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Reproductive biology of the deep water mud shrimp *Solenocera melantho* (de Man, 1907) off Visakhapatnam coast

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Original Article

Abstract

Stages of maturity and their percentages, gonado somatic index (GSI), spawning season, size at first maturity, sex ratio, and fecundity were studied in deep water mud shrimp *Solenocera melantho* off Visakhapatnam coast for two years. The shrimp was a continuous breeder with peak periods in November and December. High GSI values were recorded in April, June and November for males and for females it was in June, November and December. The sex-ratio of male to female was 1:1.09. There was no significant difference in sex ratio between males and females - but percentage of females was more with increasing size. The fecundity ranged from 41,342 to 1,24,148 in the shrimps of 84 mm to 113 mm length. A linear relationship was observed between the logarithmic form of fecundity and total length, total weight, total weight and ovary weight.

Keywords: *Deep water mud shrimp, Solenocera melantho, reproductive biology*

Introduction

Reproductive biology is an important tool for understanding the stock assessment and population dynamics of a species and reproductive parameters such as size at first maturity, maturity stages, fecundity, spawning frequency, and recruitment are of great importance in fishery prediction and management (Bal and Rao, 1984).

Kunju (1968) has made a beginning on the reproduction of the deep sea shrimps of the family Solenoceridae. It has been followed by Chalayonideja and Tanone (1971) on *S. prominentis* in Kagoshima Bay, Southern Japan and Sukumaran (1978) on *S. crassicornis* in Arabian Sea. The other researchers, who worked on various aspects of the reproductive biology of different species of the genus *Solenocera* include Kagwade (1980), Ramamurthy (1994), Ohtomi *et al.* (1998), Ohtomi and Matsuoka (1998), Baelde (1992), Dineshbabu (2003), Oh *et al.* (2005), Dineshbabu and Manisseri (2008) and Li *et al.* (2012).

There is no study on the reproductive biology of *S. melantho* from Indian waters. To create a database on the reproductive biology of the species from Indian waters, a study on the spawning season, size at first maturity, sex-ratio, maturity

stages, percentage of maturity, GSI and fecundity of *S. melantho* was undertaken during 2004 to 2006.

Material and methods

Shrimp samples were collected fortnightly from the trawl catches at Visakhapatnam fishing harbour for two years (Nov'04 to Oct'06). The specimens were brought to the laboratory, washed thoroughly and blotted to remove water. Males and females were separated. The total and carapace length (mm) and total weight (mg) were estimated. The shrimps were then dissected to note the condition of the gonad. The gonad was carefully removed, blotted, weighed and preserved in 5% formalin solution for further studies (Nalini, 1976).

Maturity stages

Maturity stages in males were determined by the size of the terminal ampoule present at the end of vas deferens in the coxa of the 5th pereopod and in female by the size, pigmentation, thinness of the connective tissue surrounding the ovary etc., (King, 1948). The percentage occurrence of different stages of maturity was calculated with reference to different months and size-groups.

Gonadosomatic Index (GSI)

GSI was estimated by the method followed by Rao (1989). For estimation, 1034 specimens (493 males measuring 60-101mm and 541 females with a size range of 54-114mm) were used. The average GSI for each month was determined by dividing the total values of shrimps examined in that month.

Size at first maturity

Size at first maturity is the size at which 50% of the population attains first maturity (Rao, 1989). To determine the size at first maturity in females, individuals with stages of immature and maturing gonads were grouped together as 'immature' while those of mature were taken as 'mature' (Rao, 1989). Males and females were grouped into 5 mm size-groups separately. Size at first maturity was determined by logistic curve method (King, 1995) by fitting the curve between proportion of mature males and females and total length of the shrimps.

Sex-ratio

Sex of the shrimp was determined by petasma in male and thelycum in female. Sex-ratio was studied from the number of specimens of each sex in every month sample and in different size-groups. Out of 1,034 specimens used for the study, 493 were males and 541 were females. Chi-square test (Cochran, 1953) was used for testing the significance.

Fecundity

It was estimated in 60 mature ovaries. Ovaries were removed, weighed and preserved in 5% formalin. A portion of the right lobe of the ovary on the right side of the abdominal region of the ovaries was taken and weighed to maintain uniformity. The number of ova/eggs present in that unit weight (sub sample) of the ovary was counted. The fecundity rate was estimated by the method of Anderson *et al.* (1949).

