Chapter 3

Architecture, Characteristics and Types of Burrows
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3.1 Introduction

The design and architecture of the burrows of animals have always attracted attention of biologists. The structure of burrows plays a significant role and provides a morphological window in the life of an organism. By comparing the architecture and different patterns of burrows it may be possible to infer ecological differences between the concerned/associated taxa and their interaction with the surrounding environment. Atkinson and Taylor (1988) reviewed a number of works dealing with the burrowing activity of the decapods. Studies on burrow morphology enhance our knowledge on the burrow characters, biological complexity, and its ecological significance. It also elaborates on reproductive, behavioural and physiological activity of the species. In semi-terrestrial decapods burrows play most important and functional role in the extreme environment conditions (Astall et al., 1997). Burrows also protect the animals by providing with them a suitable micro environmental condition. In thalassinids, the study of burrow architecture in relation to the ecology and influence of varying environmental conditions on intra-specific variation has been undertaken (Dworschak, 1983; Suchanek, 1985; Griffis and Suchanek, 1991). Burrows serve as the refuge from predators. They are needed for moistening the gills, courtship, reproduction and also as a winter abode (Crane, 1975; Powers and Cole, 1976; Ringold, 1979; Robertson et al., 1980). Burrows may also act as a locus for reproductive activity, egg incubation and co-occupancy by juveniles; many aquatic burrowing decapods use their pleopods to irrigate their burrows. In addition, the location of fiddler crab, Uca vomeris plays a vital role in determining the owners' social environment and their access to food resources. It also helps to
establish and maintain neighbourhood relations, avoid predators and pursue mating opportunities. Backwell and Jennions (2004) support that the territory-owning Australian fiddler crabs judiciously assist neighbouring crabs in defending their territories. Crabs repeatedly return to their burrows to defend themselves against other crabs, to use the burrows as refuge from predators or to replenish their water supply (Zeil, 1998). Burrows may also be of different shape and size, simple or complex, having many branches or a single opening depending upon the nature of the animals. Burrows are J-, U- or Y-shaped in Scylla serrata (Nandi and Dev Roy, 1991). Complex branched and multiple branched burrows are often found in thalassinids, living in marine and estuarine environments (Doworschak, 1983). Suchanek (1985) distinguished between the simple Y-shaped burrows of filter/suspension feeders and the deep-chambered burrows of rift catchers in the thalassinidean shrimp. Burrow morphology and mating behaviour of thalassinidean Upogebia noronhensis was studied using resin casting in the field and has been observed in the laboratory (Candisani et al., 2001). Rudnick et al. (2005) conducted studies on morphology, impact of burrows and burrow casting in Chinese Mitten crab, Eriocheir sinensis. The activities of burrow construction promote the remobilization of sediment grains and nutrient cycling, thus changing the physical and chemical features of the local environment (Griffis and Suchanek, 1991). The burrow characters reflect the burrow morphology, general ecology, types and nature of burrows as well as feeding behaviour of its inhabitants. In Uca uruguayensis the morphology of the burrow plays a significant role in the sediment characteristics. As sediment thickness increases the burrows are found to be deeper, longer and more voluminous
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(Ribeiro et al., 2005). Trueman (1970) described the mechanism of burrowing in the mole crab, Emerita.

A variety of techniques have been used by the biologists to determine the morphological patterns, and other environmental effects on the burrow architecture. Previously the moulds or casts of burrow were constructed using plaster of Paris or cement (Stevens, 1929). But recently the scientists used resins to produce finely detailed reproduction of entire burrows (Shinn, 1968; Atkinson and Chapman, 1984; Dworschak, 2001). Vaugelas (1984) suggested the archaeological method of burrow excavation that involves direct observation of burrow features by carefully removing layer by layer of sediments and direct observation of burrow features, with or without cast. Various studies in the burrow architecture of thalassinidean indicates that the basic morphology of the burrow structure remains constant with the species, but the changes in burrow structure along the tidal gradients related to burrow depth in Callianassa californiensis and Upogebia pugettensis have been observed (Swinbanks and Murray, 1981; Swinbanks and Luternauer, 1987; Griffis and Chavez, 1988). The physical and the chemical characteristics of the burrows of crab, Neopreesarma versicolor were investigated in situ using resin casts (Thongtham and Kristensen, 2003). Burrow temperature also play a vital role in the development and incubation of larvae, it also affects the mode of feeding.

Although extensive work has been carried out on the biology and fishery aspects of Brachyuran crabs, little is known regarding the burrow characteristics and burrowing behaviour in the Potamonide species, widely distributed in India. Therefore, in the present study attempts were made to determine the
characteristics of burrows of freshwater crab, *Barytelphusa cunicularis* (Potamonide).

