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Stock characteristics and population dynamics of *Heterocarpus woodmasoni* Alcock

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Abstract

Heterocarpus woodmasoni Alcock, 1901 is a major species among the deep sea prawns landed along Kerala coast. This paper describes the stock characteristics and population dynamics of *H. woodmasoni* which constituted the exploited stock in commercial trawlers. The length composition of male *H. woodmasoni* ranged from 50 to 150 mm in total length with a modal length of 97 mm. Females ranged from 40 to180 mm TL and the modal length was 92 mm. Based on the length composition of male and female prawns, the growth parameters were estimated as male: $L_t = 160.59\ [1 - \exp^{-0.82(t+0.97)}]$; female : $L_t = 188.0\ [1 - \exp^{-0.60(t+0.96)}]$. The growth performance index (ϕ) of male and female was estimated as 4.33. The life span of male estimated using the equation tmax = 3/K is 3.66 years while the same of female is 5 years. The lengths attained by males following VBGF equation at the end of I, II, and III years were estimated at 91.51mm, 130.16 mm and 147.19 mm respectively. The lengths of females at the end of I, II, III, IV and V years were estimated at 87.19 mm, 132.61 mm, 157.62 mm, 171.39 mm and 178.98 mm respectively. Results of the length converted cohort analysis revealed that prawns in the length groups 50-60 mm and above were vulnerable to exploitation. Heavy exploitation of the length class 80-90 mm was discernible in the fishery.

Keywords: Deep sea shrimp, *Heterocarpus woodmasoni*, stock characteristics, population dynamics, exploitation

Introduction

Exploitation of deep sea shrimps in India has gained great impetus during the turn of this century consequent to discrete depletion of penaeid shrimp resources by increased fishing efforts and overexploitation in inshore waters (Devaraj and Vivekanandan, 1999). Off Kerala, trawlers started deep sea fishing for prawns since 1999 and landed heavy catches of deep sea prawns comprising mainly of *Heterocarpus* spp. The average annual yield of deep sea shrimps during 1999-2000 was estimated at 23,426 t (Rajan and Nandakumar, 2001), which increased to 48,675 t during 2000-01 (Radhika and Kurup, 2005). However, their stock depleted within a very short span of four years (CMFRI, 2003). Sustainable exploitation of these important resources requires thorough knowledge on various dynamic forces acting on their population for which their stock needs to be assessed from time to time. *Heterocarpus woodmasoni* Alcock, 1901 is a commercially important deep sea prawn distributed along the southwest coast of India, Andaman Sea and Bay of Bengal. Information on age, mortality and population dynamics of some species of *Heterocarpus* are available (Dailey and Ralston, 1986; Roa and Ernst, 1996; Cessay, 2000). However, similar studies on Indian marine prawns are mainly confined to coastal penaeid shrimps (Lalitha Devi, 1986; Alagaraja *et al*., 1986; Rao, 1988; Suseelan and Rajan, 1989; Rao *et al*., 1993; Bhadra and Biradar, 2000) and solenocerid prawns (Chakraborty *et al*., 1997). The present account describes the stock characteristics and population dynamics of *H. woodmasoni* which constituted the exploited stock in commercial trawlers operated from 250 to 450 m off Kerala.