The relationship between fecundity (F) and total length (TL), fecundity and total weight (TW), fecundity and ovary weight (OW) was calculated (Snedecor and Cochran, 1968). Regression equations of fecundity (F) on total length (TL), total weight (TW), and ovary weight (OW) were obtained by the method of least squares (Snedecor and Cochran, 1968). Regression equation was also made for ovary weight (OW) and total weight (TW).

Results

Maturity stages

Testes: Three stages were identified based on the size of the terminal ampoule (Fig. 1a to 1c).
Immature: Terminal ampoule not visible through exoskeleton of the coxae of the 5th pereopod.
Maturing: Terminal ampoule small but visible through the exoskeleton.
Mature: Large, pear-shaped terminal ampoules clearly visible through exoskeleton.

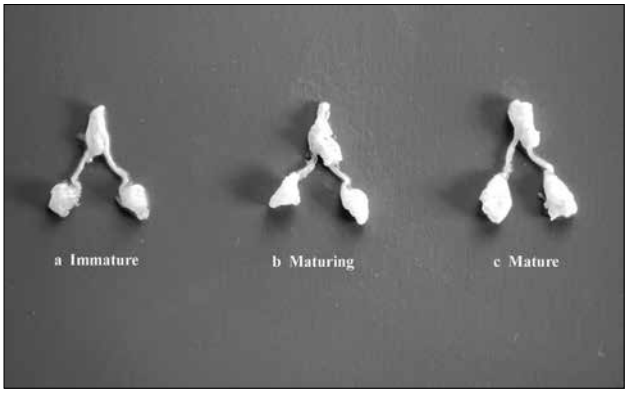

Fig. 1. Maturity stages of *S. melantho* (Male)

Ovary: Five stages of maturity were identified in females.

Stage I (Immature): Ovary thin, translucent, unpigmented. Anterior lobes of the ovary confined to the posterior half of the cephalothorax and posterior lobes situated on the dorsal part of the abdomen (Fig.2a).

Stage II (Early maturing): Increase in the size of the ovary with the anterior lobes extending forward into the cephalothorax and the middle region developing lateral lobes. The diameter

of posterior lobes similar to that of intestine. Ovary appeared light yellow in colour (Fig.2b).

Stage III (Late maturing): Ovary fully formed in the anterior, middle and posterior lobes. Anterior and middle lobes did not fill the cephalothorax completely. Ovary appeared yellow-orange and was visible through the exoskeleton (Fig.2c).

Stage IV (Mature): Ovary dark orange in colour and clearly seen through the exoskeleton. The anterior, middle lobes and posterior lobes fully developed and occupied the entire cephalothorax and also on the dorsal side of the abdominal region. Eight lateral lobes found on either side of the middle region (Fig.2d).

Stage V (Spent- recovering): The ovary appeared flaccid, shrunken, lobulated and reduced. Ovary not visible through exoskeleton (Fig.2e).

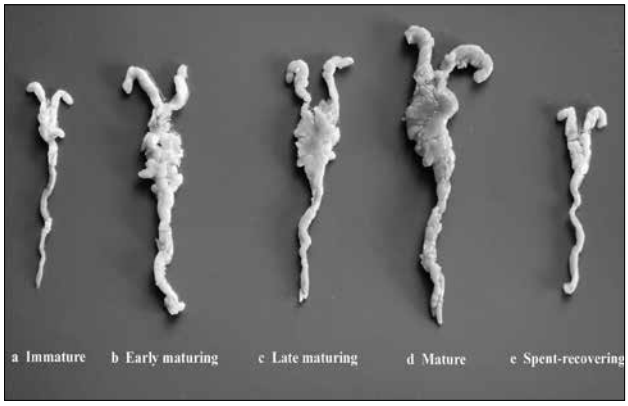

Fig. 2. Maturity stages of *S. melantho* (Female)

Gonadal maturity in different months

The month wise maturity stages in males and females were given in Fig. 3.