### 3.2 Materials and Methods

#### 3.2.1 Formula - Area of Burrow

The examination of the burrows present in an area of approximately 1200 m² was carried out at Bhilai (21°13' N, 81°26' E), Chhattishgarh, India. The site of study was fenced grassland and therefore the burrows were undisturbed. The opening of each burrow was measured. The total number of burrows having single, double and triple opening on the surface was counted. As the external opening of the burrows was ellipsoidal the length of major and minor axes was measured in order to determine the area of the burrow openings. The following formula was used to compute the area of each burrow opening:

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

Where, \(a\) = length of major axis

\(b\) = length of minor axis

![Figure 3.1 Area of Burrow](image)
3.2.2 Calculation of mean shaft area:

For calculation of mean shaft area, the circumference of the cast was measured at every 20 cm depth of the burrow and following calculations were applied.

Mean Circumference \( C = (\Sigma C_n) / n \)

Where, \( C_n = \) circumference at the \( n^{th} \) point, and

\( n = \) total number of such points

Assuming the shape to be circular for simplicity, we have:

Circumference \( C = \pi \times d \)

Where, \( d = \) diameter of circle

Hence, \( d = C / \pi \)

Area of Circle \( A = \pi \times d^2 / 4 \)

Substituting \( d \) in terms of \( C \), we have:

\( A = C^2 / (4 \times \pi) \)
Using mean circumference in the above formula, the mean shaft area was calculated. In view of the assumption of circular shape, the area may not be exactly equal but is quite accurate and good enough for analysis purposes.

3.2.3 Burrow casting

The morphology of burrows has intrigued many biologists to examine the morphological patterns and structure of burrows using a wide variety of techniques. Burrow structure of *Barytelphusa cunicularis* was investigated in situ, from the undisturbed areas and only the active burrows were taken for the burrow casting and observations. The burrow activeness was observed through the naked eyes by the excavated materials strewn around the burrow in the form of pallets. A total of 22 burrows were randomly selected with different size of mouth opening. Of these, 19 burrows had single-mouth openings, 2 had double-mouth openings and 1 with triple-mouth openings. Prior to casting, the burrow opening on the surface was counted and measured. The burrows were tagged of the known burrow entrance diameter. 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 for 4-5 days (depending upon the environment conditions). The hardened cast of each burrow was excavated by carefully digging and by removing layer by layer of sediments to minimize damage to the burrow wall.
3.2.4 Burrow patterns and measurement

Burrows were simple tunnels, descending downwards either straight or slightly slanted. The burrows exhibited U, L, S or Y like shapes. The length and width of the carapace of each crab was measured using vernier calliper up to 0.01 mm accuracy. 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.

3.3 Results

3.3.1 Burrow morphology

Three different forms of burrow openings were witnessed in the study area - burrows having single-, double- or triple-mouth opening (Figure 3.2). A total of the 98 burrows were examined, out of which 87 were with single opening, 9 had double openings and 2 were with triple openings.

3.3.2 Burrow dimensions

A frequency distribution of burrows was constructed as function of area of the openings (cm$^2$) (Figure 3.3). The average number of burrows in the area intervals of >30, 20-30, 10-20 and 0-10 cm$^2$ were found to be 11, 24, 49 and 27.
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respectively (Figure 3.3). The openings of the maximum number of burrows coincided with the area interval between 10-20 cm².

3.3.3 Burrow casts and in-situ characteristics

A total of 22 burrows were cast *in-situ* and the casts were recovered by careful digging. Some of the casts were incomplete due to rupture during digging or insufficient penetration of the mixture of cement and plaster of Paris. Morphological data of 10 casts were taken for observations that were complete and representative of particular burrow. Burrows of *Barytelphusa cunicularis* had very noticeable feature characterized by sandy sediments.

Burrows are simple tunnels, either straight or curved, descending downwards and occur with or without branches. Various patterns and shapes of burrows like L, U, S, and Y have been observed from the casts. The shapes like L and S were observed in burrow cast (BC 1-9) in burrows with single opening, whereas shapes like U and Y were observed (BC-10) in burrows with two openings. The study of cast of Y-shaped burrows revealed that though the burrow had two surface openings, the two openings connected to the same vertical structure known as shaft, near the middle of the full depth.

