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Growth and population dynamics of the Indian white prawn *Penaeus indicus* H M Edwards from Kakinada

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Abstract. The von Bertalanffy parameters of growth in *Penaeus indicus* are estimated as $L_\infty = 218{\cdot}9$ mm, $K = 2{\cdot}0$ per year, and $t_0 = 0{\cdot}01$ year in females and 227·2 mm, 1·8 per year and −0·0729 year, respectively in males. The instantaneous rates of mortality are estimated as $Z = 9{\cdot}42$, $M = 3{\cdot}30$ and $F = 6{\cdot}12$ in females and 12·73, 2·90 and 9·83, respectively in males. Various morphometric and length-weight relationships are worked out. At the current rate of fishing, the yield in weight per recruit is 23·05 g in females and 31·74 g in males. There is scope to increase the yield of this species by increasing F (i.e. effort).

Keywords. Growth; mortality rates; yield per recruit.

1. Introduction

Kakinada is an important prawn landing centre in Andhra Pradesh. Due to great demand for prawns in the export trade, the fishing industry has expanded tremendously in recent years by continuous addition of trawlers. Prawns are also fished in the inshore waters and backwaters by indigenous gear. They form about 25% of the total fish catch and among them, *Penaeus indicus* forms about 8·2%. While Kurup and Rao (1975) studied the growth and mortality rates from Ambalapuzha, west coast of India, there is no information on the growth and population dynamics of *P. indicus* from anywhere along the coasts of India. The results of a study on these aspects based on the data collected during 1979–1982 from the landings of commercial trawlers at Kakinada and the backwater landing centres are presented in this paper.

2. Materials and methods

Data on effort and catch of prawns were collected for 15–20 days in a month at the Kakinada fisheries harbour and once in a week at the backwater landing centres of Kakinada (Matlapalem, B V Palem and Pedagadimoga, 10–32 km southeast of Kakinada). Effort standardisation was made following Gulland (1968), in terms of Pomfrets. Details of the craft and gear were given by Muthu *et al* (1977). In the backwaters stakenets and dragnets were operated. Total length (from tip of rostrum to tip of telson) and individual weight of prawns were recorded to the nearest mm and mg, respectively. Throughout this study, males and females were treated separately. The data on the weight of *P. indicus* landed and its length composition were collected at weekly intervals; these data were raised to get the monthly estimates. Growth was studied by the progression of modes in the monthly length frequency distribution of the catch, and the parameters of growth in length were

estimated using the von Bertalanffy equation which is of the form

$$L_t = L_\infty \{(1 - \exp[-K\ (t - t_o)])\},$$

where L_∞ = asymptotic length, K = a constant equivalent to 1/3rd of catabolic coefficient and t_0 = arbitrary origin of the growth curve.

The values of L_∞ and K were estimated using the Ford-Walford plot (Ford 1933; Walford 1946) on the basis of the lengths attained at intervals of two months. The value of t_0 was estimated by a plot of $\text{Log}_e\ (L_\infty - L_t)$ against t. The values of K and t_0 thus obtained were converted into those of per year and year, respectively. The total length-carapace length relationship was calculated by using the equation $Y = a + bx$ (Snedecor and Cochran 1967).

The length-weight relationship was calculated using the equation (Le Cren 1951).

$$\log W = \log a + b \log L,$$

where W is weight in grams and L is length in mm. The range in total length of females and males was 48–204 and 50–216 mm, respectively.

Instantaneous rate of total mortality (Z) was estimated for each year following the catch curve of Pauly (1983). The natural mortality rate (M) was estimated using the relation $Z = M + qf$. It was also estimated taking the life span (T_{max}) of the species in the fishery and assuming that 99% by numbers would die by the time they attain T_{max} in an unexploited state (Sekharan 1975; Cushing 1981).