Material and Methods

Length measurements of 2114 males and 2641 females of *H. woodmasoni* (Family Pandalidae) of total length ranging from 54 to 143 mm and from 41 to 176 mm respectively were taken from commercial deep sea trawl landings at three centres (Sakthikulangara, Cochin and Munambam) along Kerala coast during monthly sampling surveys conducted from September, 2000 to August, 2002. Total length was measured from the tip of rostrum to the extremity of telson (Nandakumar, 1997). Length measurements were grouped into 10 mm class intervals, separately for males and females. The growth was estimated using von Bertalanffy growth formula (Bertalanffy, 1938). The growth parameters were estimated using the ELEFAN 1 programme in the FiSAT software (Gayanilo et al. 1996). The growth performance was estimated following Munro's PHI prime index, ϕ (Munro and Pauly, 1983). From the growth parameters, instantaneous rate of total mortality (Z) was estimated following length converted catch curve method of Gayanilo *et al*. (1996). Natural mortality coefficient (M) was estimated using Pauly's empirical formula (Pauly, 1980). FiSAT was used for working out probabilities of capture, relative yield per recruit (Y/R) and biomass /recruit (B/R). The exploitation rate (Beverton and Holt, 1957; Ricker, 1975) and exploitation ratio (Sparre and Venema, 1992) were also estimated. The optimum length of exploitation (l_{opt}) was estimated using the empirical equation of Froese and Binholan (2000).

Results

The total length of male *H. woodmasoni* ranged from 54-143 mm. Length groups from 60 to 140 mm dominated the catches and the modal length was found to be 97 mm. Females ranging from 40-180 mm TL were encountered in the present study and 60-140 mm size groups constituted the main catches with a modal length of 92 mm. The growth parameters of male and female of *H. woodmasoni* are given in Table 1. The growth equations for both sexes can be expressed as follows:

Table 1. Growth parameters of male and female *H. woodmasoni*

	Males	Females
L_∞ (mm)	160.59	188.0
K (per year)	0.82	0.60
t_0	-0.97	-0.96
Rn	0.265	0.343
Lmax (mm)	150mm	177mm
ϕ	4.33	4.33

The restructured length frequency data with superimposed growth curve fitted at the highest levels of Rn values in male and female *H. woodmasoni* are shown in Fig. 1a and b. The growth performance index (ϕ) (Pauly and Munro, 1984) of males and females was estimated as 4.33. The life span of males and females estimated using the equation tmax = 3/K (Pauly, 1983) was 3.66 years and 5.0 years, respectively. The lengths attained by males following VBGF equation at the end of I, II and III years were estimated at 91.51 mm, 130.16 mm and 147.19 mm respectively. The lengths of females at the end of I, II, III, IV and V years were estimated at 87.19 mm, 132.61 mm, 157.62 mm, 171.39 mm and 178.98 mm respectively. The estimated total mortality (Z) values in males and females were 4.58 and 5.57 per year

Males $L_t = 160.59\ [1 - \exp^{-0.82(t + 0.97)}]$

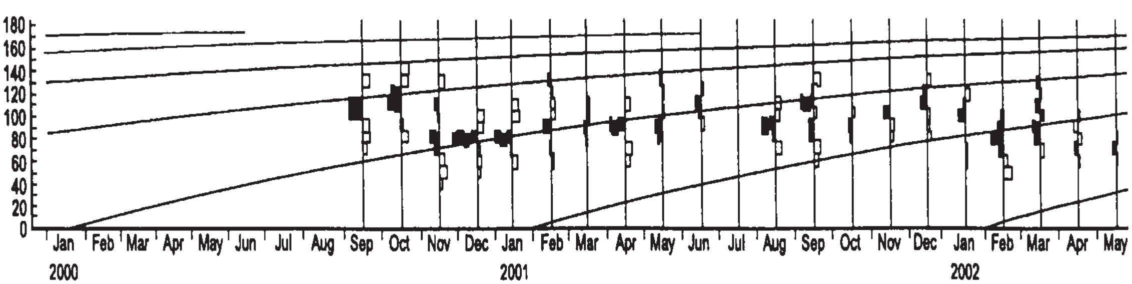

Fig. 1a. The restructured length frequency data with super imposed growth curve fitted at the highest levels of Rn values in male *H. woodmasoni*

