A PRELIMINARY ASSESSMENT OF THE SHALLOW WATER PRAWN STOCKS OFF MOCAMBIQUE, NORTH OF BEIRA

by

Øyvind Ulltang,
Institute of Marine Research, Bergen, Norway

and

Lilia Brinca and Cristina Silva
Servico de Investigacoes Pesqueiras, Maputo, Mocambique

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RESUMO

1. INTRODUÇÃO

Actualmente, a pesca de arrasto de camarão de águas pouco profundas é a única pescaria nacional industrializada em Moçambique. A maior parte da produção de camarão é exportada. Este trabalho consiste numa avaliação preliminar dos rendimentos potenciais da população de camarão entre Beira e Angoche, que permita um planeamento da expansão desta pescaria.

2. RESUMO DAS CONCLUSÕES

2.1

A falta de informação correcta sobre capturas totais e esforço de pesca durante os últimos anos na área considerada, limitou muito os tipos de modelos que poderiam ser usados neste trabalho. Contudo, a informação sobre capturas, esforço de pesca e composição das capturas por espécies e por tamanhos dos diários de bordo de uma parte da frota nacional, especialmente dos arrastões da EFRIPEL, tornou possível uma primeira estimativa das mortalidades e dimensões da população.

2.2

Das três principais espécies, P. indicus e P. monodon apresentam nítidas flutuações sazonais na abundância, indicando um recrutamento principal nas áreas de pesca durante 2-3 meses na primeira metade do ano e um tempo de vida de não mais de um ano após o recrutamento. O nível das capturas de M. monoceros é mais estável, indicando que o recrutamento ocorre mais ou menos ao longo de todo o ano. Não foi possível estabelecer conclusões sobre a longevidade das espécies.

2.3

Estimativas do coeficiente de mortalidade total mensal Z para P. indicus foram feitas por dois métodos diferentes; em primeiro lugar estudando o drecréscimo no número capturado por hora de arrasto com o tempo em períodos de recrutamento nulo ou muito pequeno e depois, comparando as capturas dos vários grupos de tamanhos, utilizando informação sobre o crescimento. Concluíu-se que durante os anos 1974-1976, Z era aproximadamente 0,4. O primeiro método foi também aplicado às capturas de P. monodon, indicando um Z ao mesmo nível ou mais elevado; no entanto, neste caso, as conclusões resultantes da aplicação do método não são tão seguras.

2.4

Utilizando a informação sobre captura total por hora de arrasto dos arrastões da EFRIPEL, estimou-se pelo método da "área varrida" que o tamanho médio anual da população de camarão de águas pouco profundas na área considerada, era aproximadamente de 5 000 toneladas em 1974-1975 e cerca de 8 000 toneladas em 1976. Estes valores são considerados como estimativas mínimas.

2.5

Supondo que o total anual das capturas em 1974-1975 era de 10 000 toneladas e em 1976 de 12 000 toneladas, as estimativas do tamanho da população dadas acima implicam um valor máximo de mortalidade por pesca mensal de 0.15 em 1974-1976. Utilizando as estimativas das mortalidades total e por pesca da espécie P. indicus durante 1974, a mortalidade natural por mês foi estimada como sendo ligeiramente inferior a 0.3.

2.6

Estudos de rendimento por recruta para P. indicus mostram que se pode esperar um aumento significativo das capturas se se elevar o esforço de pesca acima do nível do período 1974-1976 (F= 0.15). O rendimento por recruta correspondente a $F_{0.1}$= 0.35 foi estimado como sendo 45% acima do presente valor. Contudo, devido às incertezas das várias estimativas, concluiu-se que F não deve exceder 0.2. Para um aumento de F para 0.2 deve esperar-se um aumento corresponden

te de cerca de 16% do rendimento. Se o nível de captura correspondente a F= 0.15 é de 12 000 toneladas, este aumento em F deverá dar uma captura de cerca de 14 000 toneladas.
A captura correspondente a $F_{0.1}$ seria aproximadamente 17 000 toneladas.

Todos estes valores são baseados na hipótese que as principais espécies têm curvas de rendimento por recruta semelhantes a P.indicus. Estes valores devem ser tomados com precaução, especialmente devido às incertezas existentes sobre o nível actual das capturas e tamanho da população. Note-se também que os valores são baseados na suposição de que tamanhos inferiores da população reprodutora correspondente a estes elevados níveis de esforço não deverão causar qualquer redução num futuro recrutamento. Podem ser esperadas variações de ano para ano nas capturas causadas por variações no recrutamento.

3. DADOS NECESSÁRIOS PARA O FUTURO

A informação básica necessária para fazer uma avaliação mais detalhada e precisa das populações de camarão de Moçambique foi já de certo modo indicada na análise efectuada nas secções anteriores. Resumimos em seguida alguma desta informação necessária:

3.1 Estatística de captura e esforço

Deve-se dar prioridade à colheita de dados de confiança de capturas totais de camarão de águas pouco profundas e do correspondente esforço de pesca. As estatísticas de captura e esforço mais detalhadas por espécies, meses e quadrados estatísticos, devem abranger o maior número de barcos possível.

3.2 Amostragem das capturas

Parte da frota regista as capturas por espécies e por grupos de tamanho. Um programa de amostragem deve ser iniciado logo que possível de forma a:

(1) no caso de capturas que são registadas por grupos de tamanho, se obter uma estimativa mais precisa das frequências de comprimento e número por quilo, amostrando os vários grupos;

(2) no caso de capturas que não são registadas por espécies e grupos de tamanho, se determinar a composição por espécies e por tamanhos e número por quilo.

A análise feita na secção 4 frisa a necessidade de se obter estimativas do número capturado nos vários grupos de tamanho, separadamente para machos e fêmeas. Isto pode ser obtido por amostragem da composição por sexos de cada classe de comprimento.

A amostragem deve cobrir convenientemente as capturas tanto no tempo como no espaço.

3.3 Amostragem da população juvenil

Presentemente, quase não existe informação sobre o camarao antes de atingir a idade adulta em que entram na pescaria industrial. De forma a obter maior informação biológica sobre os juvenis, um programa de amostragem deve ser iniciado nas áreas costeiras de desenvolvimento (nurseries). Por amostragem da composição por tamanhos da população juvenil em intervalos de tempo regulares, pode-se identificar os vários grupos de recrutamento e estimar o crescimento do estado juvenil. De momento, as amostras podem ser obtidas mais facilmente das capturas da pesca artesanal ao longo da costa.

3.4 Cruzeiros de prospecção nas áreas de distribuição da população adulta

Deve ser levada a cabo uma prospecção por pesca de arrasto, utilizando um esquema de amostragem estratificada (estratificação por área e profundidade), para obter informação sobre

(i) distribuição das várias espécies e grupos de tamanho por área e profundidade;

(ii) variações na densidade de ano para ano e dentro de cada ano, de estação para estação;

(iii) estimativas do tamanho da população pelo método da "área varrida".

As amostras biológicas obtidas durante esta viagem fornecerão informação adicional sobre, por exemplo, maturidade, períodos de desova e de recrutamento.

3.5 Dados ambientais

A distribuição da população adulta está, provavelmente, muito ligada às condições hidrológicas; portanto, dados hidrográficos devem ser colhidos regularmente durante estes cruzeiros. De forma a obter maior informação sobre os factores que determinam a força de recrutamento, devem ser colhidos dados ambientais, tanto no mar nos períodos de desova como nas áreas de mangal. Todas as variações observáveis nas áreas de mangal devem ser seguidas em particular.

1. INTRODUCTION

At present, the trawl fishery for shallow water prawns is the only industrialized national fishery in Mocambique. Most of the catch is exported. Plans are laid for expansion of the fishery, and this report is an attempt to make a preliminary assessment of the potential yields from the stocks occypying the shallow water areas between Beira and Angoche (Fig. 1).

2. DESCRIPTION OF THE RESOURCE

2.1 Species composition

Many species of penaeid prawns have been recorded in the waters of Mocambique. In shallow waters, the most important species are the following:

Metapenaeus monoceros (Fabricius); brown or ginger prawn

Metapenaeus stebbingi Nobili

Penaeus indicus H. Milne Edwards; white prawn

Penaeus japonicus Bate; flower or banana prawn

Penaeus monodon Fabricius; tiger prawn

Penaeus semisulcatus de Haan; tiger prawn

M. stebbingi has no commercial value and occur in significant numbers only in a small fishing area in the Bay of Maputo (Fig. 1). The other species occur more or less in a mixture in a large area between Angoche and Mambone (Sofala Bank), but also further south (Bay of Maputo). As in other areas of the Indo-Pacific region, they are found on substrates of mud, silt or muddy sand and usually in shallow waters (10 - 40 m). They can, however, occur down to depths of 70 m.

The species *P. monodon* has the highest commercial value, mainly because of its large size. Crosnier (1965) quoted 337 mm as the largest recorded total length from any area. It is a species capable of withstanding a wide range of salinity, it has been recorded in sea-water, estuaries, backwaters and even in freshwater.

The various shallow water species undergo fluctuations in abundance within the year and from year to year. However, the catches of *P. indicus* and *M. monoceros* always exceed those of the other species. In average, the species composition for the Sofala Bank is approximately 45% *P. indicus*, 45% *M. monoceros* and 10% *P. monodon*, *P. semisulcatus* and *P. japonicus*.

In deep waters, the most abundant species is *Hymenopenaeus triarthrus* (Stebbing); pink or knife prawn.

It is distributed all along the coast of Mocambique between depths of 280 to 550m.

2.2 Life cycle of shallow water prawns

The prawns spawn at sea. After hatching, the successive planktonic larval stages migrate to the backwaters. The juveniles are found in low salinity zones as estuaries and particularly in the mangroves. When they reach a certain size, which differs from species to species, they migrate back to sea where they reach maturity. By the time they leave the coastal areas, they are recruited to the industrial fishery. Fig. 2 shows the general life cycle described.

For further description of the biology and life cycle of the various species, see Barnard (1950) and FAO (1970).

3. HISTORY OF EXPLOITATION AND DESCRIPTION OF THE FISHING FLEET

3.1 National fleet

Information about areas fished by both the national and foreign fleets and results of research vessel surveys seem to indicate that the richest grounds of shallow water prawns are found between Angoche and the delta of the Zambezi River, including the latter (Fig. 1).

Vessels from Moçambique have fished in this area since 1965. Until 1973 the industrial shrimp fleet fished from the port of Angoche, and most of the fishing took place between Angoche and Pebane. In 1974 some of the trawlers chose the port of Quelimane as their base, and the fishing area was extended southwards to the delta of the Zambezi River.

The quantitative development of the fleet operating in that area is shown in the table below. Information is lacking for 1972 and 1973.

Year	65	66	67	68	69	70	71	72	73	74	75	76
Number of vessels	2	10	12	10	7	19	30	-	-	53	51	51

Besides some figures for the mean gross tonnage, information about qualitative development of the fleet was not available during the study. The mean gross tonnage increased from 70 tonnes in 1971 to 115 tonnes by the end of 1976. At present most of the trawlers are equipped with double rig systems. Some characteristics of the vessels operating in the area in 1976 are shown in Table 1.

During 1977, four new vessels started to fish in the area, and in the near future six more will be added. All these vessels are modern units of between 25 and 30 m total length equipped with cold storage and quick freezers.

The catches from 1968 to 1973 in the area were as follows (Freitas and Araujo, 1973):

Year	1968	1969	1970	1971	1972	1973
Catch (tonnes)	41	232	472	1651	1746	2880

Total catch figures were not available for the years 1974 to 1976. The export values for 1974, 1975 and 1976 were 4587, 4329 and 3872 tonnes respectively. The prawns for export come mainly from the area under consideration, and may be taken as minimum values for the catch. Some prawns go to the local market or are discarded because of low quality. Data from one of the enterprises showed a ratio between export and catch of 0.85, 0.83 and 0.86 for 1974, 1975 and 1976 respectively. By dividing the export figures by these ratios and correcting for the fact that one of the enterprises had exported part of its catch as headless prawns, the following figures for total catches in the study area were arrived at:

1974: 5651 tonnes 1975: 5408 tonnes 1976: 4822 tonnes

Taking into consideration that several enterprises probably had greater problems with the quality of the prawns than the enterprise for which the ratio between export and catch was known, and that therefore these other enterprises had a significant lower ratio between export and catch, it was concluded that the total catch of the national fleet in the area considered was probably at a level of 6000 - 7000 tonnes during the years 1974 - 1976.

In addition to the fishery discussed above, there is also a fishery in the area between Beira and Mambone. This fishery is at present of much smaller importance, and very little information was available from this area. Therefore, all analysis in later sections will refer only to the areas north of Beira.

3.2 Foreign fleet

Both the shallow and deep water resources of prawns off Moçambique have been exploited by foreign fleets during the past years. According to information in a Spanish publication (J.P., 1973), 104 foreign vessels were fishing off the coast of Moçambique in 1973. They came from the following countries: Japan (35 vessels), South Africa (25 vessels), Spain (20 vessels), France (8 vessels) and Israel (2 vessels). Of these fleets, the Spanish one is the most important in the exploitation of the prawn resources. The other fleets have probably not exploited the shallow water prawns to any high extent.

