vol.). The two sets of data were combined to estimate growth parameters, since using only one set of data did not give conclusive results. Further, the combined monthly samples were pooled into an artificial year using simple addition of frequencies (Table 1).

For the estimation of mortalities, the VPA and the yield-per-recruit analyses only the Mozambican data were used, because the two data sets refer to different gears. The samples for males and females were combined for these analyses.

Growth Analysis

As described in Pauly & David (1981), the estimation of growth parameters using the ELEFAN I program is performed by identifying the von Bertalanffy curve that gives the best fit to the length-frequency data, restructured by running averages. Different sets of values of L_∞ and K can be entered or made to vary. Also, parameters can be entered which express seasonality of growth. These are "C", expressing the amplitude of the seasonal oscillation, and "WP" - winter point - the period of the year when minimum growth occurs.

Table 1. Length-frequency distribution of female and male *P. delagoae*, 1980-1984.

Month CL (cm)	J F/M	F F/M	A F/M	M F/M	J F/M	J F/M	A F/M	S F/M	O F/M	N F/M	D F/M
5.25	6 / 2	1 / 1	1 / 1	5 / 1	13 / 3	4 / 9	3 / 1	8 /	5 / 2	4 / 2	5 / 4
5.75	203 / 176	50 / 27	87 / 55	576 / 331	333 / 255	403 / 268	267 / 152	133 / 93	92 / 54	148 / 94	203 / 160
6.25	702 / 740	160 / 172	315 / 273	1476 /1296	1187 /1061	963 / 935	866 / 755	511 / 493	376 / 347	596 / 581	740 / 862
6.75	827 /1041	194 / 247	208 / 228	826 / 984	632 / 827	414 / 537	464 / 539	330 / 428	357 / 390	717 / 831	855 /1327
7.25	604 / 869	123 / 161	95 / 78	247 / 338	204 / 306	175 / 225	220 / 174	246 / 239	280 / 339	494 / 576	790 /1291
7.75	342 / 457	52 / 81	29 / 28	101 / 144	126 / 135	170 / 119	179 / 102	269 / 225	203 / 237	298 / 354	507 / 834
8.25	196 / 234	17 / 59	8 / 9	46 / 75	93 / 105	158 / 72	216 / 62	238 / 114	161 / 166	304 / 188	370 / 400
8.75	108 / 103	11 / 26	13 / 5	20 / 62	68 / 7	72 / 41	152 / 35	168 / 56	106 / 91	115 / 102	209 / 191
9.25	87 / 60	12 / 16	6 / 3	13 / 55	50 / 34	58 / 19	70 / 131	91 / 26	66 / 24	50 / 42	105 / 72
9.75	24 / 23	4 / 16	4 / 1	11 / 43	10 / 24	30 / 11	47 / 13	55 / 14	27 / 20	30 / 20	48 / 38
10.25	26 / 17	2 / 8	2 / 0	3 / 34	2 / 15	26 / 6	23 / 9	17 / 10	12 / 11	24 / 14	21 / 19
10.75	8 / 12	2 / 7	0 / 0	0 / 14	1 / 14	13 / 4	21 / 2	8 / 6	11 / 12	11 / 14	8 / 17
11.25	5 / 6	0 / 7	0 / 0	2 / 9	2 / 7	4 / 2	9 / 7	6 / 7	6 / 5	7 / 11	4 / 6
11.75	8 / 7	0 / 2	0 / 0	1 / 13	0 / 8	0 / 1	3 / 2	3 / 5	2 / 5	2 / 3	3 / 7
12.25	2 / 5	0 / 5	0 / 0	0 / 8	1 / 3	1 / 2	2 / 2	2 / 7	0 / 7	2 / 5	2 / 6
12.75	0 / 2	0 / 3	0 / 0	0 / 4	0 / 3	0 / 0	1 / 0	0 / 3	0 / 6	2 / 2	1 / 2
13.25	2 / 2	0 / 5	0 / 0	0 / 6	0 / 2	0 / 2	1 / 3	0 / 1	0 / 0	1 / 2	0 / 2
13.75	0 / 1	0 / 3	0 / 1	0 / 1	0 / 1	0 / 1	0 / 2	0 / 4	1 / 2	0 / 3	
14.25	1 / 1	0 / 4		0 / 1			0 / 0	0 / 3	0 / 1	0 / 0	
14.75	0 / 0	0 / 0		0 / 1			0 / 1	0 / 1		0 / 1	
15.25	0 / 0	0 / 0						0 / 0		0 / 1	
15.75	0 / 1	0 / 0						0 / 2			
16.25		0 / 0						0 / 0			
16.75		0 / 0						0 / 0			
17.25		0 / 0						1 / 0			
17.75		0 / 0									
18.25		0 / 1									
Sum	3151 /3759	628 / 851	768 / 681	3337 /3420	2722 /2874	2491 /2254	2544 /1992	2085 /1738	1705 /1719	2805 /2846	3871 /5238