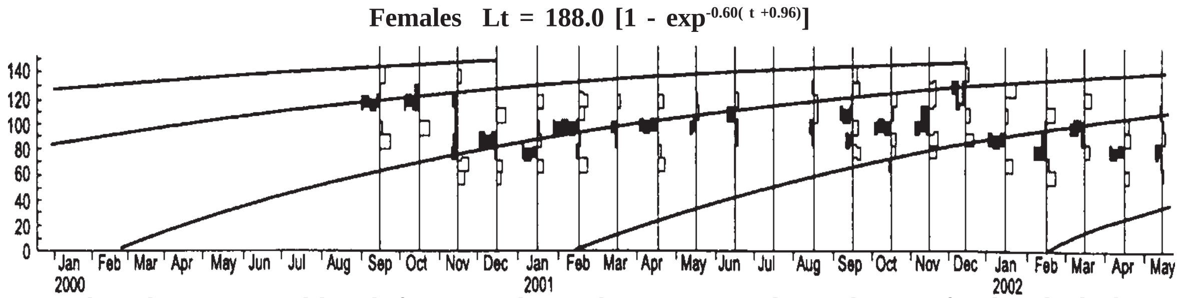

Fig. 1b. The restructured length frequency data with super imposed growth curve fitted at the highest levels of Rn values in female *H. woodmasoni*

respectively by using length converted catch curve method (Fig. 2a, b). The natural mortality coefficient (M) for males and females were estimated at 0.74 and 0.57 respectively. The fishing mortality in males and females were estimated at 3.84 and 5.00 respectively. The exploitation rate (U) in males was 0.83 while the exploitation ratio (E) was 0.84 whereas in females, the U and E values were 0.89 and 0.90 respectively. The optimum length of exploitation in males and females were estimated as 123 mm and 143 mm respectively.

The estimates of probabilities of capture and l_c values were worked out using the length converted catch curve method. The values obtained by probability of capture in males were l_{25} = 99.67 mm, l_{50} = 117.06 mm and l_{75} = 134.46 mm (Fig. 3a). The same values for females were l_{25}= 95.20 mm, l_{50} = 104.58 mm and l_{75} = 113.95 mm (Fig. 3b). These values were used as inputs for relative Y/R analysis. The L_{50}/L_{∞} and M/K used for the Y'/R analysis of *H. woodmasoni* were 0.73 and 0.90 for males and 0.56 and 0.95 for females, respectively. The relative yield per recruit and biomass per recruit using selection data for male and female populations of this species are depicted in Fig. 4a and 4b. In males, the yield per recruitment reached the maximum at an exploitation rate of 0.93 (E_{max}) and it decreased with further increase of exploitation rate. It could be noted that the present level in exploitation (0.84) is well within the optimum exploitation rate in male *H. woodmasoni*. The exploitation rate at which the marginal increase of relative yield per recruit is 1/ 10th of its value at E=0, the $E_{0.1}$ was estimated to be 0.851 while the exploitation rate at which the stock

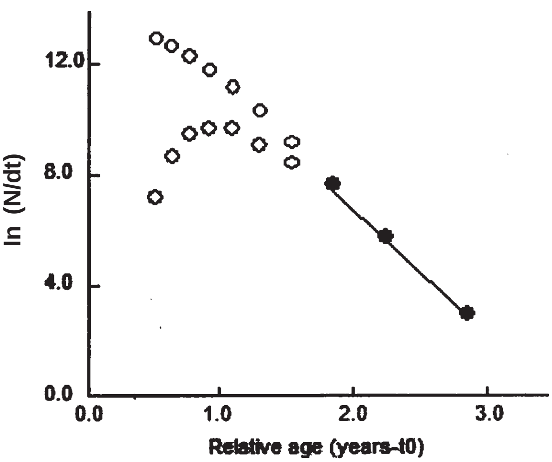

Fig. 2a. Length converted catch curve for estimation of Z of male *H. woodmasoni*