Gonadal maturity in different size groups

The size wise maturity stages in males and females were given in Fig. 4. The immature males were high in the size group of 56-60 mm (100%) and low in 76-80 mm size group (18.47%) whereas the mature males were high in 101-105 mm (100%) and low (16.37%) in the size group 71-75 mm. The immature females occurred in high percentage in the size group of 51-55 mm (100%) and low in 96-100 mm groups (4.03%). High percentage (36.37%) of mature females was recorded in the size group of 106-110 mm and low (20%) in 71-75 mm size group.

Gonadosomatic index (GSI)

High GSI (2.98) value in males was observed in the months of April and June followed by November (2.93). A low value

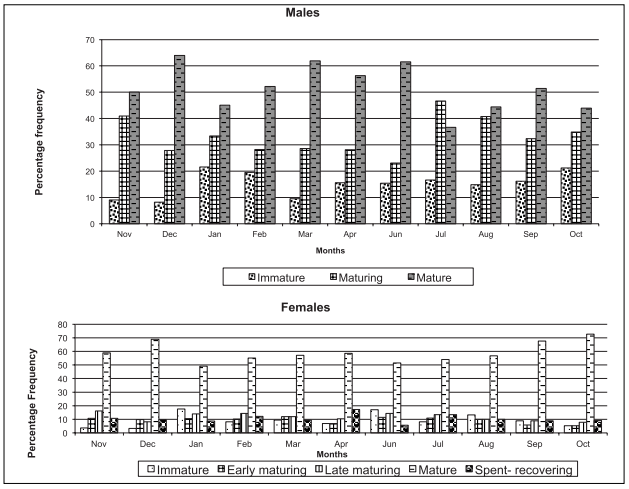

Fig. 3. Month-wise percentage maturity in males and females of *S. melantho*

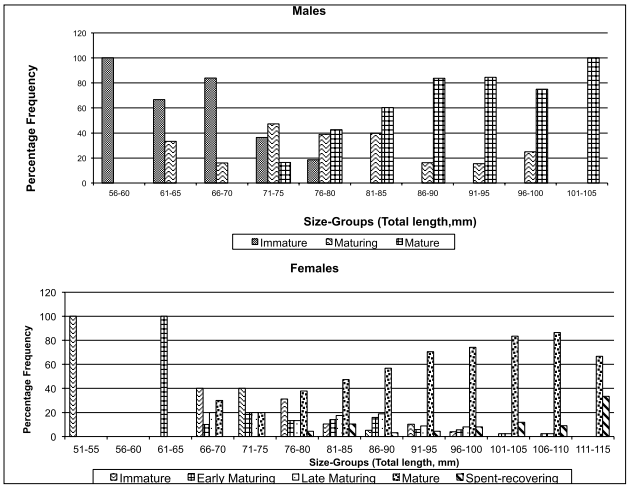

Fig. 4. Size-group wise percentage maturity in males and females of *S. melantho*

of 2.06 was recorded in September and moderate values in the remaining months (Fig.5). Females showed a peak value in November (10.11), December (9.53) and June (8.78) and a low value of 4.85 in August. The GSI values confirmed a protracted breeding season with two peaks- a major in November and a minor in June (Fig.5).

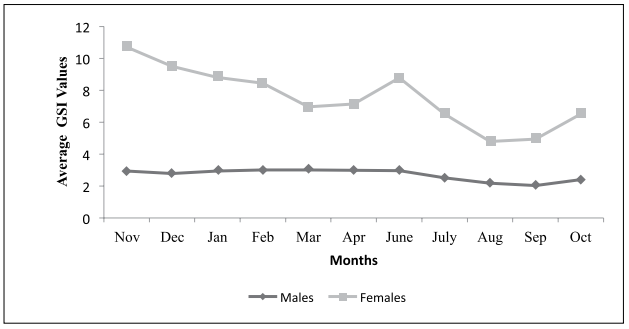

Fig. 5. Gonadosomatic index of males and females of *S. melantho*

Spawning season

Based on the percentage of maturity stages and GSI values in different months, it was confirmed that the shrimp was a continuous breeder throughout the year extending from June to February with peak stages in November and December (Figs. 4 and 5).

Size at first maturity

The minimum size at first maturity for males and females was 79 mm and 84 mm of total length respectively (Fig.6).