To estimate L_∞, the modified Wetherall plot (Wetherall, 1986; Pauly, 1986) was used. The two data sets, weighted by the % of sample total, were used to estimate L_∞ and Z/K, separately for females and for males (Fig. 2).

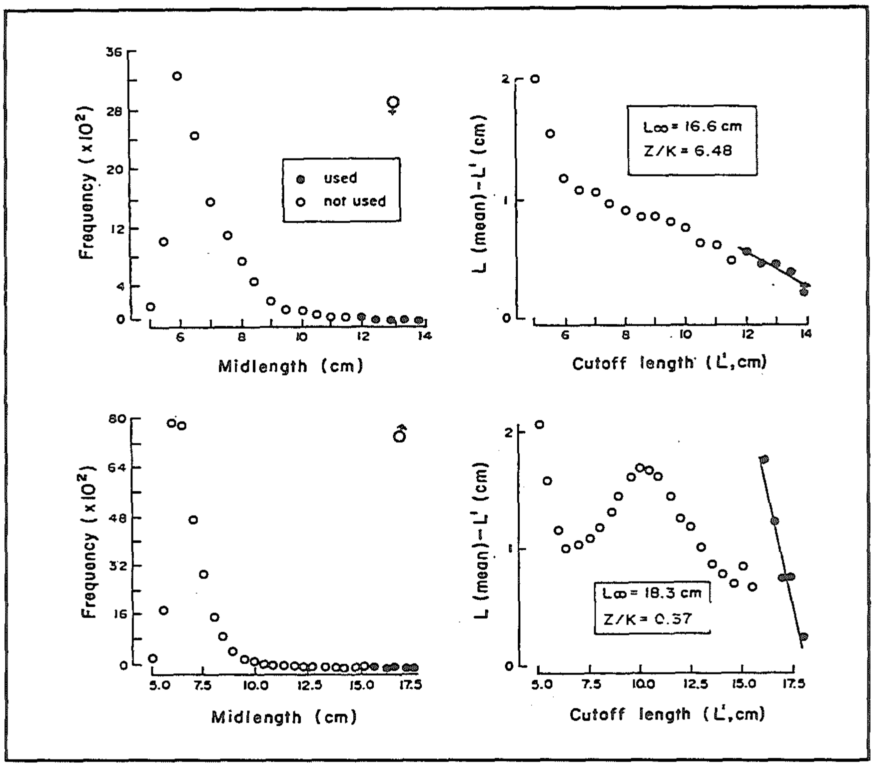

Fig. 2. Modified Wetherall plots for female (above) and male (below) P. delagoae *off Mozambique, data from 1980-1984. Note that assumptions of model may not be strictly met and that estimates are based on very few specimens.*

Furthermore, attempts were made to estimate growth parameters for the same and related species from data in the literature. The Gulland & Holt method (1959), and the "forced Gulland & Holt plot" (Pauly, 1984) were used to interpret published growth rate estimates on three lobsters species other than *P. delagoae*.

Mortality Estimates

Total mortality was estimated from a standard length-converted catch curve (Pauly, 1984) because of the relatively slow growth of *P. delagoae*, which would tend to reduce the impact of seasonal growth oscillations on estimates of Z (Pauly, this vol.). All available length-frequency data, weighted by the % of sample total, were pooled to construct the catch curve. Different cutoff lengths were used to identify three values of Z corresponding to the three different sections of the curve (Fig. 4). Natural mortality was approximated by M = 2K (Pauly, this vol.).

