Article

Burrow characteristics of the fiddler crab – *Austruca sindensis* (Alcock, 1900) from mudflats of Gulf of Khambhat, Gujarat, India

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Received 17 November 2022; *Accepted 20 December 2022*; *Published online 28 December 2022*; *Published 1 March 2023*

Abstract
The present investigation was carried out on the structural characteristics of burrows of the fiddler crab – *Austruca sindensis* (Alcock, 1900) between March 2021 to January 2022 from the mudflats of Kamboi, Gulf of Khambhat, Gujarat, India. Burrows were selected randomly from upper and middle intertidal zones for burrow casting. The unsaturated resin was poured inside the burrow and allowed to get solidify. The resident crabs were captured for morphological identification and its morphometry (carapace length - CL and carapace width - CW) and sex were recorded. A total of 94 complete burrow cast were used for burrow morphological and morphometric analysis wherein, characteristics including burrow diameter, orientation, length, width, inclination, branching and volume were recorded. A total of 7 different burrow shapes were recorded in which Single tube (27) burrow was prominently observed followed by J-shaped (25), S-shaped (21), Spiral burrows (10), etc. The crab carapace length showed significant positive correlation with carapace width, burrow opening diameter, total burrow length, total burrow depth and burrow volume. Burrow diameters are significantly smaller in the foreshore compared to that of the backshore, suggesting that larger individuals reside along the backshore, where they excavate deeper and large-diameter burrows to minimize chances of desiccation. While, the juveniles were observed utilizing shallow burrows with small opening diameter located near water line. Specific pattern was observed in the burrow temperature in which the burrow temperature dropped significantly at the greatest depth which provides suitable environment to the crab to survive in the harsh environmental conditions.

Keywords burrow architecture; mudflats; seasonal variation; temperature.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Burrow architecture is common behaviour observed in many vertebrates (Moulton et al., 2006; Schwaibold and Pillay, 2006) as well as invertebrate fauna (Matsumasa et al., 1992; Lomovasky et al., 2006). Burrows created by benthic invertebrates are a common feature of many marine, estuarine and freshwater soft sediment habitats (Little, 2000; Huhta, 2007). Brachyuran crabs are active burrowers of intertidal soft sediment causing remarkable effect on benthos present in the sediments (Iribarne et al., 1997; Herman et al., 1999). Burrows are advantageous to get protection against predator, to refuges from disturbance, thermal extremes (Ansell, 1988) and to avoid adverse environmental conditions (Kinoshita, 2002; Thongtham and Kristensen, 2003). Burrow morphology varies from species to species (Griffis and Suchanek, 1991; Wolfrath, 1992) but sometimes variation in burrow morphology is observed within same species due to several physical and biological factors such as sediment composition, vegetation type, shore height, tidal variation, sex and age of the individual etc. (Takeda and Kurihara, 1987; Morrisey et al., 1999; Lim and Diong, 2003; Chan et al., 2006). Burrow architecture is ecologically important specially to maintain semi-terrestrial mode of habit (Dubey et al., 2013). Burrowing behaviour is commonly reported in the genera *Macrophthalmus* and *Heloecius* (Griffin, 1965, 1968), *Uca* (Pearse, 1912; Crane, 1941a; Altevogt, 1955), *Ocypode* (Cott, 1929; Crane, 1941b; Tweedie, 1950; Barrass, 1963; George and Knott, 1965; Hughes, 1966), *Dotilla* (Tweedie, 1950) and *Scopimera* (Tweedie, 1950; Fielder, 1970).

Fiddler crabs are among the most common and best known for their burrowing behaviour (Crane, 1975; Lim, 2006). They abound along the shores of tropical and subtropical regions around the world where they excavate simple dwellings (burrows) in intertidal areas (Gibert et al., 2013). These crabs are known to accommodate their burrowing exercise to a varying degree of conditions like substratum conditions, salinity, temperature, tidal periodicity, anthropogenic disturbances, predators etc (Dubey et al., 2013). During high tide crabs remain inside the burrow while emerging out during low tide for feeding or other surface activities (Gherardi et al., 1999). Such behavioural adaptation helps them to avoid the need of periodically return to a burrow to replenish its water supply (Hartnoll, 1973). Nowadays, ecological functions of burrowing behaviour in specific ecosystem have received increasing attention and crab burrowing has been considered as one of the major factors of bioturbation affecting the physical and chemical processes in ecosystems (Wang et al., 2010). Therefore, the present study was planned to understand the structural characteristics of burrows of the fiddler crab *Austruca sindensis* (Alcock, 1900) which is commonly distributed on coastal region of Gulf of Khambhat.

2 Materials and Methods

2.1 Study area

Gulf of Khambhat is one of the three Gulfs of India and having largest tidal amplitude on the West Coast of India. Gulf of Khambhat owes its own peculiarity in terms of its geomorphology, hydrodynamics and high tidal amplitude. Gulf, being funnel shaped with wide mouth and narrow head (width 200 km at mouth of Gulf terminating to 6 km at the extreme end of Gulf i.e. mouth of Mahi estuary), provides geo assistance to the tidal amplitude and turbulence. The coastal area of Gulf of Khambhat is having wide variety of intertidal habitats like mudflats, sandy shores, rocky-muddy shores, estuaries and mangroves (Pandya and Vachhrajani, 2010).

The present study was carried between March 2021 to January 2022at Kamboi coast-Gulf of Khambhat (Site 1-22º12'45.10" N, 72º36'06.26" E; Site 2- 22º13'00.27" N, 72º37'02.34" E) located in Bharuch district, Gujarat, India (Fig. 1). Kamboi coast is one of the important habitats located on the narrow head region of Gulf of Khambhat, which is reach in diversity of brachyuran crabs. The intertidal area of Kamboi coast is muddy in nature. The upper intertidal zone is made up of silt and clay which is dominated by *Austruca sps*, the middle zone contains undulating muddy area which is dominated by *Ilyoplax sayajiraoi* (Trivedi et al., 2015) and lower intertidal zone is made up of sand which is dominated by brachyuran crab *Dotilla blanfordi* (Alcock, 1900) (Pandya and Vachhrajani, 2013).

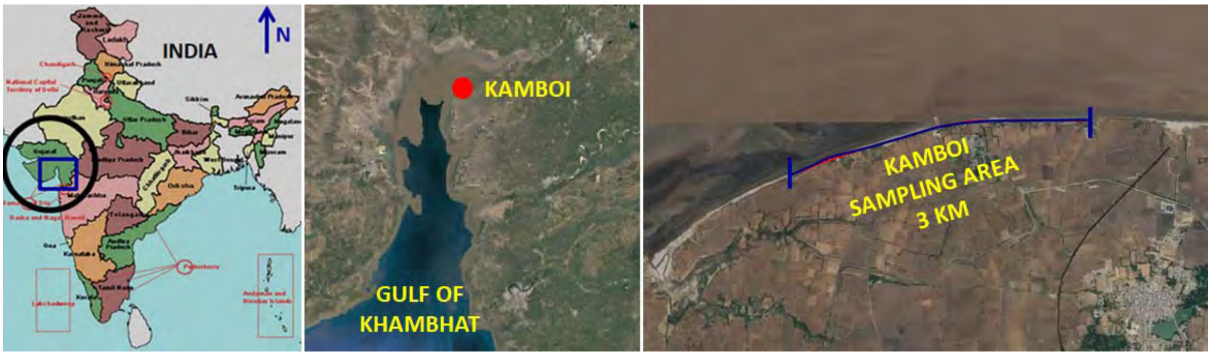

Fig. 1 Location of study site: Kamboi, Gujarat, India.