According to an article published in Ind. Moçambique (Anon. 1974), the Spanish fleet started exploiting the prawns in 1964, and a total of 20 vessels operated in the area in 1974. According to information supplied by the various Spanish enterprises, at least 38 vessels fished for prawns in the area in 1976, and the reported catches or landings give a total of about 4700 tonnes of shallow water prawns. Because a part of this total was figures for landings, it may be concluded that the Spanish catch of shallow water prawns in the area in 1976 was of the order of at least 5 000 tonnes. It is not possible to give any catch figure for 1974 or 1975 as the enterprise reporting the largest portion of the catches in 1976 (about 50% of the total) did not report for 1974 and 1975. Because there seems to have been a significant increase in number of vessels operating from 1974 to 1976, and because reported catch data from Spanish vessels indicate that a larger part of the catches was shallow water prawns in 1976 than in 1975, it is likely that the Spanish catches of shallow water prawns were considerably below the 1976 level in 1974 and 1975.

4. ANALYSIS OF CATCH AND EFFORT DATA FROM THE NATIONAL FLEET

4.1 Data available

The data analysed in this section are based on information recorded in logbooks. For each trawl operation, the following data are expected to be recorded:

Quantity of prawn caught
Position
Duration of haul
Speed
Depth

As the logbooks in use are not uniform and the shipowners are not yet really obliged to return them (the situation will probably improve from 1978 onwards), most of the information is incomplete and/or inexact. The proportion of the fleet returning logbooks decreased in 1974 - 1976, so for these years catch data are only available for the three enterprises EFRIPEL, IMPESCAL and ARPEM. The catches covered by logbooks from these enterprises are shown in Table 2.

Each of the three enterprises fulfil the logbook requirements in a different way. EFRIPEL reports catch data by species and commercial size groups. IMPESCAL reports catches only by commercial size groups, and in 1973 and 1974 only total catches per trawling operation were recorded. ARPEM reports a few catches by species, but most of them have been recorded without any classification. Table 2 shows the proportion of the logbook reported catches which are given by species and/or size groups.

The data from EFRIPEL are, by far, the most precises and reliable. Most of the analysis in later sections will be based on data from this enterprise. It is the only enterprise which reports reliable figures for fishing effort (in hours of trawling). Vessels from EFRIPEL did not start to fish in this area until 1974, therefore most of the analysis will be limited to the years 1974 - 1976. The EFRIPEL fleet consists of four trawlers (Vega I - IV) of gross tonnage of about 150 and H.P. 500, and two trawlers (Rigel I - II) of gross tonnage of about 350 and H.P. 1250.

Table 3 shows the commercial size classifications used in the logbooks. The catch is reported in standard boxes of 2 kg.

In order to process the data given by the enterprise it is necessary to make a few conversions:

1 - Conversion of commercial size groups to length groups. This was done by utilizing length- weight relationships for the various species given by Le Reste, Marcille and Barbe (1974), based on their data from Madagascar.

2 - Conversion of productionof headless shrimps to total catch.

This was made by multiplying the first value by 1.65, to compensate for the loss in weight of 39-40% when the head is taken off.

3 - Conversion of catch in weight per length group to catch in number per length group. In each length group, this was done by multiplying the catch in weight by the mean number of prawns per kg.

As neither of the two first conversion factors are based on empirical data from the area under study, and since the second factor may vary from species to species, there are of course a lot of uncertainties connected with these conversions. However, due to lack of data there are no other possibilities for calculating number caught per length group.

4.2 Monthly distribution of fishing effort, catch per hour of trawling and species composition 1974 - 1976.

Table 4 shows total monthly catches reported in logbooks from the three mentioned enterprises for 1974 - 1976, catch per hour trawling for the EFRIPEL trawlers, total fishing effort corresponding to these total catches (calculated by: Total catch/catch per hour, EFRIPEL), and species composition (in weight) by month (based on data from EFRIPEL).

(i) Monthly distribution of fishing effort.

Table 5 shows the monthly distribution of the fishing effort of 1974-1976 calculated from the data in Table 4. The fishing effort seems to be more or less uniformly distributed over the year except for some decrease in December - January.

(ii) Total catch per hour trawling.

The total catch per hour trawling shows clear seasonal variations (Fig. 3) with highest catches in the first half of the year.

The mean catch per hour trawling showed a small decrease from 63 kg in 1974 to 52 kg in 1975. In 1976 there was a pronounced increase to 90 kg per hour.

(iii) Species composition of catches.

From Table 4 and Fig. 3 it can be seen that P. indicus and M. monoceros are the two dominant species in the catch throughout the whole year. P. monodon is the third most important species, and these three species make up 98 - 100% of the monthly catches. There are clear seasonal variations in the relative abundance of the three main species. The percentages of P. indicus and P. monodon are generally higher in the first half of the year than in the second half. Fig. 3 indicates that this is caused by the higher absolute abundance of these two species in the first half of the year. There is no clear seasonal variation in the catches of M. monoceros, thus the higher total catches in the first part of the year are caused by the seasonal fluctuations of P. indicus and P. monodon. All three species showed a higher abundance in 1976 than in 1974 and 1975. The seasonal variations in the catches of each main species will be discussed in more detail in the next section.

4.3 Number caught per hour trawling by species and size groups

Tables 6-8 give number caught per hour trawling by month, both in total and by size groups of P. indicus, M. monoceros and P. monodon, for the period 1974 - 1976. All these data are based on information from the EFRIPEL trawlers only. For prawns larger than 13.5 cm (total length), it was not possible to give the data by 1 cm groups. A considerable amount of prawns larger than 13.5 cm may be landed with heads on. As seen from Table 3 these are sorted into only four size groups, usually called "king", "large", "medium" and "small" prawns. For P. indicus and M. monoceros, the "large" ones have been put into the length group > 18 cm, the "medium" ones into the 15.5 - 18 cm group and the "small" ones into the 13.5 - 15.5 cm group. There are no "king" prawns among these two species. Concerning P. monodon, all prawns are recorded in the four groups for "heads on" prawns, and the corresponding approximate sizes in cm are given in Table 8. It should be noted that the size groups used in Tables 6 - 8 may not correspond exactly to the true sizes. As pointed out earlier, there are some uncertainties in the conversion factors used.

(i) P. indicus (Table 6, Fig. 4).

Total number caught per hour trawling shows a peak in February - May in 1974 and in January - April 1975. The 1976 data indicate a higher abundance than in the previous two years, with one peak in February - June and a second one in August.

Prawns in length groups 13.5 - 15.5 cm and 15.5. - 18 cm dominated in the catches. These two groups show similar seasonal fluctuations with no observable time lag in abundance between the smaller and the larger prawns. The abundance of prawns smaller than 13.5 cm shows generally the same seasonal fluctuations as the abundance of the larger ones, but the periods of high abundance are shorter. This means that the prawns grow rapidly through the lower length groups and accumulate in the groups of larger individuals.

The data indicate that the main period of recruitment to the fishery is from January/February to April/May. Small prawns (< 13.5 cm) are to some extent found throughout the whole year, but in very small numbers from July to November. The low number of P. indicus smaller than 13.5 cm caught, compared to the number of M. monoceros caught of the same size, indicates that P. indicus of these sizes are not yet fully recruited to the fishing areas. The other possibility would of course be that they escape through the meshes (the mesh size is 55 mm stretched), but the data for M. monoceros indicate that a significant proportion will still be kept by the net. However, no mesh selection experiments have been carried out. Using selection factors estimated for the deep sea prawn Pandalus borealis in Norwegian waters (Thomassen and Ulltang, 1974) with 36 mm mesh size, the 50% retention length with 55 mm mesh size would be 11-11.5 cm. However, the validity of using selection factors estimated for quite different species caught with much smaller mesh sizes is doubtful.

Fig. 4 indicates that only a small proportion of the prawns which recruits the fishery during the first months of the year survives until the next main recruitment period. From the available data it is, however, not possible to follow each recruitment group as it grows through the various size groups. The lack of any detectable time lag between periods of peak abundance of the various size groups may be explained by large differences in growth between males and females. According to estimated growth curves for P. indicus off Madagascar (Le Reste et Marcille, 1976 a), females grow much faster than males, and, for example, when females are in length group 15.5. - 18 cm, the males will be in the 13.5 - 15.5 cm group, and some will even be below 13.5 cm (see section 4.4). One therefore has to know the size composition separately for the catches of males and females if one wants to follow a cohort as it grows through the various size groups in the fishery. Unfortunately, no data were available during the present study to make such a separation.

According to data given by Le Reste and Marcille (1976 a), females of P. indicus off Madagascar reach maturity at a total length of 12 - 13 cm. The length data presented in Table 6 and Fig. 4 therefore indicate that most of the prawns in the catches were mature.

(ii) M. monoceros (Table 7, Fig. 5)

As already stated, the catches of M. monoceros did not show seasonal fluctuations to the same extent as the catches of P. indicus. The catches of prawns smaller than 12.5 cm showed an increasing trend from March/April to June/July and thereafter a decrease both in 1974 and 1975, but this pattern was broken in 1976. For the other length groups it is difficult to see any consistent pattern from year to year. The more stable catches of M. monoceros compared to P. indicus, may mean that the fishable stock is recruited more or less throughout the year, continuously or in more or less distinct groups. The data from 1974 - 1975 indicate, however, a peak in recruitment in June-July.

By comparing growth curves estimated for P. indicus (Le Reste et Marcille, 1976 a) and M. monoceros (Le Reste et Marcille, 1976 b) off Madagascar, it can be seen that M. monoceros shows slower growth and has a much smaller length at recruitment to the adult stock, and also a considerably lower maximum length than P. indicus. This is in general agreement with the data presented in Tables 6-7. Prawns of lengths < 12.5 cm are much more abundant in the catches of M. monoceros than in those of P. indicus, while there are much fewer prawns of M. monoceros of lengths > 15.5 cm. However, while there are no obvious discrepancies between the growth curve given by Le Reste and Marcille for P. indicus and the data on size composition of catches given in this paper (Table 6), their growth curve for M. monoceros does not fit to the data on size composition of catches off Moçambique given in Table 7. For example, according to their growth curve, L_∞ is 12.0 and 14.3 cm for males and females respectively, while Table 7 shows an appreciable quantity of prawns > 15.5 cm. This probably means that the estimated growth of the tagged population studied off Madagascar is significantly different from the growth of the population off Moçambique studied in this paper.

It is impossible to draw any conclusions from Table 7 and Fig. 5 about how long a cohort contributes to the fishery. As discussed above for P. indicus, the possibilities for following a cohort through the fishery would have been much better if length compositions were available separately for males and females.

(iii) P. monodon (Table 8, Fig. 6)

Prawns of P. monodon do not appear to recruit to the fishery in significant numbers before they reach a total length of approximately 17 cm. The seasonal fluctuations of the catches were similar to those of P. indicus. From the abundance of prawns of 17 -19 cm it may be concluded that the main period of recruitment was April/June in 1974 and March/April in 1975. Also the abundance of this species was especially high in 1976. One recruitment group seems to have entered the fishery in February, while the main recruitment occured in May/July. All size groups showed low abundance during the period September - December in all the three years, indicating a life span in the fishery of less than one year. The possibilities for doing a more detailed analysis of the data would have been greatly improved also for this species if length compositions were available separately for males and females.

4.4 Total mortality estimates

(i) Direct estimates from variation with time of number caught per hour trawling.

The basic assumption which has to be made when using this method is that changes in number caught per hour trawling reflect-apart from random variations-changes in abundance, and not changes in availability only. Because of the limited knowledge of the biology and behaviour of the prawns in this area, especially the lack of information on possible variations in area of distribution over the year, it is difficult to judge how valid this assumption is. Assuming, however, that the assumption is valid, the main difficulty in estimating mortalities from the data presented in section 4.3, Tabs. 6-8, is the lack of means to identify various recruitment groups or cohorts.

The number present in the fishable stock in any month i is given by:

$$N_i = N_{i-1} e^{-Z_{i-1}} + R_i$$

where

N_{i-1} = number present in the fishable stock at the beginning of month i-1

Z_{i-1} = total instantaneous mortality coefficient in month i-1

R_i = number of recruits which have entered the stock between time i-1 and i (and are still alive at time i)

During periods of the year when there may be a significant but unknown recruitment, it is not possible to make any direct mortality estimates. From the discussion in the preceeding section, it is clear that this will be the case for the whole year concerning M. monoceros. For P. indicus and P. monodon there seems, however, to be periods of no or only a small recruitment. By assuming $R_i = 0$, and that the number caught per hour trawling, $(C/h)_i$, is proportional to N_i, the mortality during one month, Z_{i-1}, is given by

$$\ln \frac{N_{i-1}}{N_i} = \ln \frac{(C/h)_{i-1}}{(C/h)_i}$$

For a larger period of no recruitment, the mean monthly mortality during the period may be estimated as the slope of the regression line of $\ln(C/h)_i$ against i

P. indicus

In 1974, the abundance of prawns of 11 - 11.5 cm and 11.5 - 12.5 cm indicates that there was almost no recruitment during the period June/September (Table 6, Fig. 4). The regression of ln(C/h) against month for the period May/September has a slope of -0.429 (Fig. 7a).

In 1975 the abundance of prawns in the two lower length groups indicates that there was almost no recruitment during the period May-September. However, a plot of (C/h) against month for the period April - September (Fig. 7b) gives a curve which is concave upwards, indicating that some recruits were coming in. In the 12.5 - 13.5 cm group there was a consistent decrease in number caught until July, but in August the number increased again. It was therefore decided to use only results from the period April - July when calculating the regression line. This gave a slope of -0.387.

In 1976 the abundance of the smaller prawns indicated some recruitment also in May - June, and some new recruits seemed also to come into the stock in September. Therefore only the period June - August could be used for mortality estimates. The regression line of ln(C/h) against time for this period has a slope of -0.464 (Fig. 7c).