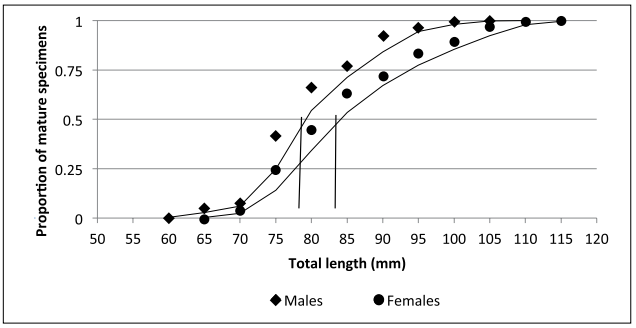

Fig. 6. Length at first sexual maturity in males and females of *S. melantho*

Sex-ratio: monthly variation

The sex-ratio of males to females was 1:1.09 with equal numbers in March and September and the rest of the months showed varied values with more males in December and April. The Chi-square test showed that the distribution of males and females in different months was not significant at 0.05% level (Fig.7).

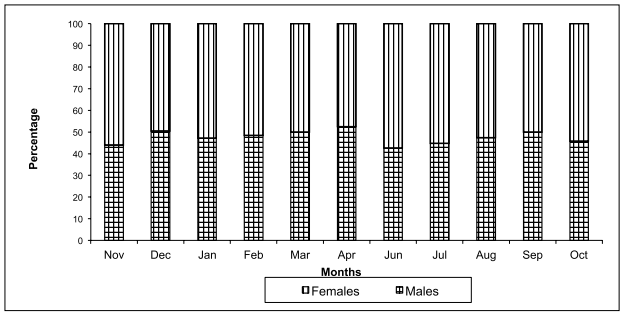

Fig. 7. Month-wise sex ratio of males and females of *S. melantho*

Size-group variation

Males were more in the size groups of 56-60 mm, 61-65 mm, 66-70 mm, 71-75 mm, 76-80 mm, 81-85 mm and 86-90 mm whereas females in 51-55 mm, 91-95 mm, 96-100 mm, 101-105 mm, 106-110 mm and 111-115 mm size groups. The percentage of females increased with the increase of size. In *S. melantho* size related variations in sex ratio was highly significant at 0.05% level for both years (Fig.8).

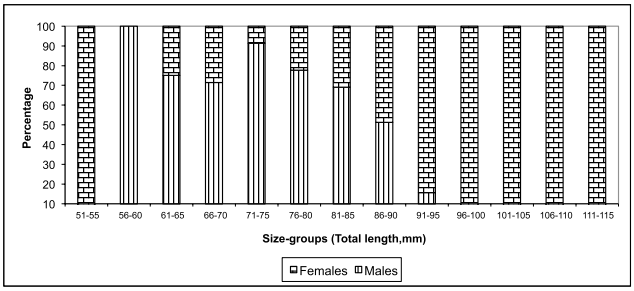

Fig. 8. Size- group wise sex ratio of males and females of *S. melantho*

Fecundity

The number of ova in the mature ovaries of female shrimps measuring 84 mm and 113 mm total length (TL) was 41,342 and 1,24,148 respectively. It was directly proportional to the length of the shrimp. A linear relationship between fecundity (F) and total length (TL) was obtained suggesting that the fecundity increased with increase in the total length and the regression equation derived was

Log F = -1.6022 + 3.2143 Log TL (Fig.9)

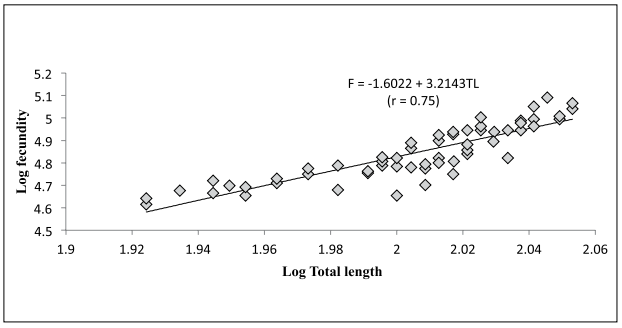

Fig. 9. Logarithmic relationship between total length (T.L) and fecundity (F) of *S. melantho*