2.2 Burrow architecture

The burrows of crabs were selected randomly from upper intertidal and middle intertidal zone. The burrow opening diameter was recorded with the help of digital vernier callipers (Yuri YUR01 Digital Vernier Calliper 0-150 mm). The mixture of unsaturated resin, cobalt and catalyst (3:1:1) was poured into the burrows until the burrows were totally filled. Crabs emerged from the burrows were collected, sexed and the carapace width and length measured using vernier callipers (±0.1 mm). When the burrow casts had solidified (˂2 h), they were dug up for subsequent measurement of burrow dimensions (Fig. 2). The volume of the burrows were determined by weighing the burrow cast (±0.01 g) and dividing the weight by the density of the unsaturated resin (0.96 g/cm^3) (Trivedi and Vachhrajani, 2016).

2.3 Vertical temperature gradient in burrows

Variation in sediment temperature was measured along the depth of the burrow during low tides. Burrows were selected randomly and their opening diameter was measured using vernier callipers (±0.1 mm). The sand surface temperature at the burrow opening was measured using a digital thermometer (Eurolab ST9269B, ±0.1°C). The temperature of sediment was measured at every 5 cm depth interval up to the depth of 25 cm.

2.4 Statistical analysis

The regression was done to establish the relationship between carapace lengths of the crab and different morphological parameters of the burrow cast. In factor analysis univariate descriptive statistics was used. Whereas in correlation matrix, two selected attributes such as 'coefficient' and 'significance level' were used. In 'factor analysis extraction' attribute display selected was 'unrotated factor' solution and 'scree plot.' Method of extraction was based on 'Eigen value > 1. All the statistical analysis was performed in "Statistical Package for the Social Sciences (version SPSS 22) software.

3 Results

3.1 Different shapes of the burrows

A total of 94 burrow casts were obtained, of which the 46 host crabs were captured (29 males and 17 females). A total of 7 different burrow shapes were recorded including J-shaped burrow (28), Single tube burrow (27), S-shaped burrow (21), Spiral burrow (10), J-shaped burrow with branch (5), U-shaped burrow with single opening (2) and Multi-branched burrow (1) (Fig. 2, 3). The relationship between various parameters was studied in three seasons.

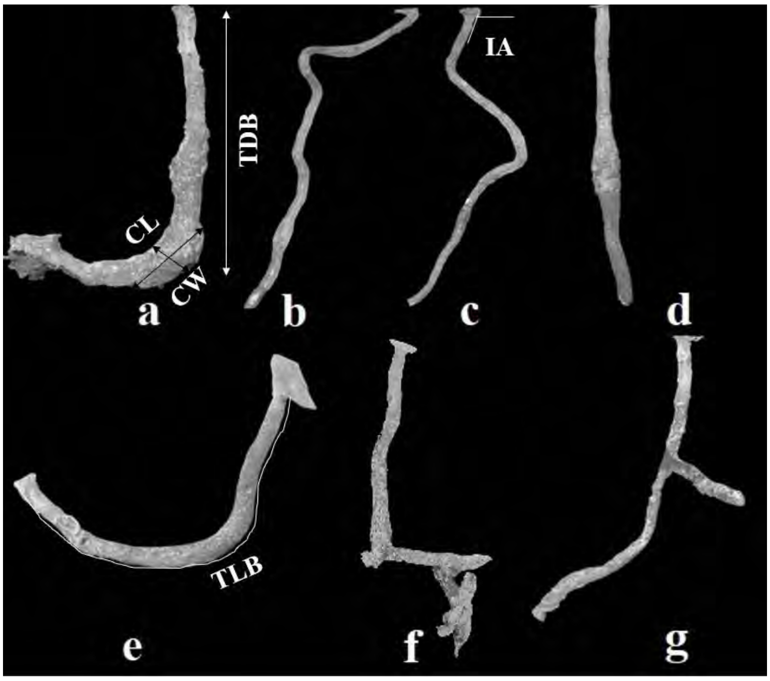

Fig. 2 Burrow architecture of *Austruca sindensis* with various measurements of burrow cast. a. J-shaped burrow, b. Spiral burrow, c. S-shaped burrow, d. Single tube burrow, e. U-shaped burrow, f. Multi-branched burrow, g. J-shaped with Branch burrow. (TDB – Total depth of Burrow; TLB – Total length of burrow; IA– Burrow inclination angle; CL – Chamber length; CW – Chamber width).

Fig. 3 Indicates number of burrow count with respect to shape of the burrow. J-shaped burrows (Fig. 2) (n = 28) had mean burrow volume of 44.59 ± 32.76 cm^3 with an average burrow opening diameter of 8.79 ± 2.29 mm. Burrows were vertically inclined with mean inclination angle of 120.2 ± 10.48°. J-shaped burrows were constructed by crab with mean carapace length of 7.87 ± 1.96 mm (n = 10). Mean length and depth of the burrows were 27.08 ± 10.12 cm and 22.43 ± 6.29 cm respectively. Mean length of the chambers situated on the centre and base was 2.45 ± 0.99 cm and 2.47 ± 0.50 cm. Mean width of the chambers situated on the centre and base was 4.37 ± 1.99 cm and 4.82 ± 1.39 cm.

Single tube burrows (ST) (Fig. 2) (n =27) had mean volume of 44.99 ± 27.66 cm^3 with mean opening diameter of 8.68 ± 2.01 mm. Burrows were constructed by the crabs having mean carapace length of 8.34 ± 2.01 mm (n =12). Burrows inclined vertically from the surface with the mean inclination angle of 118.04 ± 15.02° and ended with chamber (CL: 3.2 ± 0.58 cm CW: 9.02 ± 1.8 cm) at the base. One another chamber were constructed with mean length of 3.08 ± 0.84 cm and width 6.22 ± 2.05 cm. Mean length and depth of the burrows were 23.03 ± 7.96 cm and 21.46 ± 7.55 cm respectively.

S-shaped burrows (Fig. 2) (n = 21) had largest volume (47.12 ± 26.80 cm^3) with an average burrow opening diameter of 8.71 ± 2.20 mm. S-shaped burrows were constructed by the crabs with mean carapace length of 7.05 ± 1.66 mm (n = 10). Burrows were vertical with mean inclination angle of 117.47 ± 16.06°. In many S-shaped burrows two small chambers were constructed by the crabs either at base or in middle region of the burrow. Mean length of centrally located chamber and terminal chambers was 2.52 ± 0.63 cm and 2.6 ± 0.58 cm respectively. While Mean width of intermittent and terminal chambers was 5.53 ± 2.58 cm and 5.34 ± 1.64 cm respectively. Mean length of the burrows was 31.59 ± 9.79 cm and mean depth of the burrows was 23.77 ± 6.09 cm.

Spiral burrows (Fig. 2) (n = 10) had mean burrow volume of 37.35 ± 22.46 cm^3 with a mean opening diameter of 7.91 ± 1.80 mm and created by crabs with mean carapace length 6.33 ± 1.19 mm (n = 4). Burrows were vertically inclined with mean inclination angle of 137.5 ± 17.05°. Mean depth and mean length of the burrows was 22.73 ± 8.15 cm and 29.95 ± 10.31 cm respectively. Mean length and mean width of the chamber was 3.4 ± 0.28 cm and 5.5 ± 1.34 cm.