The yield in weight per recruit (Y_w/R) was calculated using the simplified Beverton and Holt's (1957) formula as given by Ricker (1958).

$$\frac{Y_w}{R} = F\left[\exp[-Mt_c - t_r]\right] W_\infty \left[\frac{1}{Z} - \sum_{n=0}^{3} \frac{U_n(\exp[-nk(t_c - t_0)])}{F + M + nK}\right]$$

The value of W_∞ was estimated by taking the value of L_∞ and the constants of total length-total weight relationships. The value of length corresponding to the first point in the descending straight portion of the catch curve was taken as the length at first capture, and the age corresponding to this length was taken as t_c; t_r is the age at which the prawn becomes vulnerable to some common type of fishing. The data collected from the backwaters was used only to study the growth in early stages of *P. indicus*.

3. Results

3.1 *Estimation of growth parameters*

3.1a *Length frequency analysis of the backwater catch*: Data collected during 1979 and 1980 are presented in figure 1. As there is continuous recruitment and as the prawns live for a short period in these nursery grounds, before they migrate to the sea, modal progression for a given mode could not be traced for more than 3 months. The length ranged from 20–120 mm.

3.1b *Females*: Mode *A* at 56·5 mm in January 1979 is traceable to 106·5 mm in March. Mode *B* at 46·5 mm in February 1979 could be connected to the mode at 71·5 mm in March. Mode *C* at 56·5 mm in March is taken to have grown to 86·5 mm

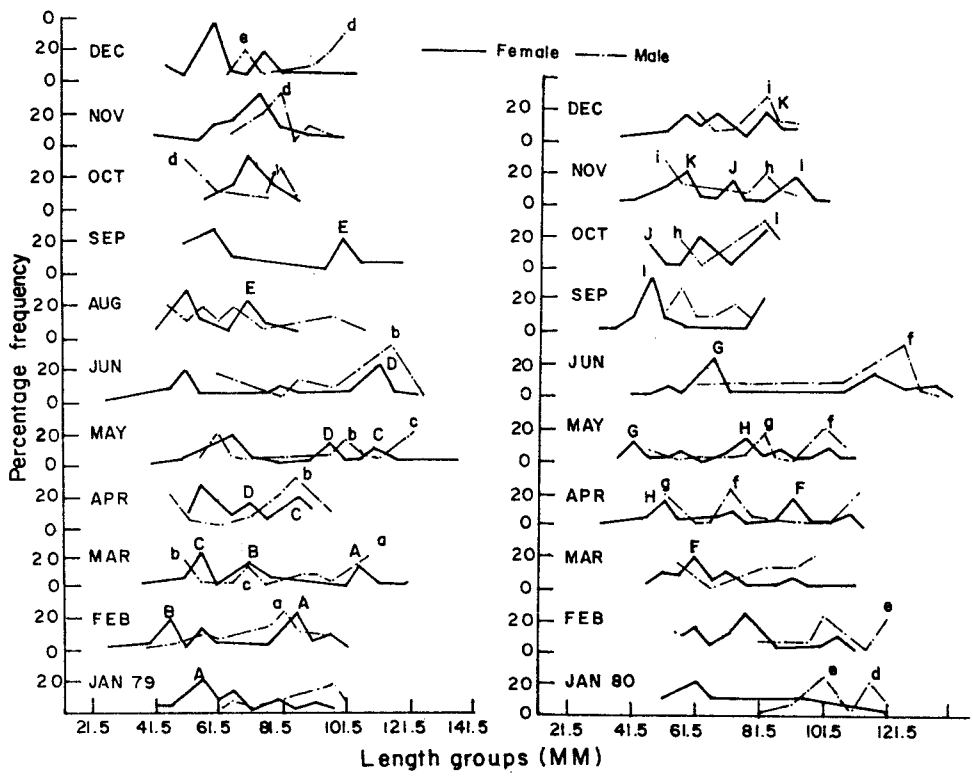

Figure 1. Monthly length frequency distribution of *P. indicus* during 1979–'80 (backwater catch).

in April and to 111·5 mm in May. Mode *D* at 71·5 mm in April 1979 is traceable to 111·5 mm in June. Mode *E* at 71·5 mm in August 1979 can be connected to 101·5 mm in September. Mode *F* at 61·5 mm in March 1980 is taken to have grown to 91·5 mm in April, mode *G* at 41·5 mm in May 1980 is traceable to 66·5 mm in June and mode *H* at 51·5 mm in April 1980 to 76·5 mm in May. Mode *I* at 46·5 mm in September can be connected to the mode at 91·5 mm in November. Likewise mode *J* at 46·5 mm in October 1980 is traceable to 71·5 mm in November and mode *K* at 56·5 mm in November 1980 is taken to have grown to 81·5 mm in December.