Of the three estimates of mean monthly mortality given above, the estimate from 1974 is regarded as the most reliable. There was a 4 month period of no, or only a small recruitment during this year. When plotting ln(C/h) against time for the corresponding 5 month period, starting with the last month of recruitment, a linear trend with no indication of curvilinear relationship was found. In 1975 a curvilinear relationship was found, even for the shorter period finally used for estimating Z, and in 1976 the period of no recruitment was too short to give a reliable estimate. The 1975 and 1976 estimates are, however, close to the 1974 estimate.

Assuming that there have been no changes in availability of the prawns to the fishing fleet during the periods studied, i.e. no changes in the catchability coefficient, the regression estimates indicate that the value of the total monthly mortality coefficient has been around 0.4 or slightly higher, as any recruitment during the periods studied would give a negative bias in the estimates.

P. monodon

Even if the catch in number shows the same kind of seasonal variations for P. monodon as for P. indicus, it is not possible from the catches by size groups (Table 8, Fig. 6) to identify periods of no recruitment. The catches of prawns less than 17 cm can not be used as an index of recruitment, because of the very few numbers caught in this size group during the whole year (except in February-March 1974), and prawns of length 17 - 19 cm probably consist of both newly recruited individuals and older ones.

To obtain a rough idea of the probable level of the monthly mortality, it was decided simply to calculate the regression of ln(C/h) against time for periods of consistent decrease in C/h. From Fig. 6 it can be seen that June - September was such a period in 1974, as was May - September in 1975. The regression lines for these two periods have slopes of -0.82 and -0.41 respectively (Fig. 8).

There is, however, an inherent danger for seriously overestimating the rate of decrease in abundance with time when using this method. There certainly are large random variations in catches from month to month which are not connected with real changes in abundance. This may be especially true for this species, which makes up only a small percentage of the total catches. When defining a period of systematic decrease in abundance by use of the total catches, one would tend to start with a month where these random variations gave especially high catches, and to finish with a month of especially low catches. This argument may be illustrated by looking at the 1974 data. It may well be the case that the peak in abundance that year was in May, as in 1975, but that the fleet just by chance found good concentrations in June. If, instead of calculating the regression line for the period June - September, we use the period May - September, the slope will be -0.55 instead of -0.82 (Fig. 8a).

To conclude, it is not possible to make any definite estimates of monthly mortality for P. monodon. The regression lines in Fig. 8 indicate, however, that the mortality may be at the same level as that of P. indicus, or higher. Because of the abnormal seasonal fluctuations in 1976, no regression estimate was made for that year.

(ii) Estimates of total mortality utilizing information on growth.

The growth curves of the various species of prawns off Moçambique have not yet been established. However, as already stated in section 4.3, Le Reste and Marcille (1976a, 1976b) have estimated the growth curves of P. indicus and M. monoceros off Madagascar.

P. indicus:

Assuming a von Bertalanffy type of growth, Le Reste and Marcille found that the growth in mm carapace length of prawns older than 3 months was given by the following equations:

Females: $L_t = L_\infty \; (1 - e^{-k(t-t_0)}) = 42.41(1 - e^{-0.344(t-1.15)})$

Males: $L_t = L_\infty \; (1 - e^{-k(t-t_0)}) = 29.88(1 - e^{-0.373(t-0.06)})$

The corresponding curves for growth in total length are shown in Fig. 9. According to these growth curves, both males and females reach a length of 10 cm at 3 months old. From this age females grow faster, reaching the length of 12.5 cm at an age of 4.1 months, 13.5 cm at an age of 4.7 months and 15.5 cm at an age of 6.7 months. Males reach 12.5 cm at an age of 5.5 months, 13.5 cm at an age of 8 months and, having a L_∞ of about 14.1 cm, never reach the length of 15.5 cm.

Assuming that males and females of one cohort recruit to the stock in the same number N_R at an age of 4.1 months (i.e. when females reach 12.5 cm total length), and thereafter suffer a constant monthly fishing mortality F and total mortality Z, the following equations will give the relative catches in number of the various size groups of the cohort throughout its life span:

$$\frac{C_{12.5-13.5\ cm}}{C_{13.5-15.5\ cm}} = \frac{C_{12.5-13.5\ cm,\ males} + C_{12.5-13.5\ cm,\ females}}{C_{13.5-15.5\ cm,\ males} + C_{13.5-15.5\ cm,\ females}}$$

$$= \frac{\int_{t=5.5}^{8.0} FN_R e^{-(5.5-4.1)Z} e^{-(t-5.5)Z} dt + \int_{t=4.1}^{4.7} FN_R e^{-(t-4.1)Z} dt}{\int_{t=8.0}^{\infty} FN_R e^{-(8.0-4.1)Z} e^{-(t-8.0)Z} dt + \int_{t=4.7}^{6.7} FN_R e^{-(4.7-4.1)Z} e^{-(t-4.7)Z} dt}$$

$$= \frac{e^{-1.4Z}(1 - e^{-2.5Z}) + 1 - e^{-0.6Z}}{e^{-3.9Z} + e^{-0.6Z}(1 - e^{-2Z})} \qquad (1)$$

By similar reasoning:

$$\frac{C_{13.5-15.5\ cm}}{C_{>15.5\ cm}} = \frac{C_{13.5-15.5\ cm,\ males} + C_{13.5-15.5\ cm,\ females}}{C_{>15.5\ cm,\ females}}$$

$$= \frac{e^{-3.9Z} + e^{-0.6Z}(1 - e^{-2Z})}{e^{-2.6Z}} \qquad (2)$$

Thus, these ratios are functions of Z. Values of (1) and (2) for selected values of Z are given in Table 9 and Fig. 10.

Assuming that the prawns are not in the fishery for more than one year and that the main recruitment period starts in December, observed catch ratios corresponding to equations (1) and (2) were calculated for the EFRIPEL catches for the three periods shown in Table 10. Data for December 1973, January 1974 and December 1975 are not available.

The resulting mortality estimates are shown in Fig. 10.[1)]

The mortalities estimated from the ratio $C_{12.5-13.5}/C_{13.5-15.5\ cm}$ are much lower than the estimates made in the preceeding section and, for the years 1975 and 1976, also much lower than those calculated from the ratio $C_{13.5\ -\ 15.5\ cm}/C_{\geq 15.5\ cm}$. This may mean that prawns of 12.5 - 13.5 cm are not fully recruited to the fishery. From the way equation (1) was derived it can be seen that if the 12.5-13.5 cm group suffer a fishing mortality of p% of the fishing mortality on the fully recruited size groups, and if the fishing mortality is small compared to the total mortality, then the expected value of $C_{12.5\ -\ 13.5\ cm}/C_{13.5\ -\ 15.5\ cm}$ is only p% of the value given by equation (1). If partial recruitment was the only explanation for the discrepancy between the estimates from the two ratios, then p could of course be estimated by assuming that prawns larger than 13.5 cm were fully recruited. There are, however, several other potential sources of discrepancy. For example there may be some systematic errors in the size grouping of the catches, or the actual growth may not follow the assumed growth curve.

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1) In the basic catch tables, the "small" prawns with heads on were allocated to the 13.5 - 15.5 cm group. These "small" prawns may however, include prawns as large as 17 cm. Therefore, a quantity or prawns originally allocated to the 13.5 - 15.5 cm group should be in the > 15.5 cm group. Even if this quantity is small compared to the total catches and does not influence conclusions made in other sections of this report, it could have an appreciable effect on the ratio $C_{13.5\ -\ 15.5\ cm}/C_{>\ 15.5\ cm}$ because it is added to the numerator and subtracted from the denominator. Accordingly, a correction was made to the original grouping of the data, by calculating the percentage of "small" heads on prawns which should be in the > 15.5 cm group from the ratio $C_{15.5\ -\ 16.5}/C_{13.5\ -\ 15.5\ cm}$ observed for the catches of prawns landed without heads.

The mortality estimates from the ratio $C_{13.5 - 15.5 \text{ cm}}/C_{>15.5 \text{ cm}}$ give a value of Z = 0.39 for both 1975 and 1976, while the 1974 data give a Z value of only 0.1. The 1975 - 1976 value is at the same level as the estimates from regression of catch per hour trawling against time given in the preceeding section. The low 1974 estimate is caused by a relatively higher abundance of prawns larger than 15.5 cm in 1974 than in 1975 and 1976. This may easily result from slightly different (more rapid) growth in 1974 than in 1975 and 1976, and illustrates how sensitive the method is for changes in growth. The 1975 and 1976 estimates indicate that the growth in those two years was similar, but this alone does not confirm the validity of the assumed growth curve. The agreement with the estimates in the preceeding section may, however, be taken as further evidence for the conclusion in that section, i.e. that the total monthly mortality has been at a level of about 0.4.

M. monoceros

As discussed in section 4.3 the growth curve given by Le Reste and Marcille (1976 b) for M. monoceros off Madagascar seems not to correspond to the data on size composition of catches given in this paper. It is therefore doubtful whether mortality estimates based on that growth curve are valid. By comparing catches of prawns in length groups 12.5 - 13.5 cm and 13.5 - 15.5 cm, the growth curve gives estimates of total monthly mortality around 0.2 for the years 1974 - 1976. (According to the growth curve these length groups consist of females only).

5. "SWEPT AREA" ESTIMATES OF STOCK SIZE AND FISHING MORTALITY.

If it is assumed that all prawns of fishable size present in the area swept by a trawl are caught, their density in that area is given by:

ρ = catch per hour trawling/area swept per hour trawling

The area swept is given by:

Width covered by the trawl x distance trawled

The EFRIPEL trawlers are double rigged, i.e. are fishing with two trawls simultaneously. According to information on the trawls used, the distance between the trawl doors is approximately 17 m, and in further calculations it will be assumed that the trawl effectively catches every prawn within that width. This will probably be an overestimate of the effective width covered.

Information in logbooks of the EFRIPEL trawlers indicated a trawling speed of 2-3 knots. If a mean speed of 3 knots is assumed, thus rather overestimating that underestimating the area swept, the area swept by two trawls during one hour of trawling will be

$$2 \times 0.017 \times 3 \times 1.85 \text{ km}^2 = 0.1887 \text{ km}^2$$

and a catch of 1 kg per hour will correspond to a density of

$$1/0.1887 \text{ kg/km}^2 = 5.3 \text{ kg/km}^2$$

This will probably give an underestimate of the density in the areas trawled, because of overestimation of area swept and the unrealistic assumption that all prawns present in this area are caught.

Figs. 11-13 show the number of days fishing in each square in the area studied of four of the EFRIPEL trawlers (Vega I-IV) during the years 1974-1976. For one of the trawlers, similar maps were made for each month, but no pronounced seasonal variations in fishing area were found. All the EFRIPEL trawlers fish from the port of Quelimane, and it can be seen that they fish in two more or less separate areas, a northern and a southern one. These two fishing areas were used to estimate a total area of prawn distribution by assuming that the prawns were distributed from the coast outwards to a depth of 40 m. The resulting areas are shown in Fig. 14, covering a total area of 17 000 km^2. Assuming that the catch per hour trawling is a measure of the mean density of prawns within this area, the total stock size is given by

$$(1)\quad S = \frac{\text{catch per hour}}{\text{area swept per hour}} \times \text{total area} = \frac{\text{catch per hour}}{0.1887} \times 17000 \text{ kg}$$

There are several potential sources of error in this method:

(i) Calculation of area swept: If the area swept is overestimated, S may be underestimated.

(ii) The assumption that all prawns within the area swept are caught: If this assumption is invalid, S may again be underestimated.

(iii) The assumption that the observed catch per hour applies to the whole area: If there are smaller areas of especially high abundance within the total area and the trawlers know these areas and concentrate their fishing there, the catch per hour trawling is not representative for the total area, and S may be overestimated.

(iv) Calculation of total area of distribution: The definition of the area is mainly based on the distribution of the EFRIPEL fishing fleet. There are, however, probably significant quantities of prawns outside the area shown in Fig. 14, both further off the coast than assumed and especially south of the southern area, where it is known that other trawlers carry out fishing.

Although local variations in prawn density may lead to considerable overestimates of overall density, as discussed under (iii), the other factors, especially (iv) will probably more than compensate for this, and therefore it is concluded that the stock size estimates given by (1) most likely will be underestimates of the total stock of shallow water prawns (of fishable size) north of Beira. However, it should be stressed that until additional information on prawn distribution from for example stratified random trawl surveys are available, it is difficult to judge the validity of the method.

The stock size estimates corresponding to the observed catch per hour for each month and species are shown in Fig. 3. The estimated mean annual stock sizes (standing stock) using the mean annual catch per hour, are shown in the Table below.

Year	Mean annual stock size (tonnes)			
	P. indicus	*M. monoceros*	*P. monodon*	Total
1974	2440	2710	480	5680
1975	2040	2270	330	4680
1976	4010	3440	580	8110

These estimates include only prawns of fishable size, and correspond therefore more or less to the adult stock.

Monthly or annual fishing mortalities may be estimated from the "swept area" method either by:

$$(2) \qquad F = qf = \frac{\text{area swept per hour}}{\text{total area}} \times f$$

where f is total fishing effort measured in EFRIPEL trawling hours, and q the catchability coefficient,

or by:

$$(3) \qquad F = \frac{C}{S}$$

where C is the total catch and S the estimated mean biomass within the month or the year. These two methods are mathematically identical when S is estimated by equation (1), and when total effort is estimated by total catch/catch per hour for the EFRIPEL trawlers.

Assuming a total annual catch of about 10-12 000 tonnes from the area during the years 1974-1976, the stock size estimates given above would imply the following values for the fishing mortality of the total stock of all species:

Year	C = 10 000 tonnes		C = 12 000 tonnes	
	F_{annual}	$\bar{F}_{monthly}$	F_{annual}	$\bar{F}_{monthly}$
1974	1.76	0.147	2.11	0.176
1975	2.14	0.178	2.56	0.213
1976	1.23	0.103	1.48	0.123

As the species are fished as a mixture, it may be assumed that the fishing mortality does not differ to any great extent between the main species.

