Chapter 6

Summary and Future Directions
6.1 Summary

The work included in this thesis entitled, “Behavioural Ecology of the Crab, *Barytelphusa cunicularis*” has been divided into five chapters. The first chapter includes an introduction to the subject and a brief review of literature. This chapter also contains the main objectives of the study. Chapter-2 deals with the temporal variation in spatial distribution of burrows of the freshwater crab, *Barytelphusa cunicularis*. Chapter-3 highlights the architecture of burrows of *B. cunicularis*. Chapter-4 concerns with the morphometric and allometric studies in *B. cunicularis*. Chapter-5 includes data on the characteristics of circadian rhythm in locomotor activity of *B. cunicularis*. This Chapter-6 includes summary of all five chapters and future directions.

6.2 Chapter-1

The freshwater crab belonging to the family Potamonidae is widely distributed in the Indian subcontinent. A review of the literature on freshwater crabs emphatically highlights that a little is known about the ecology of Indian freshwater crabs. The study of burrow characteristics does emphasize the ecological significance of burrows. It is indeed striking that there has not been a single study dealing with burrowing behaviour of any species of Indian freshwater crab. Chatterji et al. (1988) studied the growth and morphometric characteristics in marine horseshoe crabs. Statistical relationships observed between total carapace length and carapace width; telson length and body weight in male and female horseshoe crab (Vijayakumar, et al. 2000) have been carried out.
Furthermore, the study of burrow morphology has not been conducted on any species of the Indian freshwater crabs. The physical and the chemical characteristics of the burrows of crab, *Neoepisesarma versicolor* were investigated *in situ* using resin casts (Thongtham and Kristensen, 2003). Review of literature revealed that the handedness, and morphometric & allometric relationships of Indian freshwater crab have not yet been addressed adequately. Brachyuran crabs generally comprise one of the major components of coastal macro fauna of Sundarban Delta. In India, the studies on burrowing activity and distribution of the marine crab, *Scylla serrata* from Hoogly and Malta estuaries, Sundarban, West Bengal, have been carried out (Nandi and Dev Roy, 1991). However, there is not even a single study on temporal variation in the spatial distribution of burrows of Indian freshwater crabs. Mantelatto et al. (2004) studied the temporal-spatial distribution of the hermit crab, *Loxopagurus loxochelis* from Ubatuba Bay, Brazil. Similarly, spatial and temporal distributions of Horseshoe crab (*Limulua polyphemus*) spawning at Delaware Bay was reported (Smith et al. 2002).

It has been proposed that the characteristics of circadian rhythms may differ among crayfishes and crabs sharing similar habitats (Álvarez and Villalobos, 1997; López-Hernández, 1997; Miranda-Anaya, 2004). However, circadian rhythm of locomotor activity in any freshwater crab species of the Indian subcontinent has not been investigated adequately. Therefore, the main objectives of the present Ph.D. dissertation were:

1. To elucidate the temporal variation in spatial distribution of burrows of freshwater crab, *Barytelphusa cunicularis*
Chapter 6 – Summary and Future Directions

2. To study architecture of burrows of *B. cunicularis*

3. To carry out studies on morphometry and allometry in *B. cunicularis*

4. To investigate the characteristics of circadian rhythm of locomotor activity in *B. cunicularis*

6.3 Chapter-2

Morphometry of burrows of freshwater crab, *Barytelphusa cunicularis* was carried out every month over a period of 24 consecutive months. The area of each burrow was calculated using the formula:

\[ \text{Area} = \pi \times a \times b / 4 \]

Where, \( a \) = length of burrow opening

\( b \) = width of burrow opening

The distribution of burrows was classified as clustered, random or regular using nearest neighbour distance (NND) analysis technique. The NND was computed using the following formula:

\[
R_n = \frac{D \text{ (Obs)}}{0.5 \times (a / n)^{0.5}}
\]
Where, \( R_n \) = nearest neighbouring distance value

\[
\bar{D} (OBS) = \text{mean of the observed nearest neighbour distances}
\]

\( a \) = area under study

\( n \) = total number of points

The time series on the temporal distribution of all active crab burrows was analyzed for documenting a circannual rhythm (\( \tau = 12 \) month) employing the Cosinor rhythmometry (Nelson et al., 1979). The rhythm was characterized by three parameters: the annual mean, \( M \) (rhythm-adjusted mean); amplitude, \( A \) (one half of the difference between the minimum and maximum of the fitted cosine function); and the peak, \( \phi \) (timing of the highest value of the fitted cosine function).

The burrows were also classified according to the area of their openings. The average number of burrows with the area intervals of >30, 20-30, 10-20 and 0-10 cm\(^2\) were found to be 6, 17, 56, 20, respectively. The openings of the maximum number of burrows coincided with the area interval between 10 and 20 cm\(^2\). The maximum \( R_n \) values of 0.78 and 0.8 in 2003 and 2004, respectively, were recorded in the month of September, whereas the minimum values of 0.62 and 0.59 was noted in the month of March 2003 and April 2004, respectively. The peak of \( R_n \) value was detected in the month of September with a spread between the beginnings of July and October. The peak spreads for total number of burrows,
and number of burrows having single or double opening also coincided with the peak spread of the Rn values.

