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Mortality and stock assessment of two marine portunid crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) along the southwest coast of India

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ABSTRACT

The stock assessment of the marine crabs, *Portunus (Portunus) sanguinolentus* and *Portunus (Portunus) pelagicus* exploited by the mechanised trawl fishery was made based on the data collected from the commercial catches landed at Mangalore, Malpe and Karwar; three important fish landing centres in the Karnataka state along the southwest coast of India during 1992-'94 and the results presented. In *P. (P.) sanguinolentus,* the mean values of total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) were 4.2 ± 0.51, 1.6 and 2.6 for males and 3.9 ± 0.42, 1.5 and 2.4 for females respectively. In *P. (P.) pelagicus,* the average values of Z, M and F were 5.6 ± 0.71, 1.7 and 3.9 for males and 4.9 ± 0.69, 1.6 and 3.2 respectively for females. The standing stocks were 308 tonnes for *P (P.) sanguinolentus* and 161 tonnes for *P. (P.) pelagicus.* The annual average stocks were 1,272 tonnes for the former species and 834 tonnes for the latter. The maximum sustainable yield (MSY) was 776 tonnes for *P. (P.) sanguinolentus* and 567 tonnes for *P.(P.) pelagicus.* Based on the results obtained, it is felt imperative to increase the cod end mesh size of trawl to 40 mm and also to restrict the level of effort at the present level (1,130 trawlers per day or 234 x 10^3 boat days) which would prevent overexploitation of the stocks of crabs in the coastal fishery sector of Karnataka.

Introduction

Although the contribution of crabs to all India marine fish catch was low in the early sixties amounting to 4,000 tonnes, it increased steadily to 25,000 tonnes by the nineties due to the expansion of trawl fisheries. The marine crab fishery in India is mainly supported by *Portunus (Portunus) sanguinolentus* and *P. (P.) pelagicus,* and these two species together contribute upto 90% of the crab landings in the country. The heavy exploitation by mechanised trawlers, operating mainly in the narrow coastal water regions, has

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resulted in wide fluctuations in abundance of these crabs as indicated by commercial catch statistics. This situation warranted better understanding of the magnitude and dynamics of exploitation of the individual species and the present study is directed to provide information on mortality, yield-per-recruit and stock assessment of these crabs from the southwest coast of India. The results of the study are also useful to evolve rational management strategies for the judicious exploitation of these valuable resources on a national basis.

Materials and methods

For stock assessment, the data collected from the commercial trawl catches landed at Mangalore, Malpe and Karwar; the three major fish landing centres in Karnataka for the period 1992-'94 are used.

Growth parameter estimates derived by Sukumaran and Neelakantan (MS) were used for mortality estimates and stock assessment. Since it is not known, which method gives a true and realistic estimate of the total instantaneous mortality coefficient Z, various methods were used to estimate this para-meter (Murthy, 1990; Rao, 1994) to facilitate comparison and cross checking. The Z in respect of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* was estimated from the size frequency data using the Beverton and Holt method (1957), the length converted catch curve method of Pauly (1983), the cumulative catch curve method of Jones and van Zalinge (1981), and the Ssentongo and Larkin method (1973), for 1992-'93 and 1993-'94 fishing seasons separately. Since there is variation in growth parameters, the Z has been estimated sex-wise.

Since there is uncertainity in the value of instantaneous natural mortality coefficient M, different methods were used to estimate this parameter. In the present study M was estimated by the following methods.

1. The Sekharan's (1974) method
2. The Rikhter and Efanov's (1976) method
3. The Pauly's (1980) empirical method

Although, Pauly (1980) has cautioned against the use of his formula for crustaceans, it is useful in getting a reasonable estimate of M in penaeid prawns (Garcia *et al.,* 1981) and in the present study it has been used along with other methods for comparison.

Since there was considerable variation in the Z and the M estimates, the mean values of these parameters were considered for the rest of the studies.

The instantaneous fishing mortality coefficient (F) was computed from the following relationship.

$F = Z - M$

For size at capture (l_c) the value of carapace – width corresponding to the mid-point of the first part in the descending part of the catch curve was taken. Mid-point of the smallest size group in the catch was taken as the size at recruitment (l_r).

Since the exponent of the carapace width – body weight relationship is nearer to 3 (Sukumaran and Neelakantan, MS) the BH yield-per-recruit analysis was adopted to study the present status of the stock. The yield-per -recruit (Y/R) as a function of annual fishing intensity and F (or annual exploitation ratio, E = F/Z) for the present age at capture (t_c) were estimated as per the analytical model of Beverton and Holt (1957) by employing the equation suggested by Gulland (1969).

The weight asymptote, W_∞ was calculated as the weight in g at L_∞, using the carapace width – weight relationship of the respective species.

For yield in weight (Y_w) the average annual catch of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* for the period 1991-'93 was taken (this was estimated from the annual average crab landing in the state, using the mean percentage composition of these two species for Mangalore, Malpe and Karwar).

To estimate maximum sustainable yield (MSY), the absolute annual yield (Y) was calibrated graphically from the yield-per-recruit curve after plotting the mean annual Y for 1991-'93 against the corresponding values of F or E (Corten, 1974). Since the yield curve was flat topped without any maxima, it was not possible to estimate the MSY by this graphical method. Hence, the MSY was estimated by obtaining the F_{max} and finding out the corresponding yield. Stock in weight and number, absolute number of recruits, yield in number and mean weight of the species in the catch for various levels of Y/R as function of F and t_c were estimated as suggested by Devaraj (1983). The annual exploitation rate (U) was estimated by the equation of Ricker (1958).