As pointed out in section 4.2, the national fishing effort seems to be more or less uniformly distributed over the whole year. This is probably also the case for the Spanish effort. It may therefore be assumed that the F for a given month or period of the year is not significantly different from the mean F.

If the stock size estimates are minimum ones, and the catch estimates are maximum values, than the estimated F values are maximum estimates. According to the discussion in sections 3.1 and 3.2 the catches in 1976 may have been close to 12 000 tonnes (6000 - 7000 from the national fleet and 5000 from the Spanish fleet), while the catches in 1974 and 1975 may have been closer to 10 000 tonnes because of the probably smaller Spanish catches during those years.

According to the table above this gives F values of 0.147, 0.178 and 0.123 in 1974, 1975 and 1976 respectively, with a mean of 0.149. F = 0.15 may therefore be regarded as a first maximum estimate of the mean monthly fishing mortality during the years 1974-1976.

If a trawling speed of 2.5 instead of 3 knots is assumed, the corresponding estimate of the mean monthly F will be 0.125.

6. YIELD PER RECRUIT STUDIES FOR P. INDICUS

6.1 Value of natural mortality (M)

Le Reste and Marcille (1976 a) estimated the value of M for P. indicus off Madagascar from a large tagging experiment. There was considerable variation in values obtained from the various parts of the experiment. For mature prawns the authors concluded that a monthly M = 0.22 could be regarded as a first approximation, and M = 0.37 as a maximum value.

The total mortality estimates given in section 4.4 of this paper, indicate that the monthly mortality for P. indicus in the area under consideration has been at a level of about 0.4 during the most recent years (1974 - 1976). If the 1974 estimate of 0.43 is taken as the most reliable (see section 4.4), and the estimated mean F for 1974 of 0.15 is subtracted from this value, the Mozambican data indicate an M = 0.43 - 0.15 = 0.28. Therefore, a value of about 0.3 could be assumed as a first approximation. It should be noted that this is approximately the mean of the two values suggested by Le Reste and Marcille for P. indicus off Madagascar.

6.2 Yield per recruit curves

Yield per recruit curves were calculated separately for males and females, using the growth curves from Madagascar (Fig. 9), assuming that total weight was proportional to the cube of the carapace length. M was assumed to be 0.3, and the mean length at time of recruitment to the fishery (l_r) was assumed to be 12.25 cm for both males and females. l_r will probably differ to some extent between males and females, but there was no possibility to estimate the l_r's from the present data, and the value used should be regarded as a first approximation only.

The resulting Y/R-curves (relative values) are shown in Fig. 15. Most of the yield comes from the female population. There is no clear maximum on the curves. The value of $F_{0.1}$ or F_{opt} (ICES 1977) is approximately 0.35 for the total yield per recruit curve.

Yield per recruit curves were also calculated assuming l_r = 11.5 cm and l_r = 13 cm. For F values in the range 0 - 0.4, the Y/R increased a little when decreasing l_r to 11.5 cm, and decreased a little when increasing l_r to 13.0 cm.

6.3 Preliminary conclusions from the yield per recruit curves

In section 5 it was concluded that the monthly fishing mortality during the years 1974 - 1976 was probably at a level of 0.15 or less. Because Y/R curves are steep at low values of F, the conclusions from the Y/R studies are very dependent on the exact value of F. For example, if the Y/R corresponding to $F_{0.1}$ = 0.35 is taken as an optimum value, F = 0.15 gives a Y/R of approximately 69% of the optimum, while F = 0.10 gives a Y/R of approximately 54% of the optimum. This means that by increasing F to 0.35, Y/R would increase by 45% or 85%, depending on whether the present level is 0.15 or 0.10.

Taking F = 0.15 as a maximum value for the fishing mortality during the recent years, a minimum estimate of the expected increase in Y/R by increasing F to the $F_{0.1}$ level would thus be 45%, under the assumption that the assumed growth parameters and natural mortality are correct. Of these factors, the value of M is by far the most uncertain and critical. A lower value of M would imply a smaller expected increase in yield per recruit.

The expected increase in Y/R can be converted to expected increase in total yield if the increase in F does not reduce the spawning potential to such an extent that future recruitment is affected. An increase in F from 0.15 to 0.35 would reduce the biomass of the fishable stock by approximately 38%, the fishable stock biomass being proportional to the catch per unit of effort plotted in Fig. 15. Compared to the unexploited stock, the reduction would be approximately 63%. If the exploited stock and the mature stock are identical, these percentages could be taken as approximations for the reduction in the spawning potential. As some juveniles are also probably caught, the reduction of the spawning potential would be a little higher. Thus, a fishing mortality of 0.35 would probably reduce the spawning stock to about 1/3 of its unexploited level.

As far as the authors know, there exist no data on the relationship between spawning stock and resulting recruitment for penaeid prawns. For exploited fish stocks, 1/3 of the unexploited stock has in a number of cases been recommended as a safety level below which the spawning stock should not be reduced. Choosing this minimum constraint on the size of the spawning stock, both spawning stock considerations and Y/R studies indicate that the monthly fishing mortality should in any case not exceed 0.35.

A fishing mortality of 0.2 will reduce the fishable biomass to about 50% of the unexploited one. Until more exact information is available, this could be taken as a first upper level above which the fishing mortality should not extend.

Table 11 shows expected values of yield per recruit and catch per unit of effort for selected values of F, relative to F = 0.10. An increase in F from 0.15 to 0.2 would give an increase in yield of about 16%. Above this level any further increase in fishing effort would give much smaller increases in yield and should therefore not be allowed before a much more detailed assessment, based on data accumulated during the period, has been carried out. As fishing effort increases, economical considerations have to be taken more and more into account, because the additional yield which may be expected from a certain increase in fishing effort, will steadily decrease.

It was not possible to carry out any yield per recruit studies for the other species because of lack of information on growth and natural mortality. The conclusions arrived at for P. indicus will be valid for the other two main species if their yield per recruit curves have a similar form (assuming that F is the same for all species).

This may of course not be the case, but lacking further information the conclusions from the yield per recruit for P. indicus were, as a first approximation, transferred to the whole population of shallow water prawns in the area considered. Although P. indicus makes up nearly 50% of the total catches, some extra uncertainties are introduced by this generalization.

If the catch level corresponding to F = 0.15 is 12 000 tonnes, an increase in F to 0.2, i.e. 33% increase in fishing effort, would increase catches to about 14 000 tonnes. The catches corresponding to the $F_{0.1}$ level would be about 17 000 tonnes. These figures should, however, be interpreted with caution, especially because of uncertainties about the 1974-1976 fishing mortalities and catch levels. If the monthly fishing mortality during the period 1974-1976 was at a significant lower level than 0.15, an increase in fishing effort of 33% would give much larger increases in yield than indicated above. Data on the development in catches and fishing effort since 1976 would give the first indication of whether the F level indicated by the present study is far from the truth. It should however be noted that variations in recruitment would give variations in the catches corresponding to a certain effort level. The present study indicates for example that the recruitment in 1976 was higher than in 1974-1975. It may also be expected that, for example, unfavourable conditions in the mangrove areas some years can result in much lower recruitment than in 1974-1975 and therefore lower catches.

7. SUMMARY OF THE PRESENT ASSESSMENT

7.1

The lack of precise information on total catches and fishing effort during the recent years in the area considered, limited to a large extent the types of models which could be used in this preliminary assessment. However, information on catches, fishing effort and size and species composition of catches from logbooks of a part of the national fleet, especially the EFRIPEL trawlers, made it possible to make some first estimates of mortalities and stock sizes.

7.2

Of the three main species, P. indicus and P. monodon show pronounced seasonal fluctuations in abundance, indicating a main recruitment to the fishing areas during 2-3 months in the first half of the year and a life time of not more than one year after recruitment. Catches of M. monoceros showed a much more stable level, indicating that recruitment occur more or less throughout the whole year. No conclusions could be drawn about the longevity of this species.

7.3

Estimates of total monthly mortality coefficient Z for P. indicus were made by two different methods; firstly by studying the decrease in number caught per hour trawling with time during periods of no, or only a small recruitment, and secondly by comparing catches of various size groups, utilizing information on growth. It was concluded that Z during the years 1974-1976 was probably at a level of around 0.4. The first method was also applied to the catches of P. monodon, indicating a Z at the same level or higher, but the method was in this case more uncertain.

7.4

Utilizing information on total catch per hour trawling for the EFRIPEL trawlers, it was estimated by the "swept area" method that the mean annual stock size of shallow water prawns in the area considered was about 5000 tonnes in 1974-1975 and about 8000 tonnes in 1976. These figures are considered to be minimum estimates.

7.5

Assuming that the total annual catches were at a level of 10 000 tonnes in 1974-1975 and 12 000 tonnes in 1976, the stock size estimates given above would imply a maximum value of the mean monthly fishing mortality of 0.15 in 1974-1976. Utilizing the estimates of total and fishing mortality for P. indicus in 1974, the monthly natural mortality was estimated to be slightly below 0.3.

7.6

Yield per recruit studies for P. indicus show that significant increases in catches may be expected if the fishing effort is increased above the 1974-1976 level (F = 0.15). The yield per recruit corresponding to $F_{0.1}$ = 0.35 is estimated to be 45% above the 1974-1976 value. However, because of all uncertainties in the various estimates, it is concluded that, as a first approach, F should not exceed 0.2. By an increase in F to 0.2, an increase in yield of about 16% could be expected. If the catch level corresponding to F = 0.15 is 12 000 tonnes, this increase in F would give catches of about 14 000 tonnes. The catch corresponding to $F_{0.1}$ would be approximately 17 000 tonnes. All these figures are based on the assumption that the main species have yield per recruit curves similar to P. indicus. It is pointed out that the figures must be interpreted with caution, especially because of uncertainties about the 1974-1976 level of catches and stock size. It should also be noted that the figures are based on the assumption that the lower spawning stock sizes corresponding to these higher effort levels will not cause any reduction in future recruitment. Variations in catches from year to year caused by variations in recruitment may be expected.

8. FUTURE DATA REQUIREMENTS

The basic data which are required to make a more detailed and precises assessment of the prawn stocks off Moçambique have to some extent been indicated in the discussion in the preceeding sections. Some basic requirements are summarized below.

8.1 Catch and effort statistics

Collection of reliable figures for total catches of shallow water prawns and corresponding fishing effort should have the highest priority. More detailed catch and effort statistics broken down into species, month and statistical squares, should be collected from as large a part of the fleet as possible.

8.2 Sampling of catches

Part of the fleet already reports catches by species and size groups. A sampling programme should, however, be initiated as soon as possible in order to

(1) get a more precise estimate of length frequency and number per kilo by sampling the various size groups in the catches which are reported by such groups;

(2) check the size and species composition, and number per kilo, in the catches which are not reported by species and size groups.

The discussion in section 4 stresses the need for obtaining estimates of number caught in the various size groups separately for males and females. This could be achieved by sampling each length group for sex composition.

The sampling should cover the catches adequately both in time and area.

8.3 Sampling of the juvenile population

At present, almost no information is available about the prawns before they come into the industrial fishery as adults. In order to get more biological information about the juveniles, a sampling programme should be initiated in the coastal nursery areas. By sampling the juvenile population for size composition at regular time intervals, the various recruitment groups could be identified and the growth at the juvenile stage could be estimated. At present, samples could be most easily obtained from catches made for local consumption along the coast.

8.4 Research vessel surveys in areas of distribution of the adult population.

Stratified random trawl surveys (stratification by area and depth) should be carried out to get information on

(i) distribution of the various species and size groups by area and depth;

(ii) changes in density from year to year, and from season to season within a year;

(iii) stock size estimates from the "swept area" method.

Biological samples obtained during such surveys would give additional information on, for example, maturity, times of spawning and times of recruitment.

Part of the first surveys could be allocated to mesh selection experiments.

8.5 Environmental data

The distribution of the adult population is probably closely connected to hydrographical conditions, and hydrographical data should be collected regularly during research vessel surveys. In order to get more information about the factors which determine recruitment strength, environmental data should be collected both at sea during times of spawning and in the mangrove areas. Any changes in the mangrove areas should be followed especially closely.

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Table 1. Characteristics of the national fleet fishing in the area north of Beira in 1976.

Classes of gross tonnage	Number of boats	Engine Power (H.P.)		Number of boats that utilize ice to conserve the prawns	Boats with cold storage of $-20^{\circ}C$			Boats with quick freezers of $-35/-40^{\circ}C$ and cold storage		
					Number	Cold storage capacity (tonnes)		Number	Quick freezing capacity (tonnes/day)	
		Mean	Range			Mean	Range		Mean	Range
9-50	8	179	100-425	8	0	0	0	0		
50-100	5	368	230-560	0	4	22	12-32,5	1	x	
100-200	35	415	231-650	0	18	27	5-32,5	17	2	1,5 - 3
200-365	3	1000	500-1250	0	1	17	0	2	14	0

x Data not available

Table 2. Catches 1973-1976 of the three enterprises EFRIPEL, IMPESCAL and ARPEM reported in logbooks, and the proportions of these catches which are reported by species and/or commercial size groups.

Year	Catches (tonnes)	Catches reported by species and commercial size groups	Catches reported by commercial size groups only	Catches reported without any classification
1973	593	0 %	67 %	33 %
1974	2727	36 %	53 %	11 %
1975	2054	46 %	46 %	8 %
1976	2752	49 %	41 %	10 %

Table 3. Commercial size classifications used in the logbooks.