The above observations indicate an average growth rate of 25–30 mm/month.

3.1c *Male*: Mode *a* at 81·5 mm in February 1979 is traceable to 111·5 mm in March, mode *b* at 51·5 mm in March 1979 can be connected to the mode at 101·5 mm in May and to 116·5 mm in June. Mode *c* at 71·5 mm in March 1979 is taken to have grown to 121·5 mm in May. Mode *d* at 51·5 mm in October 1979 is traceable to 81·5 mm in November, and to 116·5 mm in January 1980. Mode *e* at 71·5 mm in December 1979 is taken to have grown to 101·5 mm in January 1980, and to 121·5 mm in February 1980. Mode *f* in April 1980 at 71·5 mm can be connected to the mode at 101·5 mm in May and to 126·5 mm in June. Mode *g* at 51·5 mm in April 1980 is traceable to 81·5 mm in May. Mode *h* in October 1980, at 56·5 mm is taken

to have grown to 81·5 mm in November and mode *i* at 51·5 mm in November 1980 is traceable to 81·5 mm in December.

The above observations indicate 35 mm monthly increase in length between 51 mm and 86 mm and 30 mm between 81 and 111 mm, which gives an average growth of 32 mm/month.

3.2 *Length frequency analysis of the marine catch*

Data collected during 1979–1981 are presented in figure 2. The length range of the females and males observed in the fishery was 48–204 and 51–216 mm, respectively.

3.2a *Females*: Mode *A* in February 1979 at 146·5 mm is traceable to 171·5 mm in April. Mode *B* at 126·5 mm in February 1979 can be connected to the mode at 151·5 mm in April. Mode B_1 at 96·5 mm in February is traceable to 141·5 mm in April. Mode *C* at 121·5 mm in May 1979 is taken to have grown to 161·5 mm in August. Mode *D* at 181·5 mm in September 1979 is traceable to 191·5 mm in November. Mode *E* at 121·5 mm in October 1979 can be connected to the mode at 166·5 mm in January 1980. Mode *F* at 111·5 mm in October 1979 is taken to have grown to 161·5 mm in February 1980. Mode *G* at 106·5 mm in January 1980 is traceable to 126·5 mm in February, mode *H* at 136·5 mm in February 1980 can be connected to the mode at 161·5 mm in April, mode *I* at 136·5 mm in June 1980 is taken to have grown to 166·5 mm in September; mode *J* at 96·5 mm in July 1980 can be connected to the mode at 136·5 mm in October, mode *K* at 116·5 mm in July 1980 is taken to have grown to 131·5 mm in August, mode *L* at 136·5 mm in September 1980 is traceable to 156·5 mm in November; mode *M* at 156·5 mm in September 1980 can be connected to the mode at 176·5 mm in November. Mode *N* at 81·5 mm in October 1980 is taken to have grown to 161·5 mm in April 1981, mode *O* at 121·5 mm in November 1980 is traceable to 161·5 mm in February 1981, mode *P* in March 1981 at 126·5 mm can be connected to the mode at 146·5 mm in May, mode *Q* at 111·5 mm in March 1981 is traceable to 131·5 mm in May; mode *R* at 96·5 mm in April 1981 to 176·5 mm in November, mode *S* at 91·5 mm in July, 1981 is taken to have grown to 131·5 mm in October and mode *T* at 81·5 mm in September 1981 is traceable to 121·5 mm in November.

