Revista de Investigação Pesqueira
Maputo No. 21 (1992): 1-13

Population Dynamics of *Penaeus indicus* at Sofala Bank, Mozambique: A Preliminary Study

by

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ABSTRACT

Length-based methods are used to estimate growth and mortalities of *Penaeus indicus* at Sofala Bank, in Mozambique. This penaeid shrimp is one of the most important species in the fishery as it constitutes 45% of the catches and has a great influence in their trend. First estimates of growth parameters for this species in Mozambique are presented and a comparison of the derived mortalities with the previous estimates is made.

RESUMO

Foram utilizados métodos baseados em distribuições de frequências de comprimentos para estimar o crescimento e mortalidades da espécie *Penaeus indicus* do Banco de Sofala em Moçambique. Este camarão peneídeo constitui 45% da captura total e influencia grandemente na tendência das capturas, sendo considerada uma das espécies mais importantes na pescaria. Apresentam-se as primeiras estimativas dos parâmetros de crescimento para esta espécie em Moçambique e é feita uma comparação das mortalidades obtidas com estimativas anteriores.

Introduction

Shallow-water shrimps occur along much of the coast of Mozambique. Their distribution is closely related with the occurrence of mangrove areas and estuaries, which probably serve as nursery areas for the juveniles (see Garcia & Le Reste, 1981 and contributions in Gulland & Rothschild, 1984).

The main fishing areas are Sofala Bank off Central Mozambique, from 16° to 21°S, and Maputo Bay, in the southernmost part of the country. Fishing occurs in shallow waters, down to 35 m (Fig. 1).

This resource is exploited by artisanal, semi-industrial and industrial fisheries. The semi-industrial and industrial fisheries work with single or double-rigged trawlers while the artisanal fishery uses mainly beach seines and mosquito nets. The industrial fishery is conducted only in the Sofala Bank area.

There are two main species, *Penaeus indicus* and *Metapenaeus monoceros*, which constitute 90% of the total shrimp catch. The remaining 10% include *P. monodon, P. japonicus, P. semisulcatus* and *P. latisulcatus*. Of the two main species, *Penaeus indicus* has a great influence on the total catch trends, either between or within years (Silva, 1988).

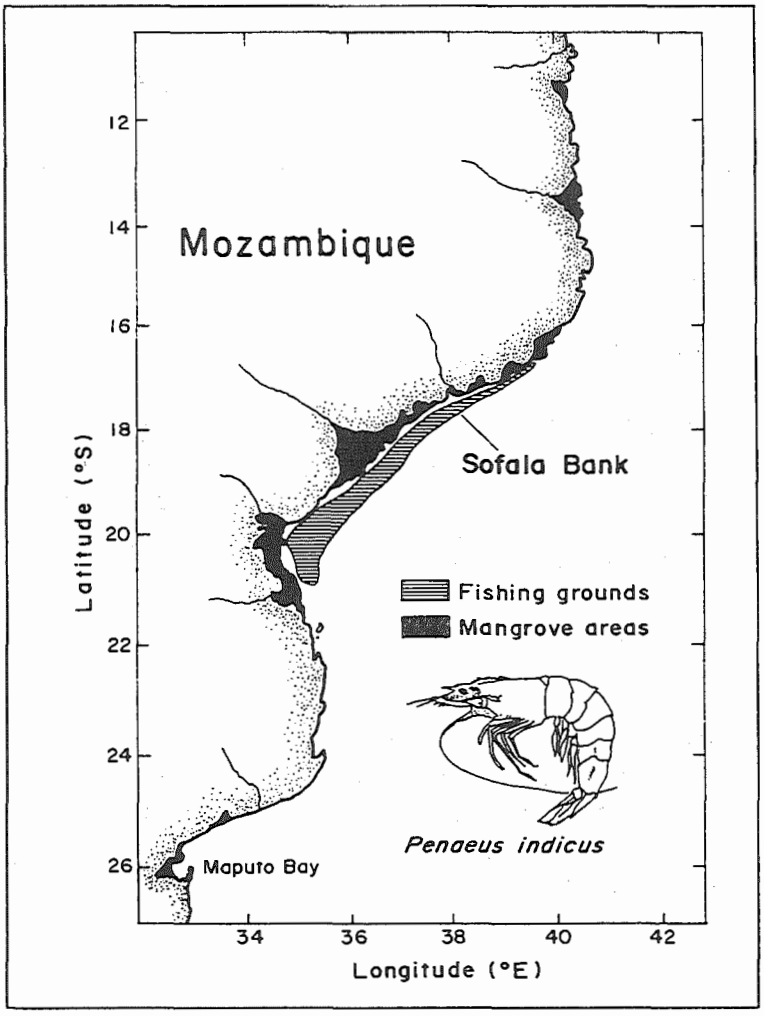

Fig. 1. Distribution of mangrove areas and main shrimp fishing grounds in Mozambique.

