Indian J. Fish., 61(4) : 10-17, 2014

Fishery and biology of *Plesionika quasigrandis* Chace, 1985 off Sakthikulangara, south-west coast of India

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ABSTRACT

The fishery and biology of *Plesionika quasigrandis* Chace, 1985 from Sakthikulangara Fishing Harbour was studied for the period 2006-2008. The average annual catch was 2400 t, forming 28% of the total deep sea shrimp landings at Sakthikulangara. August to November was the most productive period in terms of catch and catch rate. The growth parameters L_∞ and K y^{-1} for males and females were 124 mm, 0.7 and 130 mm, 0.8 respectively. The growth performance index (φ') and t_0 were 4.032, -0.0036 and 4.131, -0.00275 for males and females, respectively with a longevity of 5 years. Recruitment pattern was bimodal with two peaks, one in March and the other in June. The relationship between total length (TL) and total weight (W) revealed an isometric growth in case of females and allometric growth in males. The length at recruitment (L_r) and length at 50% capture (L_{c50}) was 73; 84.8 mm (males) and 78; 93.4 mm (females), respectively which corresponded to an age (t_c) of 1.6 years. The natural mortality, fishing mortality, total mortality, exploitation ratio, exploitation rate and E_{max} were 0.81, 2.14, 2.95, 0.62, 0.72, 0.90 and 0.88, 2.97, 3.85, 0.71, 0.77, 0.93 for males and females, respectively. The rate of exploitation for *P. quasigrandis* was found to be lower than the E_{max} which indicates sustainable utilisation of the resource.

Keywords: Fishery, Growth, Mortality, *Plesionika quasigrandis*, Population dynamics

Introduction

The past decade has witnessed the occurrence of deep sea shrimp resources along the south-west and south-east coast of India. In Kerala, deep sea shrimps are landed at Sakthikulangara Fishing Harbour (60%), Cochin Fisheries Harbour (11%), Vypeen Fish Landing Centre (24%) and a minor quantity at Munambam Fishing Harbour. Based on the data collected from Sakthikulangara Fishing Harbour during 2006-08, the age, growth, mortality and stock of the deep sea shrimp, *Plesionika quasigrandis* was assessed. An area of 3300 sq. km lying between Quilon and Alapuzha, popularly known as 'Quilon Bank' located off Sakthikulangara between lat. 8°51'N and long. 76° 30'E was found to be a rich ground for deep sea shrimps and lobsters, where trawling operations were carried out at a depth of 200-400 m (Rajan *et al*., 2001). The deep sea shrimp landings at Sakthikulangara Fishing Harbour forms 20% of the total shrimp landings of Kerala which is constituted by deep sea penaeid (41.4%) and deep sea non-penaeid (58.6%) shrimps. The genus *Plesionika* is the most abundant in the family, which includes about 92 species (De Grave and Fransen, 2011), all of which are edible and have economic value. Among these 92 species, 11 are so far identified from Indian waters. Besides *P. quasigrandis* Chace, 1985 which was earlier misidentified as *P. spinipes* (Spence Bate, 1888); *Plesionika martia* (A. Milne Edwards, 1883), *Plesionika ensis* (A. Milne-Edwards, 1881), *Plesionika adensameri* (Balss, 1914), *Plesionika alcocki* (Anderson, 1896), *Plesionika bifurca* Alcock and Anderson, 1894, *Plesionika longicauda* (Rathbun, 1901), *Plesionika ocellus* (Bate, 1888), *Plesionika sindoi* (Rathbun,1906), *Plesionika unidens* Bate, 1888 and *Plesionika williamsi* Forest, 1963 are the other species identified from India, which are not known to form a sizeable portion of any commercial catch. The other common species of shrimps representing the deep sea non-penaied catch are *Heterocarpus woodmasoni* (14%), *Heterocarpus gibbosus (17%)* and *P. martia (0.6%)* and the rest of the catch is composed of deep sea penaeid shrimps. The pandalid decapod crustacean *Plesionika spinipes (=quasigrandis*) commonly found along the south-west coast has been recorded from 250 to 400 m depth (Rekhadevi and