The above observations indicate that the monthly growth rates are 20 mm between 81·5 mm and 121·5 mm, 12·5 mm between 126·5 and 151·5 mm, 10 mm between 156·5 mm and 176·5 mm and 5 mm between 181·5 and 191·5 mm. Since a growth of 25–30 mm/month is observed in the backwaters, individuals of the modal length 81·5 mm were taken as 2·9 months old.

3.2b *Male*: Mode *a* at 116·5 mm in January 1979 is traceable to 146·5 mm in April. Mode *b* at 121·5 mm in March 1979 can be connected to the mode at 136·5 mm in April, mode *c* at 91·5 mm in April 1979 is taken to have grown to 136·5 mm in June, mode *d* at 101·5 mm in May 1979 is traceable to 141·5 mm in August, mode *e* at 121·5 mm in September 1979 can be connected to the mode at 161·5 mm in November, mode *f* at 106·5 mm in December 1979 is taken to have grown to 136·5 mm in February 1980, mode *g* at 121·5 mm in December 1979 is traceable to 166·5 mm in February, mode *h* at 116·5 mm in March 1980 can be connected to the

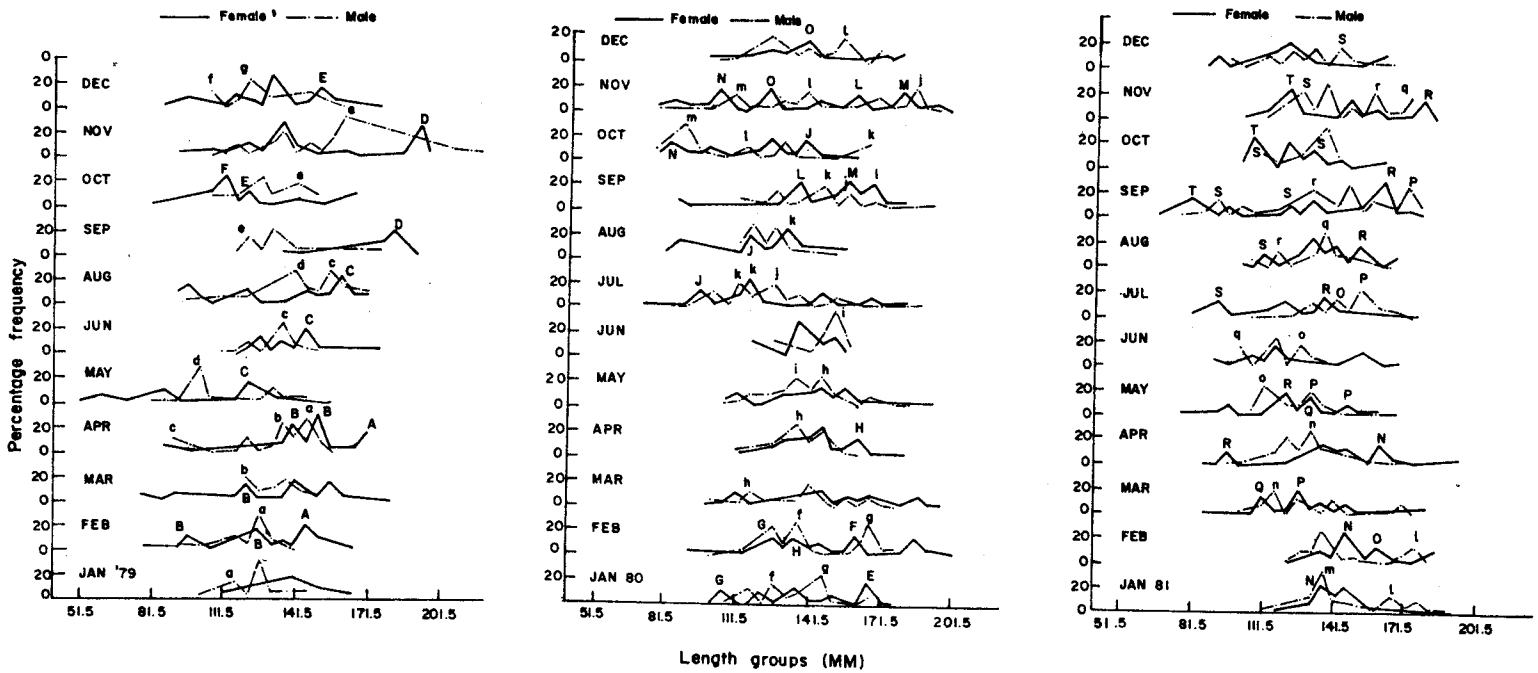

Figure 2. Monthly length frequency distribution of *P. indicus* during 1979–'81 (marine catch).

