Indian J. Fish., 60(2) : 7-12, 2013

Fishery and population dynamics of the sand lobster *Thenus unimaculatus* (Burton & Davie, 2007) landed by trawlers at Sakthikulangara Fishing Harbour in the south-west coast of India

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ABSTRACT

The average annual landing of *Thenus unimaculatus* from trawlers at Sakthikulangara during 2005-2010 was 19 t forming 0.73% of the total marine fish landings. Males slightly outnumbered females in the catch (1:0.9) and peak fishery was observed from November to February. Total length varied between 61-230 mm in males and 46-250 mm in females. Length at recruitment (L_r) was 48 mm. Carapace length-weight relationship was not significantly different (p>0.05) between the sexes, The parameters of the length-weight relationship were estimated as: a = 0.00237, b = 2.64, r^2 = 0.95 for males and a = 0.00156, b = 2.758, r^2 = 0.96 for females. Growth parameters estimated by von Bertalanffy's growth equation were: L_∞ = 240 mm, K (monthly) = 0.042 for males and L_∞ = 260 mm, K (monthly) = 0.05 for females. Exploitation rate was found to be higher in males (0.86) than in females (0.78). The length at 50% capture (L_{c50}) was 147 mm for males and 153 mm for females which corresponded to an age (t_c) of 1.9 and 1.6 years, respectively. Absolute fecundity varied from 14750 to 33250 mature eggs.

Keywords: Carapace length, Growth, Mortality, Sand lobster, *Thenus unimaculatus*

Introduction

In the last 30 years, tremendous research has been done on various aspects of lobster biology which focused primarily on clawed and spiny lobsters. Despite the extensive body of research concerning palinurid and nephropid lobsters (Cobb and Phillips, 1980), scyllarid lobsters, encompassing over 70 species, have been given little importance. Biological research has been limited and in most instances has dealt with species of some economic importance (Ben-Tuvia, 1968).

Thenus is the only genus in 7 scyllarid genera that is economically significant (Jones, 1990). Species of this genus contribute to many of the demersal trawl fisheries which operate along the tropical coasts of the Indian Ocean and the Western Pacific region (Ivanov and Krylov, 1980) and are becoming commercially exploited species (Department of Fisheries 1997; FAO, 2010). The species in India was described earlier as *Thenus orientalis* (Chhapgar and Deshmukh, 1964). On re-examination of the species along the Indian coast based on the morphological and molecular characteristics, the species was found to be *T. unimaculatus* (Burton and Davie, 2007; Jeena *et al*., 2011). In India, although *T. unimaculatus* is landed all along the coast, it forms an important fishery only along the north-west and south-east coasts. It is commonly known as sand lobster, slipper lobster or shovel-nosed lobster. Sand lobsters are bottom dwellers and prefer sandy and muddy habitats of 10-50 m depth (Uraiwan, 1977; Jones, 2007; FAO, 2010).

Landing reports in India available on this species date from the present to nearly six decades ago (Alikhuni, 1948; Prasad and Tampi, 1960; Chhapgar and Deshmukh, 1964; Hossain, 1978; Radhakrishnan *et al*., 1995). Although commercial exploitation of sand lobsters in India began in the 1960s, demand and good price for the species in the export market has risen only in the recent past. These lobsters are increasingly targeted by commercial fishery operations and biological understanding of these animals is the need of the hour to have sustainable management schemes which ensure the survival of sand lobster stocks. The present study is based on the landings of *T. unimaculatus* from trawlers operating off Sakthikulangara Fishing Harbour during the period 2005-2010.

Materials and methods

Data on catch and effort expended for *T. unimaculatus* landings at Sakthikulangara Fishing Harbour were collected fortnightly from trawls for a period of six years from January 2005 to December 2010. Samples collected at random on each day of observation were analysed for sex, length and maturity stages including berried condition of females. Each sample consisted of around 150-200 specimens and lengths were grouped into 5 mm class intervals. A total of 3292 males in the size range of 61-230 mm and 2775 females in the size range of 46-250 mm were measured for their total length (TL), which is the distance between the notch in the carapace in front and the posterior margin of the telson behind and carapace length (CL), which is the distance between the notch in front and the posterior margin of the carapace behind. For decapod crustaceans, the carapace length is deemed to be a more consistent measure than the total length (Farmer, 1986). Hence, in the present study, carapace length was used for all the analysis.