Fishing mortality was estimated using length-structured VPA ("VPA II" in the Compleat ELEFAN package), i.e., the VPA version of R. Jones' length cohort analysis (Jones, 1984; Pauly, 1984). This method, given catch-at-length data covering the life span of several cohorts, growth parameters and natural mortality, allows to reconstruct an average cohort and to estimate the different levels of fishing mortality according to sizes.

Stock Assessment and Fishing Pattern

The yield-per-recruit model of Beverton & Holt (1966) as modified by Pauly & Soriano (1986) relates the evolution in time of an average cohort, given growth parameters and mortalities, and probabilities of capture for each size class. The yield-per-recruit routine incorporated into ELEFAN II allows the simultaneous use of five sets of probabilities. Here, ten different sets of probabilities were used as input, assuming for each set that another class of small lobster is left unfished.

RESULTS AND DISCUSSION

Figs. 2 and 3 present the modified Wetherall plot and the estimates of growth parameters, separately for females and for males. The catch curve (Fig. 4) shows the three levels of total mortality for the aggregated data.

The results of the VPA can be seen in Fig. 5 clearly show three levels of fish mortality. Overall, it appears that F is very high on small individuals, intermediate on medium-size individuals and low on large individuals. Table 2 presents the results of length-structured VPA on females and males, and Fig. 6 shows the Y/R curve for different fishing patterns, for $E = 0.65$, i.e, for the exploitation rate corresponding to the present mean level of fishing mortality over all length classes ($F \approx 1.2$ $year^{-1}$).

The different fishing patterns correspond to different hypothetical selection curves; at the present (1988) level of fishing effort, the Y/R curve suggests that a long-term yield at least 50% higher than the present one could be obtained by increasing the size at first capture from about 6 cm (carapace length) to about 10 cm.