Number per pound of prawns with head on	Number per pound of headless prawns
<6 6-7 8-10 >10	<16 16-20 21-25 26-30 31-40 41-50 51-60 61-7C

Table 4. Total logbook reported catches (C), catch per hour trawling for the EFRIPEL trawlers (C/h), total effort (f) in EFRIPEL units corresponding to C, and species composition by month.

Year : 1974

Month	C (tonnes)	C/h	f (hours trawling)	Species composition (% weight)			
				P.indicus	M.monoceros	P.monodon	P. japonicus
January	117.5	65*	1807				
February	228.6	65	3517	49.8	44.3	5.7	0.1
March	261.8	62	4222	61.8	32.3	5.8	0.2
April	307.5	98	3138	58.2	30.8	9.8	1.2
May	393.7	90	4375	49.1	39.1	10.1	1.7
June	389.2	78	4989	40.6	42.6	16.4	0.4
July	253.1	54	4687	40.0	48.7	10.5	0.8
August	215.3	50	4306	46.6	45.8	6.6	1.1
September	186.5	42	4442	22.9	72.3	2.5	2.4
October	168.1	48	3503	29.7	65.8	4.1	0.4
November	143.7	47	3058	21.6	75.1	3.2	0.1
December	62.2	64	972	41.7	53.4	4.7	0.2
Total	2727.3	63	43016	43.0	47.7	8.4	0.9

* No data available. Value of February used.

Table 4 (Cont.)

Year : 1975

Month	C (tonnes)	C/h	f (hours trawling)	Species composition (% weight)			
				P.indicus	M.monoceros	P.monodon	P. japonicus
January	185.7	67	2771	45.2	52.4	2.3	0.1
February	247.6	74	3346	65.3	31.9	2.6	0.3
March	193.2	52	3716	56.2	35.5	7.9	0.3
April	213.5	73	2925	57.1	32.6	9.0	1.3
May	178.9	58	3085	37.1	44.5	17.9	0.5
June	185.9	60	3099	29.3	60.5	9.9	0.4
July	199.4	48	4155	32.5	55.3	10.6	1.6
August	196.9	37	5321	37.7	52.6	8.8	0.9
September	146.0	38	3843	45.6	47.7	4.4	2.4
October	136.3	39	3496	26.0	69.2	3.7	1.1
November	141.6	46	3078	24.7	70.0	5.2	0.2
December	28.5	62*	460				
Total	2053.6	52	39295	43.6	48.5	7.1	0.8

* No data available. Mean between December 75 and January 76 used.

Table 4 (Cont.)

Year : 1976

Month	C (tonnes)	C/h	f (hours trawling)	Species composition (% weight)			
				P. indicus	*M. monoceros*	*P. monodon*	*P. japonicus*
January	62.2	77	808	48.9	45.5	5.4	0.2
February	261.5	85	3076	58.8	26.7	14.3	0.1
March	268.2	96	2793	55.0	38.7	5.4	1.0
April	328.9	119	2764	58.2	33.4	7.7	0.7
May	319.8	114	2805	60.5	30.8	8.6	0.1
June	341.1	115	2966	60.0	33.1	6.4	0.5
July	250.9	111	2260	42.4	42.3	14.8	0.5
August	226.6	81	2798	39.1	52.8	6.6	1.5
September	211.9	92	2303	65.3	30.3	3.2	1.2
October	151.1	48	3147	18.9	78.2	2.6	0.3
November	182.0	63	2889	15.8	82.3	1.8	0.0
December	148.3	75	1977	26.6	64.3	3.6	5.6
Total	2752.5	90	30586	49.4	42.4	7.1	1.1

Table 5. Monthly distribution of fishing effort (%).

Month	Year 1974	1975	1976
January	4.2	7.1	2.6
February	8.2	8.5	10.1
March	9.8	9.5	9.1
April	7.3	7.4	9.0
May	10.2	7.9	9.2
June	11.6	7.9	9.7
July	10.9	10.6	7.4
August	10.0	13.5	9.1
September	10.3	9.8	7.5
October	8.1	8.9	10.3
November	7.1	7.8	9.4
December	2.3	1.2	6.5

Table 6. P. indicus. Number caught per hour trawling by length groups.

Year: 1974

Month	Hours trawling	Length (cm total length)						Total
		11-11,5	11,5-12,5	12,5-13,5	13,5-15,5	15,5-18	> 18	
January								
February	594	48	96	257	701	214	2	1319
March	1216	28	40	110	799	341	4	1322
April	1169	20	81	399	1110	505	3	2119
May	1654	12	50	267	747	488	17	1581
June	1812	1	12	107	437	458	24	1040
July	1797	0	2	37	183	325	40	587
August	1910	0	3	22	123	282	84	514
September	1840	0	8	28	119	103	6	263
October	1991	4	16	63	225	155	+	464
November	1153	1	11	39	153	117	+	320
December	669	11	41	172	525	251	1	1003

Table 6. (Cont.) Year: 1975

Month	Hours trawling	Length (cm total length)						Total
		11-11,5	11,5-12,5	12,5-13,5	13,5-15,5	15,5-18	> 18	
January	1790	12	98	258	615	218	1	1202
February	1656	7	115	437	1021	365	1	1946
March	1948	0	88	261	625	223	+	1197
April	1086	+	46	189	843	425	+	1503
May	1109	0	7	36	444	239	1	726
June	1557	+	6	33	322	175	+	537
July	2051	+	2	18	274	162	+	457
August	2079	1	5	35	228	146	0	415
September	1868	1	6	30	254	182	0	473
October	1708	1	10	39	181	88	0	319
November	1029	0	5	33	234	96	0	368
December								

Table 6. (Cont.) Year: 1976

Month	Hours trawling	Length (cm total length)						Total
		11-11,5	11,5-12,5	12,5-13,5	13,5-15,5	15,5-18	> 18	
January	418	27	99	174	807	229	0	1336
February	1325	33	157	371	1211	231	0	2004
March	1574	21	97	217	1126	451	+	1912
April	1452	7	64	193	1398	663	0	2326
May	1285	9	68	239	1428	599	0	2343
June	1244	2	28	179	1339	680	0	2228
July	1004	0	4	59	878	466	1	1408
August	1402	0	2	45	552	283	0	881
September	1352	9	22	129	1175	454	+	1789
October	830	0	2	37	158	97	0	296
November	1277	0	6	24	180	102	0	311
December	1538	50	70	139	432	107	+	798

Table 7. M.monoceros. Number caught per hour trawling by length groups.

Year : 1974

Month	Hours trawling	Length (cm total length)						Total
		< 11.5	11.5 - 12.5	12.5 - 13.5	13.5 - 15.5	15.5 - 18	> 18	
January								
February	594	116	203	248	342	104	+	1013
March	1216	72	127	170	251	61	-	681
April	1169	30	149	172	498	135	-	984
May	1654	33	167	160	595	141	-	1096
June	1812	170	255	219	475	108	-	1229
July	1797	224	410	233	329	76	-	1271
August	1910	57	242	264	338	106	+	1007
September	1840	49	311	301	457	170	-	1287
October	1991	41	211	296	514	198	+	1259
November	1153	69	232	298	551	243	-	1393
December	669	35	174	256	577	224	1	1267

Table 7 (Cont.)

Year : 1975

Month	Hours trawling	Length (cm total length)						Total
		< 11.5	11.5 - 12.5	12.5 - 13.5	13.5 - 15.5	15.5 - 18	> 18	
January	1790	40	236	365	672	131	-	1443
February	1656	16	139	184	466	96	-	901
March	1948	10	102	119	343	86	-	660
April	1086	21	144	166	476	76	-	883
May	1109	66	253	267	487	43	-	1116
June	1557	161	527	392	589	59	-	1727
July	2051	268	489	325	385	37	-	1504
August	2079	161	284	244	324	45	-	1059
September	1868	160	286	229	304	30	-	1009
October	1708	112	282	413	483	79	-	1370
November	1029	185	342	424	508	142	-	1600
December								

Table 7 (Cont.)

Year : 1976

Month	Hours trawling	Length (cm total length)						Total
		< 11.5	11.5 - 12.5	12.5 - 13.5	13.5 - 15.5	15 5 - 18	> 18	
January	418	75	312	487	616	140	-	1632
February	1325	18	136	245	428	95	-	922
March	1574	47	233	316	680	193	-	1470
April	1452	48	231	289	771	159	-	1497
May	1285	22	147	209	640	163	-	1182
June	1244	16	137	174	758	146	-	1231
July	1004	31	184	289	873	280	-	1658
August	1402	98	370	335	793	133	-	1729
September	1352	46	218	224	587	61	-	1136
October	830	38	226	317	647	297	-	1524
November	1277	69	306	465	936	351	-	2128
December	1538	75	306	534	845	268	-	2041

Table 8. P.monodon. Number caught per hour trawling by length groups.

Year : 1974

Month	Hours trawling	Length (cm total length)				Total
		< 17	17 - 19	19 - 21	> 21	
January						
February	594	50	3	9	4	65
March	1216	37	3	9	6	55
April	1169	7	35	28	26	96
May	1654	2	37	17	28	85
June	1812	1	73	27	33	134
July	1797	-	27	12	16	55
August	1910	1	24	6	7	38
September	1840	+	4	2	3	10
October	1991	+	10	3	6	19
November	1153	+	8	3	4	15
December	669	3	6	3	12	24

Table 8 (Cont.)

Year : 1975

Month	Hours trawling	Length (cm total length)				Total
		< 17	17 - 19	19 - 21	> 21	
January	1790	4	4	1	5	15
February	1656	+	6	2	7	15
March	1948	1	21	5	13	39
April	1086	1	31	11	20	63
May	1109	2	46	20	31	99
June	1557	1	25	14	17	57
July	2051	+	26	13	14	53
August	2079	1	26	8	6	41
September	1868	1	6	3	5	15
October	1708	+	5	3	4	13
November	1029	+	5	7	8	20
December						

Table 8 (Cont.)

Year : 1976

Month	Hours trawling	Length (cm total length)				Total
		< 17	17 - 19	19 - 21	> 21	
January	418	0	5	3	18	26
February	1325	2	52	9	43	106
March	1574	+	14	6	19	40
April	1452	+	18	7	38	63
May	1285	+	41	10	34	86
June	1244	0	30	16	22	68
July	1004	0	99	33	42	174
August	1402	2	33	10	13	58
September	1352	3	12	4	9	28
October	830	4	16	2	1	22
November	1277	2	6	4	2	14
December	1538	1	11	5	8	25

Table 9. P. indicus. Expected ratios of catches of selected size groups for various values of monthly total mortality Z.

Z	$\frac{C_{12.5-13.5\ cm}}{C_{13.5-15.5\ cm}}$	$\frac{C_{13.5-15.5\ cm}}{C_{>15.5\ cm}}$
0.1	0.296	1.099
0.15	0.428	1.173
0.20	0.547	1.263
0.25	0.652	1.371
0.30	0.744	1.499
0.35	0.824	1.648
0.40	0.893	1.820
0.45	0.953	2.017
0.50	1.005	2.240
0.55	1.051	2.493
0.60	1.092	2.779
0.80	1.233	4.306
1.0	1.369	6.662

Table 10. P. indicus. Observed ratios of catches of selected size groups.

	Period		
	Febr. 74 - Nov. 74	Dec. 74 - Nov. 75	Jan. 76 - Nov. 76
$\frac{C_{12.5-13.5\ cm}}{C_{13.5-15.5\ cm}}$	0.281	0.285	0.161
$\frac{C_{13.5-15.5\ cm}}{C_{>15.5\ cm}}$	1.103	1.785	1.786

Table 11. P. indicus. Relative values of yield per recruit (Y/R) and catch per unit of effort (CPUE) for selected values of fishing mortality (F).

F	Y/R	CPUE
0.1	1	1
0.15	1.28	0.86
0.20	1.49	0.75
0.25	1.64	0.66
0.30	1.76	0.59
0.35	1.85	0.53

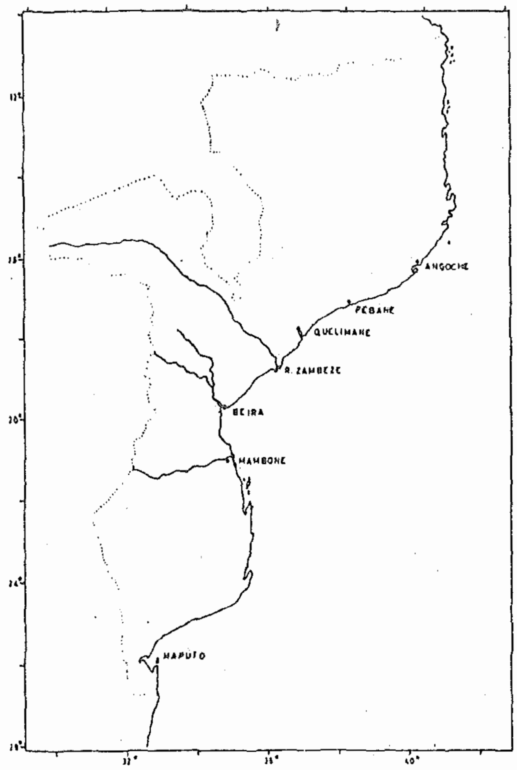

Figure 1.