mode at 146·5 mm in May, mode *i* at 136·5 mm in May 1980 is traceable to 151·5 mm in June, mode *j* at 126·5 mm in July 1980 is taken to have grown to 181·5 mm in November, mode *k* at 111·5 mm in July 1980 is traceable to 161·5 mm in October, mode *l* at 111·5 mm in October 1980 can be connected to the mode at 176·5 mm in February 1981 mode *m* at 86·5 mm in October 1980 is traceable to 136·5 mm in January 1981, mode *n* at 116·5 mm in March 1981 can be connected to the mode at 131·5 mm in April, mode *o* at 111·5 mm in May 1981 is traceable to 141·5 mm in July, mode *p* at 131·5 mm in May 1981 is taken to have grown to 171·5 mm in September; mode *q*, at 101·5 mm in June 1981 is traceable to 171·5 mm in November, mode *r* at 116·5 mm in August 1981 can be connected to the mode at 156·5 mm in November and mode *s* at 91·5 mm in September 1981 is taken to have grown to 141·5 mm in December.

From the above observations, the monthly growth rates are 20 mm between 86·5 mm and 126·5 mm, 15 mm between 126·5 and 156·5 mm and 12·5 mm between 146·5 mm and 171·5 mm. Since a growth of 32 mm/month was observed in the backwaters, the prawns forming a mode at 91·5 mm can be reasonably taken as 2·9 months old.

Using the above growth rate and from the Ford-Walford plot (figures 3A, B) the values of L_∞ and K for females and males were estimated as 218·9 mm and 2·0 per year and 227·2 mm and 1·8 per year, respectively. The t_0 value was estimated as 0·01