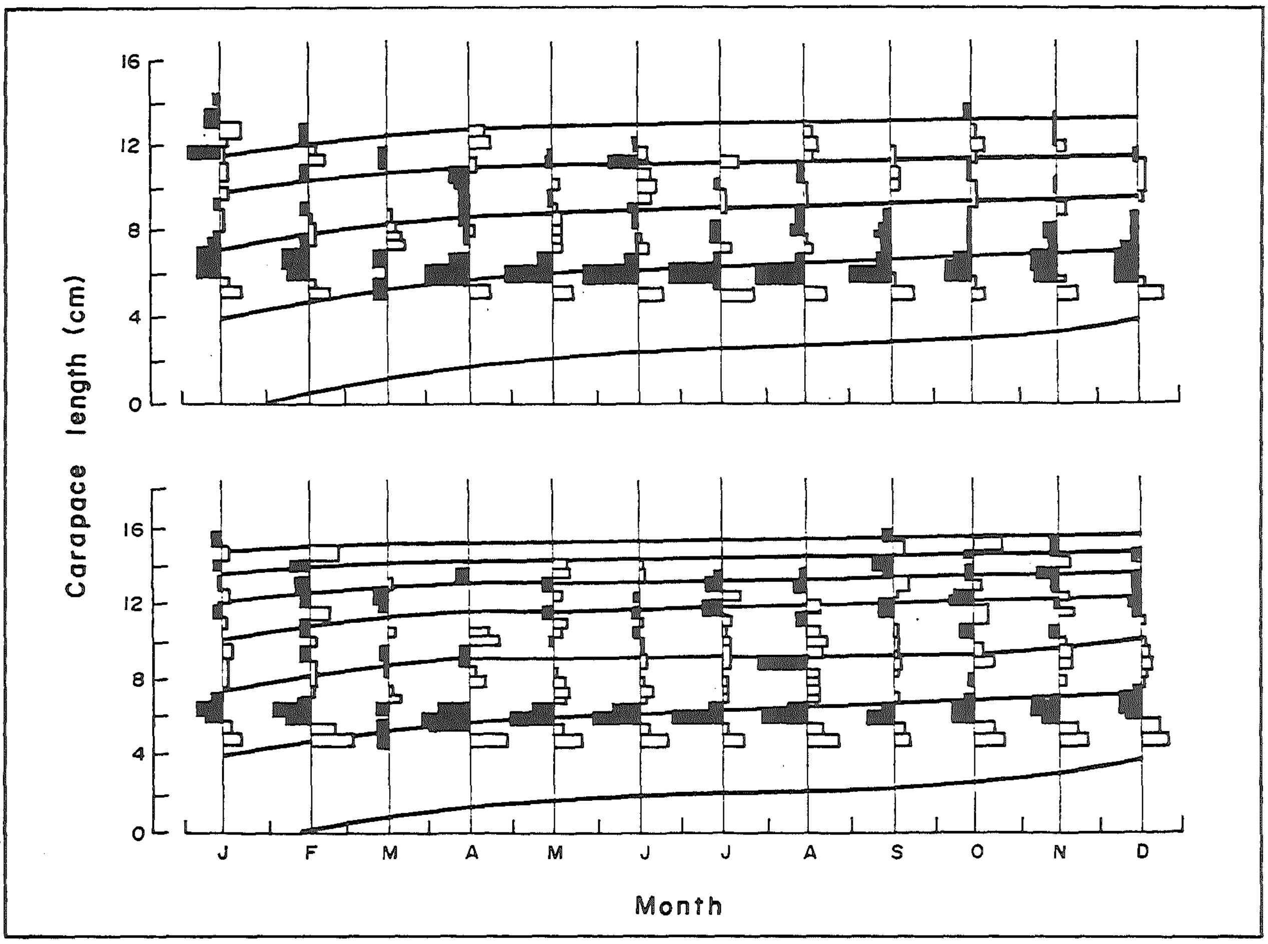

Fig. 3. Growth curve of female and male P. delagoae, *based on data for 1980-1984; the parameters for females are $CL_\infty = 17$ cm, $K = 0.3$ year^{-1}, $C = 0.9$ and $WP = 0.6$. The parameters for males are $CL_\infty = 18.2$ cm, $K = 0.3$ year^{-1}, $C = 1.0$ and $WP = 0.55$.*

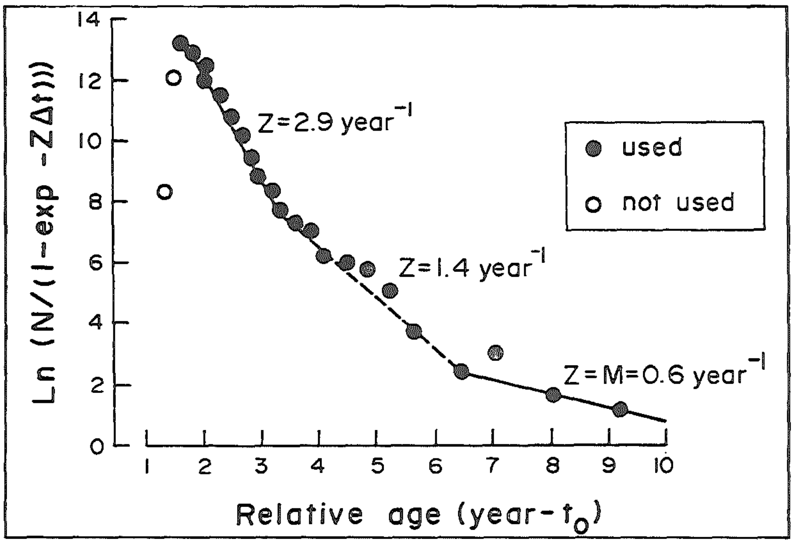

Fig. 4. Length-converted catch curve for female and male P. delagoae, *1980-1984, suggesting decreasing levels of Z for small, medium and large lobsters. Based on $CL_\infty = 17.6$ cm and $K = 0.3$ year^{-1}.*