The length-weight relationship of *T. unimaculatus* was calculated as $W = aCL^b$ (Le Cren, 1951) for both sexes separately and difference between the slopes of the regression lines of males and females were tested by ANACOVA (PAST, Version 2.11).

For estimating fecundity, eggs attached to the pleopods of the specimens (n=48; 61-84 mm carapace length) were separated carefully and full weight of berry was recorded. A sub-sample was weighed and the number of eggs present in it was counted and fecundity was calculated using the formula *i.e.*, fecundity (F) = log Y (fecundity) = a + b log X (carapace length).

For estimating von Bertalanffy growth parameters, L_∞ and K, the month-wise length composition data of four years (2006-2009) were pooled and grouped with 5 mm class interval and analysed using the ELEFAN I module of FiSAT software version 1.2.0 (Gayanilo *et al.*, 1994). 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 the final values. Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980), taking the mean sea surface temperature (28 ± 1 ^{0}C) (Selvaraj *et al.*, 2005) and total mortality (Z) calculated from length converted catch curve (Pauly, 1983b) using FiSAT software. Fishing mortality (F) was estimated by F = Z – M. Exploitation rate was estimated from the equation, E = F/Z and exploitation ratio from $U = F/Z*(1-e^{-z})$ where, F is the fishing mortality rate. 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 & B/R) values on Y-axis with the input values of size at first capture (L_c/L_∞) and M/K ratio.

Growth performance index (φ) was calculated from the final estimates of L_∞ and K (Pauly and Munro, 1984). The probability of capture and size at first capture (L_c) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's (1979) empirical equation, Log ($-t_0$) = - 0.392 - 0.275 Log L_∞ - 1.038K. Growth and age were determined using the von Bertalanffy growth equation, $L_t = L_\infty (1-e^{-k(t-t_0)})$. The mid point of the smallest length group in the catch was taken as length at recruitment (L_r). Longevity was estimated from $t_{max} = 3/K + t_0$ (Pauly, 1983a). The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated from Beverton and Holt Yield per Recruit model (Beverton and Holt, 1957).

Results

Fishery

The average annual catch of *T. unimaculatus* during 2005–2010 was 19 t, forming 0.73% of the total marine fish landings at Sakthikulangara. The catch, which hovered initially around 13 t during 2005, increased moderately to around 32 t during 2008 with a sharp dip during 2009 (17 t) and finally to a catch of 12 t in 2010 (Fig. 1).

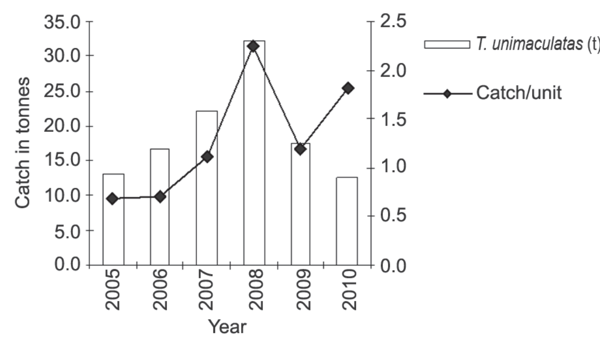

Fig. 1. *Thenus unimaculatas* landings (tonnes) at Sakthikulangara Fishing Harbour during 2005-2010

The species formed 0.48% of annual trawl landings in 2005 and 1.16% in 2010. The effort expended by trawlers during the period increased from 19,445 units in 2005 to 23,884 units in 2006 and decreased to 6,877 units during 2010 with the CPUE increasing from 0.03 to 0.2 kg h^{-1}. *T. unimaculatus* catch in the total marine catch was found to increase continuously till 2007 (1.16%) but decreased during the last two consecutive years (0.51%). However, the overall catch rate was found to increase from 0.67 to 1.82 kg per unit. The average CPUE during the period was 0.09 kg h^{-1}; the maximum CPUE was recorded in the year 2010 (0.2 kg h^{-1}) and the minimum in 2006 (0.03 kg h^{-1}). The fishery was observed during September-February, with peak abundance in October and November; and the fishery was lean during the warmer months between March and May.