Several assessments of the Sofala Bank shrimp stocks were made since 1977, based on catch-and-effort data. As growth parameters for the main species were not available for this area, the yield-per-recruit studies were performed using growth parameter estimates from Madagascar (Ulltang, 1980; Ulltang et al., 1980, 1985; Silva & Sousa, 1987).

The aim of this report is to present estimates of growth parameters of *Penaeus indicus* at Sofala Bank, and to use these to obtain mortality estimates for comparison with earlier values.

MATERIALS AND METHODS

Data Sampling and Preprocessing

Monthly data were collected for the period 1985-1987 from two different companies, Pescamar and Efripel, working at Sofala Bank, using a stratified sampling scheme.

Two boxes of each size category were taken from the landings. The sample was separated by species and sexes, and carapace lengths were recorded. These data were grouped in classes of 2 mm and raised to the total catch of each company. For each company and sex, an artificial year was constructed to reduce the fluctuations among years; the data were then regrouped in classes of 3 mm (Tables 1 and 2). All analyses were performed with the Compleat ELEFAN software package (Pauly, this vol.).

Estimation of Growth Parameters

A modified Wetherall plot was used to obtain an initial estimate of L_∞ for females (Wetherall, 1986; Pauly, 1986a and this vol.). However, as the estimates of L_∞ obtained were low compared to the largest female sampled, a value of L_∞ slightly higher than the highest length class was assumed. Then, values of L_∞ and K available from the literature (Table 3) were used to obtain values of ϕ' ($= \log_{10}K + 2\log_{10}L_\infty$), from which, given L_∞, initial estimates of K were derived.

As trawl nets are selective, a correction for selection was made using a backward projection of the descending right arm of a length-converted catch curve and the resulting probabilities of capture (Pauly, 1986b). Preliminary growth parameter estimates ($L_\infty = 56$ mm and $K = 0.89$ year^{-1}) were used for this.

For the males, L_∞ was calculated using the mean ratio between the length of males and that of females, based on the data for the different species included in Table 3, and an initial estimate K was obtained via the mean value of ϕ', as described for the females.

Table 1. Size-frequency data of *P. indicus* caught at Sofala Bank, Mozambique by the Efripel fishing company (above: females; below: males); data from 1985 to 1987, regrouped into an "artificial year".