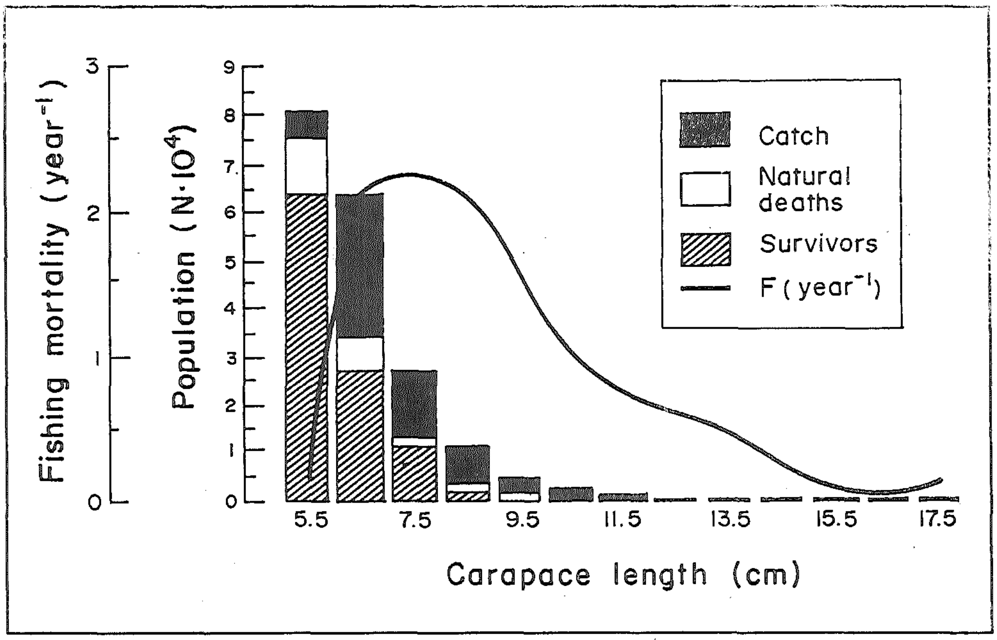

Fig. 5. Length-structured VPA of female and male P. delagoae *(mean for 1980-1984), suggesting decreasing levels of F for small, medium and large lobsters. The parameter used were* $CL_\infty = 19$ *cm, K = 0.257 year*$^{-1}$ *and M = 0.6 year*$^{-1}$ *(see also Fig. 4 and text).*

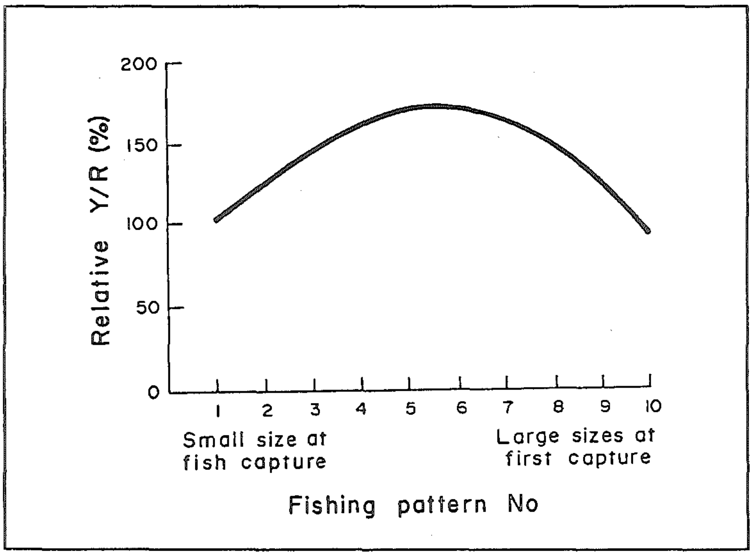

Fig. 6. Yield-per-recruit of P. delogoae, *for E = 0.65 (mean level of exploitation rate in Mozambique in the late 1980s), for different fishing patterns.*

Growth

Although there are plentiful results on morphometry, reproduction, moulting, and even population structure of the spiny lobster *Palinurus delagoae* in the literature (Berry, 1971, 1973; Brinca & Palha De Sousa, 1983), there is nothing about growth parameters. The only estimates found were for *Jasus lalandii* and *Panulirus homarus*.

Table 2. Results of length-structured VPA on female and male *P. delagoae* caught in Mozambican waters (see also Fig. 5). Parameters used were CL_{∞} = 19 cm, K = 0.3 and M = 0.6.