Carapace length-weight composition

Size-distribution of the population included multiple size-modes of different age-groups. Females were slightly larger with the overall size-range (total length) of 46-250 mm with two distinct modes appearing at 153 and 168 mm, as compared to males measuring between 61-230 mm length with a single mode at 143 mm (Fig. 2).

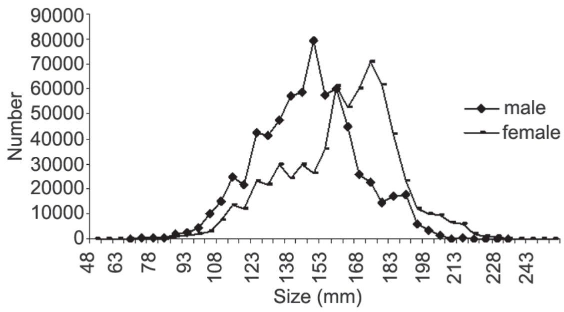

Fig. 2. Size frequency distribution of *T. unimaculatus* landed at Sakthikulangara Fishing Harbour during 2005-2010

The estimated carapace length – weight relationship for females was: log W = 0.001558 + 2.76 log CL (r = 0.96) and that of males was: log W = 0.00237 + 2.65 log CL (r = 0.95) (Fig. 3).

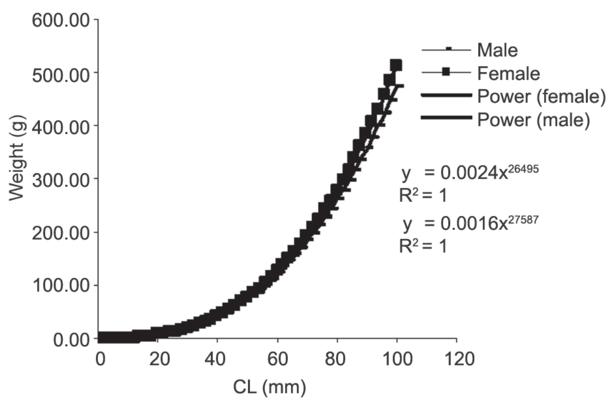

Fig. 3. Carapace length weight relationship of *T. unimaculatus* landed at Sakthikulangara Fishing Harbour during 2005-2010

Sex ratio

The sex-ratio did not significantly deviate (Snedecor and Cocharan, 1967) from 1:1 although it tilted slightly in favour of males (1:0.9) during 2005-2010. The percentage of berried females varied from 12.9 to 23 with an average of 16.9 during the period. Sex-ratio specific to size showed that males outnumbered in most of the size-classes, but the difference was often very small, with increasingly wider margins among the larger size-groups above 220 mm size.

Fecundity

The eggs of *T. unimaculatus* attached to the pleopods were spherical, with different stages of development indicated by yellow, orange, light brown and dark brown colours. Fecundity varied from 14750 to 33250 eggs in individuals with carapace length of 61-84 mm. The relationship between fecundity and carapace length was derived as :

log fecundity = 0.208738 + 2.75109 log CL
(r = 0.635, n = 48, $p<0.05$)

Growth

Estimates of the growth parameters L_∞ and K (monthly) obtained through ELEFAN I were 240 mm, 0.042 and 260 mm and 0.05, for males and females, respectively, and were almost comparable with the values obtained for L_∞ and Z/K (239 mm, 9.04; 261 mm, 5.48) by Powell and Wetherall plot. Thus, the von Bertalanffy growth equations derived were :

$$L_t = 240\,[1 - e^{-0.5\,(t + 0.00382)}] \quad \text{(male)}$$

$$L_t = 260\,[1 - e^{-0.6\,(t + 0.00293)}] \quad \text{(female)}$$

Growth performance index ϕ was 3.97 and 4.92 and t_0 was -0.00382 and -0.00293 years for males and females, respectively. The length at 50% capture (L_{c50}) was 147 mm for males and 153 mm for females which corresponded to an age (t_c) of 1.9 and 1.6 years, respectively. Males grew from 94 to 151 mm and females from 117 to 181 mm at the end of 1 and 2 year with longevity of 6 and 5 years, respectively. The fishery was dominated by fishes of 1 and 2 year classes. The asymptotic weight (W_∞) estimated from the length-weight relationship was 806 g for female and 800 g for male.