Nandakumar, 2012) and contributes maximum to the non-penaied shrimp landings (Jayaprakash *et al*., 2006). Earlier studies on deep sea shrimp distribution from exploratory cruises have reported the abundance of deep sea shrimps from Arabian Sea (Suseelan, 1985, 1990 Suseelan *et al.,* 1989a, b), Kakinada (Lalitha devi, 1980), Gulf of Mannar, off Mandapam (Thomas, 1979), off Kerala (Kurup *et al*., 2008) and Tamil Nadu and Pondicherry (Thirumulu and Rajan, 2003); Silas (1969) and Mohamed and Suseelan (1973) have given general accounts of the distribution and relative preponderance of common species of shrimps in the continental shelf-edge and upper continental slope of the south-west coast of India. Along the Barents Sea, investigations indicated abundance of deep sea shrimp in areas with temperature between -1^oC and 7^oC (Nedreaas and Oynes, 1986). Few more studies on deep sea shrimps include food and feeding analysis of *H. gibbosus* and *H. woodmasoni* (Radhika, 2004) and *Penaeopsis jerryi* (Kurian, 1965). Although *P. quasigrandis* is considered a targeted resource showing increasing trend of exploitation, there is scarcity of information on fishery, biology and population dynamics of this species and hence the present study was conducted.

Materials and methods

The biological data pertaining to *P. quasigrandis* in the present study was collected fortnightly from Sakthikulangara Fishing Harbour (08° 56' N; 76° 32' E) for the period 2006-2008. The specimens were identified up to species level using FAO Species Catalogue (Fischer and Bianchi, 1984). Samples collected at random on each day of observation were analysed for sex, length and berried condition of females. Each sample consisted of around 150-200 specimens and lengths were grouped into 5 mm class intervals. Most of the specimens were separated with respect to their ovigerous or non-ovigerous condition, and were subsequently counted. The total length (TL) *i.e.,* the length of the specimen from the tip of the rostrum to the end of the telson was recorded to the nearest mm and body wet weight (W) of each shrimp was recorded to the nearest g using electronic weighing balance. From the non-ovigerous samples (mixture of females and males), sex determination was performed based on presence/absence of appendix masculina on the endopod of the second pleopod. The length-weight relationship of *P. quasigrandis* was calculated as $W=aL^b$ (Le Cren, 1951) for both sexes separately and difference between the slopes of the regression lines of males and females were tested by ANCOVA (PAST, Version 2.11).

Length data were grouped into 5 mm length groups. The monthly length frequency of *P. quasigrandis* was analysed using the FiSAT computer program. The parameters of von Bertalanffy's growth function (VBGF), asymptotic length (L_∞) and growth coefficient (K) were estimated using ELEFAN-1 routine in FiSAT-II software. K scan routine was conducted to assess a reliable estimate of the K value (Pauly and David, 1981). The VBGF was fitted to estimate the length at age curve using nonlinear squares estimation procedures. The VBGF is defined by the equation: $L_t = L_\infty (1-e^{-k\ (t-t0)})$ (von Bertalanffy, 1960).

An additional estimate of L_∞ and Z/K values obtained using the Powell Wetherall plot (Gayanilo *et al*., 1996) was compared with that obtained from ELEFAN I before arriving at final values. Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980), taking the mean sea surface temperature (20$\pm$1^0C) (Selvaraj *et al*., 2005) and total mortality (Z) calculated from length converted catch curve (Pauly, 1983) using FiSAT –II software. Fishing mortality (F) was estimated as F = Z - M. Exploitation rate was estimated from the equation, E = F/Z and exploitation ratio from $U = F/Z*(1-e^{-z})$. E_{max} was calculated from Beverton and Holt yield per recruit analysis (FiSAT-knife edge selection) by using different values of E on the X-axis and relative yield per recruit and biomass/recruit (Y'/R and B'/R) values on Y-axis with the input values of size at first capture (L_c/L_∞) and M/K ratio. The mid point of the smallest length group in the catch was taken as length at recruitment (L_r). The recruitment pattern was studied from recruitment curves using final estimated values of L_∞, K and t_0. The value of asymptotic weight (W_∞) was derived from the value of L_∞ using the estimated length-weight relationship.

For estimating fecundity, eggs attached to the protopods of the specimens (n=35) were separated carefully and full weight of berry was recorded. A sub-sample was weighed, colour of eggs recorded, and the number of eggs present was counted. Fecundity was calculated using the formula: Fecundity (F) = Log Y (Fecundity) = a + b Log X (carapace length).

