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Burrow Morphology of Brachyuran Crab *Dotilla blanfordi* Alcock, 1900 from Gulf of Khambhat, Gujarat, India

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Abstract: The present study was conducted to understand the burrow morphology of brachyuran crab *Dotilla blanfordi* Alcock, 1900 at Dandi beach located in Gulf of Khambhat of Gujarat state, India. Burrows were selected randomly and their opening diameter was recorded. Diluted resin was poured in the burrows to generate burrow cast. If the occupant crab emerges out of the burrow, it was captured and carapace width and gender was recorded. The shapes of complete burrow casts were identified and measurements of various morphological characters of burrow cast were recorded. Total 7 different burrow shapes were identified, out of which single tube burrow was the most common as compared to other burrow shapes. The crab carapace width showed significant relationship with burrow opening diameter, burrow depth, burrow length and burrow volume. Juveniles (<3.45 mm CW) were making burrow of only 3 shapes while adults (>3.45 mm CW) were making burrow of all the seven shapes. Burrow depth, length and volume were significantly higher in adult crabs as compared to juveniles. No significant variation was observed between burrows of male and female individuals. The present study showed that burrow morphology is highly affected by the crab body size and also varies significantly with different life stages of the crab. Juveniles make shallow and simple burrows as their smaller gill areas stores lesser amount of respiratory water which needs to be changed frequently. However, adults make complex burrows to perform various tasks including copulation and reproduction.

Keywords: Behavioural adaptation, Burrow architecture, Burrow shapes, Crab, *Dotilla blanfordi*, Sandy shore

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Introduction

Burrowing is a widespread behaviour observed in several invertebrates (Matsumasa *et al*., 1992; Lomovasky *et al*., 2006) as well as in vertebrate fauna (Moulton *et al*., 2006; Schwaibold and Pillay, 2006). The biogenic structures and the process involved for the constructing and maintaining it, create complex interactions along the trophic webs (Reise, 2002; Kristensen, 2008). Burrow architecture is ecologically important specially to maintain semi-terrestrial mode of habit (Dubey *et al*., 2013). Generally, the morphology of burrow is species specific (Griffis and Suchanek, 1991; Wolfrath, 1992) which might be modified according to the varying physical and chemical factors (Griffis and Chavez, 1988). Several crab species are such conspicuous burrowers with certain species showing significant intraspecific variation in the burrow architecture in relation to the environmental factors like substratum hardness, sediment composition and root-mat density of the surrounding vegetation (Bertness and Miller, 1984; Takeda and Kurihara, 1987; Morrisey *et al*., 1999). The architecture of burrow could also be affected by the shore height, tidal period, gender and life stage of the crabs (Lee and Koh, 1994; Lim and Diong, 2003; Chan *et al*., 2006). Several crab species are active burrowers of intertidal soft sediment causing remarkable effect on benthos present in the sediments (Iribarne *et al*., 1997; Herman *et al*., 1999). Constructing burrows can be advantageous in several ways like protection against predator, refuge from disturbance, thermal extremes (Ansell, 1988) and adverse environmental conditions (Kinoshita, 2002; Thongtham and Kristensen, 2003). Burrow morphology varies from species to species (Griffis and Suchanek, 1991; Wolfrath, 1992; Trivedi and Vachhrajani, 2016) as well as variation in burrow morphology is sometimes observed within same species due to several physical and biological factors (Takeda and Kurihara, 1987; Morrisey *et al*., 1999; Lim and Diong, 2003; Chan *et al*., 2006). Burrowing behaviour is studied well for species belonging to genera like *Macrophthalmus, 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), *Scopimera* (Tweedie, 1950; Fielder, 1970) and *Dotilla* (Tweedie, 1950).

Crabs of genus *Dotilla* are active burrowers and build their burrow in sandy-muddy shore habitat. Species of genus *Dotilla* are small in size and form dense population that play important role in the ecology of mudflat habitat because of their burrowing and feeding activity (Allen, 2010). During high tide these crabs remain inside the burrow while emerging out during low tide for feeding or other surface activities (Gherardi *et al*., 1999). Species of *Dotilla* are distributed in the Indo-Pacific region (MacNae and Kalk, 1962; Silas and Sankarankutty, 1967; McIntyre, 1968; Hartnoll, 1973; Hails and Yaziz, 1982; Matsumasa *et al*., 1992). *Dotilla blanfordi* is reported from the Gujarat, Maharashtra, Andhra Pradesh, Odisha and West Bengal states of India (Trivedi *et al*., 2018). In Gujarat state, the species is abundantly found in the intertidal region of Dandi beach, of Navsari district, Gulf of Khambhat. However, ecological aspects of the species have not been studied yet. So, the present study was aimed to understand the correlation between crab morphology and different burrow morphometry. The relationship between the life stages and sex of the individuals with the morphological characters of the burrow produced by the individual were also investigated.