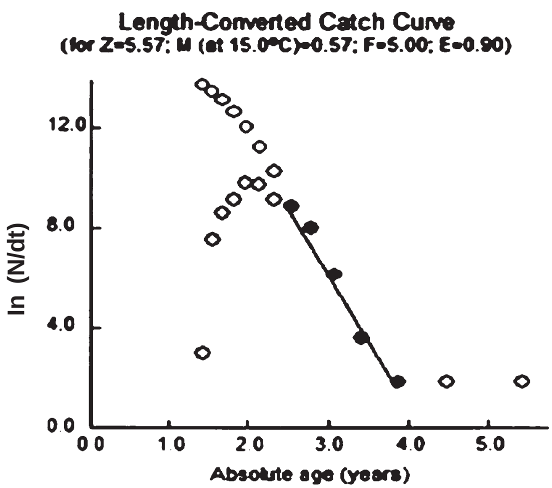

Fig. 2b. Length converted catch curve for estimation of Z of female *H. woodmasoni*

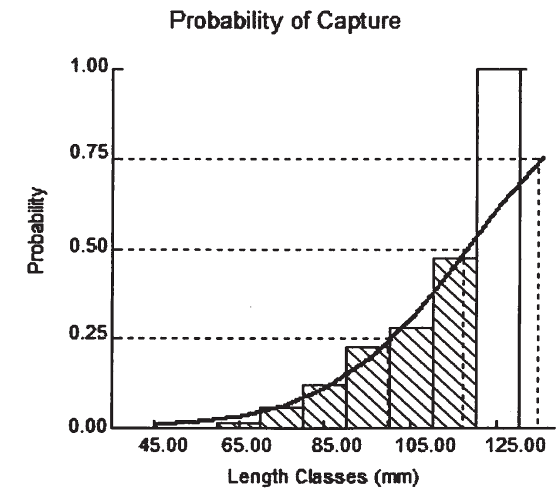

Fig. 3a. Probability of capture in male *H. woodmasoni*

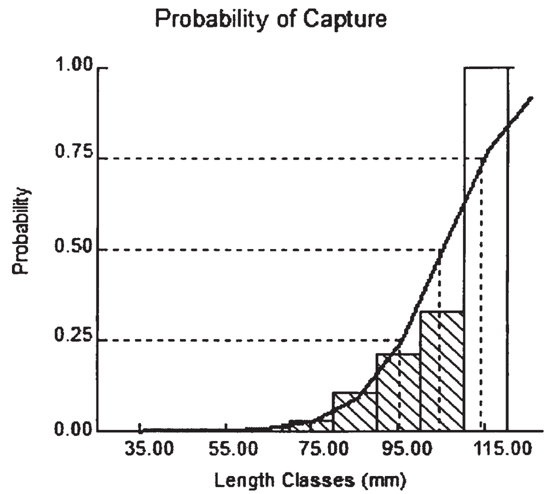

Fig. 3b. Probability of capture in female *H. woodmasoni*

would be reduced to 50% of its unexploited biomass, the $E_{0.5}$ was found to be 0.428. In contrast, the present level of exploitation in females (0.90) exceeded the optimum exploitation rate E_{max} 0.72 (Fig. 4b). The values of $E_{0.1}$ and $E_{0.5}$ for females were estimated as 0.606 and 0.382, respectively.

Results of the length converted cohort analysis revealed that in males and females, specimens in the length groups 50-60 mm and above were vulnerable to exploitation. However, heavy exploitation of length groups from 90 mm to 120 mm was quite discernible (Fig. 5a). In females also, the exploitation started from the length group 50-60 mm onwards which attained peak at 80 mm to 120 mm length groups. The fishing mortality showed a gradual increase up to 120 mm (Fig. 5b). The total stock (Y/U) is estimated as 5876 t and the MSY was estimated following the formula of Gulland (1965) as 2573 tonnes. Results of length based Thompson and Bell analysis conducted on pooled population of *H. woodmasoni* showed that MSY of 3104 t could be obtained by a reduction of 86% of fishing effort from the present level.