J-shaped burrows with branch (JB) (Fig. 2) (n = 5) had mean burrow volume of 21.09 ± 11.38 cm^3 with an average opening diameter of 9.03 ± 0.88 mm. Burrows were constructed by the crabs with mean carapace length of 7.27 ± 0.16 mm (n=3). Burrows were vertical in shape with mean inclination angle of 128.8 ± 8.54° and depth of 15.6 ± 4.13 cm. Main shaft of the burrow takes turn towards the surface in the form of branch which does not extend to the surface and ends in the forms of spherical blind end. Second branch is formed from the base of the main shaft and ends making small chamber at the base. The mean length of the burrows was 17.7 ± 2.95 cm.

U-shaped burrows with single opening (U with SO) (Fig. 2) (n = 2) had mean burrow volume of 40.63 ± 0.11 cm^3 with an average burrow opening diameter of 7.54 ± 0.87 mm. U-shaped burrows were constructed by the crab with carapace length of 7.55 mm (n = 1). Burrows were vertical with mean inclination angle of 138 ± 2°. Mean depth and mean length of the burrows were 17.5 ± 0.8 cm and 28.4 ± 0.9 cm. Mean length and width of the chamber at base was 2.9 cm and 8.3 cm.

Multi-branched burrow (MB) (Fig. 2) (n = 1) had mean volume of 79.58 cm^3 with opening diameter of 10.53 mm. The burrow looked almost similar to J-shaped with branch burrows, except one extra branch attached to the base of the secondary branch. In this burrow except primary arm no other branch reach the surface and they all ended with spherical blind lobe. The extra branch attached with secondary branch base, had multiple chambers. The burrow was constructed by the crab having carapace length of 7.72 mm (n=1). The burrow inclined vertically with inclination angle of 87°. The burrow had depth of 30.4 cm and total length of the burrow was 51.3 cm.

3.2 Seasonal variation in burrow architecture

In winter, crab carapace length showed positive correlation with carapace width (R^2=0.90), burrow opening diameter (R^2=0.82), total burrow length (R^2=0.57), total burrow depth (R^2=0.56) and burrow volume (R^2=0.49) (Fig. 4). In summer, carapace length showed strong positive correlation with the carapace width (R^2=0.93), burrow opening diameter (R^2=0.96), total burrow length (R^2=0.74), total burrow depth (R^2=0.57) and burrow volume (R^2=0.63) (Fig. 5). Crab carapace length was positively correlated with the carapace width (R^2=0.92), burrow opening diameter (R^2=0.91), total burrow length (R^2=0.64), total burrow depth (R^2=0.57) and burrow volume (R^2=0.44) in monsoon season (Fig. 6). The crab carapace length did not show significant correlation with burrow inclination angle in all three seasons (R^2=0.06, 0.01, 0.01 respectively for winter, summer and monsoon) (Fig. 4, 5, 6).

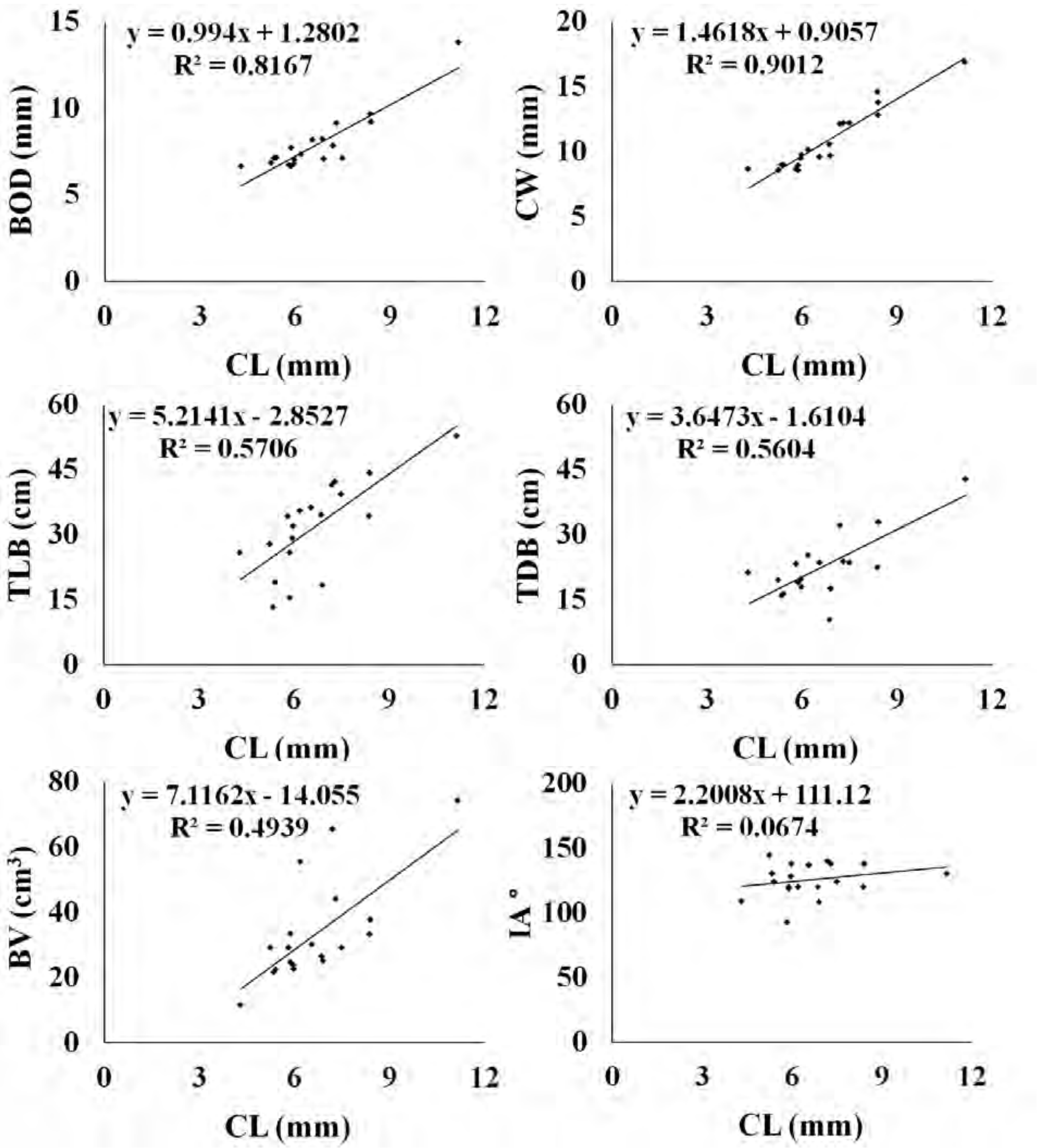

Fig. 4 Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in winter season.