For studying the effect of change in the cod end mesh size, the following procedure was followed. For each species, the present l_c values were converted into t_c values using VBG parameters employing the inverse von Bertalanffy's equation.

The present t_c values were decreased and increased by the same factor (as -10%, -20%, +10%, +20% etc.). Using these t_c values, the present F and other relevant parameters, the Beverton and Holt (1957) yield-per-recruit analysis was made using the computer programme BHYR incorporated in LFSA sub package (Sparre, 1987) for creating yield-mesh-curves. To obtain the yield at different t_c, the Y_w/R obtained at different t_c for the current F were raised to the R estimated as mentioned above. The Y_w/R as a function of F for different M, keeping t_c and other parameters constant, were estimated for males and females of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* to find out the influence of M on the yield curve. The optimum age of exploitation (t_y) and potential yield-per-recruit (Y') were estimated from the equation developed by Kutty and Qasim (1968).

For Karnataka, the annual trawler effort in boat hour (bh) for 1983-'93 was calculated by dividing the annual crab catch by the average crab catch per boat hour estimated for the major centres (Mangalore and Malpe) for the respective years. The total annual effort in boat hour was divided by the average trawling hours per day (8 hours) to convert effort into boat day (bd) which was then divided by the observed number of fishing days per year (215 days) for expressing the effort in trawlers per day (tpd) as suggested by Smitha and Devaraj (1990). The trawler effort for several years was calculated (Table 1) in order to monitor the growth of trawler fleet and also to facilitate the regulation of effort.

As there was no size composition

TABLE 1. *Crab catch and trawl effort estimated for 1983-'93 for the Karnataka coast*

Year	total crabs (t) Y	catch rate (t) Y/f	Effort bd x 1000	Effort tpd
1983	533	0.722	158.6	738
1984	476	0.769	83.8	390
1985	596	0.963	133.0	619
1986	1,868	3.565	112.8	524
1987	2,575	1.703	325.1	1,512
1988	762	0.344	476.2	2,215
1989	771	0.809	205.0	953
1990	948	1.135	179.5	835
1991	1,181	1.136	223.6	1,040
1992	2,069	1.377	323.3	1,503
1993	1,174	1.376	182.4	853
Average for 1983-'93	1,179	1.158	218.6	1,016
Average for 1991-'93	1,475	1.303	243.1	1,132

bd = boat day; tpd = trawl per day.

data in respect of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* from 1983 to 1991, Z was estimated from the mean values of catchability coefficient (q = F/f) determined for the period 1992-'94 (assuming that the mean values of q for 1992-'94 to be true for the previous years, 1983-'91 also) for which both annual fishing mortality coefficient (F) and fishing effort (f) are available. The F values for the previous years were estimated to study the variability in fishing intensity over the years.

The optimum level of effort, $f_{(msy)}$ and maximum sustainable yield (MSY) were also estimated using the surplus production models of Schaefer (1954) and Fox (1970).

Results

Instantaneous total mortality coefficient (Z)

The Z estimated by different methods for *P. (P.) sanguinolentus* and *P. (P.) pelagicus* are as follows. In males of *P. (P.) sanguinolentus* it ranged from 1.63 to 5.96, while in females, it ranged from 2.00 to 5.94 (Table 2). In the case of *P.(P.) pelagicus*, it ranged from 2.94 to 8.08 and from 2.75 to 8.10 in males and females respectively (Table 3). The mean values of Z estimated for males and females in respect of trawl were 4.2 ± 0.51 and 3.9 ± 0.42 for *P. (P.) sanguinolentus* and 5.6 ± 0.71 and 4.8 ± 0.69 for *P. (P.) pelagicus.*

Instantaneous natural mortality coefficient (M) and fishing mortality coefficient (F)

The natural mortality coefficient (M) varied from 1.08 to 1.85 in males and from 0.96 to 1.8 in females in the first species (Table 4). In the second species, it ranged from 1.15 to 2.09 in males and from 1.04 to 2.01 in females. The mean values of M in males and females were 1.6 and 1.5 for *P. (P.) sanguinolentus* and 1.7 and 1.6 for *P. (P.) pelagicus.*

The F values obtained in males and females were 2.6 and 2.4 for *P. (P.) sanguinolentus* and 3.9 and 3.2 for *P. (P.) pelagicus.*

Size at capture (l_c)

The size at capture (l_c) for *P. (P.) sanguinolentus* was 72.5 mm (t_c = 0.45 year) in males and 82.5 mm (t_c = 0.61 year) in females. The l_c values for *P. (P.) pelagicus* were 92.5 mm (t_c = 0.49 year) and 97.5 m (t_c = 0.60 year) in males and females respectively.