The logarithmic relationship between fecundity (F) and other variables like total weight (TW) and ovary weight (OW) was linear and significant. The regression equations for the above were

Log F = 3.759 + 0.9851 Log TW (Fig.10)

Log F = 4.6475 + 1.8461 Log OW (Fig.11)

Similarly a significant linear relationship was found between ovary weight (OW) and total weight (TW) and the regression equation was

Log OW= -0.384 + 0.4429 Log TW (Fig.12)

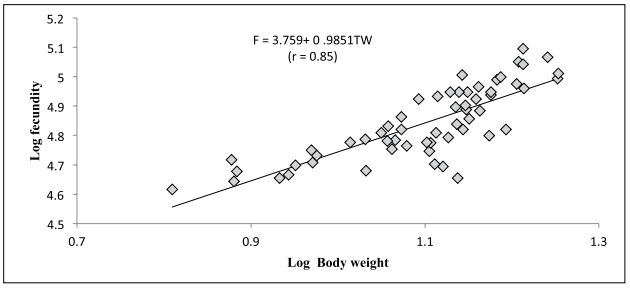

Fig. 10. Logarithmic relationship between total weight (TW) and fecundity (F) of *S. melantho*

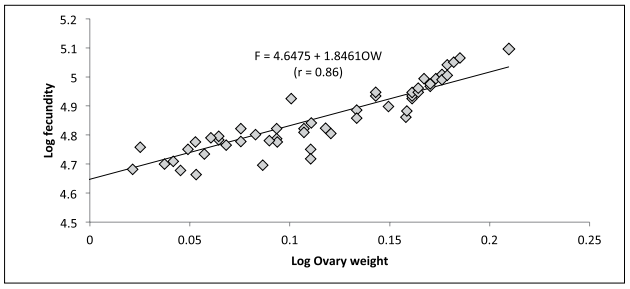

Fig. 11. Logarithmic relationship between ovary weight (OW) and fecundity (F) of *S. melantho*

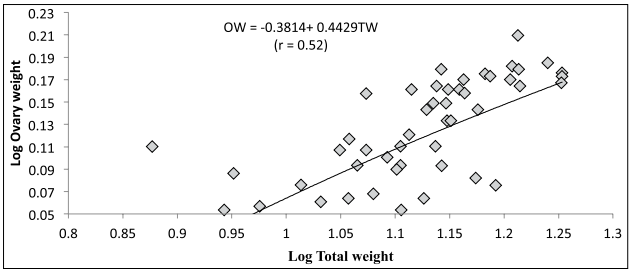

Fig. 12. Logarithmic relationship between total weight (TW) and ovary weight (OW) of *S. melantho*

Discussion

S. melantho breeds throughout the year with peak in November and December. According to Kunju (1968) *Solenocera indica* spawns throughout the year with two spawning peaks in December and April. Ohtomi *et al.* (1998) observed the spawning season in *S. melantho* from June to December with peak period during October and November in Kagoshima Bay. Ohtomi and Matsouka (1998) reported September to April as the spawning season of *Haliporides sibogae* and peak periods during late January and late March off Southern-Western Kyushu, Japan.

Dineshbabu (2003) has recorded November-December as the peak spawning season for *Solenocera crassicornis* along Saurashtra coast. Oh *et al.* (2005) have found that spawning period of *S. melantho* from August to early November and with a peak phase from October to early November. Dineshbabu and Manisseri (2008) found that *Solenocera choprai* is a continuous breeder with two peaks- a major peak in November and the minor during January- February. Li *et al.* (2012) observed the spawning season of *S. melantho* starts from July to November with peaks during August to November in East China Sea.

Gonadal weight in relation to body weight (GSI) is an indication of the spawning season (Crocos, 1985). In the males of *S. melantho*, high GSI of 2.98 is observed in the months of April and June followed by November (2.93) whereas in case of females a high GSI is noticed in November (10.11) followed by December and June (8.78). The GSI values have confirmed a protracted breeding season with two peaks, a major in November and a minor in June. Ohtomi *et al.* (1998) reported GSI of female *S. melantho* as ≥ 12 in Kagoshima Bay. Dineshbabu and Manisseri (2008) observed that an increasing trend of GSI with the advancement of maturity of the ovary and the monthly mean GSI showed a positive correlation with monthly percentage of spawners in *S. choprai*.