Length class (CL, cm)	Catches	Population	Fishing mortality	Fishing pattern #1[a]
5 - 6	4250	80036	0.21	0.095
6 - 7	28610	63431	2.16	1.000
7 - 8	13066	26867	2.23	1.000
8 - 9	5116	10212	2.13	1.000
9 - 10	1603	3736	1.58	0.723
0 - 11	486	1526	0.98	0.449
11 - 12	187	741	0.66	0.304
12 - 13	91	385	0.54	0.251
13 - 14	49	194	0.52	0.236
14 - 15	15	88	0.28	0.130
15 - 16	4	41	0.13	0.054
16 - 17	0	18	0.00	0.023[b]
17 - 18	1	7	0.10	0.023[b]

[a] This fishing pattern was obtained by averaging the three highest F values (which gives F = 2.17), setting these equal to one, and dividing all other Fvalues by 2.17.

[b] Assuming that F is constant from 16 to 18 cm.

Table 3 compares the growth performance in these two species with that of *P. delagoae*, as estimated here. As might be seen, the comparison suggests that the estimate of K = 0.3 $year^{-1}$ presented above for *P. delagoae* might be too high, and could indeed be as low as K = 0.1 $year^{-1}$. Future research will decide which of these possibilities is most likely. This, however, does not affect the results of the yield-per-recruit analyses since K does not appear in these as an independent parameter. Rather, it is M/K = 2 which was used, which is insensitive to the specific value of K.

Stock Assessment and Fishing Pattern

It is clear from the different analyses that *P. delagoae* is being caught at sizes that are far too small. The catch curve (Fig. 4) shows that total mortality on the smaller size classes is much higher than in the rest of the population.

Table 3. Comparison of estimate of growth performance in lobsters from South Africa.

Species	CL_∞ (cm)	K ($year^{-1}$)	ϕ'[a]
Jesus lalandii[b] (female)	13.9	0.139	1.43
Palinurus homarus[c] (female)	12.0	0.180	1.41
Palinurus homarus[d] (male)	9.4	0.340	1.48
Jasus lalandii[e] (juv.)	13.9	0.123	1.38
Palinurus delagoae[f] (female)	17.0	0.300	1.94
Palinurus delagoae[f] (male)	18.2	0.300	2.00

[a] $\phi' = \log_{(10)}K + 2 * \log_{(10)} CL_\infty$
[b]Based on analysis, using a forced Gulland & Holt plot of tagging and recovery data in table XXI of Heydorn (1969).
[c]Based on analysis, using a forced Gulland & Holt plot of tagging and recovery dat in Smale (1978).
[d]Based on analysis, using a forced Gulland & Holt plot of tagging and recovery data in Smale (1978).
[e]Based on analysis, using a forced Gulland & Holt plot of growth curve of lobsters kept in aquaria; from Fig. 4 in Pollock (1973).
[f]This study.

From the VPA (Fig. 5) it is also seen that fishing mortality is very high on the smaller animals, decreasing rapidly toward the larger sizes. This is not the most appropriate shape for such curve: at the start of fishery it is usually the medium-sized and large adults which are caught first.

The yield-per-recruit curve (Fig. 6) was constructed by starting from the present fishing pattern (pattern # 1) where lobsters are first caught at about 6 cm, then increasing this size by steps of 0.5 cm. As stated above, the maximum yield-per-recruit from the fishery is reached with fishing pattern #5, where the size at first capture is approximately 10 cm. The analyses were done using the standard measure for shelled animals, carapace length; the corresponding values in other measures are as follows:

Carapace length (cm)	Total length (cm)	Total weight (g)
6.0	19.0	170
10.0	28.7	655

The observed present exploitation rate of E = 0.65 means that 65% of total mortality is caused by fishing, which is a very high value. Nevertheless, since the samples were taken at a time when only one vessel was exploiting the resource (at least officially), no attempt was made here to study the potential effects of a decrement of fishing effort.

It should be noted that regulations exist which forbid the marketing of lobsters of the species *Panulirus* spp. with sizes smaller than 5 cm CL (Despacho de 20 de Julho de 1971). This legislation was apparently issued based on advice by the colonial fisheries authorities, but the study upon which this legislation was based was not found. This size was probably meant to protect the lobsters that had not yet spawned, i.e., to prevent recruitment overfishing (see Pauly, this vol.). Brinca & Palha de Sousa (1983) give a value of 6.5 cm for the size at first maturity in *P. delagoae*.

However, the results obtained here strongly suggest that growth overfishing is presently the real problem and it is strongly reccommended that the mesh size of the traps be increased, such that relatively more large lobsters are caught.

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