TABLE. 2. *Estimates of total mortality coefficient (Z) in* P. (P.) sanguinolentus *at Mangalore, Malpe and Karwar during 1992-'93 and 1993-'94*

Centre/gear	Fishing season	Pauly's method (1983)	Cumulative catch curve method of Jones & van Zalinge (1981)	Beverton & Holt method (1956)	Ssentango & Larkin method (1973)	Average
Male						
Mangalore (TN)	1992-'93	5.62±1.83	2.57±0.46	2.66	3.12	3.49
	1993-'94	4.24±1.42	4.14±0.34	4.93	5.37	4.67
Malpe (TN)	1992-'93	1.63±0.82	2.26±0.72	2.78	3.24	2.48
	1993-'94	4.93±0.40	5.49±0.23	5.01	5.47	5.23
Karwar (TN)	1992-'93	4.33±1.01	5.07±0.35	5.53	5.96	5.22
	1993-'94	4.19±0.72	3.38±0.97	4.23	4.66	4.13
Karwar (SS)	1992-'93	4.35±1.01	4.44±0.30	5.06	5.41	4.82
	1993-'94	4.91±1.39	4.75±0.47	5.16	5.62	5.11
Average for (TN)		4.17	3.82	4.19	4.64	4.20
Female						
Mangalore (TN)	1992-'93	2.00±1.02	2.80±0.97	2.69	3.06	2.64
	1993-'94	5.19±0.88	5.31±0.50	5.58	5.94	5.50
Malpe (TN)	1992-'93	3.78±0.63	4.33±0.43	4.57	4.94	4.40
	1993-'94	3.72±1.40	4.18±0.38	3.60	3.99	3.87
Karwar (TN)	1992-'93	3.49±0.45	3.71±0.34	3.90	4.25	3.84
	1993-'94	2.64±1.37	2.91±0.19	3.09	3.45	3.02
Karwar (SS)	1992-'93	3.63±0.97	5.02±0.59	5.39	5.79	4.95
	1993-'94	4.20±1.09	4.36±0.67	4.12	4.52	4.30
Average for TN		3.47	4.87	3.90	4.27	3.88

TN = trawl net; SS = shore seine.

The sizes at recruitment (l_r) in males and females were 22.5 mm (t_r = 0.11 year) and 17.5 mm (t_r = 0.02 year) for *P. (P.) sanguinolentus* and 27.5 mm (t_r = 0.12 year) and 32.5 mm (t_r = 0.11 year) for *P. (P.) pelagicus*.

Yield-per-recruit (Y/R)

The values of W_∞ corresponding to L_∞ were calculated as 457.5683 g for males and 355.6378 g for females of *P. (P.) sanguinolentus*. The similar values for *P. (P.) pelagicus* were 816.2474 g and 535.4558 g respectively.

The yield-per-recruit in weight (Y_w/R) for males (at M=1.6; t_c = 0.46 year) and females (at M = 1.5; t_c = 0.61 year) for varying F in respect of *P. (P.) sanguinolentus* is depicted in Figs. 1A and 1B. Similarly, the Y_w/R for males (at M = 1.7; t_c = 0.49 year) and females (M = 1.6; t_c = 0.60 year) for varying F in the case of *P. (P.) pelagicus* is given in Figs. 2A and 2 B.

It is seen that the Y_w/R, at M = 1.6 and t_c = 0.46 year, steadily increased and reached a maximum of 21.95 g at F_{max} = 2.23 (E = 0.53) for 970 tpd (208.4

In the males of *P. (P.) sanguinolentus*, the yield increased with increasing effort and reached the maximum of 403.0 tonnes at 85% of the present effort (Fig. 1 A). In the female of the same species, the yield at MSY level was realised at 130 % of the present effort (Fig. 1B).

In the males of *P. (P.) pelagicus* the yield increases with the increasing effort and reaches maximum of 275.0 tonnes at 79% of the present effort (Fig. 2A). In the female of the same species, it is seen that the yield increases with increasing effort and attains a maximum of 292.0 tonnes at 120% of the present effort (Fig. 2B).

Keeping M at the present level (M = 1.6 and 1.5 in males and females respectively of *P. (P.) sanguinolentus* and 1.7 and 1.6 in males and females of *P. (P.) pelagicus* respectively), the Y_w/R as a function of F for different values of t_c (Figs. 3A, 3 B, 4A, 4B), and yields as the % of the present t_c for the present F in males and females of these species have been calculated (Figs. 3C, 3D, 4C, 4D). In addition, yields as percentage of the present t_c were also estimated for varying F for males and females of these crabs. This study has indicated that the yield of *P. (P.) sanguinolentus* could be increased by 10.2 % in males and 3.8% in females if the size at capture (l_c) is

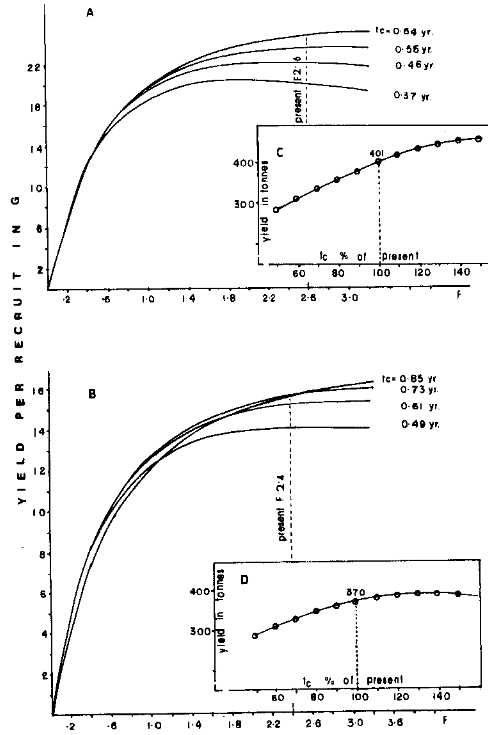

Fig. 3. Yield per recruit (in g) as a function of F with different age of exploitation (t_c) for males (A) and females (B) of *P. (P.) sanguinolentus*. Yield as % of the present t_c for males (C) and females (D). M = 1.6 for males and 1.5 for females.