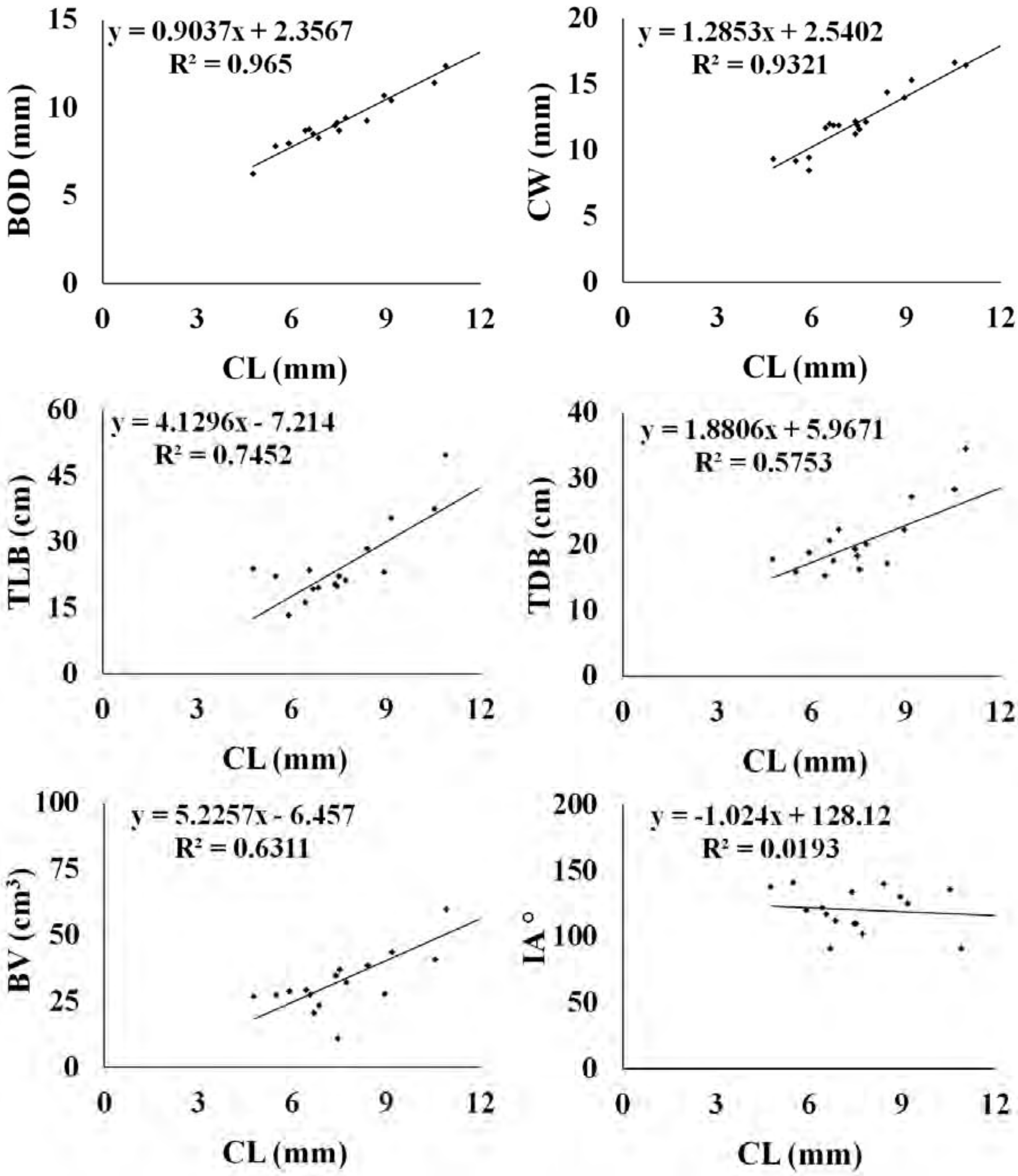

Fig. 5 Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in summer season.

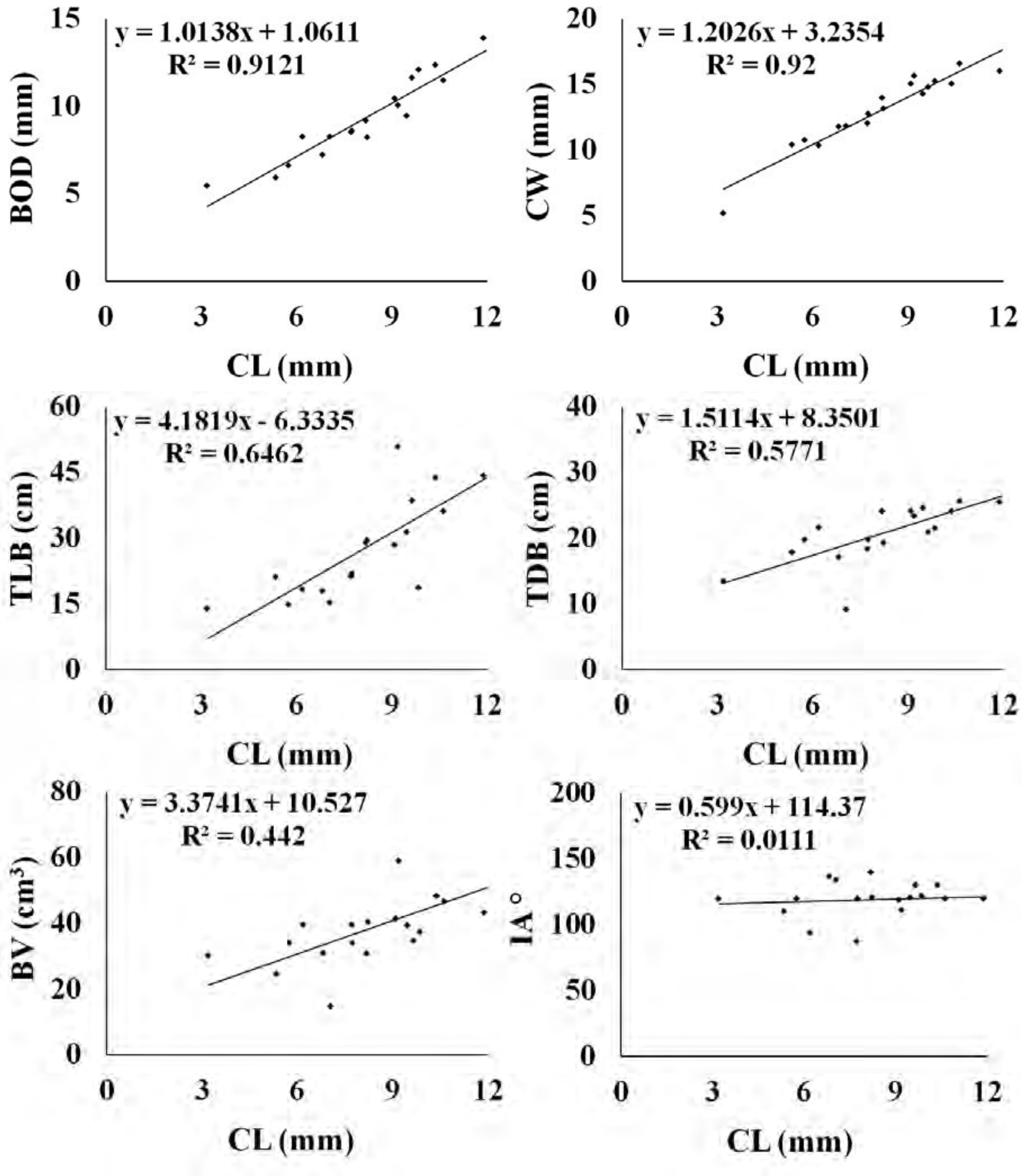

Fig. 6 Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in monsoon season.