Results

Fishery

During 2006-2008, deep sea shrimp landings constituted an average of 8,571 t consisting of both penaeid (40%) and non-penaeid shrimps (60%) which showed a declining trend (Fig.1). The major component of deep sea non-penaeid catch comprised of *P. quasigrandis* (28%)

which hovered initially around 3,058 t (42%) during 2006, showed a declining trend to 2,581 t (63%) in 2007 and then showed a steep fall to 1,564 t (45%) in 2008 (Fig. 2). The catch rate of *P. quasigrandis* fluctuated over the years with the maximum of 14.1 kg h^{-1} in 2008 and minimum of 10.63 kg h^{-1} in 2007 while the catch was found to be maximum during 2006 with 3,058 t. The average highest monthly catch of 536 t was recorded in October while catch per unit effort (CPUE, 2.1 kg h^{-1}) was found to be maximum during September. Deep sea shrimp landings were observed during October to May, while the most productive period was during November to December and at times February and March also accounted for very good catches.

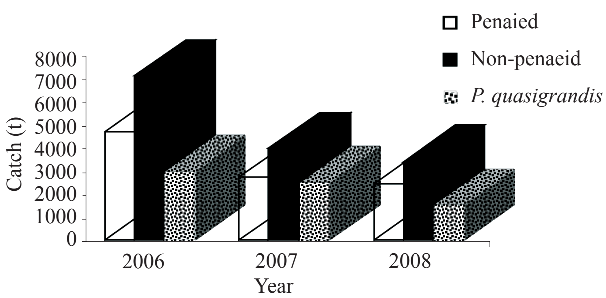


Fig. 1. Deep sea shrimp landings (t) at Sakthikulangara Fishing Harbour during 2006-2008

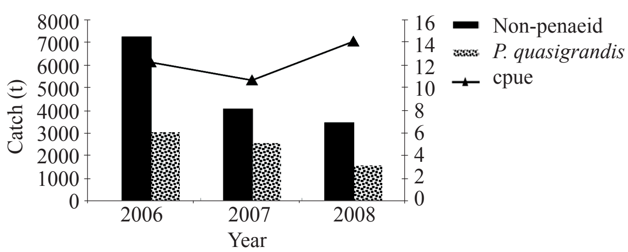


Fig. 2. *Plesionika quasigrandis* landings (t) and CPUE (kg h^{-1}) at Sakthikulangara Fishing Harbour during 2006-2008

Length frequency

In general, size of the females ranged from 78 to 123 mm with the mode at 98 mm while the males ranged from 73 to 113 mm with a dominant mode at 88 mm. However, there were slight variations in the size range and mode in different years. The size ranges of females were 78 to 118 mm with a major mode at 85-90 mm in 2006 and 2007, but during 2008 both size class and mode were at higher length groups of 78-123 mm and 95-100 mm, respectively. In case of males, size range (73-113 mm) and mode at 85-90 mm was observed in all the years except for a higher modal class (91-95 mm) in 2008.

Length -weight relationship

The length-weight relationship of females and males were as follows:

Female : $W = 0.004564\ L^{3.01}$ (r=0.92)

Male : $W = 0.003204\ L^{3.11}$ (r=0.94)

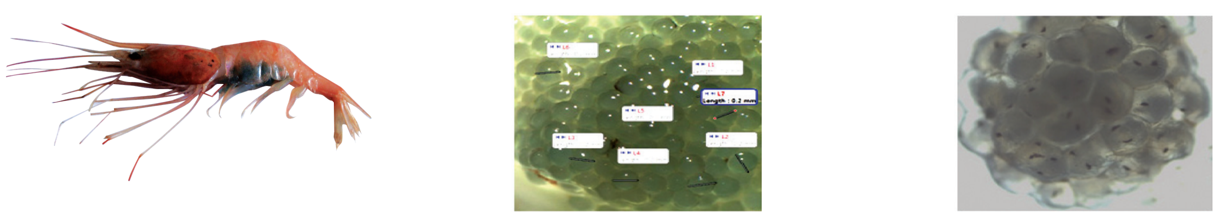
where W' is the weight in grams and 'L' is the length in centimeter. In the present study, the log transformed data was used for the analysis and the results revealed females having isometric growth (b=3) while males showed a positive allometric growth (b>3) and b value differed significantly from 3 (t-test, p>0.05).