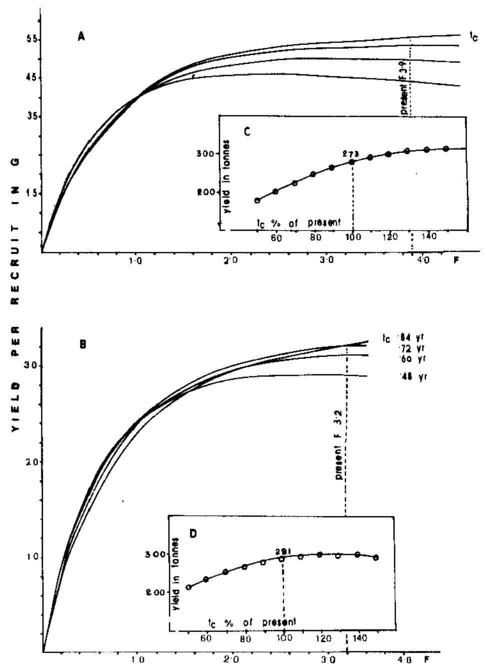

Fig. 4. Yield per recruit (in g) as a function of F with different age of exploitation (t_c) for males (A) and females (B) of *P. (P.) pelagicus*. Yield as % of the present t_c for males (C) and females (D). M = 1.7 for males and 1.6 for females.

increased by 20% in both sexes (from 72.5 mm (0.46 year) to 87 mm (0.58 year) in males and from 82.5 mm (0.61 year) to 99 mm (0.81 year) in females). Similarly, in the case of *P. (P.) pelagicus,* the yield could be increased by 10.1% in males and 2.6 % in females by increasing the l_c by 20% in both sexes (from 92.5 mm (0.49 year) to 110 mm (0.63 year) in males and from 97.5 mm (0.61 year) to 117 mm (0.82 year in females).

The Y_w/R as a function of fishing intensity for different values of M, keeping t_c constant are shown in Figs. 5A, 5B and 6A, 6B. It is seen that the variation in the magnitude of M can have great influence on the shape of the curve of Y_w/R. The range of M (the maximum and the minimum values obtained in the study) is taken as a possible range within which the mean natural mortality might lie. All the curves have the general same shape. It is seen that as M increases there is a marked decrease in $(Y_w/R)_{max}$ and an appreciable increase in the corresponding value of F_{max}.

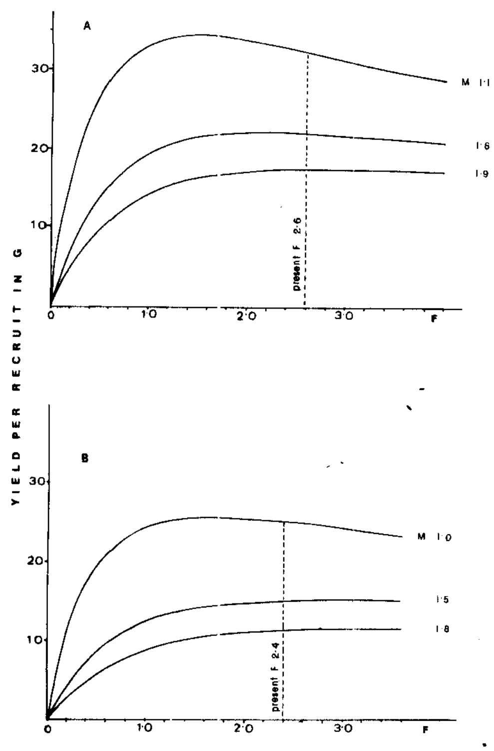

Fig. 5. Yield per recruit (in g) as a function of F with different natural mortality coefficient (M) for males (A) and females (B) of *P. (P.) sanguinolentus.* The vertical line indicates the Yw/R at the present F (t_c = 0.46 year for males and 0.61 year for females).

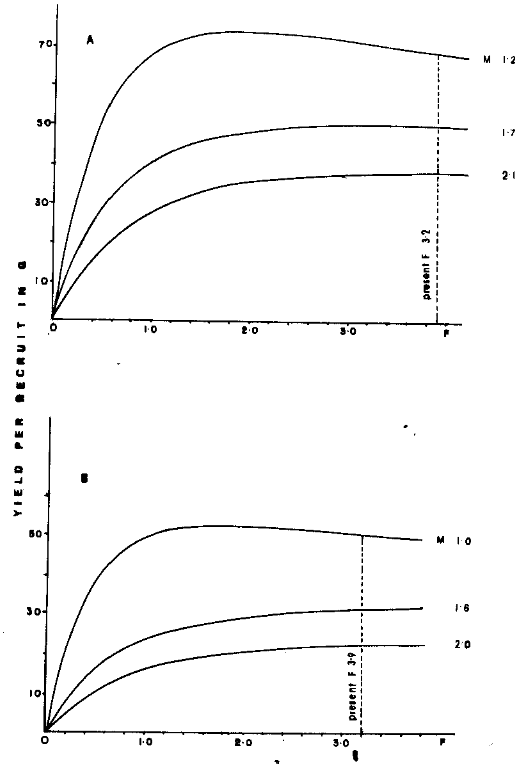

Fig. 6. Yield per recruit (in g) as a function of F with different natural mortality coefficient (M) for males (A) and females (B) of *P. (P.) pelagicus.* The vertical line indicate the Yw/R at the present F (t_c = 0.49 year for males and 0.6 year for females).