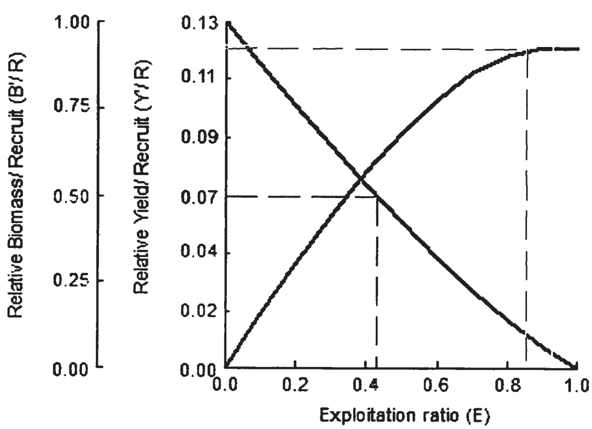

Fig. 4a. The relative yield per recruit and biomass per recruit using selection data in male *H. woodmasoni*; the declining line is B`/R and the asymptotic line is Y/R

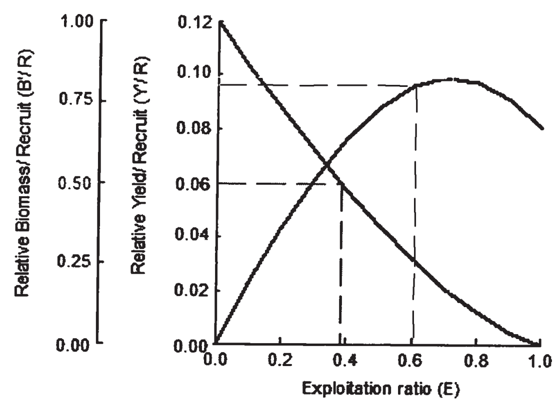

Fig. 4b. The relative yield per recruit and biomass per recruit using selection data in female *H. woodmasoni*; the declining line is B`/R and the parabola is Y/R

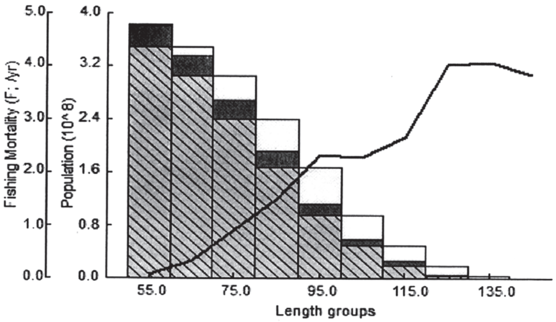

Fig. 5a. Length converted cohort analysis in male *H. woodmasoni*

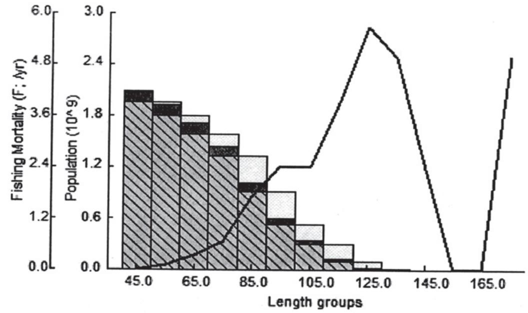

Fig. 5b. Length converted cohort analysis in female *H. woodmasoni*

Discussion

H. woodmasoni constitutes a major component of the exploited deep-water fisheries of Kerala in recent years. These shrimps have attracted considerable scientific interest mainly because of their export demand and reproductive strategy. The L_{max} recorded in the present study in both males and females of *H. woodmasoni* is much less than the estimated L∝. The L∝ value of males was lower compared to that of females. Higher L∝ of females has already been reported in other pandalid shrimps (Dailey and Ralston, 1986; Ohtomi, 1997; Colloca, 2002). In contrast, the growth coefficient of males was higher than that of females. According to Company and Sardá (2000), the growth coefficient values were in the range between 0.40 and 0.94 in 5 pandalid species namely, *Plesionika heterocarpus*, *P. edwardsii*, *P. giglioli*, *P. martia* and *P. acanthonotus* of western Mediterranean waters.