3.3 Variation in burrow architecture in male and female crabs

The carapace length (mm) of the male and female crabs were not significantly different (males: 7.94 ± 1.8, females: 7.17 ± 1.87). In the case of burrow characteristics, both sexes constructed 6 different shaped burrows and their burrow shapes were not different. However, the diameters of male crab burrows were larger compared to the diameters of female crab burrows, male crab burrows were longer and more voluminous than those of the female crabs (Table 1).

Table 1 Burrow characteristics of *Austruca sindensis* (Alcock, 1900).

Burrow Morphology	Male	Female
Total shape	6	6
Total burrow	29	17
carapace length (mm)	7.94 ± 1.8	7.17 ± 1.87
Burrow opening diameter (mm)	9.22 ± 1.97	8.47 ± 1.77
Burrow length (cm)	30.55 ± 10.94	27.56 ± 10.56
Burrow depth (cm)	21.81 ± 6.34	21.18 ± 5.04
Inclination angle °C	123.28 ± 13.29	124.71 ± 11.22
Volume (CM^3)	39.19 ± 13.33	30.62 ± 8.99

3.4 Vertical temperature profile of burrows

The depth wise variation in burrow temperature was studied for various burrow shapes recorded in the present study. Results revealed similar pattern in temperature variation for all the burrow shapes. In winter, the sand surface temperature recorded 26-30°Cwhich remained similar for all the burrow types (Fig. 7). The sand surface temperature was recorded 38-44°C and 32-40°C during summer season and monsoon season respectively (Fig. 8, 9). The temperature declined to 2 to 2.5°C at a depth of 5 cm. After the depth of 5 cm the rate of temperature drop decreased to 1 to 1.5°C at every 5 cm. The temperature recorded at the deepest part of the burrow that could be measured up to 25 cm was 22-27.5°C, which was cooler than the surface temperature in all the season.

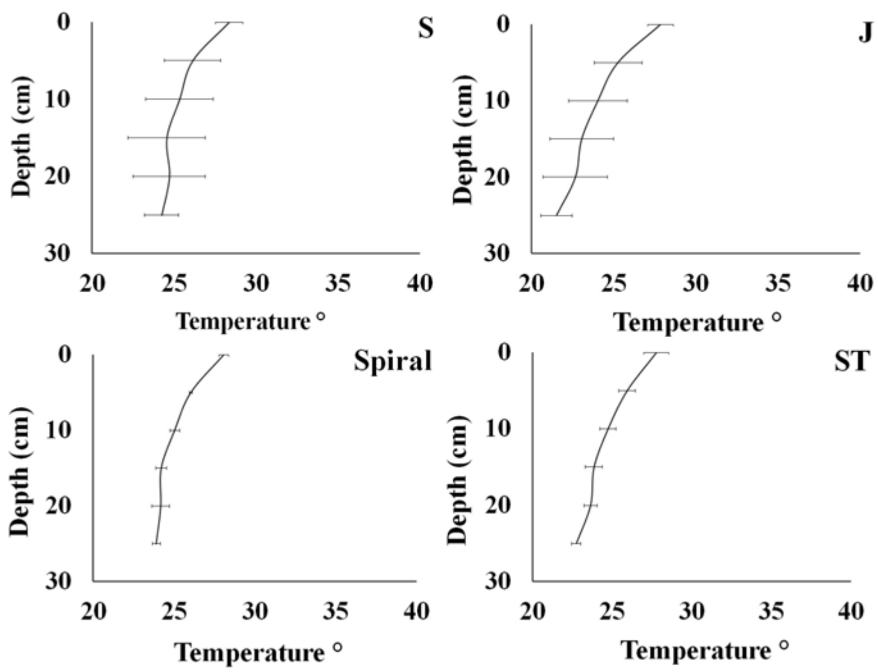

Fig. 7 Vertical temperature profiles with the burrow depth for different shapes of the burrows during winter season.

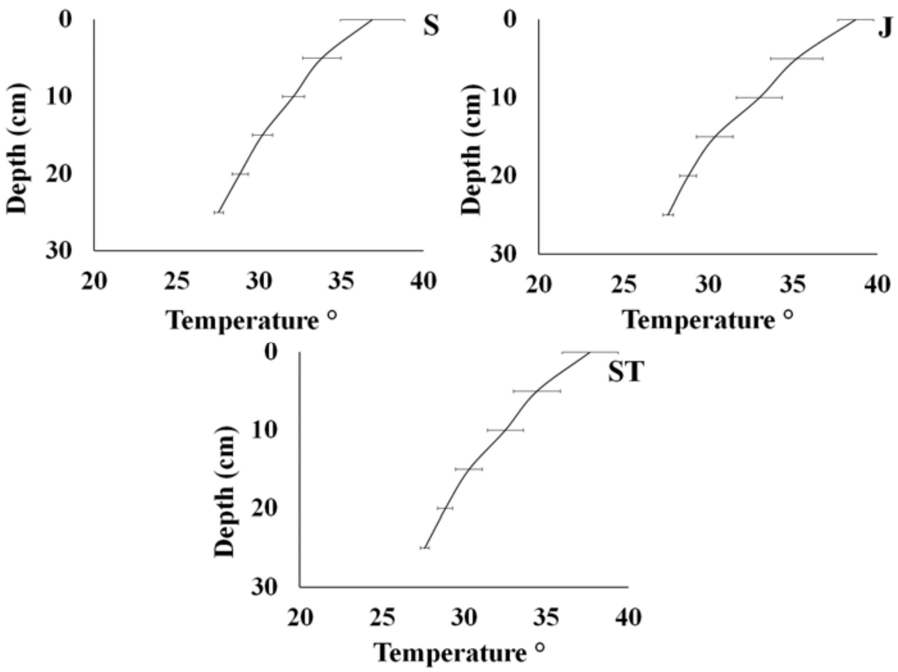

Fig. 8 Vertical temperature profiles with the burrow depth for different shapes of the burrows during summer season.

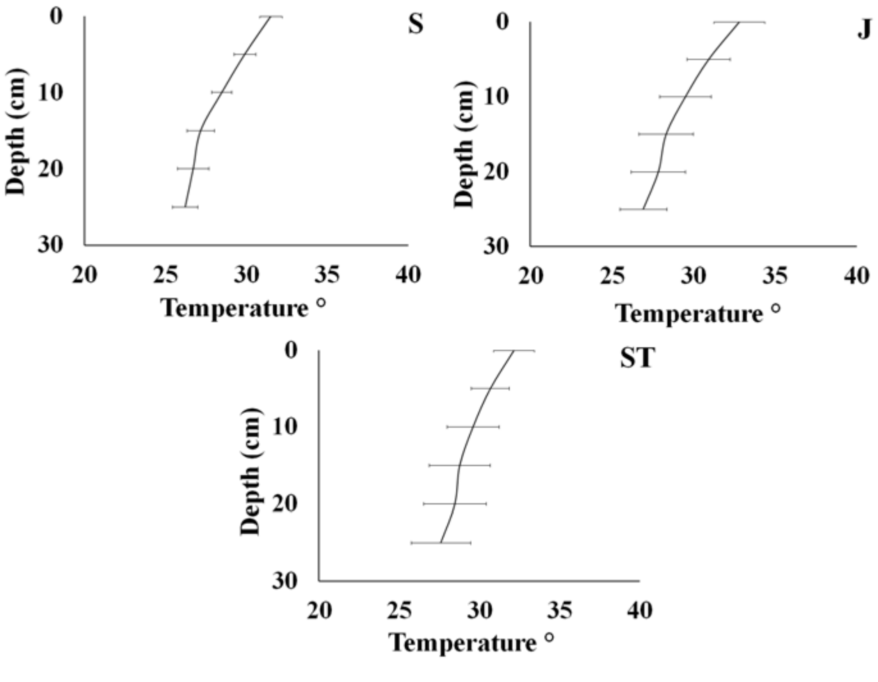

Fig. 9 Vertical temperature profiles with the burrow depth for different shapes of the burrows during monsoon season.