The Figs. 7A, 7B and 8A, 8B show isopleths of annual yield in weight per recruit (Y_w/R) as a function of F and t_c for males and females of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* respectively. The change in $(F)_{max}$ with t_c is shown approximately by the dotted line AA' (MSY curve). The value of $(t_c)_{max}$ increases with F. The course of this increase is indicated by the upper dotted line BB' (Eumetric fishing curve). The maximum possible value of Y_w/R is at $F = \infty$ $(E = 1)$ corresponding to the value of t_c between 0.9 and 1 which is the meeting point of eumetric fishing curve with MSY curve. This is the optimum age of exploitation (t_y) and Y_w/R at t_y is the potential yield per recruit (Y') according to Kutty and Qasim (1968).

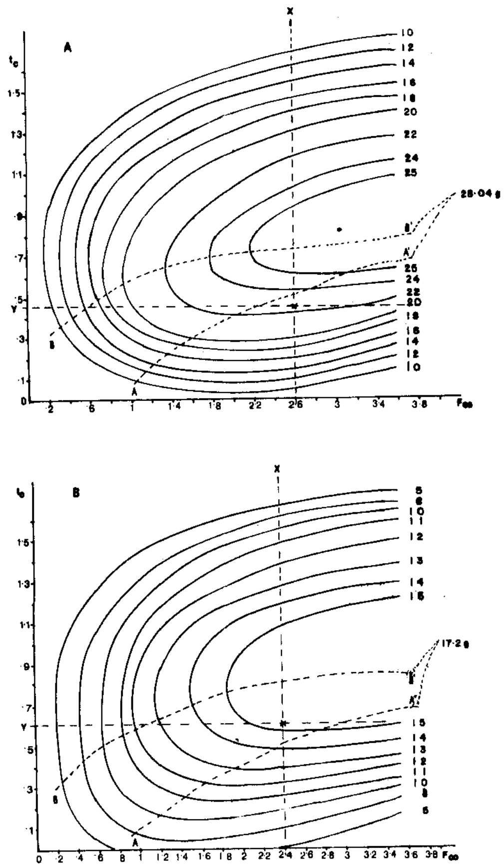

Fig. 7. Isopleth diagram for yield per recruit (in g) for males (A) and females (B) of *P. (P.) sanguinolentus*. BB' line = eumetric fishing line; AA' = MSY curve; the vertical line at X indicates the present F and horizontal line at Y, the present t_c.

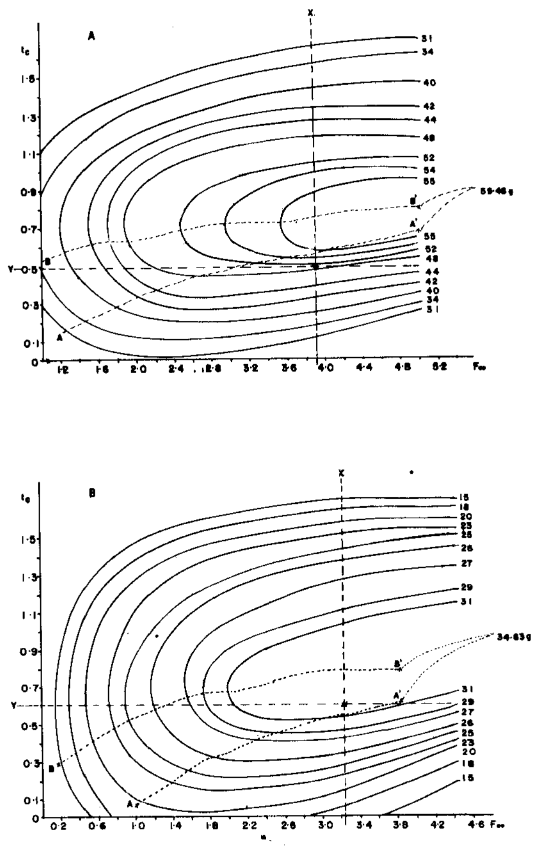

Fig. 8. Isopleth diagram for yield per recruit (in g) for males (A) and females (B) of *P. (P.) pelagicus*. BB' line = eumetric fishing line; AA' = MSY curve; the vertical line at X indicates the present F and horizontal line at Y, the present t_c.

For *P. (P.) sanginolentus*, the optimum age of exploitation (t_y) and potential yield per recruit (Y') were estimated independently, according to the method of Kutty and Qasim (1968) at 1.07 years (l_c = 128 mm) and 27.55 g for males and 1.08 years and 19.28g for females respectively. For *P. (P.) pelagicus*, the independent estimates of t_y and Y' were 47.3 g and 1.06 years (l_c = 149 mm) in males and 30.9 g and 1.05 years (125 mm) in females respectively. These independent estimates of t_y and Y' which were close to the values determined by yield per recruit analysis are shown in Figs. 7A, 7B and 8A, 8B.

Stock assessment

The annual average yield (Y), the standing stock (Y/F), the average stock (Y/U), the MSY, mean population number (P_n), yield in number (Y_n), mean population number per recruit (P_n/R), mean number per recruit (Y_n/R), yield in weight per recruit (Y_w/R) and biomass per recruit (P_w/R) estimated for the present F and t_c in respect of males and females of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* for Karnataka waters are given in Tables 6-7. The initial population number (N_0) is estimated at 99.228 million for *P. (P.) sanguinolentus* and 40.563 million for *P. (P.) pelagicus.*

The standing stocks were estimated at 308.0 t for *P. (P.) sanguinolentus* (154.0 t for males and 154.0 t for females) and 161.0 t for *P. (P.) pelagicus* (70.0 t for males and 91.0 t for females).