Midlength (CL, mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
13.5	4.97	2.15	4.93	2.41	0.69	0.15				0.20	2.25	2.66
16.5	71.24	36.63	33.14	31.97	8.28	1.28	0.37	0.10	0.04	1.61	12.80	20.87
19.5	342.60	185.30	177.55	209.84	122.70	19.81	2.03	0.59	2.28	12.31	45.61	91.52
22.5	655.73	430.00	462.23	306.16	244.73	66.54	14.31	4.81	9.74	31.48	110.52	231.41
25.5	1074.32	797.76	681.26	420.59	330.32	145.48	46.29	21.76	56.01	153.57	241.91	607.89
28.5	1526.08	1259.85	1095.63	833.15	494.48	208.22	99.69	72.08	126.99	327.66	483.86	912.50
31.5	1792.57	1453.62	1871.41	1494.18	1139.36	474.10	311.06	316.36	411.73	722.72	862.76	1182.79
34.5	1339.83	1047.67	1916.13	1479.41	1609.93	760.08	492.63	474.04	527.77	701.71	764.63	951.93
37.5	972.31	699.44	1522.80	1956.58	2592.47	1341.66	934.00	903.11	567.40	654.98	830.52	824.01
40.5	443.47	373.62	957.30	981.65	2011.83	1613.99	1471.29	1388.43	749.72	458.75	682.61	612.10
43.5	252.01	152.82	221.85	263.27	835.46	1586.94	1237.29	1335.13	482.41	279.69	309.20	280.73
46.5	91.75	48.60	47.25	50.42	197.80	546.68	322.78	446.91	143.41	94.32	130.57	92.20
49.5	11.91	5.92	2.85	2.88	11.72	38.90	26.24	71.77	38.52	16.68	56.97	19.22
52.5	2.41	1.17	0.55	0.35	1.05	4.90	3.53	11.90	2.53	1.76	6.61	3.06
55.5	1.09	0.77										
13.5	2.21	0.94	2.23	0.19	0.16	0.03				0.09	1.04	1.17
16.5	59.51	27.94	26.31	16.05	4.88	1.25	0.09	0.03	0.28	3.80	11.52	17.10
19.5	408.62	237.82	238.92	261.38	101.79	21.25	3.68	1.48	3.89	23.25	85.14	152.43
22.5	1140.72	703.65	703.30	457.50	267.89	85.24	28.62	11.42	23.17	98.89	278.74	588.65
25.5	2157.40	1787.46	1518.70	949.05	642.79	252.30	127.60	102.93	199.49	544.46	528.30	1390.62
28.5	1799.55	2206.09	2611.46	1703.23	1210.59	419.92	193.75	217.41	360.27	463.33	736.41	1065.93
31.5	818.44	672.24	1887.98	1348.48	2348.87	771.43	478.13	745.82	788.69	375.24	507.41	615.77
34.5	251.51	190.18	461.39	289.42	1117.05	685.50	569.11	924.63	616.34	298.54	251.40	264.17
37.5	29.58	23.99	44.15	37.95	63.42	68.03	46.99	81.67	25.83	24.84	38.81	38.60
40.5	6.70	5.42	10.20	9.06	12.00	12.91	8.94	6.20	4.16	4.82	8.23	8.26

Table 2. Size-frequency data of *P. indicus* caught at Sofala Bank, Mozambique by the Pescamar fishing company (above: females; below: males); data from 1985 to 1987, regrouped into an "artificial year".

Midlength (CL, mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16.5	5.50	15.04	7.95								5.98	31.29
19.5	124.57	364.37	683.06	29.73	49.42	107.72	2.30		17.72	17.90	89.48	259.81
22.5	501.10	957.50	1039.64	254.25	297.94	301.74	16.83		136.32	78.80	225.81	503.36
25.5	276.52	399.72	1254.67	1077.90	594.08	741.72	115.52	12.77	492.49	180.32	400.28	1021.94
28.5	155.63	496.20	1277.43	1972.81	819.57	1662.25	145.02	73.21	347.79	507.37	660.51	1170.27
31.5	278.32	930.71	2243.13	1058.63	1477.93	2584.92	319.02	197.64	426.45	615.14	614.06	1114.98
34.5	197.54	787.81	2199.73	1259.35	1897.38	1385.69	473.73	518.60	627.99	999.21	660.72	588.22
37.5	69.04	301.74	1178.71	1333.42	1668.21	1484.21	569.44	749.18	843.15	794.83	466.57	376.48
40.5	65.81	202.88	540.98	819.55	1253.29	1407.83	1036.48	784.85	739.69	714.53	387.52	314.94
43.5	33.24	20.94	297.22	549.12	373.48	531.52	682.66	920.08	417.46	553.71	256.66	232.69
46.5	16.61	15.70	109.57	87.13	112.24	136.71	428.49	520.29	155.56	265.28	134.90	179.18
49.5	9.97		23.83	20.42	9.28	80.11	71.10	213.10	20.95	92.61	157.09	98.04
52.5	13.30		4.03					16.22	2.31	23.19	44.33	35.50
55.5	6.65									5.15	9.54	14.12
16.5	27.66	11.53	245.96	2.58		29.95					2.79	21.44
19.5	277.93	496.30	1990.48	7.74	138.27	245.26	10.28		89.65	73.99	95.76	306.83
22.5	836.59	587.72	2143.40	454.23	385.14	392.27	112.40	1.00	725.42	259.70	435.20	1181.08
25.5	651.47	780.55	2334.85	2590.29	889.21	1036.06	216.02	106.47	631.16	693.96	1140.18	1993.76
28.5	938.03	1311.34	4904.12	3587.00	1900.65	1517.04	366.64	448.65	745.35	1097.73	1232.44	1741.17
31.5	234.54	742.02	2646.98	2554.31	4545.49	1228.43	1864.07	1147.79	778.49	546.25	501.35	952.60
34.5	138.36	170.02	222.84	624.88	2198.71	620.58	2271.52	991.09	807.49	562.26	309.44	415.83
37.5	110.60	30.16	8.38	163.45	123.20	33.69	350.35	93.55	134.77	173.47	222.51	138.98
40.5	19.00			40.86			33.20		3.69	7.89	36.85	14.71
43.5	3.25										1.66	0.00
46.5	3.25										1.66	0.00
49.5	3.25											4.64