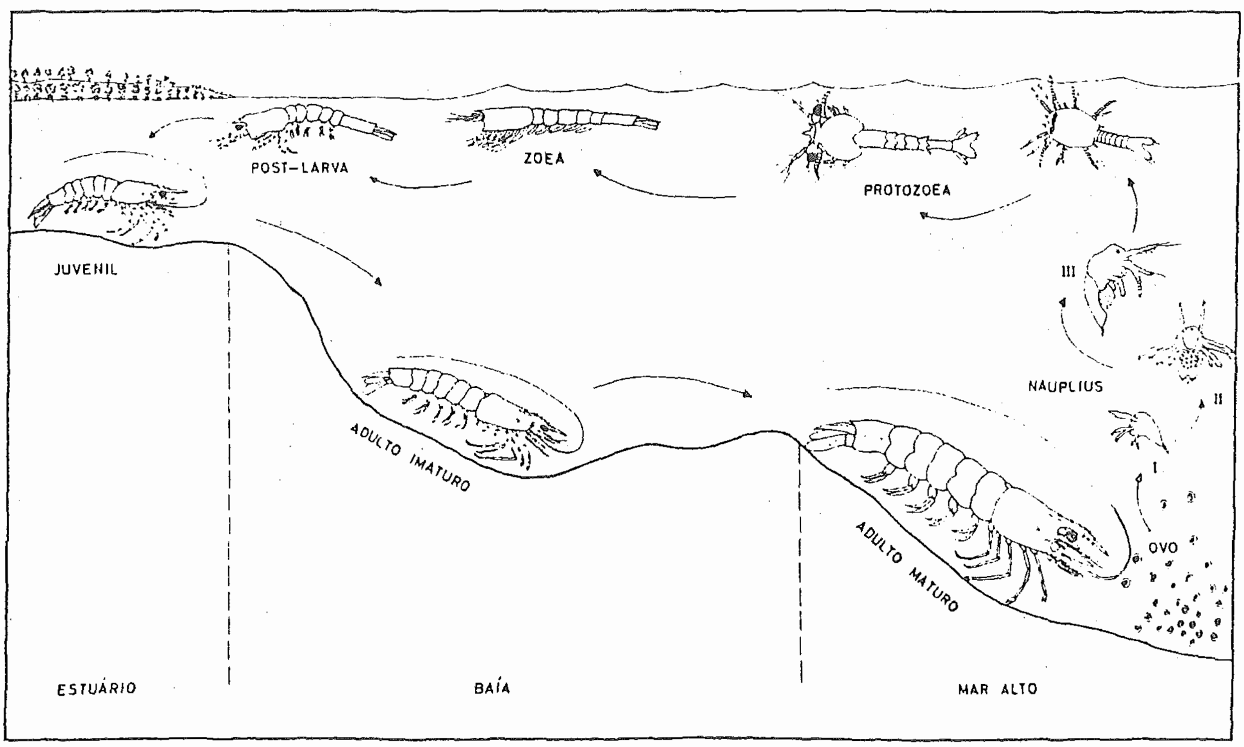

Figure 2. Illustration of the life cycle of the shallow water prawns.

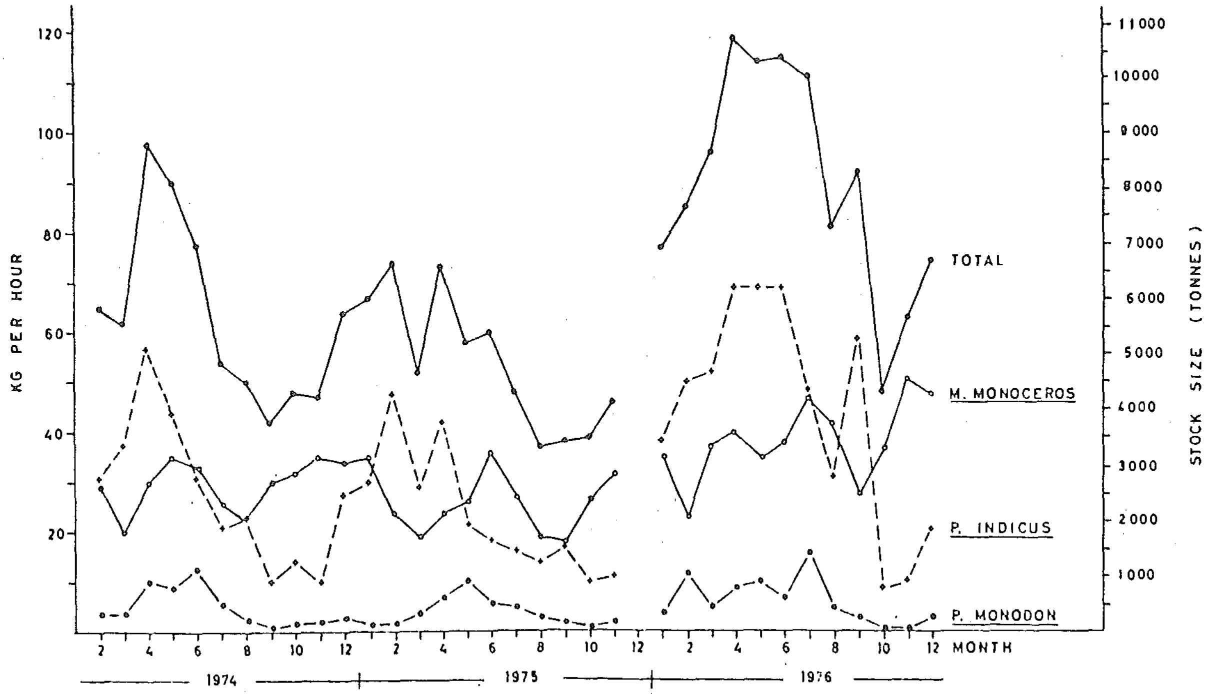

Figure 3. Total catch per hour trawling and catch per hour trawling of the three main species plotted against month for the period 1974-1976. The right hand ordinate shows the corresponding stock size estimates from the "swept area" method (see section 5).

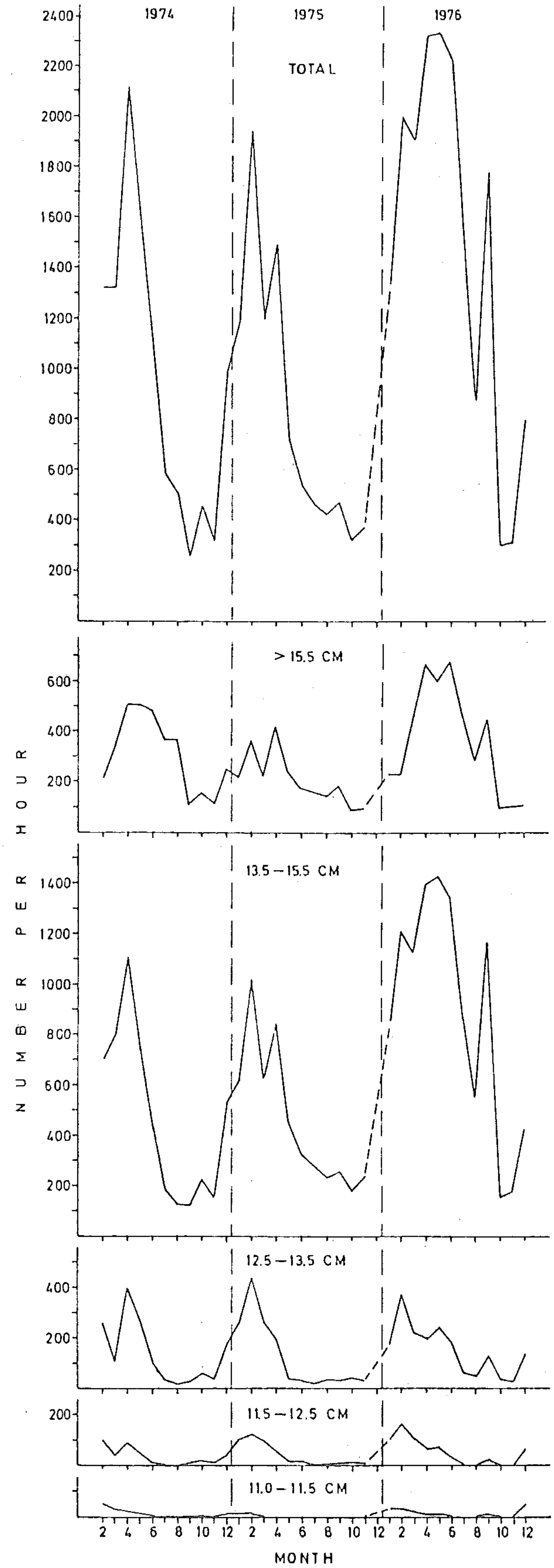

Figure 4. P.indicus. Number caught of the various length groups per hour trawling plotted against month for the period 1974-1976.

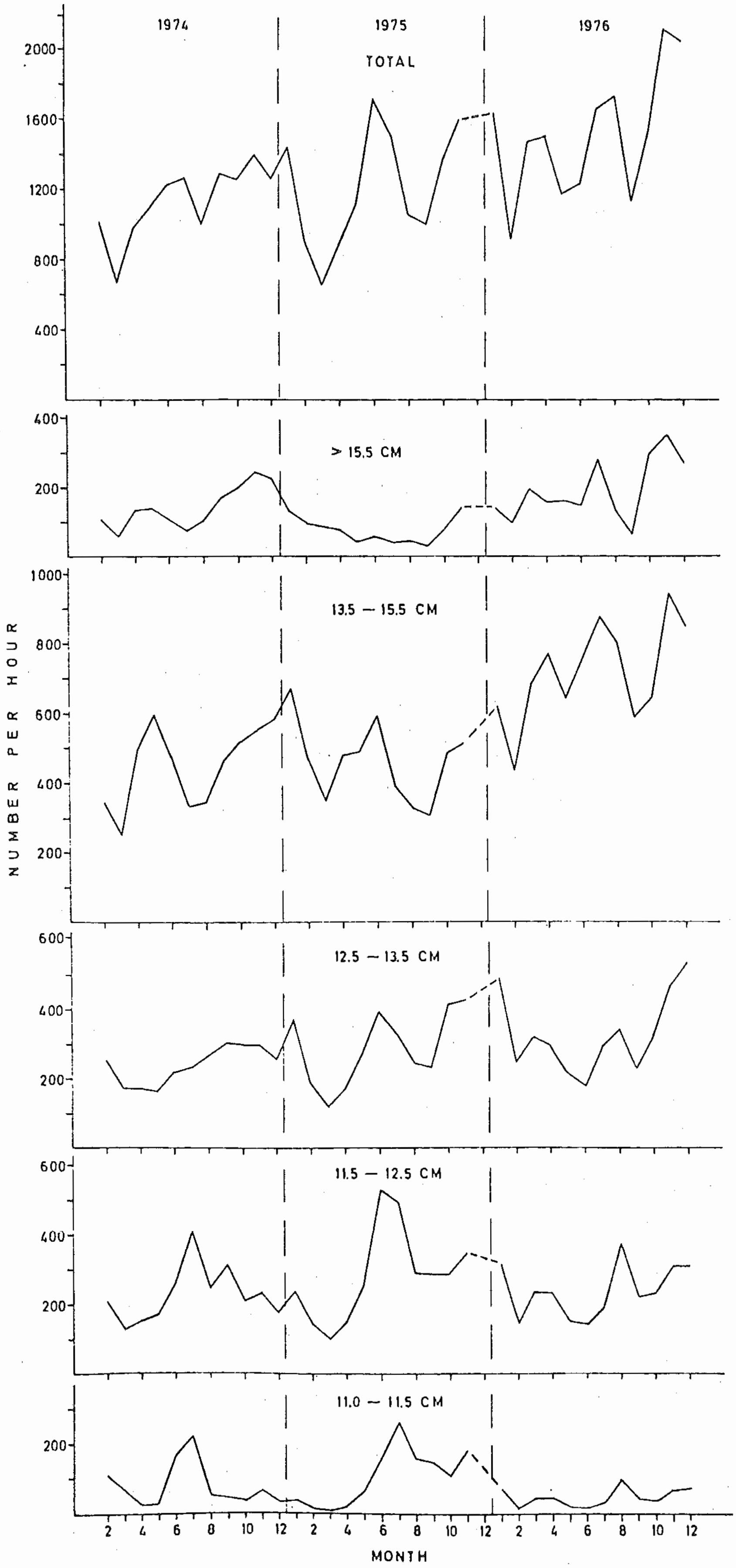

Figure 5. <u>M.monoceros</u>. Number caught of the various length groups per hour trawling plotted against month for the period 1974-1976.