As a first approximation, the MSYs for the species (sex-wise) were pooled to arrive at a 'pooled MSY' for the crab stocks and the corresponding $f_{(msy)}$ were estimated graphically. The MSYs estimated by Beverton and Holt model were 776.0 t (403.0 t for males and 373.0 t for females) for *P. (P.) sanguinolentus* and 567.0 t (275.0 t for males and 292.0 for females) for *P. (P.) pelagicus,* while the annual average yields for the period 1991-'93 were 771.0 t (401.0 t and 370.0 t for males and females respectively) for the former species and 564.0 t (273.0 t for males and 291.0 t for females) for the latter.

The annual average stock or *P. (P.) sanguinolentus* and *P. (P.) pelagicus* were 1,272.0 t (658.0 t for males and 614.0 t for females) and 834.0 t (394.0 t for males and 440.0 t for females) respectively.

The annual mean number of the population (P_n) in the exploited area and the yield in number (Y_n) for the present level of F and t_c in *P. (P.) sanguinolentus* were 24.149 million and 59.965 million respectively. For *P. (P.) pelagicus,* the Pn and Yn were 7.897 million and 27.251 million respectively (Tables 6-7).

The MSY and $f_{(msy)}$ estimated for *P. (P.) sanguinolentus* and *P. (P.) pelagicus* by different methods given in Table 5.

TABLE 5. *MSY and $f_{(msy)}$ estimated for* P. (P.) sanguinolentus *and* P. (P.) pelagicus *by different methods*

Method	MSY	$f_{(msy)}$
Beverton and Holt	1,343 t	1,190 tpd (225.8 x 10^3 bd)
Fox	1,100 t	1,120 tpd (240.8 x 10^3 bd)
Schaefer	1,450 t	1,660 tpd (356.9 x 10^3 bd)

TABLE 6. *Estimates of total annual stock (Y / U), annual standing stock (Y / F), yield-per- recruit (Yw / R), biomass-per-recruit (Bw / R), recruits in numbers and maximum sustainable yield (MSY), mean population (in number), yield (in number) mean population number per recruit and yield (in number) per recruit for* P. (P.) sanguinolentus *in the Karnataka waters*

	Z	M	F	E	U	Annual average yield (t)	Total annual stock (t) (Y/U)	Average standing crop (t) (Y/F)	Yw/R (g)	Bw/R (g)	Recruits ('000 nos.)	MSY (t)	Pn (millions)	Pn/R (millions)	Yn (millions)	Yn/R (millions)	Wy (g)
Male	4.2	1.6	2.6	0.62	0.61	401.0	658.0	154.0	21.8	8.4	18,334.7	403.0	10.029	0.547	26.076	1.422	15.38
Female	3.9	1.5	2.4	0.62	0.60	370.0	614.0	154.0	15.1	6.3	24,557.0	373.0	14.120	0.575	33.889	1.380	10.92
Total						771.0	1,272.0	308.0	36.9	14.7	42,891.7	776.0	24.149	1.122	59.965	2.802	12.86

Z = Instantaneous total mortality coefficient; M = natural mortality coefficient; F = fishing mortality coefficient; E = exploitation ratio; U = exploitation rate; Pn = mean population number; Yn = yield in number; Pn/R = population number per recruit; Yn/R = yield in number per recruit.

TABLE 7. *Estimates of total annual stock (Y / U), annual standing stock (Y / F), yield-per-recruit (Yw / R), biomass-per-recruit (Bw / R), recruits in numbers and maximum sustainable yield (MSY), mean population (in number), yield (in number), mean population number per recruit, and yield in number per recruit in* P.(P.) pelagicus *in the Karnataka waters*

	Z	M	F	E	U	Annual average yield (t)	Total annual stock (t) (Y/U)	Average standing crop (t) (Y/F)	Yw/R (g)	Bw/R (g)	Recruits ('000 nos.)	MSY (t)	Pn (millions)	Pn/R (millions)	Yn (millions)	Yn/R (millions)	Wy (g)
Male	5.6	1.7	3.9	0.70	0.70	273.0	394.0	70.0	49.6	12.7	5,507.1	275.0	2.827	0.503	11.027	2.001	24.76
Female	4.8	1.6	3.2	0.67	0.66	291.0	440.0	91.0	31.0	9.7	9,374.1	292.0	5.070	0.541	16.224	1.731	17.94
Total						564.0	834.0	161.0	80.6	22.4	14,881.2	567.0	7.897	1.054	27.251	3.732	20.70

Discussion

Despite their economic significance, the dynamics of the exploited population of these crabs remain poorly understood as there is no information on mortality and stock assessment of brachyurans from anywhere.

It is well known that information on mortality is extremely critical to the study of population dynamics. Considering the fact that there was no previous record on the estimation of Z in portunids, care was taken to estimate this vital parameter. As a cross-check, different methods were employed in estimating Z in the present study. Similarly, in view of the uncertainity in the estimation of M, it was estimated by three different methods.

In the first half of eighties (1983-'86), the Z was relatively low ranging from 2.0 to 3.3 in males and 2.3 to 3.0 in females of *P. (P.) sanguinolentus* (Table 8). In *P. (P.) pelagicus,* it ranged from 3.5 to 4.2 in males and 2.7 to 3.3 in females. Since the second half of eighties, the fishing became more intense due to the addition of more and more trawlers resulting in higher values of Z (3.5-6.7 in males and 3.5 - 6.4 in females of *P. (P.) sanguinolentus* and 4.6 - 9.2 in males and 3.9 - 7.8 in females of *P. (P.) pelgicus*).