3.5 Principle component analysis (PCA) of burrow morphology

3.5.1 PCA of burrow morphology in winter season

In winter season the number of variables in upper intertidal zone (UTZ) (U1 to U21) are twenty-one and middle intertidal zone (MTZ) (M1 to M11) are eleven. Scree plot in figure 10 shows data has three major components as shown in Table 2. Per cent variance for component 1 is 77.837%, 2 is 17.369% and 3 is 4.795%.

Cumulative percentage for component 1 is 77.837%, component 2 is 95.205% and component 3 is 100% shown in Table 2. Fig. 11 indicates most of the burrow are concentrated in one quadrate and only M10, U8 and U12 are concentrated in another quadrate. All burrows are closely present giving out maximum correlation.

Table 2 Total variance in winter season.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	24.908	77.837	77.837	24.908	77.837	77.837
2	5.558	17.359	95.205	5.558	17.359	95.205
3	1.534	4.795	100	1.534	4.795	100

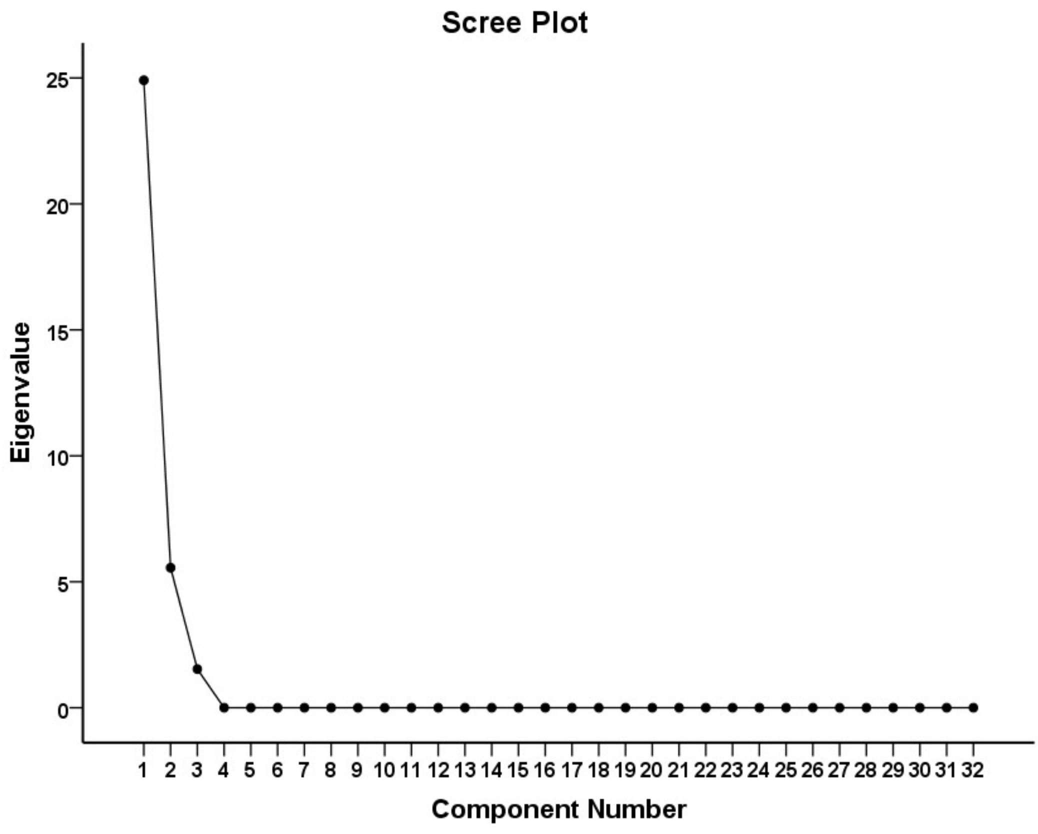

Fig. 10 Scree plot indicating major 3 plots for winter season.

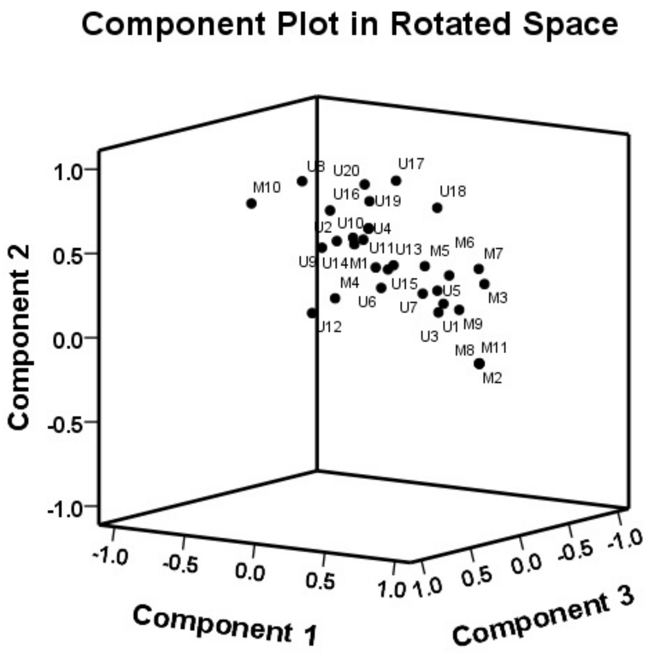

Fig. 11 Component plot in rotated space for winter season.

3.5.2 PCA of burrow morphology in summer season

In summer season number of variables in upper intertidal zone (UTZ) (U1 to U13) are thirteen and middle intertidal zone (MTZ) (M1 to M21) are twenty-one. Scree plot in Fig. 12 shows data has two major components as shown in Table 3. Per cent variance for component 1 is 85.503% and 2 is 16.497%. Cumulative percentage for component 1 is 85.503% and component 2 is 100% shown in Table 3. Fig. 13 indicates most of the burrow are concentrated in one quadrate and only M9 and M11 are concentrated in another quadrate. All burrows are closely present giving out maximum correlation.