Nine of reproduced burrow casts showed single opening, whereas a solitary burrow cast presented two openings on the surface. The number of crabs embedded in the burrow is difficult to determine unless the crab comes from the burrow when the cast was poured or it get entombed in it. Out of 22 cast study, in 13 casts the crab comes out from the burrow as slurry of cement and plaster of
Paris was poured in it and in the 5 burrows the crab was embedded in the cast while in rest 4 burrows the crab was not found. Observations during the casting and study of the cast indicate that only one crab was normally resident in one burrow. A few of the burrow casts were such that one crab was entombed in the cast. This suggests that burrows were inhabited by solitary animal. In the cast of (BC-11) a portion of the crab was embedded in the cast. The (BC-12) highlights the carapace width of the crab entrenched in the cast.

Regression analyses were conducted to establish the relationship between area of burrow aperture, burrow depth, carapace length, and carapace width of crab. Statistically significant linear relationship between the area of the burrow openings with respect to the carapace length and carapace width of the crabs was observed (Figure 3.4 and Figure 3.5). The total depth of the burrow was observed to be in proportion with the size of the burrow opening, i.e., greater the area of the burrow opening, higher is the depth of the burrow (Figure 3.6).

3.3.4 Burrow shape and in-situ measurement

A linear correlation between the carapace width and length of the crab and total depth of the burrow cast was observed (Figure 3.7 and Figure 3.8).

The total depth of the burrow, in the burrow cast (BC-8) was 175 cm, having single opening and exhibited S shape. The area of the mouth of the burrow opening was 35.72 cm². The mean shaft area was 43.97 cm²; the carapace length and width of the crab were 42.62 and 58.24 cm, respectively.
The burrow cast (BC-4) has single opening and exhibited J shape. Surface area opening of the cast was 30.62 cm² and total depth of the burrow cast was 128 cm and the carapace length and width of the crab were 39.62 and 54.2 cm, respectively.

The burrow cast (BC-10) has double openings and exhibited Y shape. The surface areas of opening A and B were 25.91 and 17.66 cm², respectively. The total depth of the burrow cast with respect to opening A was 110 cm whereas with opening B it was 90 cm. The mean shaft areas of opening A and B were 30.59 and 27.77 cm², respectively. The mean area of the burrow for the cast burrows also depend on the burrow depth (Figure 3.9).

In the ten burrows for which the complete cast study was carried out, the burrow surface area opening ranged between 10.60 to 35.72 cm². The depth of the burrow varied from 70 to 175 cm. The width of the carapace ranged from 25.62 to 58.24 mm (Table 3.1). The depth of the burrow was strongly dependent on the animal size \(y = 0.31x - 11.74, R^2 = 0.86\).

### 3.3.5 Burrow temperature

The temperature inside the burrow is less than the ambient temperature as a result of decrease in exposure to direct solar radiation and possibly a host of other conditions, like soil moisture, etc. It was observed that the temperature at half of the depth of burrow was more or less same as the temperature at the bottom of the burrow. Further the temperature at half depth was observed to vary linearly in a narrow band of 24.2 to 25.6°C (Figure 3.10). However, the temperature at the
bottom of the burrow was more consistent and was observed to vary in the range from 23.8 to 24.8°C as a function of second order polynomial. This indicates that the crabs may be comfortable in a particular temperature band and they make doubly sure that the temperature is to their liking inside the burrow and it does not vary too much.

Figure 3.2 Burrows with single, double and triple openings
Figure 3.3 Distribution of burrows as per area of burrow opening

\[ y = 0.9796x - 9.7209 \]
\[ R^2 = 0.8852 \]

Figure 3.4 Relationship between carapace length and area of opening for cast burrows
Figure 3.5 Relationship between carapace width and area of opening for cast burrows

\[ y = 0.7235x - 9.5723 \]

\[ R^2 = 0.9008 \]

Figure 3.6 Relationship between burrow depth and area of opening for cast burrows

\[ y = 0.2511x - 5.1928 \]

\[ R^2 = 0.872 \]
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Figure 3.7 Relationship between carapace width and burrow depth for cast burrows

\[ y = 2.5945x - 5.5339 \]
\[ R^2 = 0.8376 \]

Figure 3.8 Relationship between carapace length and burrow depth for cast burrows

\[ y = 3.3732x - 1.7568 \]
\[ R^2 = 0.7589 \]
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Figure 3.9 Relationship between burrow depth and mean area of burrow for cast burrows

![Graph showing the relationship between burrow depth and mean area of burrow for cast burrows.](image)

\[
y = 0.3088x - 11.742 \\
R^2 = 0.8638
\]

Figure 3.10 Temperature profile at surface, half depth and full depth of burrows.