The catchability coefficient (q) could be estimated only for 1992-'94 season since Z and f values were available only

TABLE 8. *Z, F, E and Yw/R estimated for males and females of* P. (P.) sanguinolentus *and* P. (P.) pelagicus *during 1983-'93 along the Karnataka coast*

year	*P. (P.) sanguinolentus*								*P. (P.) pelagicus*							
	Males				Females				Males				Females			
	Z	F	E	Yw/R	Z	F	E	Yw/R	Z	F	E	Yw/R	Z	F	E	Yw/R
1983	3.3	1.7	0.52	21.7	3.0	1.5	0.50	14.2	4.2	2.5	0.60	49.6	3.2	2.1	0.57	29.9
1984	2.5	0.9	0.36	18.7	2.3	0.8	0.35	11.6	4.0	1.3	0.33	44.3	2.7	1.1	0.41	25.4
1985	3.0	1.4	0.47	21.1	2.8	1.3	0.46	13.7	3.8	2.1	0.55	48.8	3.3	1.7	0.52	28.8
1986	2.8	1.2	0.43	20.4	2.6	1.1	0.42	13.0	3.5	1.8	0.51	47.8	3.2	1.5	0.47	27.9
1987	5.1	3.5	0.69	21.4	4.7	3.2	0.68	15.2	6.8	5.1	0.75	48.5	5.8	4.2	0.72	31.0
1988	6.7	5.1	0.76	20.8	6.4	4.7	0.73	15.3	9.2	7.5	0.82	47.5	7.8	6.2	0.79	30.4
1989	3.8	2.2	0.58	22.0	3.5	2.0	0.57	14.8	4.9	3.2	0.65	49.9	4.3	2.7	0.63	30.7
1990	3.5	1.9	0.54	21.8	3.3	1.8	0.55	14.6	4.5	2.8	0.62	49.9	3.9	2.3	0.59	30.3
1991	4.0	2.4	0.60	21.9	3.7	2.2	0.59	15.0	5.2	3.5	0.67	49.8	4.5	2.9	0.64	30.9
1992	5.1	3.5	0.69	21.4	4.7	3.2	0.68	15.2	6.8	5.1	0.75	48.5	5.8	4.2	0.72	31.0
1993	3.6	2.0	0.56	21.9	3.5	1.8	0.51	14.6	4.6	2.9	0.63	49.9	4.0	2.4	0.60	30.4
Average for '83-'90	3.9	2.3	0.59	22.0	3.7	2.1	0.57	14.9	5.2	3.4	0.65	49.9	4.5	2.6	0.58	30.7
Average for 91-'93	4.2	2.6	0.62	21.9	3.9	2.4	0.62	15.1	5.5	3.8	0.68	49.6	4.8	3.2	0.67	31.0

F estimated from the catchability coefficient (q=F/f) determined for 1992-'94 data.

E and Yw/R given for the respective F values.

for this period. Although, q may vary significantly from year to year, a constant value of q was used to estimate F for the previous years as there was no alternate means of estimating F for this period. However, this method gave a fairly accurate values of F as is evident from Figs. 1A, 1B and 2A, 2B where the catches during 1983-'93 were superimposed against F or E. In addition, the values of average annual F estimated by this method for 1983-'93 period (Table 8) and the same arrived at by several other methods for 1992-'94 in males and females of *P. (P.) sanguinolentus* and *P. (P.) pelagicus* were more or less same.

For Karnataka waters, the annual average stock was estimated at 2,106 t (*P. (P.) sanguinolentus* = 1,272 t + *P. (P.) pelagicus* = 834 t), whereas the maximum sustainable yield (MSY) was estimated at 1,343 t (*P. (P.) sanguinolentus* = 776 t + *P. (P.) pelagicus* = 567 t) by the yield per recruit model of Beverton and Holt which is found to be very close to the annual average yield of 1,335 t (*P. (P.) sanguinolentus* = 771 t + *P. (P.) pelagicus* = 564 t) obtained during 1991-'93 period.

The estimates of the MSY and the $f_{(msy)}$ for total crabs for Karnataka waters were 1,610 t and 1,840 tpd (395.6 x 10^3 bd), whereas the similar values got by employing the Fox model were 1,220 t and 1,250 tpd (268.7 x 10^3 bd) respectively for 1983-'93 period. Since the MSY estimated by these two models include other crabs (which form about 10% of all crabs) also, the MSY for *P. (P.) sanguinolentus* and *P. (P.) pelagicus* alone may be around 90 % of these estimates (i.e. 1,450 t by the Schaefer model and 1,100 t by the Fox model). The MSY estimates by the yield per recruit model (1,343 t for these two species together) was between the estimates obtained by the Schaefer model and the Fox model and found to be fairly accurate. Although the annual yield was lower than the MSY in most of the years, it exceeded MSY level in 1986, 1987 and 1992.

The annual average of $f_{(msy)}$ for *P. (P.) sanguinolentus* and *P. (P.) pelagicus* together was estimated at 1,190 tpd which is very close to the value obtained by the Fox model (1,120 tpd which is 90% of $f_{(msy)}$ estimated for all crabs). The estimate of $f_{(msy)}$ by the Schaefer model was found to be on the higher side (1,660 tpd or 356.9 x 10^3 bd).