ELEFAN I was then run for females and males, and for each company separately to refine the preliminary estimates of L_∞ and K. Herein, the growth of *Penaeus indicus* was assumed to follow a seasonally oscillating version of the von Bertalanffy equation, as suggested by Fig. 2.

In these runs, L_∞ was fixed at the values assumed before for each sex; C was assumed equal to 0.5 based on the difference between the minimum and maximum mean monthly water temperatures in the Sofala Bank area (about 5° C) and on Fig. 2; WP (winter point) was set as 0.7, corresponding to the month with the minimum mean water temperature; only K was permitted to vary.

Estimation of Mortalities

Total mortalities were estimated through length-converted catch curves accounting for seasonal growth (Pauly, 1990).

Also, the growth parameter estimates and the average catch of the two companies (60% of the total catch) were used to run a length-structured VPA.

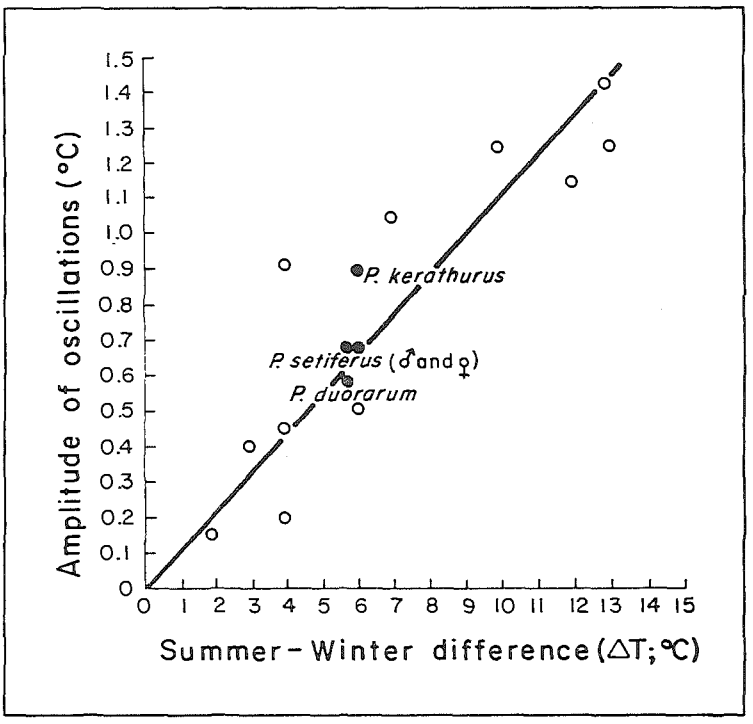

Fig. 2. Relationship between intensity of seasonal growth oscillation, as expressed by the parameter C of the generalized VBGF and the difference between highest and lowest mean monthly water temperature in the course of one year (ΔT). From Pauly et al. (1984).

RESULTS AND DISCUSSION

Growth Parameter Estimates

The initial growth parameters were for the females: CL_∞ = 56 mm, K = 0.89 $year^{-1}$, and for the males: CL_∞ = 49 mm, K = 1.18 $year^{-1}$, and these were used for the initial catch curve analysis to estimate probabilities of capture. These probabilities, for females and males for each company, are summarized in Table 4. (The two companies use the same mesh size in the cod-end, but their nets are made of different materials).

Figs. 3 and 4 present the growth curves obtained using the catch-raised length-frequency distributions corrected for selection. These parameters are presented in Table 5; as might be noted, they differ

Table 3. Growth parameters and ϕ' values for some penaeid species.