![Graph showing temperature profile at different depths.](image)
Figure 3.11 Cast of Burrows BC 1, BC 2, BC 3 & BC 4
Figure 3.12 Cast of Burrows BC 5, BC 6, BC 7 & BC 8
Figure 3.13 Cast of Burrows BC 9, BC 10, BC 11 & BC 12
### Table 3.1 Burrow characteristics and carapace measurements of *B. cunicularis*

<table>
<thead>
<tr>
<th>Cast Number</th>
<th>Opening (cm)</th>
<th>Major axis</th>
<th>Minor axis</th>
<th>Surface Area of Opening (cm²)</th>
<th>Depth (cm)</th>
<th>Mean Shaft Area (cm²)</th>
<th>Size of Crab</th>
</tr>
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<tbody>
<tr>
<td>BC 1</td>
<td>5</td>
<td>6.5</td>
<td></td>
<td>25.51</td>
<td>115</td>
<td>17.30</td>
<td>39.68</td>
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<tr>
<td>BC 2</td>
<td>3</td>
<td>4.5</td>
<td></td>
<td>10.60</td>
<td>76</td>
<td>10.53</td>
<td>22.36</td>
</tr>
<tr>
<td>BC 3</td>
<td>4.5</td>
<td>5</td>
<td></td>
<td>17.66</td>
<td>108</td>
<td>18.52</td>
<td>30.52</td>
</tr>
<tr>
<td>BC 4</td>
<td>6</td>
<td>6.5</td>
<td></td>
<td>30.62</td>
<td>128</td>
<td>26.84</td>
<td>39.52</td>
</tr>
<tr>
<td>BC 5</td>
<td>4.5</td>
<td>5.5</td>
<td></td>
<td>19.43</td>
<td>89</td>
<td>12.69</td>
<td>24.92</td>
</tr>
<tr>
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<td>4</td>
<td>4.5</td>
<td></td>
<td>10.60</td>
<td>72</td>
<td>12.44</td>
<td>21.32</td>
</tr>
<tr>
<td>BC 7</td>
<td>4</td>
<td>3.5</td>
<td></td>
<td>10.99</td>
<td>70</td>
<td>10.84</td>
<td>19.68</td>
</tr>
<tr>
<td>BC 8</td>
<td>6.5</td>
<td>7</td>
<td></td>
<td>35.72</td>
<td>175</td>
<td>43.97</td>
<td>42.62</td>
</tr>
<tr>
<td>BC 9</td>
<td>4.5</td>
<td>5</td>
<td></td>
<td>17.66</td>
<td>79</td>
<td>14.51</td>
<td>31.94</td>
</tr>
<tr>
<td>BC 10-a</td>
<td>5.5</td>
<td>6</td>
<td></td>
<td>25.91</td>
<td>110</td>
<td>30.59</td>
<td>35.42</td>
</tr>
<tr>
<td>BC 10-b</td>
<td>5</td>
<td>4.5</td>
<td></td>
<td>17.66</td>
<td>90</td>
<td>27.77</td>
<td>49.84</td>
</tr>
</tbody>
</table>

10-a and 10-b are two openings of the same burrow. Common shaft depth was 40 cm. BC 11 and BC 12 show crab embedded in the cast.
3.4 Discussion

Burrows can be of different shape and size, simple or complex, having many branches or a single opening depending upon the nature of the animals. In the present study the burrows of *B. cunicularis* were found to have ellipsoidal openings on the surface. Casting and excavation of burrows, however, revealed that burrows were simple, sometimes branched either straight or slightly slanted descending downwards. The burrows with single opening had straight branch, and exhibited S, J or L shape whereas burrows having two or three openings on the surface had branches with interconnections between them and exhibit U or Y shapes. The S shaped burrow may be unique to *B. cunicularis* as no earlier reference to it could be located in the available literature for the fresh water species. Morphology of the burrows has been investigated in the marine crab, *Scylla serrata* (Nandi and Dev Roy, 1991), using mixture of plaster of Paris and cement. Burrows have one, two or three openings on the surface and exhibit J-, U- or Y-shapes. Complex branched and multiple branched burrows have been often observed in thalassinids (Doworschak, 1983; Nash et al., 1984). The burrows of two species of crab *Ocypoda* have been studied on the sandy beach of western Sunderban, Bengal delta (Baksi et al., 1980). Li et al. (2008) observed that the burrows of mud shrimp exhibit Y and U shaped burrows, with a lower central shaft. The two openings extended to the surface and the tunnels of the burrows are circular narrow and smooth. According to Iribarne et al. (1997) the shape of burrow varies as function of background areas. In the vegetated area the burrows are straight and nearly vertical, but in mud flats the burrows are oblique to vertical with funnel-shaped entrance and larger diameter. Chan et al. (2006) examined that
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the difference in the burrow architecture of ghost crab, *Ocypode ceratophthalma* appears to be related with the crab age and behaviour. The juveniles produced shallow J-shaped burrows, and the larger crabs have Y-shaped and spiral burrows. Burrows of *Upogebia noronhensis*, a thalassinidean shrimp showed a typical Y-shaped burrow pattern in about 70% of the cases, the remaining 30% comprised U-shaped burrows (Candisani et al., 2001). Dworschak (2001) using resin casting observed that the burrows of *Lepidophthalmus louisianensis* (the shafts and chambers) follow the spiral shape.