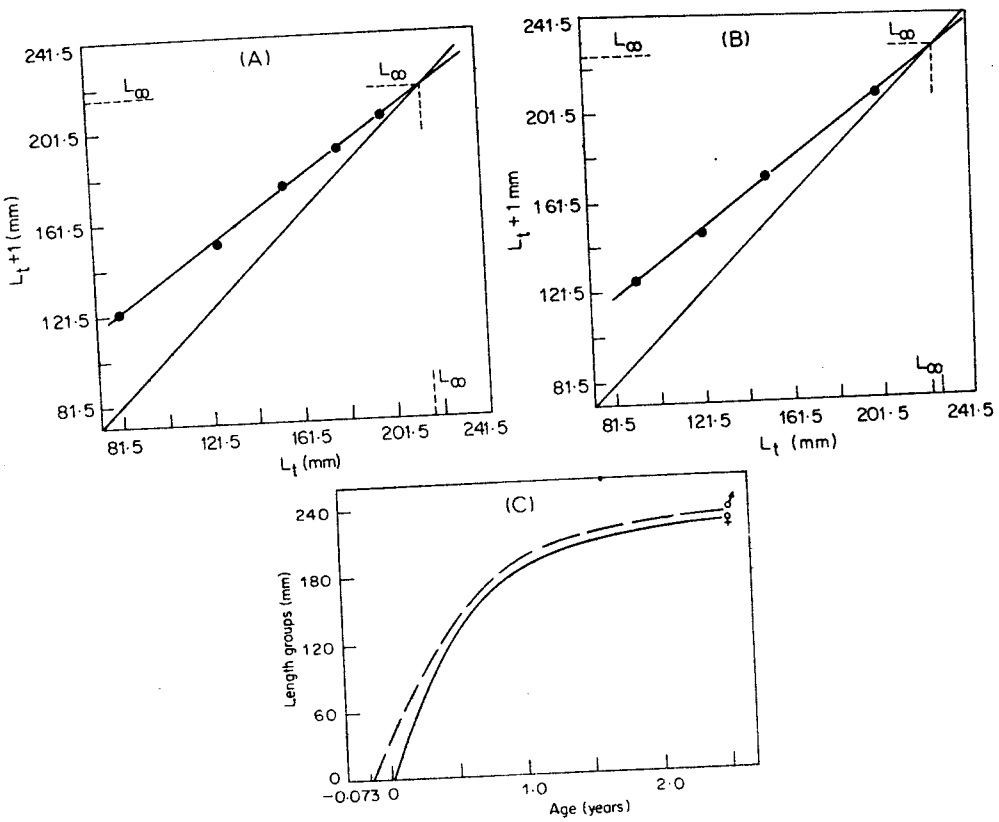

Figure 3. Ford-Walford plot in *P. indicus*. **A.** Female. **B.** Male. **C.** Theoretical growth curve in *P. indicus*.

year in females and −0·0729 year in males. The theoretical growth curves of male and female *P. indicus* are shown in figure 3C.

The maximum lengths of the male and female observed in the fishery are 216 and 204 mm, respectively. The age (T_{max}) of these prawns is calculated as 1·6 and 1·4 years respectively.

3.3 *Morphometric and length-weight relationships*

The parameter values of the regressions of various morphometric and length-weight relationships are presented in table 1. The regression lines between sexes in the total length-carapace length relationship showed significant difference (table 2). Comparison of slopes and elevations obtained for various length-weight relationships are not significant at 1% level. Hence the data of the sexes were pooled and combined equations were given.

3.4 *Estimation of mortality rates*

3.4a *Total mortality* (Z) (figure 4): In each year, the total mortality rate of males was

Table 1. Morphometric and length-weight relationships of *P. indicus*.

Relationship	Sex	N	a	b	r^2
Carapace length (Y) on total length (X)	F	66	1·559	0·3946	0·9976
	M	142	4·478	0·3679	0·9924
* Total weight (Y) on total length (X)	Data of the sexes pooled	104	−6·0438	3·4584	0·9500
* Head less weight (Y) on total length (X)	Data of the sexes pooled	177	−7·1896	3·9469	0·9308
Head less weight (Y) on total weight (X)	Data of the sexes pooled	340	0·0637	0·7645	0·9671
* Total weight (Y) on carapace length (X)	Data of the sexes pooled	340	−5·8635	4·1641	0·8998

*After logarithmic transformation.

Table 2. Analysis of co-variance to test the significance of differences between regression lines of sexes in the total length-carapace length relationship of *P. indicus*.

Sources of variation	Deviation	From SS	Regression MS
Due to regression within sexes	204	97·3054	0·47698
Differences between regression co-efficients	1	25·9727	25·9727
Residuals due to regression pooled within	205	123·2781	0·60443
Differences between adjusted mean	1	67·87795	67·879
Total	206	191·15065	–

Comparison of slopes $F = 54·452$ (df 1,204) HS
Comparison of elevation $F = 112·3007$ (df 1,205) HS
HS, Highly significant at 1%