Species	L_∞(TL,cm)	K(year^{-1})	ϕ'^{f}	$L_{\infty\sigma}/L_{\infty\varphi}$
P. duorarum ♂[a]	17.6	1.45	2.652	-
P. duorarum ♂[a]	17.6	1.20	2.570	
P. kerathurus ♀[a]	21.0	0.80	2.548	0.857
P. kerathurus ♂[a]	18.0	0.90	2.465	
P. setiferus ♀[a]	22.5	1.25	2.801	0.856
P. setiferus ♂[a]	19.2	1.55	2.759	
P. semisulcatus ♀[b]	21.9[d]	1.07	2.710	0.982
P. semisulcatus ♂[b]	21.5[d]	0.96	2.647	
P. indicus ♀[c]	19.5[d]	2.52	2.981[e]	0.769
P. indicus ♂[c]	15.0[d]	3.00	2.829[e]	
	Mean	2.644	0.866	

[a]From Pauly et al. (1984).
[b]From Mathews et al. (1987).
[c]From Le Reste (1978).
[d]CL converted to TL using the relationships from Le Reste et al. (1974).
[e]Values not included in the computation of mean ϕ' because of the large difference with the other stocks, and because this is the only stock in the table in which seasonal oscillations of growth were not explicitly considered.
[f]$\phi' = \log K + 2 \log TL_\infty$ (Pauly & Munro, 1984).

Table 4. Probabilities of capture for females and males of *P. indicus* for Pescamar and Efripel.[a]

Midlength (CL; mm)	Females		Males	
	Pescamar	Efripel	Pescamar	Efripel
13.5	-	0.00023	-	0.00004
16.5	0.00578	0.00069	0.00062	0.00028
19.5	0.01618	0.00202	0.00262	0.00203
22.5	0.04443	0.00592	0.01091	0.01448
25.5	0.11620	0.01723	0.04435	0.09593
28.5	0.27103	0.04910	0.16331	0.43388
31.5	0.51252	0.13201	0.45085	0.84700
34.5	0.74831	0.30935	0.77544	0.97560
37.5	0.89370	0.56882	0.93559	1
40.5	0.95964	0.79531	0.98389	1
43.5	0.98534	0.91964	1	1
46.5	1	0.97118	1	1
49.5	1	1	1	1
52.5	1	1	1	1
55.5	1	1	1	1
CL_{50}(mm)	31.4	36.7	31.9	28.9

[a]Values of P > 0.990 set equal to 1.

Table 5. Growth parameters for *P. indicus* at Sofala Bank, for C = 0.5 and WP = 0.7.

Sex	Company	CL_∞ (mm)	K ($year^{-1}$)
Females	Pescamar	56	0.93
	Efripel	56	0.89
Males	Pescamar	49	1.19
	Efripel	49	1.20