Table 3 Total variance in summer season.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	28.391	83.503	83.503	28.391	83.503	83.503
2	5.609	16.497	100	5.609	16.497	100

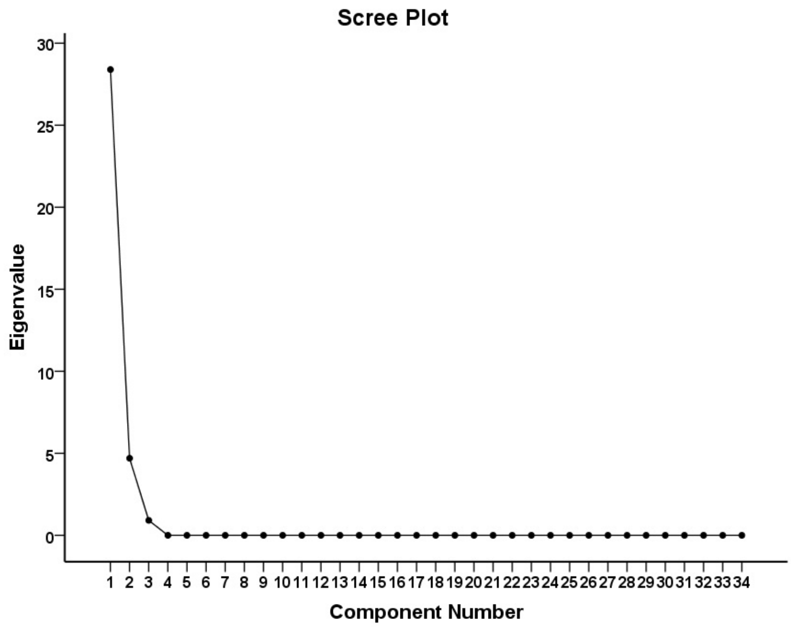

Fig. 12 Scree plot indicating major 2 plots for summer season.

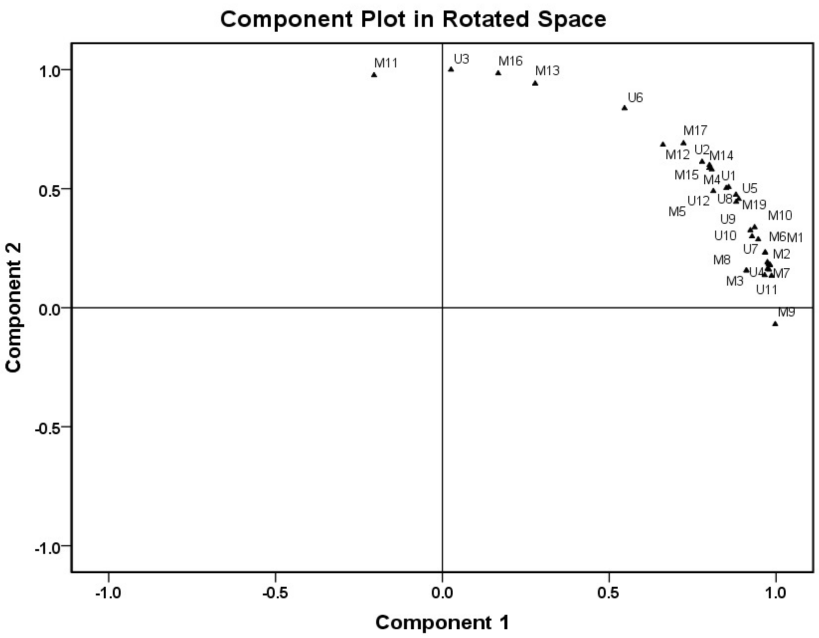

Fig. 13 Component plot in rotated space for summer season.

3.5.3 PCA of burrow morphology in monsoon season

In monsoon season number of variables in upper intertidal zone (UTZ) (U1 to U16) are sixteen and middle intertidal zone (MTZ) (M1 to M12) are twelve. Scree plot in Fig. 14 shows data has three major components as shown in Table 4. Per cent variance for component 1 is 91.679% and 2 is 8.322%. Cumulative percentage for component 1 is 91.679% and component 100% shown in Table 4. Fig. 15 indicates all the burrow are concentrated in one quadrate.

Table 4 Total variance in monsoon season.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	25.670	91.679	91.679	25.670	91.679	91.679
2	2.33	8.322	100	2.33	8.322	100

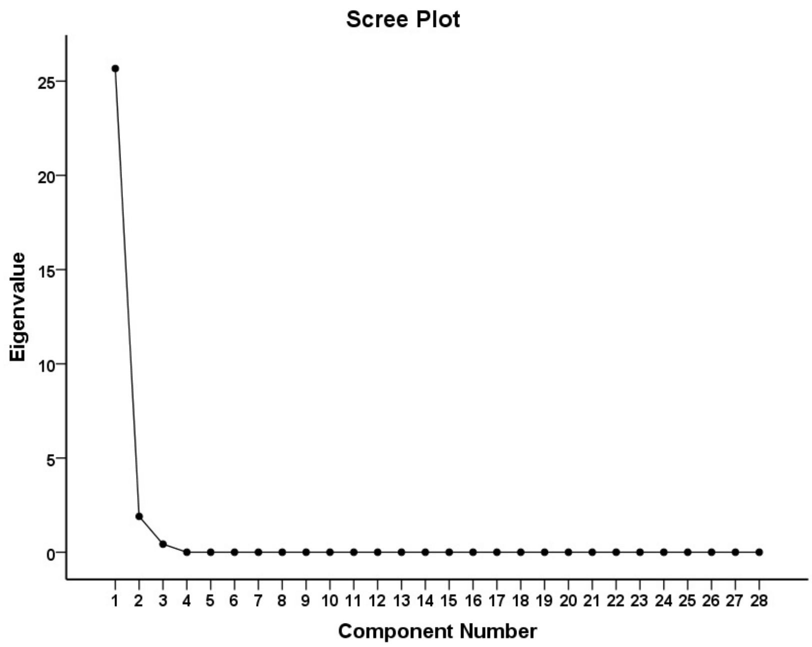

Fig. 14 Scree plot indicating major 2 plots for monsoon season.

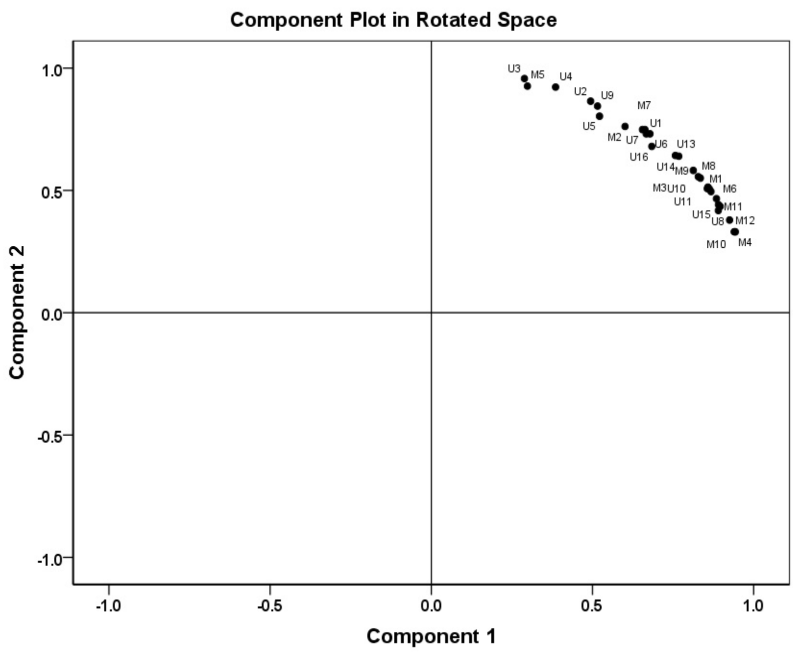

Fig. 15 Component plot in rotated space for monsoon season.