Sex ratio

The sex-ratio did not deviate significantly (Snedecor and Cocharan, 1967) from 1:1 although tilted in favour of females (1:1.3) during 2006-2008. The chi-square values indicated significant ($p<0.05$) dominance by females. Dominance of females was found to increase gradually with a ratio of 1:1.3 (2006), 1:1.4 (2007) to 1:1.5 (2008). The percentage of berried females varied from 17 to 21 with an average of 20 during the period with 75% of berried females during April, October and November. Sex-ratio specific to size showed that females out numbered males in particular size range from 91-105 mm while males dominated in the size range of 81-100 mm.

Fecundity

The relative fecundity in *P. quasigrandis* ranged from 1630 to 17376 for the specimens weighing about 2.8 to 7.5 g. The average width of the egg was found to be 0.2 to 0.3 mm, (Fig. 3a). Eggs were oval in shape with bluish green colour in the freshly acquired berry



(a) (b) (c)

Fig. 3. (a) Deepsea shrimp *Plesionika quasigrandis* with greenish blue eggs; (b) Fresh berry before eyestalk development; (c) Formalin preserved eggs after eye stalk development

while the colour was found to fade away gradually and became dull white when the eye spots of the embryo were clearly visible to the naked eye. Length and width of ova were found to increase as the development advanced (Fig. 3b, c).

Log Y (fecundity) = 0.007634 + 4.44 Log X (carapace length) ($r = 0.614$, $n = 35$, $p<0.05$).

Estimation of growth parameters

Growth parameters of von Bertalanffy's growth equation for *P. quasigrandis* was estimated separately both for females and males as $L_\infty = 130$ mm, $K = 0.8\ y^{-1}$ and $L_\infty = 124$ mm, $K = 0.7\ y^{-1}$ respectively.

Size frequency data collected for the samples were plotted by von Bertalanfy's growth frequency curve and progression of monthly modes were traced by a smooth growth curve using FiSAT-ELEFAN I (Fig. 4). The lengths thus obtained for 1, 2 and 3 year old males in respective periods were 62.4, 93.4 and 109 mm where as, the size of females were 71.6 mm, 103.8 mm and 111.8 mm, respectively. The length at first capture (L_{c50}) for females and males was estimated at 93 mm and 85 mm, respectively which corresponds to an age (t_c) of 1.6 years. The asymptotic weight (W_∞) estimated from

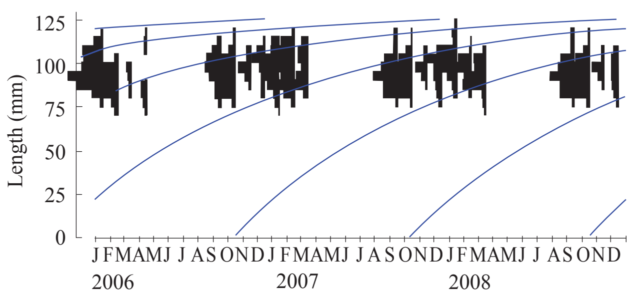


Fig. 4. von Bertalanffy growth curves for *P. quasigrandis* during 2006-2008

the length-weight relationship was 7.98 and 10.05 g for males and females, respectively. The growth performance index, φ' was 4.032, 4.131 and t_0 was calculated at -0.0036 and -0.0028 years for males and females, respectively. The von Bertalanffy's growth equation for male was $L_t = 124\ [1 - e^{-0.7\,(t + 0.0036)}]$ and $L_t = 130\ [1 - e^{-0.8\,(t + 0.0028)}]$ for female.

Estimation of mortality and exploitation

The estimated mortality parameters *viz*., natural mortality (M), fishing mortality (F) and total mortality (Z) for males and females were 0.81, 2.14, 2.95 and 0.88, 2.97, 3.85 respectively. According to Sparre and Venema (1992), the fishes with moderate K values show moderate natural mortality, and it is related to age and size of the fish. K values for male and female in the present study were 0.7, 0.8 y^{-1} and the corresponding M values were 0.81, 0.88 respectively. Hence, the M/K ratio for male was 1.1 and female it was 1.15. Exploitation rate (E), exploitation ratio (U) and E_{max} were found to be 0.72, 0.62, 0.90 for males and 0.77, 0.71, 0.93 for females (Fig. 5a and b). The rate of exploitation for both male (0.72) and female (0.77) was found to be lower than the E_{max} obtained from the selection curve, indicating the resource, is not over-exploitated.

Recruitment pattern

Results of the analysis of recruitment pattern of *P. quasigrandis* during the study period are shown in Fig 6. There are two recruitment peaks throughout the year, one around March and the other around June. The highest (13.79%) and lowest (4.78%) percentage of recruitment was observed in the months of June and January. The smallest length at recruitment (L_r) was 7.3 cm.