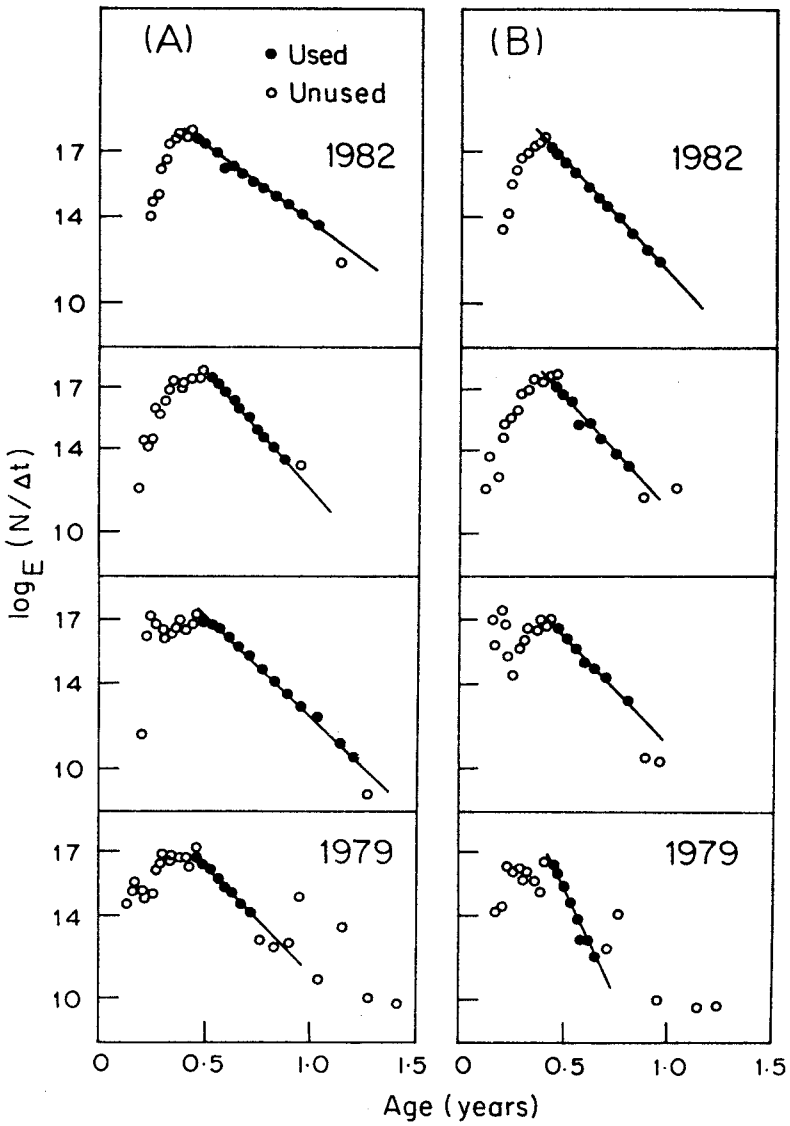

Figure 4. *P. indicus* estimation of Z by catch curve method of Pauly 1983. (**A**) Female; (**B**) Male.

greater than that of females except in 1981. The average for females and males was estimated as 9·42 and 12·73, respectively (table 3).

3.4b *Natural mortality rate* (M): Plot of Z values of males and females of *P. indicus* against the corresponding effort showed poor correlation ($r = 0{\cdot}083$ in females and 0·671 in males). Hence the M values obtained by taking the life-span into account were considered (table 3).

Table 3. Estimated values of mortality rates in *P. indicus*

	Total mortality rates	
Year	Females	Males
1979	9·95	20·45
1980	9·36	9·77
1981	11·36	10·61
1982	7·01	10·10
Average Z	9·42	12·73
Natural mortality rate (M)	3·30	2·90
Fishing mortality rate (F)	6·12	9·83

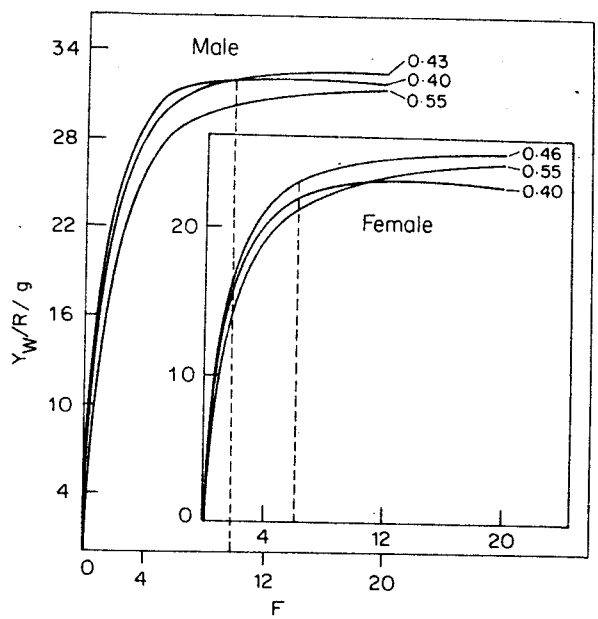

Figure 5. Yield in weight per recruit in *P. indicus*. Vertical lines show the present F. The numerals indicate the t_c in years.