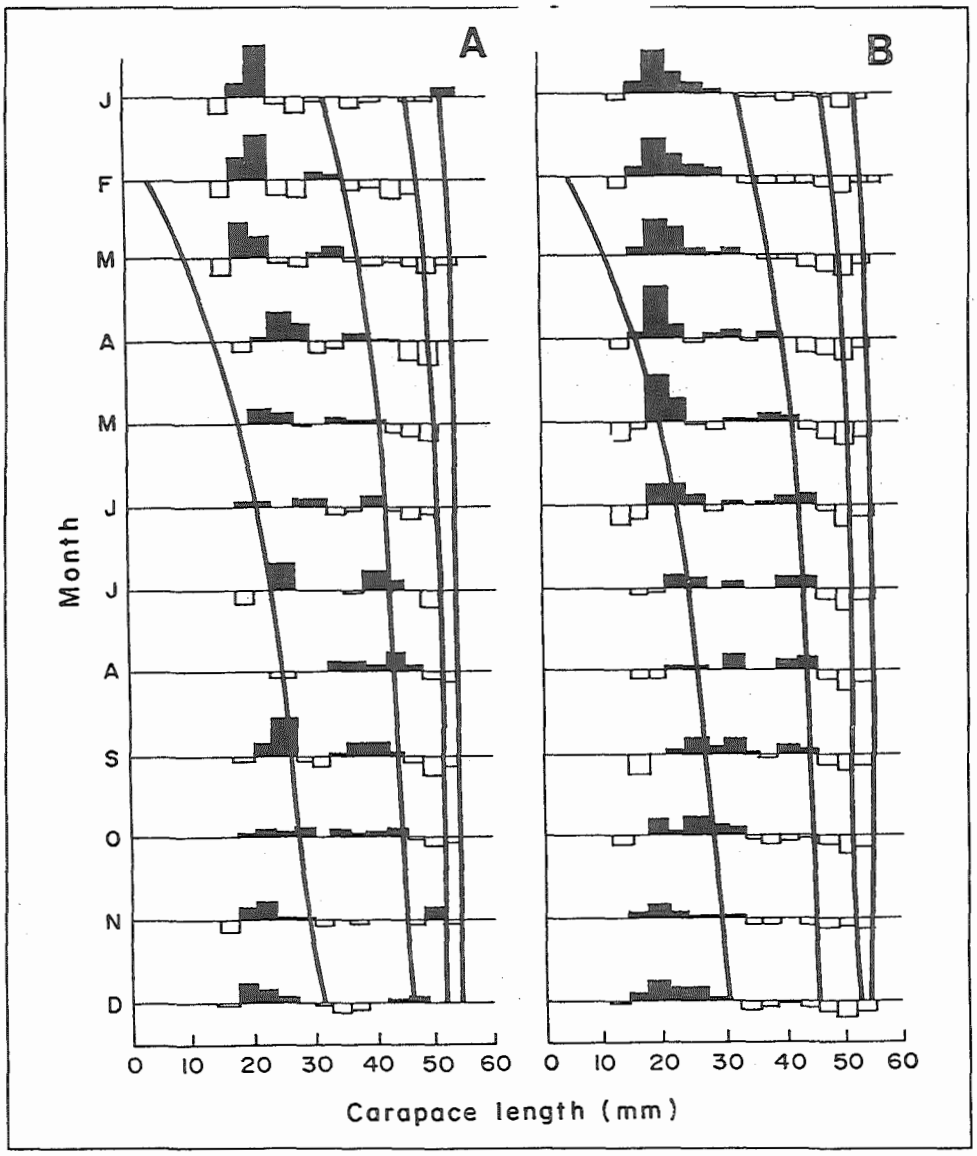

Fig. 3. Growth curves fitted to restructured length-frequency distributions of Penaeus indicus *(female) for Pescamar (A) and Efripel (B) fishing companies, Mozambique.*