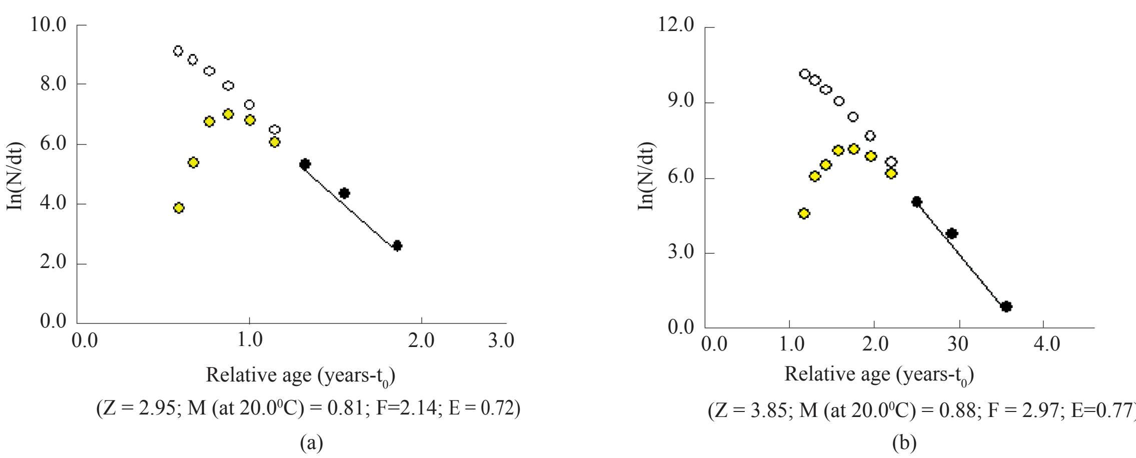


Fig. 5. Mortality of *P. quasigrandis* landed at Sakthikulangara Fishing Harbour during 2006-2008 (a) Male and (b) Female

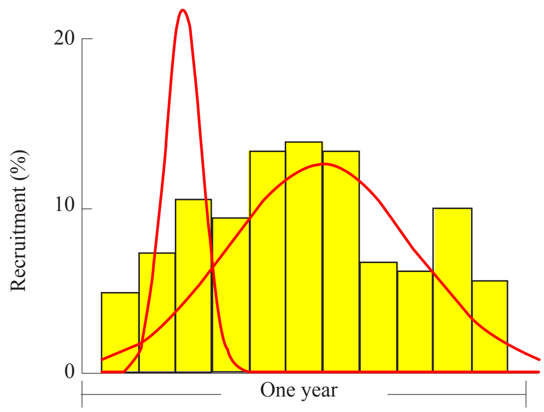


Fig. 6. Annual recruitment pattern of *Plesionika quasigrandis*

Virtual population analysis (VPA)

Results of the *VPA* using the length frequency data showed that fishing mortality (F) was maximum in the size group of 103-118 mm (Fig. 7). At fishing mortality of 0.01 to 1.8 highest numbers were caught.

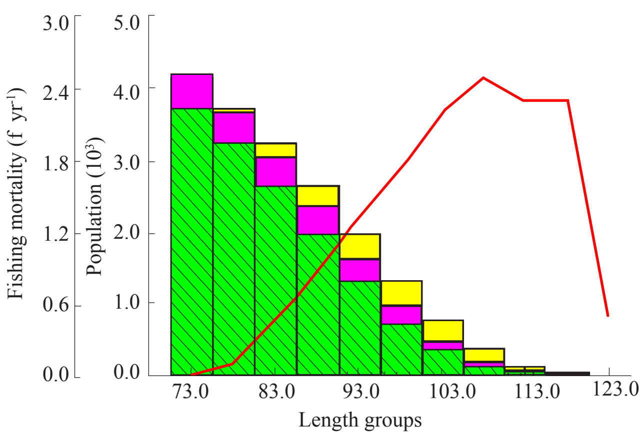


Fig. 7. Length - structured virtual population analysis of *Plesionika quasigrandis* during 2006-2008

Relative yield per recruit (Y/R) and biomass per recruit (B/R)