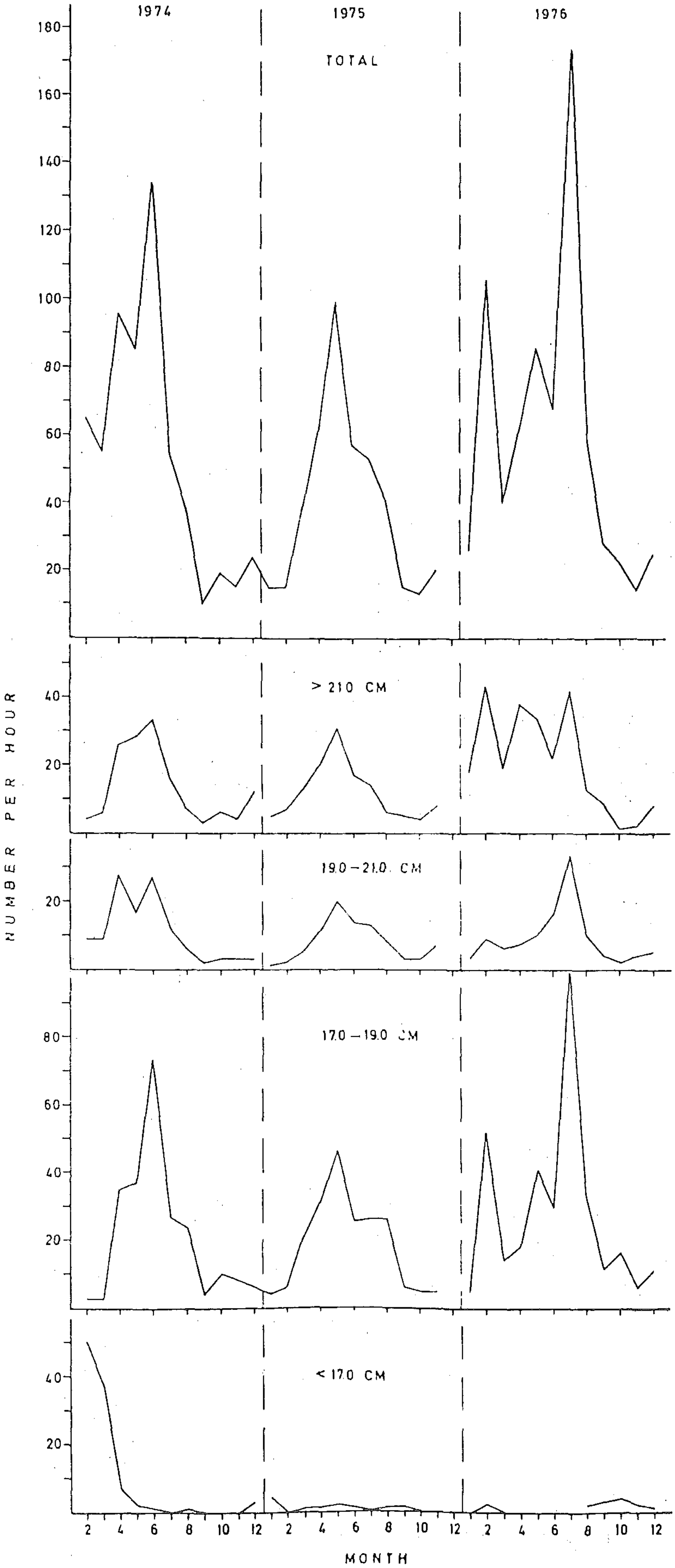

Figure 6. P.monodon. Number caught of the various length groups per hour trawling plotted against month for the period 1974-1976.

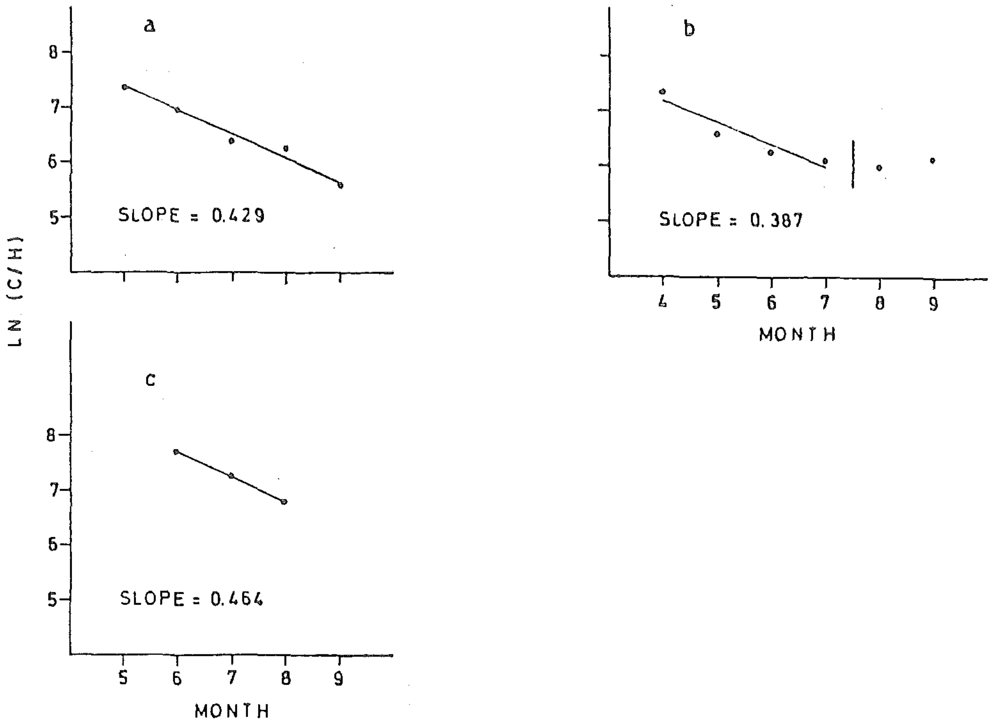

Figure 7. P. indicus. Regression of the logarithm of total number caught per hour trawling (ln C/h) against month.

a) May - September 1974 b) April - July 1975
c) June - August 1976.

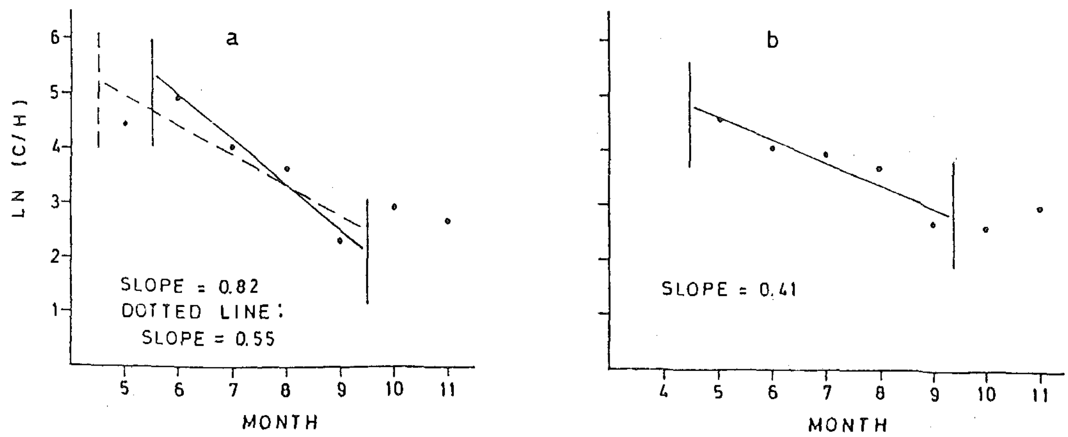

Figure 8. P. monodon. Regression of the logarithm of total number caught per hour trawling (ln C/h) against month.

a) ———— June - September 1974,
- - - - - May - September 1974,
b) May - September 1975.

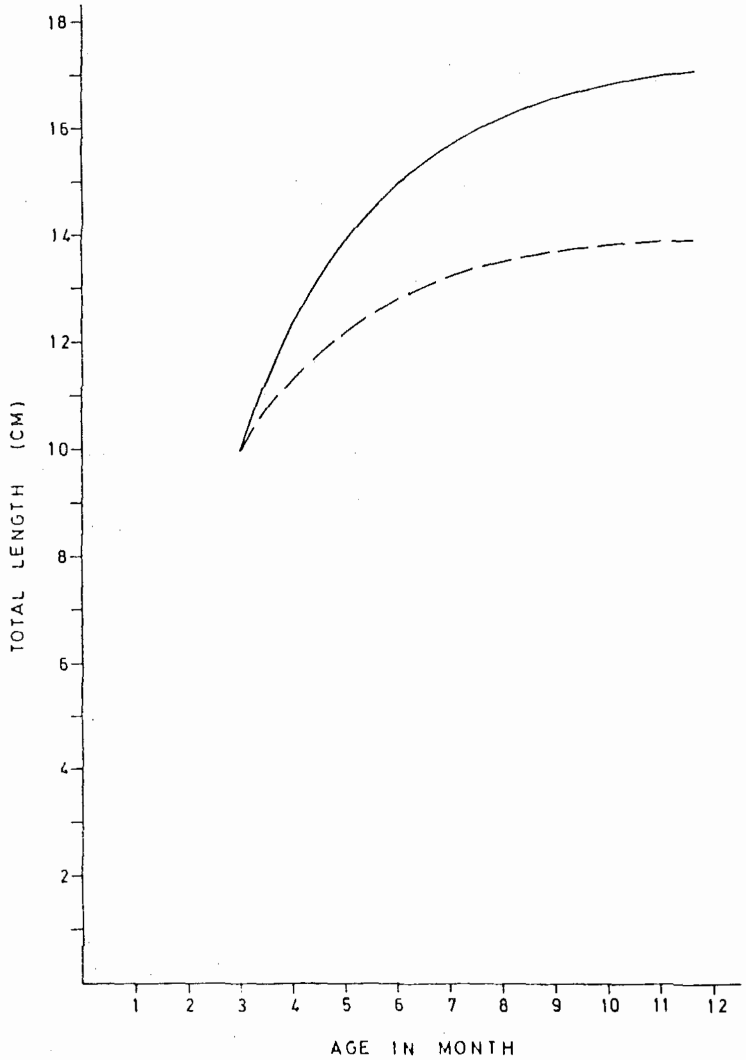

Figure 9. Estimated growth curves for *P.indicus* at Madagascar (Le Reste et Marcille, 1976a) for males (dotted line) and females.

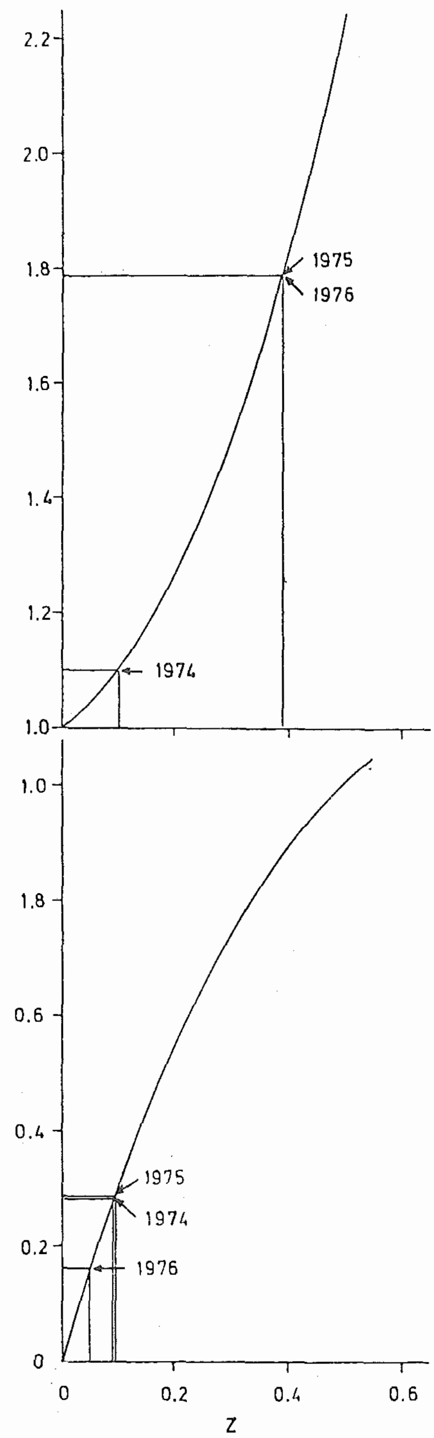

Figure 10. P.indicus. Expected value of $C_{13.5-15.5\ cm}/C_{>15.5\ cm}$ (upper figure) and $C_{12.5-13.5\ cm}/C_{13.5-15.5\ cm}$ (lower figure) plotted against monthly total mortality Z.

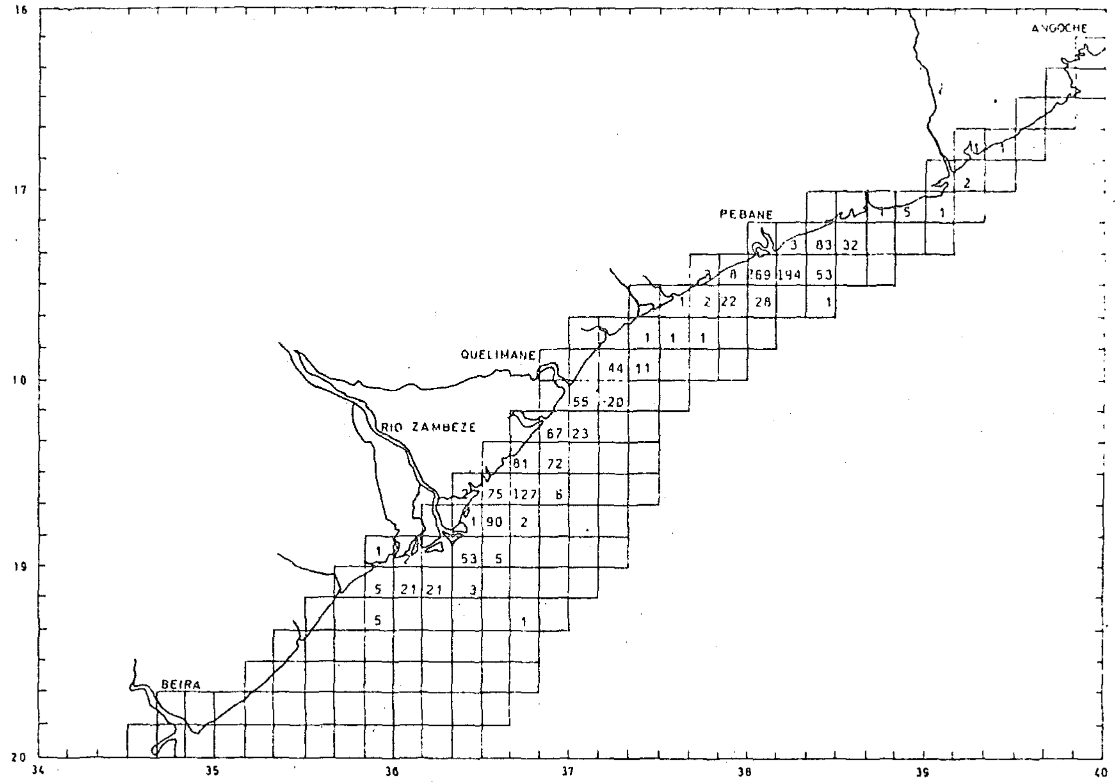

Figure 11. VEGA I-IV, 1974. Number of days fished in the various squares.