Mortality, exploitation and VPA

The mortality rates M, F, Z, exploitation rate (E) and exploitation ratio (U) computed for males and females were 0.64, 3.89, 4.52, 0.86, 0.85 and 0.7, 2.58, 3.29, 0.78, 0.75 respectively (Fig. 4). The exploitation ratio (U) and exploitation ratie (E) for both the sexes was found to be higher than E_{max} of 0.544 indicating overexploitation of this species.

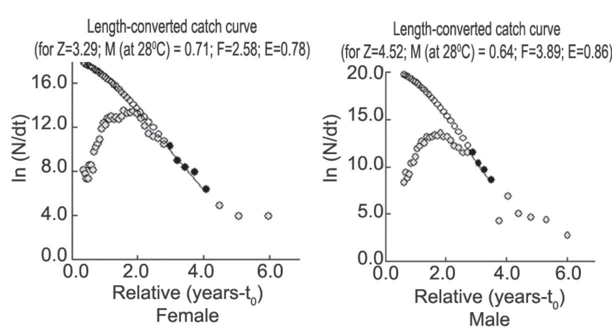

Fig. 4. Mortality of *T. unimaculatus* landed at Sakthikulangara Fishing Harbour during 2005-2010

Yield per recruit

The yield and biomass per recruit and yield and biomass curves showed that although the maximum yield and yield per recruit could be obtained at present level of fishing, biomass and biomass per recruit were found to increase by decreasing the present level of fishing by 20%. The maximum yield and yield per recruit obtained at present fishing effort were 137.0 t and 28.6 g, whereas at 20% decreased level of fishing, it is slightly less by 4 t and 0.8 g which is highly insignificant (Fig. 5a and 5b). The biomass and biomass per recruit achieved at 80% of the present effort is 111 t and 19 g, respectively but with the present fishing effort, the biomass and biomass per recruit is found to be low with values reaching 91.33 t and 19 g. The relative yield would be just 3 t less at the reduced effort at 80% of the present level of fishing.

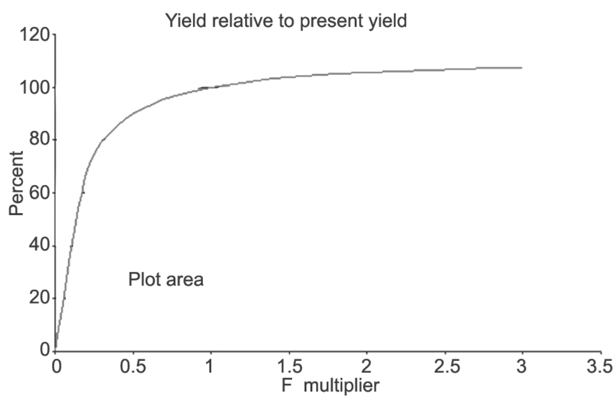

Fig. 5a. Yield of *T. unimaculatus* for different multiples of F

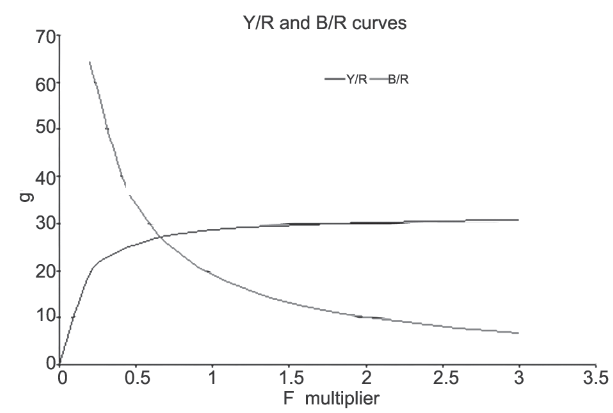

Fig. 5b. Yield per recruit and biomass per recruit *T. unimaculatus* for different multiples of F