The estimates of probabilities of capture and L_c values were worked out using length converted catch curve method. The values obtained by probability of capture in males were: L_{25}= 82.68 mm, L_{50} = 84.8 mm and L_{75} = 87.34 mm (Fig. 8a). The same for females were: L_{25}= 91 mm, L_{50} = 93.4 mm and L_{75} = 96.20 mm (Fig. 8b). These values were used as inputs for relative yield per recruit (Y/R) analysis. The L_c/L_∞ and M/K values used for Y'/R analysis of *P. quasigrandis* were 0.68 and 1.15 for males and 0.71 and 1.1 for females, respectively. The relative yield per recruit and biomass per recruit using selection data for male and female population of this species are depicted in Fig. 9a and b. In *P. quasigrandis*, the yield per recruit reached the maximum at an exploitation rate of 0.92 and it decreased with further increase of exploitation rate. The present level of exploitation (0.72) is well within the optimum exploitation rate in male *P. quasigrandis*. The $E_{0.1}$, *i.e.* the exploitation rate at which the marginal increase of relative yield per recruit is $1/10^{th}$ of its value at E=0, was estimated to be 0.81 while $E_{0.5}$, *i.e.* the exploitation rate at which the stock would be reduced to 50% of its unexploited biomass, was found to be 0.41. Similarly, the present level of exploitation in females (0.77) was also within the optimum exploitation rate and $E_{0.5}$ was 0.42.

Discussion

Saktikulangara is one of the leading fishing centers in the country and enjoys a unique position both in inshore and deep sea fishery, in the shrimp fishing map of Kerala. Fishery of deep sea shrimp in general occurs from October to March with two major peaks during February and October. Rajan *et al*. (2001) observed best landings during December followed by February and

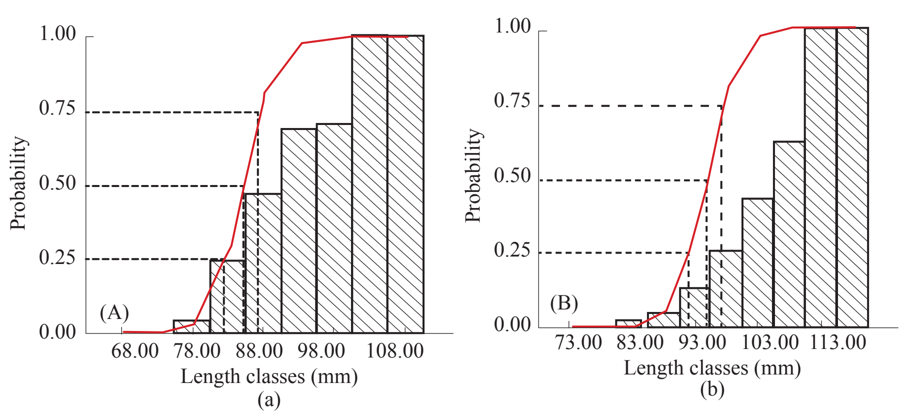


Fig. 8. Probability of capture in *Plesionika quasigrandis*; (a) Male and (b) Female

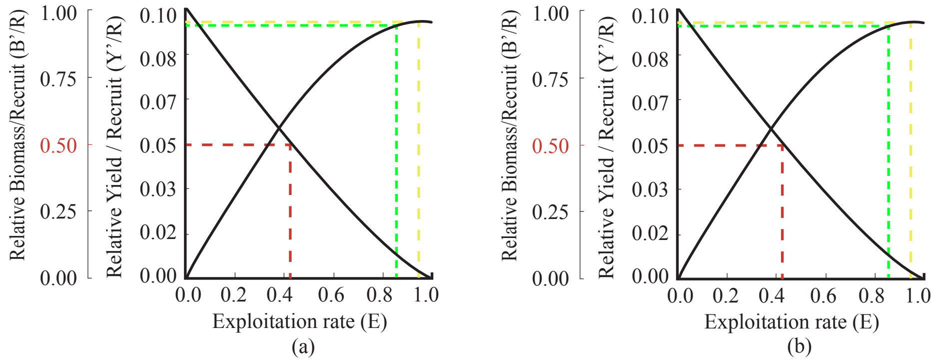


Fig. 9a. Relative yield/recruit and biomass/recruit (knife-edge selection) in *Plesionika quasigrandis*; (a) Male; (b) Female