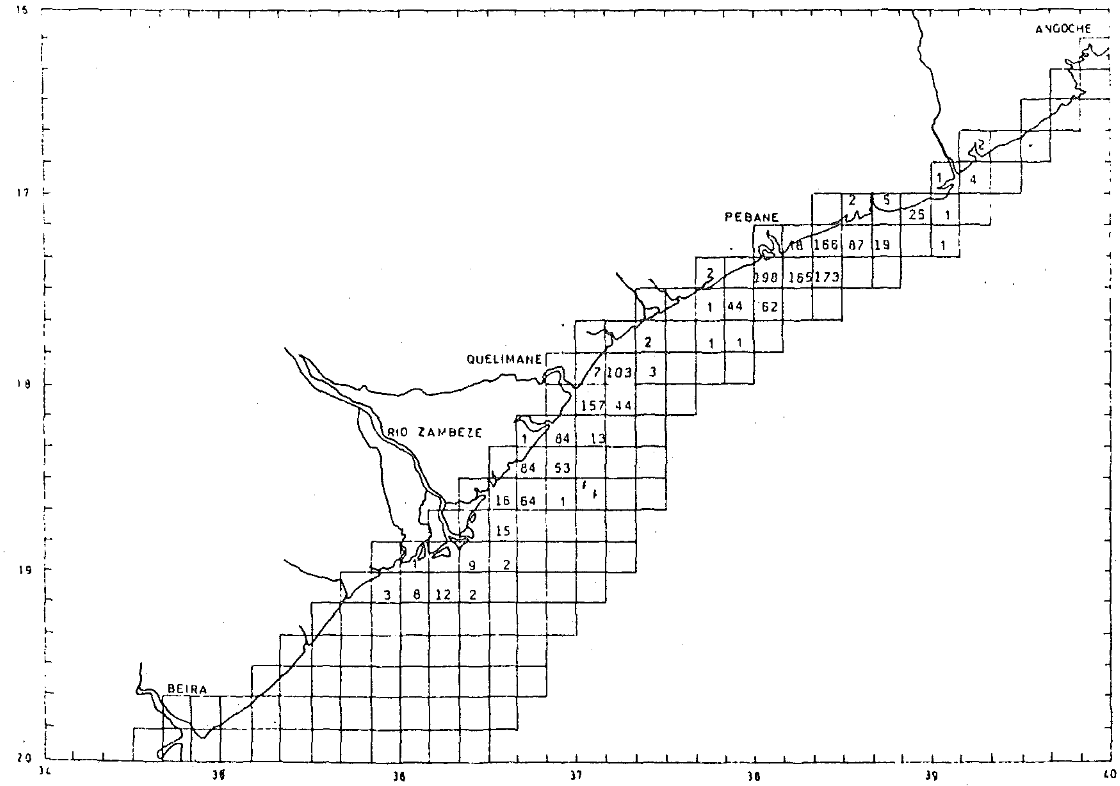

Figure 12. VEGA I-IV, 1975. Number of days fished in the various squares.

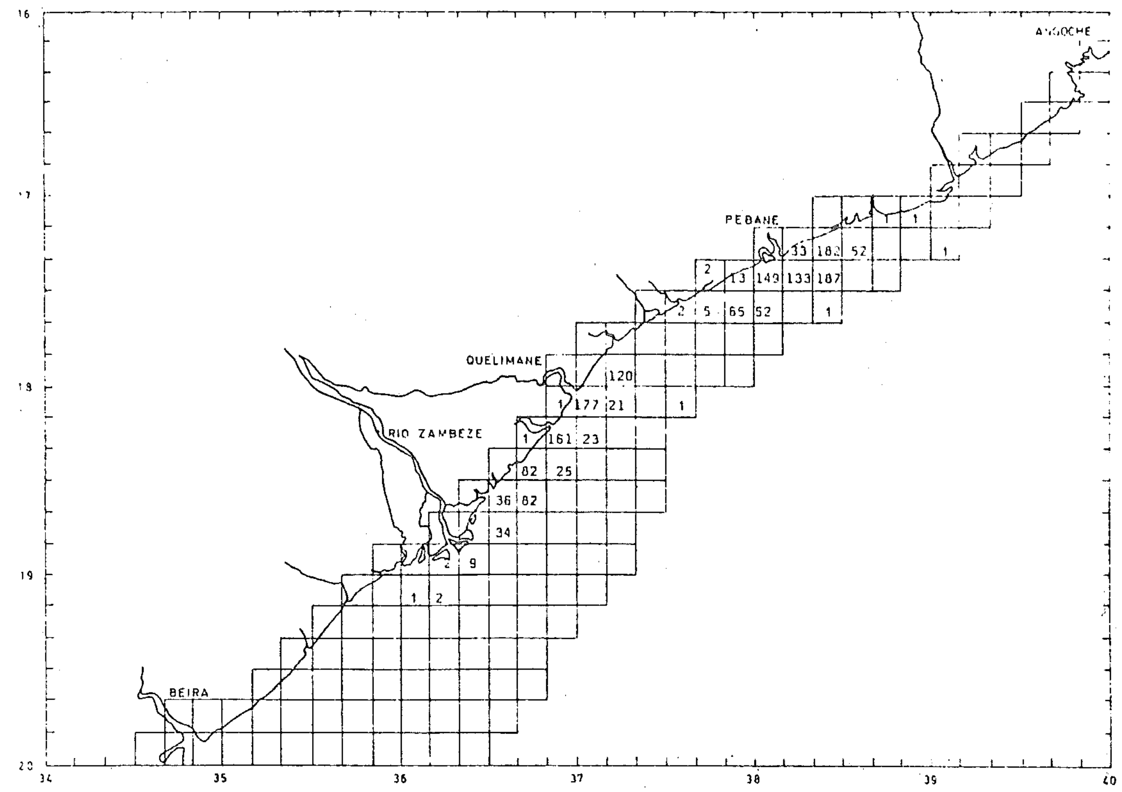

Figure 13. VEGA I-IV, 1976. Number of days fished in the various squares.

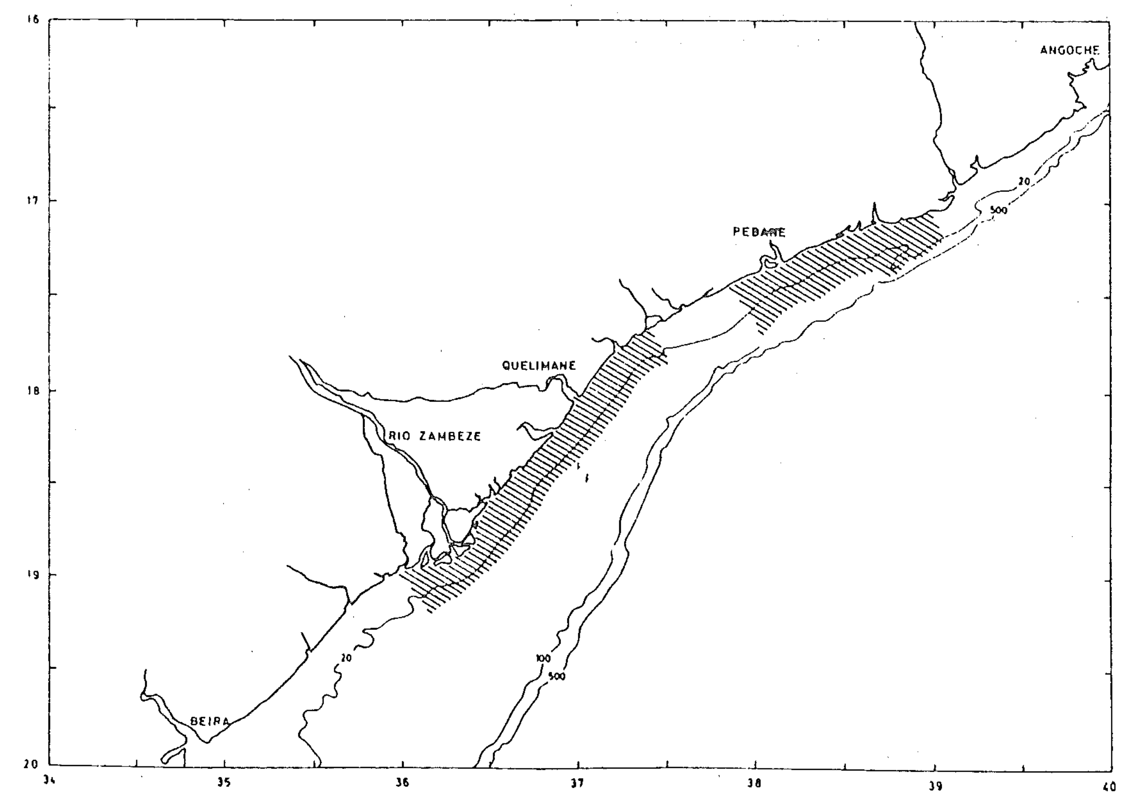

Figure 14. Area of prawn distribution (shaded) assumed in the "swept area" method.

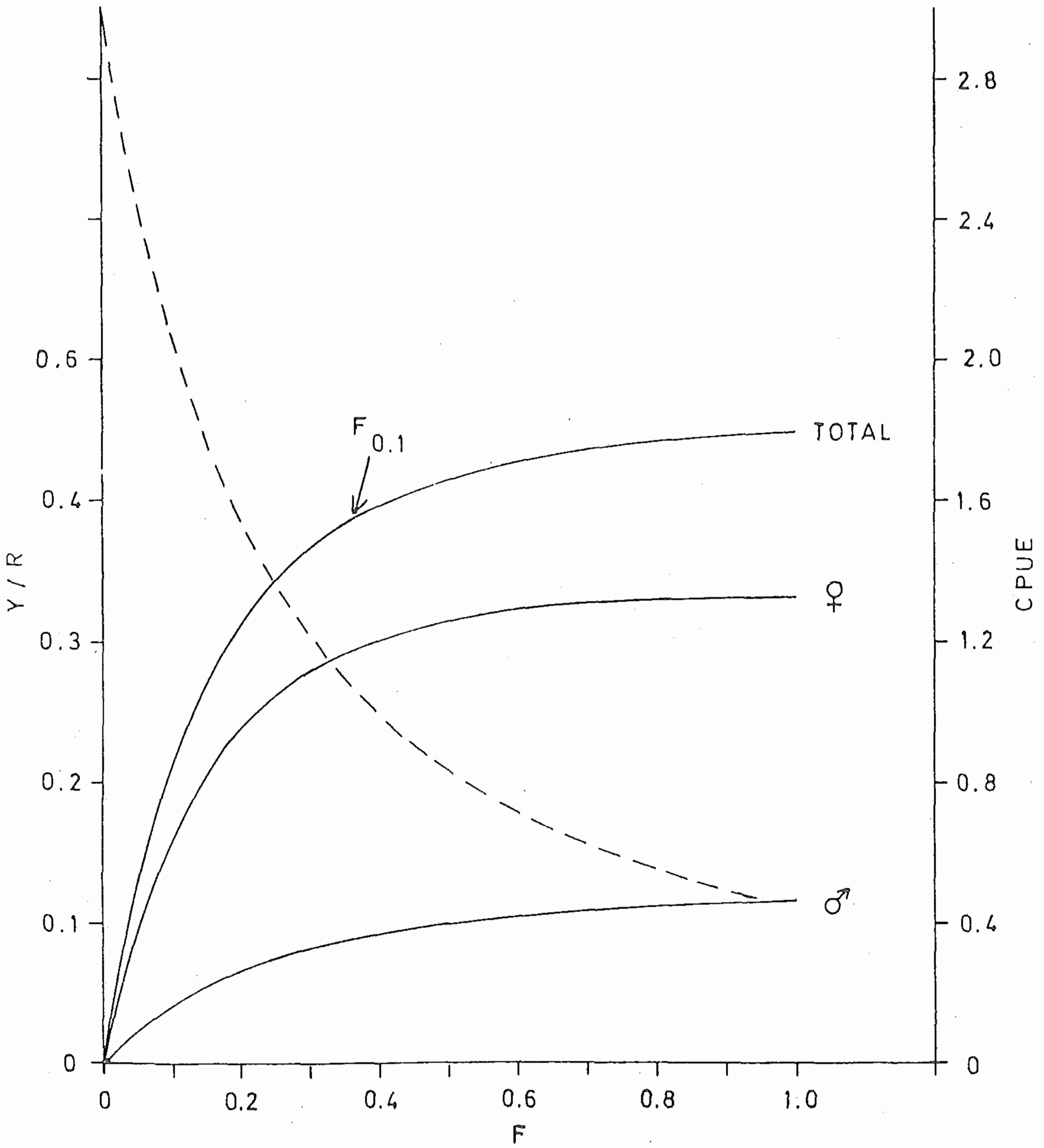

Figure 15. P.indicus.Yield per recruit (Y/R) and catch per unit of effort (C.P.U.E., dotted line) plotted against monthly fishing mortality.