4 Discussion

Burrows constructed in soft sediments play a significant role in the reproductive activity of the burrowing crabs of Ocypodidae and Dotillidae families (Lim, 2006). The morphology of *Austruca sindensis* (Alcock, 1900) burrows showed considerable variation in shape, size and complexity, ranging from single entrance shafts with no branches to multiple entrances. In the present study, total seven different burrow shapes were recorded like J-shaped, Single tube, S-shaped, Spiral, J-shaped with branch, U-shaped with single opening and Multi-branched burrow (Fig. 2). Crabs with smaller carapace length had constructed single tube and J-shaped burrows, while larger sized had created single tube, J-shaped, J-shaped with branch, multi-branched, U-shaped with single opening and spiral burrows. According to Chakrabarti (1981) and Chan et al. (2006), the burrows like J-shaped and single tube burrows of juvenile crabs were shallow in depth with narrower opening diameter and lesser volume. Temporary burrows of the adult crabs are often shallow and single tubular structures.

In the present study, multi-branched and J-shaped with branched burrows were constructed by adult crab. The function of the branches of single tube and J-shaped burrows is still unknown but it has been assumed that the branch may provide shelter to the individual crab from the splash of the waves and predators (Chakrabarti, 1981). According to Chan et al. (2006), adult crabs can tolerate longer periods of exposure to air by digging deeper and more complex burrows. These crabs stay entirely in their burrows during daytime and as a result, their burrows were deeper and more complex as compared to the burrows of the juvenile crabs (Chan et al., 2006; Katrak et al., 2008, Gul and Griffen, 2018). More complex burrow provides greater underground surface area, which is favourable for increased gaseous exchange and microbial colonization. This also delivers greater access of resources to organisms inside the burrow (Thongtham and Kristensen, 2003).

Uca pugilator (Bosc), *Sesarma longipes* (Krauss), *Cardisoma carnifex* (Herbst) and *Macrophalmus parvimanus* (Guerin) has created temporary burrows like single tube and bulb shape for refuges during high tides or to get protection from the predator (Braithwaite and Talbot, 1972; Christy, 1982). During investigation, adult carb excavated spiral burrow with end chamber. Previously, crabs of *Ocypode ceratophthalmus* (Pallas, 1772) and *O. saratan* (Forskal, 1775) constructed spiral burrow with the sole purpose of providing a place for copulation (Hughes, 1973; Vannini, 1980). Nonetheless, simpler forms consisting of unbranched, subvertical to inclined, irregularly twisted to J-shaped shafts are very common among species of Macrophthalmidae, Myctiridae, Dotillidae, Gecarcinidae, Gecarcinucidae, and Portunidae (Gilbert et al., 2013).

In the present study, crab length showed significant positive relationship with burrow opening diameter, burrow length, burrow depth and burrow volume. Here, mean burrow length and depth were recorded around 30.55 ± 10.94 cm and 21.81 ± 6.34 cm respectively for the crab with mean carapace length of 7.94 ± 1.8 mm. Qureshi and Saher (2012) have also studied the burrow architecture of *Uca sindensis* (synonym of *A. sindensis*). They excavated burrows with mean length and depth of 22.02 ± 7.10 cm and 15.04 ± 6.2 cm respectively for crab with the mean carapace length of 2.212 + 0.591 mm. The burrow morphology is species specific (Griffis and Suchanek, 1991; Wolfrath, 1992; Griffis and Chavez, 1988) but variation in burrow morphology is observed within same species due to changes in physical and biochemical properties of the sediment (Lucrezi et al., 2009). Larger-sized crabs had greater burrow diameter, larger burrow volume and bigger chamber diameter than small and medium sized crabs (Upadhyay et al., 2022). Lim and Diong (2003) studied burrow morphology of the crab *U. annulipes* (Milne Edwards, 1837) and found that larger crabs generally excavated wider, more spacious burrows than small and medium-sized individuals.

Previous studies showed that burrow architecture get affected by several environmental factor such as temperature, moisture level, wind (Lucrezi et al., 2009), and geomorphological properties of the sandy shores like sand compaction, beach slope and sand grain size (Dixon et al., 2015; Pombo et al., 2017) and as well as erosion (Hobbs et al., 2008). Burrow architecture also varies based on size and sex of the resident crab (Lim and Diong, 2003). Present study revealed that both male and female *A. sindensis* built six different shaped burrow and male crabs burrows were longer and voluminous than the female crab burrows. Males build longer and deeper breeding burrows to attract females for mating purpose (Christy, 1982; Backwell and Passmore, 1996; Tina et al., 2018). Mate selection occurs mostly based on the quality of breeding burrows, because mating and egg incubation take place inside the male breeding burrows (Christy, 1982, 1987; Christy and Salmon, 1984; Christy and Schober, 1994; Ribeiro et al., 2010).

Vannini (1980) and Atkinson and Taylor (1988) discussed that burrow provides protection against high external temperatures and environmental extremes. Furthermore, Lim and Diong (2003) working upon fiddler crabs hypothesized that high intertidal areas might help to maintain lower burrow temperature during ebb tides. According to Dubey et al. (2013), temperature and moisture levels in the substratum could influence the burrow depth by playing an important ecological role in the life history and habitat dependency of *O. macrocera*. In the present study, the temperature of the sand surface dropped along the depths of the burrows which suggests that the burrows can provide the resident to the crab and helps to get refuges during the stressful period in summer. Temperature could be even lower when going further down the burrow, although measurement cannot be obtained at further depths. As burrows are important to get refuge from desiccation for intertidal crabs (Takeda and Kurihara 1987; Thongtham and Kristensen, 2003), the depth of burrows will be influenced by the water content of the sediment.

A few previous studies also observed that the burrows acted as refuge for fiddler crabs during very high or very low temperatures (Edney, 1961; Powers and Cole, 1976; Wolfrath, 1992). According to Wolfrath (1992), temperature variation inside the crab burrows was inversed with outside air temperature, and burrow temperature was lower during the day and higher during the night than the outside temperature. It was also concluded that temperatures higher than the optimal peak temperature reduces the ventilator and cardiac performance in crabs, resulting in a lesser supply of oxygen to the tissues and a reduced endurance capacity (Frederich and Portner, 2000; Allen et al., 2012). In PCA analysis, during summer and winter season less cluster formation was observed. While in monsoon season, PCA analysis demonstrated better cluster formation as all burrow parameters were closely correlated. This is may be because this season cab be a season for breeding and reproduction. Thus, burrows are highly developed for mating with appropriate breeding chambers and for an ovigerous female to stay inside the burrow for a longer time and with the least disturbance.

Acknowledgements
Authors would like to thank Head, Department of Zoology, The Maharaja Sayajirao University of Baroda, Vadodara for the laboratory, storage and museum facilities. The first author would like to thank Dr. Khushali Pandya, Ms. Foram Jadeja, Ms. Jalpa Jadeja, Ms. Vaishali Prajapat and Mr. Dhaval Bhatt for their valuable help during field surveys. The local fishermen of Kamboi village are thank fully acknowledged for their help during field surveys. The authors would like to thank Dayabhai Patel and Hasumatiben Patel for providing accommodation at Kamboi during surveys. The first author would like to thank SHODH - ScHeme of Developing High quality research fellowship provided by Education Department, Gujarat State. The authors are also thankful to the reviewers for their critical review of the manuscript.

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