3.5 *Yield per recruit*

Yield in weight per recruit as a function of fishing mortality rate F, for various t_c values are shown in figure 5. At present, F for females and males is 6·12 and 9·83, respectively. Present t_c is 0·46 year for females and 0·43 year for males. At the current rate of fishing, the yield per recruit is 23·05 g in females and 31·74 g in males. In both the sexes, the yield curves indicate increase in the yield with increase in F (i.e. effort). By keeping M constant and varying t_c, the yield curve in females indicates (figure 5) better yield at $t_c = 0{\cdot}40$, but it is not advisable to reduce t_c to 0·40, as the age at which *P. indicus* attains first maturity is 0·42 year. Increase of t_c to 0·55 year, though results

in a marginal decrease in the yield, but is desirable, since the prawn is allowed to spawn before it is fished. In males, increase in fishing effort with increase in selection size upto 0·55 year would give better yield.

4. Discussion

Observations on the length frequency analysis at the backwaters indicate a monthly growth rate of 30–35 mm (average 32 mm) in the case of males and 25–30 mm/month (average 27·5 mm) in females. These results are in agreement with those of Suseelan (1975), Sultan *et al* (1973) as mentioned by Mohammed (1970) and tag recovery experiments (Anonymous 1982) wherein the growth rates observed were 30·55 mm/month, 25·8 mm/month and 21–36 mm/month, respectively.

The values of the growth parameter K of *P. indicus* obtained in this study indicate that at Kakinada, the females attain the asymptotic length faster than males whereas Kurup and Rao (1975) observed faster growth in males than in females and females attained maximum length. Though there is disparity in the growth rates of males and females, the longevity of the male and female prawns are comparable.

The average annual total mortality rate, Z in males is greater than in females as is generally the case in penaeid prawns (Garcia and Le Reste 1981). Kurup and Rao (1975) estimated Z as 3·1 in males and as 2·1 in females. They did not estimate M. By taking into account, the growth parameters and the maximum length of females at 180 mm and males at 175 mm given by them, the T_{max} is estimated as 1·95 years in females and 1·3 years in males. Following the same method as adopted in the present work, the values of M were estimated as 3·5 for males and 2·4 in females. These M values thus obtained for the population in the Ambalapuzha area are slightly greater than the Z values estimated by these authors. According to Kurup and Rao (1975) 'trawling for prawns in the offshore fishing grounds has also been introduced recently' (p 184). Hence, the Z values obtained by Kurup and Rao (1975) can be reasonably taken as to represent M. The values of M obtained for *P. indicus* in the present study are comparable to those obtained for the same species from Ambalapuzha. Hence, the high values of Z from the Kakinada region can only be due to high fishing mortality. This is reasonable because the data pertain to the period 1979–1982 and trawling is carried out almost exclusively to catch prawns (Rao *et al* 1981).

It is known that estimation of M of a particular species in a multispecies fishery using the regression of Z against effort is difficult (Pauly 1983). This may be due to the difficulty in measuring the effective effort for each species. It is obviously for this reason the regression of Z against effort showed poor correlation in this study.

According to Le Reste (1978) and Marcille (1978), in *P. indicus*, the M values are 0·21/month and 0·15–0·25/month i.e. 2·52 and 1·8–3·0/year, respectively at Madagascar. They did not treat the sexes separately. It may be noted that the present average M (for both the sexes) worked out to 3·1 and the M/K ratio to 1·63 which is within the range given by Beverton and Holt (1959) and as quoted by Garcia and Le Reste (1981) for fast growing organism with short life span.

The yield per recruit analysis shows that at present the effort has no adverse effect on the stock and further increase in effort with increase in the selection size would give better yield.

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