The maturity stages in the males are divided into three *i.e.,* immature, maturing and mature and five in females *i.e.,* immature, early maturing, late maturing, mature and spent- recovering following King (1948). Kunju (1968) has reported five stages of maturity in *S. indica* with two peaks in October and February. According to him the early maturing stages are found in October and February, the maturing- late stage in March and mature and spent prawns in February and April. Aravindakshan and Karbhari (1994) have recorded fully mature and gravid females in the size group of 100 mm in September in *S. choprai*. Ohtomi *et al.* (1998) have observed four developmental stages in the ovary *i.e.,* quiescent, developing, early ripe and ripe in *S. melantho*. Oh *et al.* (2005) have found that the mature female shrimps of *S. melantho* are 12% at 16 mm, 33% matured at 18 mm and 75% matured at 22mm of the carapace length. Dineshbabu and Manisseri (2008) have observed five stages of maturity in females of *S. choprai* with high percentage of mature females in November (23.96%).

The size at first maturity in females of *S. crassicornis* is 60-65 mm (Sukumaran, 1978). Kagwadae (1980) has determined the size at first maturity in females of *S. indica* as 88.5 mm from Bombay waters. Ohtomi *et al.* (1998) have reported the size at first sexual maturity in females as 25.3 mm carapace length in *S. melantho* in Kagoshima Bay. Dineshbabu (2003) has observed the size of first matured females of *S. crassicornis* as 68 mm along Saurashtra coast. Oh *et al.* (2005) have found the size at first maturity of the female shrimps of *S. melantho* to be 20.65 mm in carapace length in Korean

waters. Dineshbabu and Manisseri (2008) have estimated the size at first sexual maturity of males and females of *S. choprai* as 54.5mm and 66.5 mm respectively along south west coast of India. Li *et al.* (2012) have observed the size at first maturity of *S. melantho* was at 28.7 mm carapace length of female shrimps in East China Sea. In the present study the size at first maturity in *S. melantho* is 79 mm in male and 84 mm in females in the Bay of Bengal waters.

Sex-ratio indicates segregation or aggregation of sexes based on feeding, breeding or migration and deviation from the expected 1:1 ratio are observed because of differential sex behaviour, environmental conditions, fishing etc. (Bal and Rao, 1984). The sex ratio in *Solenocera membranacea* is 1: 3.25 and the females with ripe eggs in the ovary throughout the year exceeding the number of males (Heegard, 1966). According to Kunju (1968) females are more than the males in all months in case of *S. indica* (*S. crassicornis*), whereas the sex ratio is equal up to a size of 48 mm and males dominated after 48 mm. Oh *et al.* (2005) have found 51.3% females in *S. melantho* in Geomun Island, Korea. Dineshbabu and Manisseri (2008) have observed an insignificant sex ratio of female to male as 1.04:1 in *S. choprai* and the percentage of females has increased with size in Arabian waters. Li *et al.* (2012) have found the sex ratio of *S. melantho* close to 1:1 with males slightly more than females in East China Sea. In the present study, the sex ratio of males to females is 1:1.09 with equal numbers in March and September, more males in December and April and more females in rest of the months. The chi-square value confirms that there is no significant difference between the males and female populations. Percentage of females has increased with increasing size.

Fecundity varies with species and within the same species in different spawning seasons and it depends on the length, weight, age, etc. (Bal and Rao, 1984). In the present study the fecundity of *S. melantho* has been found to be 41,342 to 1, 24,148 in the shrimps of 84 mm and 113 mm total length respectively. A linear relationship has been found between logarithmic form of fecundity and total length, total weight and ovary weight. A similar relationship has also been noticed between ovary weight and body weight. Total weight of the shrimp is observed to be a better index of fecundity than total length. Sukumaran (1978) has observed the average number of eggs produced by a female with a size of 61-102 mm is 49,200 in *S. crassicornis*. Oh *et al.* (2005) have reported the fecundity of *S. melantho* as 87,500 to 4, 05,200. According to Dineshbabu and Manisseri (2008) the number of ova in the mature ovary of the shrimp *S. choprai*, measuring 80-110 mm is 38,532 to 1, 33,689.

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