Discussion

As a minor fishery resource, little attention has been paid to scyllarid lobsters in comparison with other, more lucrative resources, such as spiny lobster or clawed lobsters. So, there is a clear need to improve the understanding of their fishery and biology. Studies from the north-west coast indicate that the catches of *T. orientalis* gradually reduced from 185 metric tonnes (Kagwade *et al.,* 1991) to 2 metric tonnes during 1994 and 1996, leading to the entire collapse of the fishery (Deshmukh, 2001). In contrast, *Thenus* fishery of northern Australia appears to be sustainable (Courtney, 2002). In the present study, the commercial catches comprised of males up to 2 years and females above 1.5 years. Females were bigger in size than the males in the catches. The growth rates were found to be identical for both the sexes till they attained 2 years but afterwards females grew faster than males. Studies carried out along the Bombay waters however, recorded higher rate of growth in males than in females (Kagwade and Kabli, 1996a). Relationship between carapace length and weight between the two sexes of *T. unimaculatus* was found to be very narrow, females showed more gain in weight after a certain stage. The present study revealed the sex ratio slightly in favour of males compared to females (1:0.9). Smallest female either with maturing or spent ovary or in berried condition measured 61 mm in carapace length, but substantial number of females above 72 mm were found to be mature. Subramaniam (2004) stated that sex ratio slightly tilted in favour of females in most of the size classes above 220 mm of total length and size at maturity of females lowered by 5 mm along the east coast. The spawning period of *T. unimaculatus* extended from September to April with peak abundance of berried females during November-February with an average fecundity of 28209 eggs for 72 mm (CL) sized females. These values fall within the range of 20,050-53,280 mentioned by Kagwade and Kabli (1996b) with a well defined single breeding period (Radhakrishnan *et al*., 2007) along Bombay waters. However, the studies carried out along the Chennai coast showed two annual spawning spells during June-August and February-March (Subramanian, 2004). A close survey of literature indicated that very less work on the age and growth of the *T. unimaculatus* has so far been done. Since the knowledge on age and growth is a prerequisite for stock assessment and for management of the fishery, an attempt was made here to study the same. These growth parameters estimated in the present study were found to be very low in comparison with the studies carried out by Kagwade and Kabli (1996b). However, these values coincided with the results of Radhakrishnan *et al*. (2007) from Mumbai waters. Kagwade and Kabli (1996b) estimated age and growth of the sand lobster and reported that it is a slow growing species; the commercial catches consisted of 3 years old males and 4.5 years old females. But in the present study, males were found to be older than females. During the entire six year period, the exploitation rates for male and female was above 0.5 (E_{opt}) indicating that this particular species was overexploited.

T. unimaculatus constitutes only a minor fraction of lobster landings and are landed primarily along the north-west and south-east coast as bycatch from the shrimp fishery. Therefore, application of any management measures such as mesh size regulation or gear restriction for fishery, or closure of fishery during breeding season cannot be practical. However, the Ministry of Commerce and Industry of the Government of India enforced MLS (minimum legal size) for the export of *T. unimaculatus* by banning export of whole lobsters weighing <150 g. Closed season during monsoon from June 15th to August 1st, has been enacted in the state but this will not help in protecting the spawning stock as the peak breeding takes place during November-February. Therefore, conservation measures such as protection of ovigerous females by throwing them back into the sea could be adopted in future which can be achieved by educating and creating awareness among the fishermen.

Acknowledgements

The authors express their gratitude to Dr. G. Syda Rao, Director, CMFRI for the facilities provided and encouragement. Thanks are also due to Dr. V. D. Deshmukh, Principal Scientist & SIC, Research Centre of CMFRI, Mumbai for critical reading and valuable suggestions. We also gratefully acknowledge receipt of data on landings of lobsters by trawlers from the Fishery Resources Assessment Division of the Institute.

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Date of Receipt : 02.05.2012
Date of Acceptance : 07.02.2013