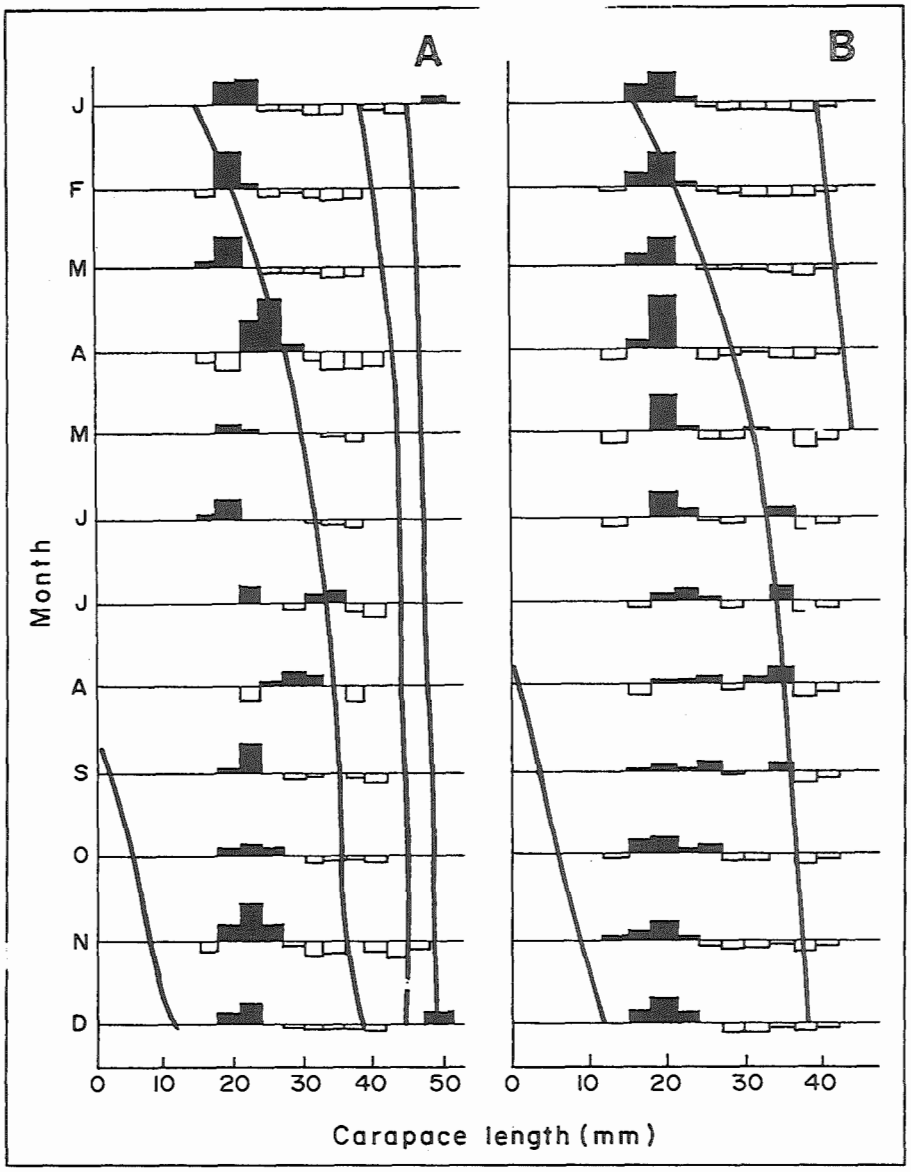

Fig. 4. Growth curves fitted to restructured length-frequency distributions of Penaeus indicus *(male) for Pescamar (A) and Efripel (B).*

strongly from previous estimates for the same species (Le Reste, 1978), where the value of K is much higher, but which do not account for seasonal growth oscillations.

Estimates of Mortalities

Figs. 5 and 6 show the results of our estimates of mortality in *P. indicus* at Sofala Bank; the results are recalled in Table 6, which also includes previous estimates obtained from catch-and-effort data and from the swept-area method.

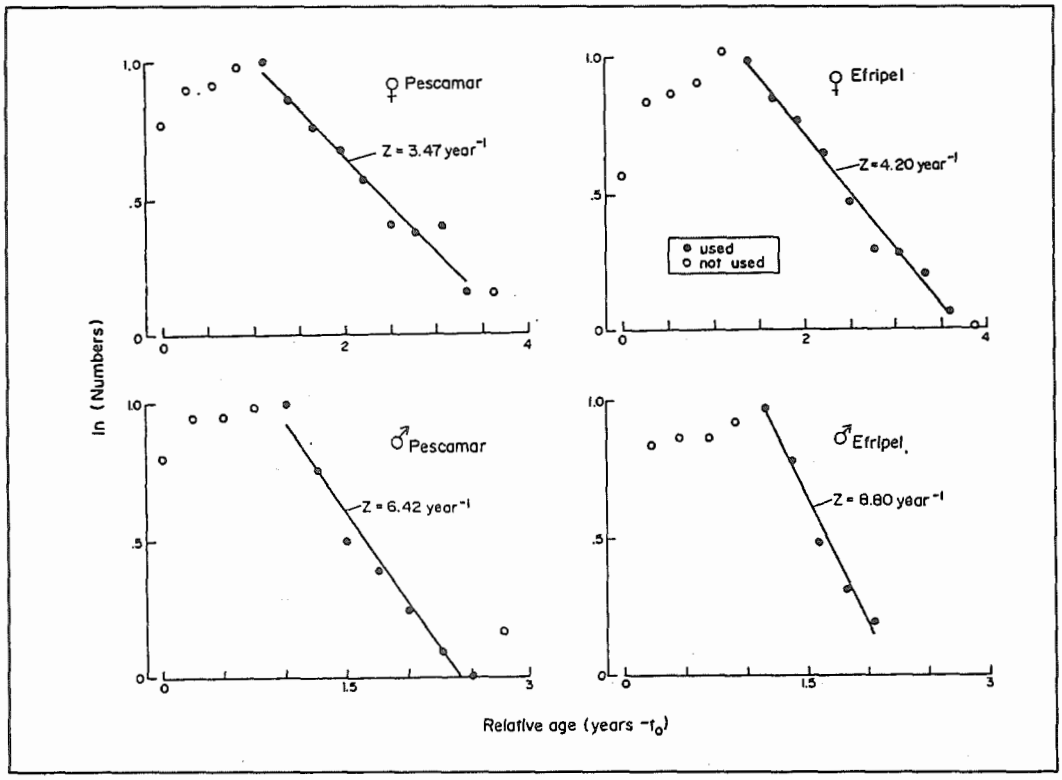

Fig. 5. Length-converted catch curves of Penaeus indicus *(♀ & ♂) using data from two companies.*