It seems that the peak reproductive activities in the monsoon (mid June-September) might be the underlying reason of detection of large number of crab burrows of the smaller dimensions in September. In the present study, the chronobiological analyses of Rn values add a new dimension to the interpretation of spatial distribution of crab burrows. This study documents a circannual rhythm in an ecological phenomenon.

6.4 Chapter-3

The burrow architecture of *Barytelphusa cunicularis* was investigated *in situ*, from the undisturbed areas. A total of 22 burrows were randomly selected. The selected and tagged burrows were filled with thin slurry of cement and Plaster of Paris in the ratio 7:3. The mixture was poured into the mouth of the burrow openings and allowed to harden over a period of 4-5 days. Measurement of total length of burrow cast was carried out using measuring tape. The circumference of burrow casts was measured at every 20 cm starting from the opening of the burrow and its mean was calculated. Temperature at half and full depth of the burrow was also measured using a digital thermometer.

Ten complete casts were selected for final measurements. Various patterns and shapes of burrows, like ‘L’, ‘U’, ‘S’, and ‘Y’ were observed. Nine out of 10 casts had single surface openings. The study of a Y-shaped cast revealed that although
the burrow had two surface openings; both were connected to the same vertical structure (shaft) near the middle of the full depth of the burrow. It was revealed that each burrow was occupied by an individual crab.

Statistically significant linear relationship between the area of the burrow openings and carapace length or carapace width of the crabs was observed. The depth of the burrow was observed to be proportional to the size of the burrow opening, i.e., greater the area of the burrow opening, higher is the depth of the burrow.

6.5 Chapter-4

Morphometric and allometric relationship was carried out in a total of 393 specimens (224 males, 139 females and 30 juveniles). The specimens were randomly caught from the site of the study, gender wise segregated and various body measurements, such as carapace length, carapace width, total carapace length, chela length, body weight, chela height and chela width, were made. The handedness of all crabs (left major, right minor or right major, left minor) was determined. The specimens of B. cunicularis with a specific range of carapace length (4.28-44.28 mm) and carapace width (2.20-61.82 mm) were used for the analyses of relative growth and morphological maturity. The females attained greater size than males. The analysis of the relationship between the carapace length (CL) and carapace width (CW) showed positive correlation. Further a positive relationship was noticed between chela morphometric data and the carapace characteristics.
Out of 149 females, 118 were found with leptocheilous chela (larger left chela) and others had brachycheilous chela (larger right chela). Out of 224 males, 193 were leptocheilous and 31 were brachycheilous. The results of this study clearly revealed that in *B. cumulatus* the handedness is independent of gender. The CI and CW showed a positive linear relationship with the body weight.

6.6 Chapter-5

In the present study, circadian rhythm of locomotor activity was investigated in Indian freshwater crab, *Barytelphusa cumulatus* under LD 12:12 photo cycles. The characteristics of this rhythm were further studied following the transfer of crabs from LD to DD or LL. The pattern of locomotor activity under LD, DD and LL schedules was investigated.

The locomotor activity of the crabs was monitored and recorded by using IR sensors placed in the middle of the aquatic zone of the specially designed aquaria. The sensor alignment was confirmed through light indicators positioned in the rear part of each sensor. IR beam interruptions caused by the movement of crabs were fed to a 20-channel Angus event recorder. Data were analyzed for documenting a circadian rhythm in locomotor-activity (τ = 24 h) with the help of Cosinor rhythmometry (Nelson et al., 1979). A power spectrum method was also employed for detecting prominent period (τ) in individual time series for locomotor activity (De Prins et al., 1986).
Crabs, irrespective of their gender, were more active during the onset of dark phase. A bout of increased activity was also noticeable corresponding to the timings of light onset. The male crabs were noticed to be more rhythmic as compared to the female crabs as gauged from the analysis of rhythm detection ratio. This observation was independent of light schedules. In general both male and female crabs exhibited bimodal locomotor activity rhythm under LD 12:12 schedule. However, this bimodality disappeared when they were exposed under constant conditions of light (DD or LL). Free-running rhythms were observed under DD and LL. This was the first comprehensive study on circadian clock of any Indian species of crabs.

6.7 General conclusions & Future directions

The present dissertation is the first one that includes comprehensive data on behavioural ecology of an Indian freshwater species of crab, *B. cunicularis*. The major findings include: (1) validation of circannual rhythm in an ecological phenomenon, i.e., spatial distribution of crab burrows, (2) information on burrow architecture, (3) gender independence of handedness in *B. cunicularis*, and (4) discovery of functional circadian clock that underlies the overt rhythm of locomotor activity in *B. cunicularis*.

Extensive future studies should be conducted to establish *B. cunicularis* as a suitable laboratory model to explain the phenomenon of distribution ecology to undergraduate and postgraduate students in the domain of Life Science subjects. Since *B. cunicularis* is widely distributed in the Indian subcontinent, studies
should be conducted to explore the role of its burrows in the natural process of groundwater recharging.