Burrow sizes vary, depending on season and carapace size of the crab. In the present study, a total of 98 burrows were examined, out of which 87 were with single opening, 9 had double openings and 2 were with triple openings. Most of the burrows of *B. cunicularis* had single openings. This finding corroborates the results of an earlier study Nandi and Dev Roy (1991) of burrow casts of *Scylla serrata*. They reported that 94% burrows had single external opening, 5% with two openings and 0.83% had triple burrow openings. Similar pattern was observed in the present study.

Observations while casting the burrows of *B. cunicularis* indicated that normally one crab occupies one burrow. Always a solitary crab came out from the burrow, while the slurry of cement and plaster of Paris was being poured into 13 burrows out of a total of 22. In the cast of 5 burrows, the crab was found to be embedded in the cast. In the remaining 4 burrows no crabs were observed either coming out of the burrow or embedded in the cast. One burrow cast presented two openings on the surface but only one crab was entrenched in the cast. This indicates that though the burrows have V- or Y-like configuration, they are occupied by single
organism. The number of observations may not be statistically significant and hence it can be a subject for further study. Griffis and Suchanek (1991) observed the burrow morphology in thalassinidean shrimp having a simple Y-shaped pattern with two surface openings with one occupant per burrow.

In *Barytelphusa cunicularis* the area of the burrow opening varied from 10.6 to 35.72 cm². The depth of the crab varied from 72 to 175 cm, where as the carapace length and width of the crab were in the range of 19.68 to 42.62 and 25.62 to 58.24 mm, respectively. This indicates that possibly the larger crabs create deeper and more complex burrows for mating and refuges and can tolerate prolonged periods without renewing their respiratory water. In contrast, the Juvenile crabs have smaller gill areas and move out of the burrows regularly to renew their respiratory water and as a result they do not have deep burrows. According to Nandi and Dev Roy (1991) the longest diameter of the burrows of *Scylla serrata* varied from 53 to 117 mm, occupied by the crabs of carapace width 40 to 112 mm. Stieglitz et al. (2004) investigated the mean and maximum tunnel diameter of the crustaceans’ burrows; which was 7 cm and 11 cm, respectively. Candisani et al. (2001) reported that in thalassainidean shrimp the internal diameter of the burrow strongly depended on the size of the animal with most of the burrows being as wide as the animal carapace.

Temperature may play a significant role in burrow architecture and behaviour of the crab. During the day time periods, the burrow shelters the crabs from heat and desiccation stress. The temperature at half depth burrow in *B. cunicularis* varied in a small range from 24.2 to 25.6°C and displayed a linear trend. Variation in the temperature at the bottom of the burrow was even less; it varied in the range from...
23.8 to 24.8°C. The bottom temperature follows a trend defined by second order polynomial. The temperatures of the burrows were quite stable at the bottom and were not affected by environmental and biological factors. According to Reaney and Blackwell (2007) in fiddler crab, *Uca mjoebergi* the warmer burrows are influenced by the developmental rate, incubation rate and ensure the timely release of their larvae. It also affects in mate choice to increase their reproductive success. Benny et al. (2006) investigated burrow temperature of the ghost crab *Ocypode ceratophthalma* during summer in day time; the surface temperature at the burrow opening was 48°C but it was 32°C inside the burrow. Kelemec (1979) observed in soldier crab, *Mictyris longicarpus* that the emergence is more at higher temperatures when feeding is more rapid than at lower temperatures. Early emergence enables the crab to undertake long treks to obtain food. According to Katz (1980) burrows not only increase the transport of O₂ into and CO₂ out of the sediments but also serve as vents to remove toxic H₂S and enhance detoxification of the sediment.

Burrows provide crabs with protection from particularly high temperature, desiccation and predators while maintaining tolerable conditions with respect to other essential parameters. It has functional attributes and is associated with reproduction, behavioural, or physiological characteristics of the species. All these evidences suggest that crab burrow architecture may have adaptive significance in several ways, which merit further studies.

The burrows of the crab, *Barytelphusa cunicularis* might also play an important role in the process of groundwater recharge. However, this proposition needs validation through rigorous studies.