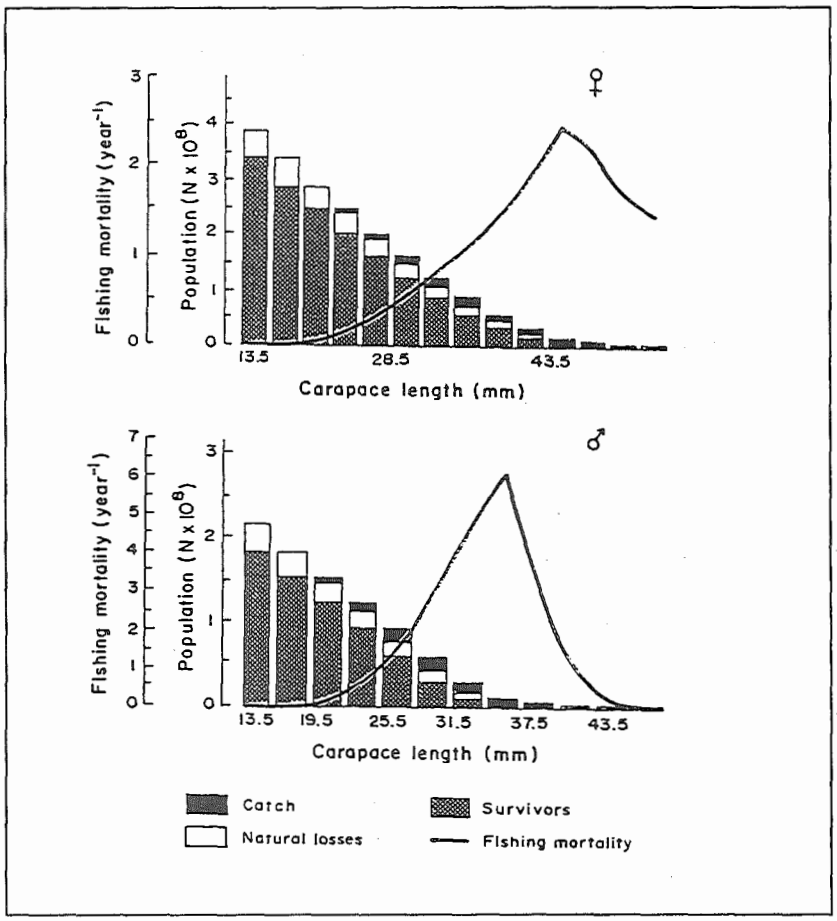

Fig. 6. Length-structured VPA applied to Penaeus indicus.

Table 6. Mortality estimates (year^{-1}) for *P. indicus* at Sofala Bank for the period 1985-1987.

Method	Length range (mm)	Z	F	M
1. Catch curve				
female	36-57 Efripel	4.2	2.4[a]	1.8[c]
	36-57 Pescamar	3.5	1.7[a]	1.8[c]
male	30-45 Efripel	8.8	6.4[a]	2.4[c]
	33-48 Pescamar	6.4	4.0[a]	2.4[c]
2. VPA II				
female	30-54	3.5[b]	1.7	1.8[c]
male	24-39	6.1[b]	3.7	2.4[c]
3. Trend of C/f[d]				
(females & males)	-	4.4	2.2[a]	2.2[e]
4. Swept area[d]				
(females & males)	-	4.4[b]	2.2	2.2[e]

[a] F = Z - M
[b] Z = F + M
[c] M = 2K
[d] From Silva & Sousa (1987).
[e] M assumed values.

As might be seen, the "seasonal" catch curve estimates of Z (mean = 5.7 year^{-1}) are compatible with (i.e., neatly bracket) those obtained through the other methods; this is an improvement over the results obtained using standard length-converted catch curves, which provided much higher estimates of Z. This is encouraging as it suggests that the array of methods used here provides results that are mutually compatible, and hence usable for routine assessments.

On the other hand, we think it will be important, in the future, to give more attention to the determination of sex ratios and size composition onboard the fishing vessels, as this will help improve sex-specific mortality estimates.

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