The results of the present study show that differential growth exists between males and females, especially from second year onwards when females grow faster than males, attaining larger length at age. After the initial retarded growth, the females attain 132.61 mm by the end of 2nd year while the males attain only 130.16 mm. The life span of males was estimated as 3.66 years and for females 5 years. The results agree with the findings of Roa and Ernst (1996) who estimated the average life span of *H. reedi* as 5 to 7 years with the females growing massive in size than males of the same length at later ages. The longevity of both males and females of *H. woodmasoni* were found to be two times more than that of the coastal shrimps. In view of their slow growth rate, it can reasonably be inferred that the time required for their recruitment to the usable stock will be at least two times more than their counterparts in the coastal waters. The life span of deep aristeid shrimp *Aristaeomorpha foliacea* was estimated to be about 7-8 years in females and 5-6 years in males from the northwestern Ionian Sea (D'onghia *et al*., 1998) and they showed a faster growth rate in the first two years which decreased sharply thereafter, registering very low growth rates in subsequent years. The growth performance index in the present study was worked out to be 4.3 for both the sexes of *H. woodmasoni* which indicated that they followed more or less the same growth pattern (Pauly and Munro, 1984). Availability of food and prevailing water temperature are the two main environmental factors affecting growth rates of deep sea prawns. The abundance of *H. woodmasoni* in Arabian Sea is strongly related to low temperatures ranging from 10.5^0C to 14^0C. The slower growth rates observed in the present study can well be attributed to the low water temperature prevailing in the deeper waters.

Between the two sexes studied, fishing mortality was higher in females. The mortality due to fishing (F) far exceeded the natural mortality, which is indicative of heavy exploitation level of *H. woodmasoni*, especially in female population. M/K ratio for both the sexes was found to be within the limits of 1 to 2.5 as suggested by Beverton and Holt (1959). The sex ratio analysis of the exploited stock of *H. woodmasoni* indicated that the females were represented far in excess of males, 1:1.62 and 1:2.04 in the first and second years respectively (Radhika and Kurup, 2005). Furthermore, peak occurrence of berried females could also be encountered coinciding with the peak fishing season. Higher level of exploitation ratio of females nearing optimum exploitation levels may thus be justified. The modal size group in the fishery revealed the dominance of size group 90-100 mm in both the sexes of *H. woodmasoni* and the size at first maturity of male and female were worked out at 96.75 mm and 100 mm respectively (Radhika and Kurup, 2005). The length cohort analysis also showed very high fishing mortality in 90-120 mm length groups. This finding clearly shows that the entire population does not get a chance to reproduce even once during their lifetime. The exploitation of these new deeper water resources must be carefully developed; taking into consideration that deep water species can generally withstand only low levels of exploitation in terms of long term sustainable fishery (Colloca, 2002).

The results of Y/R analysis revealed higher exploitation of female population which exceeded optimum exploitation levels. This could be because of larger size ranges of females especially from second year onwards as they cannot escape from the gear in contrast to the smaller sized males. Amin *et al*. (2009) also suggested that higher exploitation rate of females could be due to their larger body sizes when compared to males. It may also be noted that the males are also fast approaching optimum exploitation rates. It would thus appear that the stock of male and female *H. woodmasoni* is prone to the threat of both growth and recruitment overfishing as defined by Pauly (1982) and may collapse in near future unless the fishing effort is judiciously regulated at optimal levels giving due emphasis to maximum sustainable yield. The average annual landings of this species in Kerala coast was estimated at 5147 t (Radhika and Kurup, 2005) which clearly exceeded the MSY estimates. It is also found imperative to enact legislation and conservation measures to protect this stock from the risk of overexploitation very soon. In view of the fact that the smaller size classes were prone to intense exploitation, a closed season during the recruitment period together with the enforcement of statutory mesh size of 35mm for bottom trawling shall be implemented as the immediate measure of conservation for the sustenance of the stock of deep sea prawns off Kerala coast.

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