The present studies indicate that for *P. (P.) sanguinolentus* and *P. (P.) pelagicus*, the prevailing fishing intensity for males (F = 2.6 or E = 0.62 for the former species, F = 3.9 or E = 0.70 for the latter) was more, whereas it was low for females (F = 2.4 or E = 0.62 for the former species, and F = 3.2 or E = 0.67 for the latter). However, since the current yield of males and females of these two crabs are very close to MSY level, it will be advantageous if the effort is maintained at the current level (1,130 tpd or 243.0 x 10^3 bd) itself to obtain biologically optimum yields.

Since the cod-end mesh size is small (28-35 mm), large quantities of juveniles of these crabs are retained by trawl net all through the year. This is detrimental to the crab stocks and warranted some urgent regulatory measures for the conservation of the resources. As the exploited area contains several species of commercial importance that are caught simultaneously by the same gear, any method of regulation applied for one resource should not affect another resource adversely. Hence several factors have to be taken into account in arriving at the most suitable form of regulation for the area as a whole. Eventhough there are several methods of regulation (minimum mesh size, minimum legal size, reduction of power of fishing vessels, reduction of catch, control of fishing activity, closed season, closed areas, controlled building of fleets etc.), mesh size regulation along with certain amount of control of fishing intensity appears to be the most appropriate and suitable method for the conservation and management of the marine crab resources in Karnataka.

In the light of the requirements for optimum fishing and also to increase the size at capture (l_c) by 20% (t_c by around 30%) to permit the young crabs to escape through the meshes of the net and thereby enhance the yield subsequently, an increase in cod end mesh size to 40 mm from 33 mm (mean) would seem to be practical and ideal. In addition, there is an urgent need to restrict the effort at the present level (1,130 tpd or 243.0 x 10^3 bd) as a management strategy to prevent over-exploitation of these valuable resources in the coastal waters of Karnataka.

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References

Beverton, R.J.H. and S.H. Holt 1957. On the dynamics of exploited fish populations. *Fishery Investigations (Ministry of Agriculture, Fisheries and Food, London), Series II,* Vol. XIX, 533 pp.

Corten, A. 1974. Recent changes in the stock of Celtic sea herring (*Clupea harengus* L.). *J. Cons. perm. int. Explor. Mer.,* **35** : 194-201.

Devaraj, M. 1983. Fish population dynamics. Course manual. *Bull. Central Institute of Fisheries Education,* **3**(10) : 98pp.

Ford, E. 1933. An account on the herring investigations conducted at Plymouth during the years 1924-'33. *J. mar. biol. Ass. U.K.,* **19** : 305-384.

Fox, W.W. Jr. 1970. An exponential surplus-yield model for optimising exploited fish populations. *Trans. Am. Fish. Soc.,* **99** : 80-88.

Garcia, S and L. Le Reste 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Pap.,* (203) : 215pp.

Gulland, J. A. 1969. Manual of methods for fish stock assessment. Part 1. Fish population analysis. *FAO Man. Fish. Sci.,* (4) : 154 pp.

Gulland, J.A. and S.J. Holt 1959. Estimation of growth parameters for data at unequal time intervals. *J. Cons. CIEM,* **25**(1) : 47-49.

Jones, R. and N.P. van Zalinge 1981. Estimates of mortality rate and population size for shrimp in Kuwait waters. *Kuwait Bull. Mar. Sci.,* **2** : 273-288.

Kutty, M.K. and S.Z. Qasim 1968. The estimation of optimum age of exploitation and potential yield in fish populations. *J. Cons. perm. int. Explor. Mer.,* **32**(2) : 249-255.

Murty, V.S. 1990. Biology and population dynamics of the silver belly *Secutor insidiator* (Bloch) from Kakinada. *J. mar. biol. Ass. India,* **32**(1&2) : 10-24.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and environmental temperatures in 175 fish stocks. *J. Cons. inst. Explor. Mer.,* **39** : 175-192.

Pauly, D. and N. David 1981. Elefan I, a basic programme for the objective extraction of growth parameters from length frequency data. *Meeresforschung,* **28**(4) : 205-211.

Pauly, D. 1983. Length converted catch curves: A powerful tool for fisheries research in tropics (Part I). *ICLARM Fishbyte,* **1**(2) : 9-13.

Rao, G. Sudhakara 1994. Mortality and stock assessment of *Metapenaeus monoceros* along the Kakinada coast. *J. mar. biol. Ass. India,* **36**(1&2) : 1-18.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish population. *Bull. Fish. Res. Bd. Canada,* **119**, 300 pp.

Rikhter, V.A. and V.N. Efanov 1976. On one of the approaches to estimation of natural mortality of fish populations. *ICNAF Res. Doc.*, 76/VI/8, 12pp.

Sekharan, K.V. 1974. Estimates of the stocks of oil sardine and mackerel in the present fishing grounds off the west coast of India. *Indian J. Fish.* **2**(1) : 177-182.

Schaefer, M. 1954*. Some aspects of the dynamics of polulations important to the management of the commercial marine fisheries. *Bull. I-ATTAC/ Biol. CIAT,* 1/(2) : 27-56.

Smitha, P and M. Devaraj 1990. Population dynamics of the prawn *Metapenaeus dobsoni* (Miers) exploited in the trawl fishery along the southwest coast of India. *Fish. Res.,* **8** : 381-395.

Ssentongo, G.W. and P.A. Larkin 1973. Some simple methods of estimating mortality rates of exploited fish populations. *J. Fish. Res. Bd. Canada,* **30**(5) : 695-698.

* not referred to in original.