March. Although more than a dozen species of shrimps often occur in the deep sea catches, only five of them representing the family Pandalidae namely *Heterocarpus woodmasoni, H. gibbosus, Plesionika spinipes, P. martia* and *P. ensis* constitute the bulk of the catches (Suseelan, 1974). In the present study, *P. quasigrandis* (28%) formed a major species in the deep sea shrimp catch followed by *H. gibbosus* (16%) and *H. woodmasoni* (14%). The average annual catch of *P. quasigrandis* for the period 2006 – 2008 was 2400 t forming nearly 28% of the total deep sea shrimp catch and these observations were found to be almost similar to the deep sea catch (2,260 t) with *P. spinipes* (=*quasigrandis*) amounting to 28% during 2001 (Rajan *et al.*, 2001) and in 1999-2011 and in 2011 (Radhika *et al*., 2011). *P. spinipes* (=*quasigrandis*) was also the principal species in exploratory surveys and in the commercial deep sea shrimp landings (19-40%) during 2001-2002 (Radhika and Kurup, 2005) at a depth of 200-400 m. However during 1999-2000, *H. gibbosus* formed the dominant (37%) species. Suseelan (1974) reported the presence of *P. spinipes* (=*quasigrandis*) in 226-250 m while it continues to be the main constituent in the catches at depth 251-275 m. Current study showed different size ranges for females (78-123 mm) and males (73-113 mm) with a mode at 98 mm and 88 mm, respectively. Earlier studies from this area reported slightly higher size ranges for males (63-115 mm) and females (75-125 mm) (Suseelan, 1974 and Rajool shanis *et al*., 2012). However in the recent past, slightly lower size ranges were reported for males (71-120 mm) and females (76-120 mm) (Rajan *et al.,* 2001). In this study, females (1.3) outnumbered males throughout the period of observation with 70% of berried females occurring during December to March. Similar results were recorded by Rajan *et al.* (2001) in the shrimp catches off Cochin, while Suseelan (1974) observed dominance of females during October-December. As opined by Kurup and Rao (1974) the dominance of females in the present study may be due to differential growth. Total length and wet weight relationship for each sex suggest an isometric growth in females while a positive allometry was noted in males. Coefficients of correlation showed high values ranging from 0.92 to 0.94, indicating a strong relationship and degree of predictability between the total length and the wet weight of shrimps.

The modal progression analysis provided different values of L_∞ (120 mm and 115 mm, respectively, for females and males) and growth co-efficient (K) was found to be 0.9 for both sexes. Since the value of L_∞ obtained for females was less than the observed size of 125 mm, new values of K y^{-1} (0.7 for male and 0.8 for female) were calculated according to Taylor (1962), who considered that the maximum observed size is 95% of the L_∞. Based on the phi prime index (φ'= log k + 2 log L_α), females of *P. quasigrandis* seems to have higher growth rates than males. Similar observations were made for *P. narval* from the Canary Islands (Gonzalez *et al*., 1997). Sparre *et al.* (1989) pointed out that species within the same family have similar phi prime values, and found that these values are normally distributed. This goes in agreement with the values of growth performance index (φ) as 4.33 for *H. woodmasoni* (Pandalidae) from south-west coast of India (Radhika *et al.,* 2011).

Fertilised eggs attached to the ovigerous setae were found on the inner edge of the protopods of the pleopods 1 to 4. The endopods and exopods did not carry eggs and they project freely from the egg mass. This species appeared to be a continuous breeder as ovigerous females were observed in the catches throughout the year and variation in the colour of the berry was noted as development advanced. However, the percentage of berried individuals showed fluctuations in different months. Similar observations were made by Suseelan and Mohamed (1968) and Suseelan (1974). Gonzalez *et al*. (1997) reported the decline of ovigerous females with increasing depth in *P. narval* which could be a protandrous hermaphrodite species, as has been reported for a large number of other pandalids (King and Moffitt, 1984).

The results of the present study conclude that the rate of exploitation for *P. quasigrandis* is lower than the E_{max} obtained from the selection curve, indicating the resource is not over-exploitated.

Acknowledgements

The authors express their gratitude to Dr. G. Syda Rao, former Director, CMFRI, Kochi. for the facilities provided and encouragement. Thanks are also due to Dr. E. V. Radhakrishnan, Principal Scientist and former Head, Crustacean Fisheries Division for the guidance and valuable suggestions. We also gratefully acknowledge Fishery Resources Assessment Division of the Institute for providing us the data on landings of shrimps by trawlers from Sakthikulangara and Neendakara fishing harbours.

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Date of Receipt : 08.08.2013
Date of Acceptance : 02.07.2014