Materials and Methods

Study area:

The present study was carried out at the intertidal region of Dandi beach (20º53'10"N, 72º47'47"E) located in Navsari district, Gulf of Khambhat, Gujarat, India (Fig. 1). The upper intertidal zone is sandy shore which is dominated by brachyuran crabs of *Ocypode* sp. while the middle and lower intertidal zone is covered by mudflat habitat which is dominated by *Dotilla blanfordi.*

Sampling methodology:

The present study was carried out from June 2019 to February 2020. Burrows were selected randomly and their opening diameter was measured using vernier calipers (±0.01 mm). Unsaturated resin was poured into the burrows until they were completely filled. If the host crab emerges, it was captured, its gender was identified

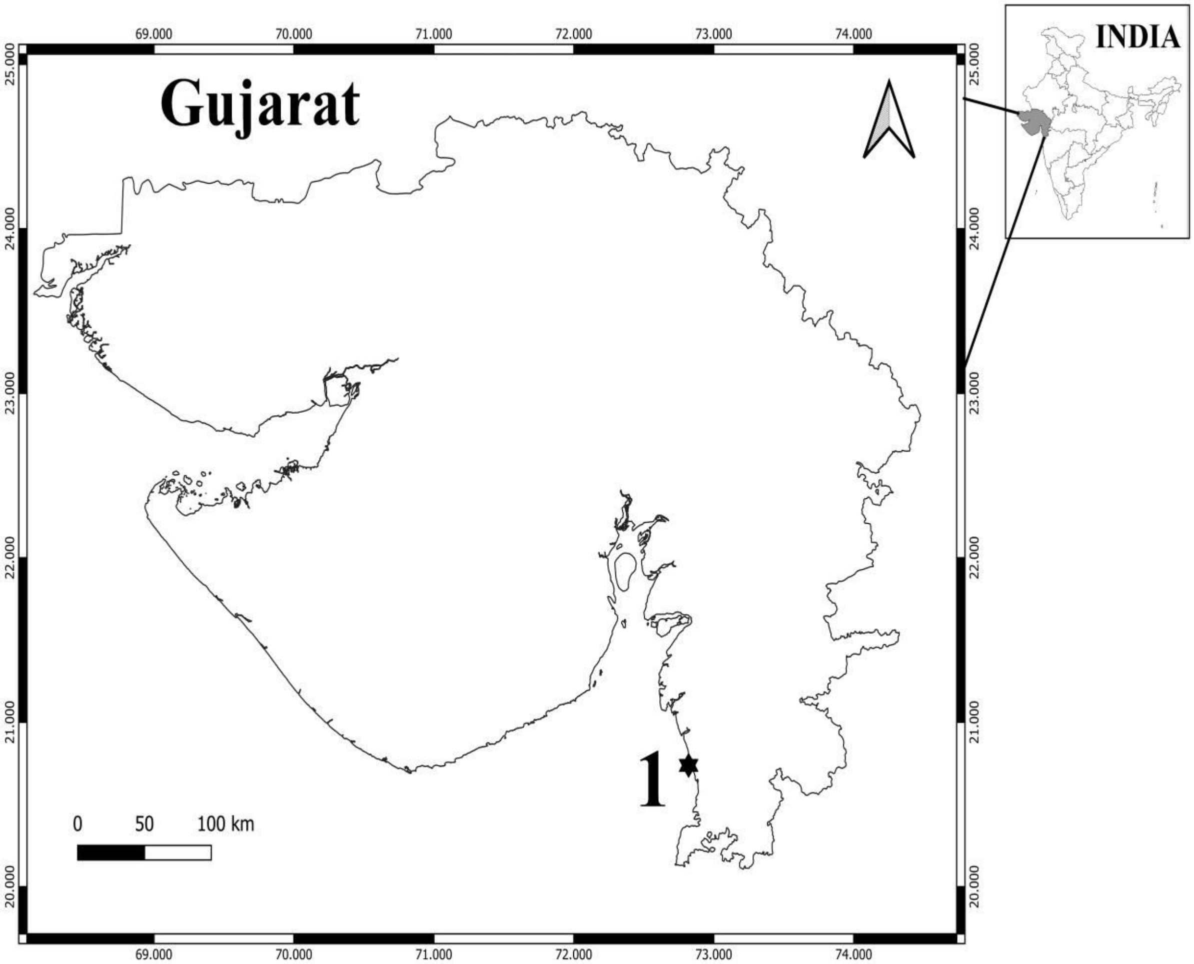

Fig. 1: Map of study area. 1. Dandi beach, Gulf of Khambhat, Gujarat, India.

and the carpace width (CW) of the individual was recorded using digital vernier calipers (± 0.01 mm). Individuals smaller than the smallest ovigerous female were considered as juvenile (<3.45 mm CW). After the cast solidifies, they were excavated and brought to laboratory for further analysis. In laboratory, burrows were allowed to dry for two more days. The cast were cleaned to remove any sediment on the cast surface and only complete cast were used for the analysis. Further on the basis of the cast shape the burrows were classified and various morphometric analysis were recorded including burrow inclination angle (IA), total depth of burrow (TDB), total length of burrow (TLB) and burrow volume (BV). The burrow volume was measured by weighing the burrow (± 1g) and dividing the burrow weight with the density of the unsaturated resin (0.96 g/cm^3).

Regression analysis was carried out to establish the relationship between crab carapace width and different morphological parameters of burrow cast. The mean values of various morphological characters of burrow cast were also compared using paired t test. All the statistical analysis were carried out using MS Excel.

Results and Discussion

Total 84 complete burrow casts were examined in the present study from which the host crab were captured. Seven different shapes of burrow cast were identified viz. single tube burrow (53 burrow cast), single tube with branch (one burrow cast), J shape burrow (20 burrow cast), J shape with

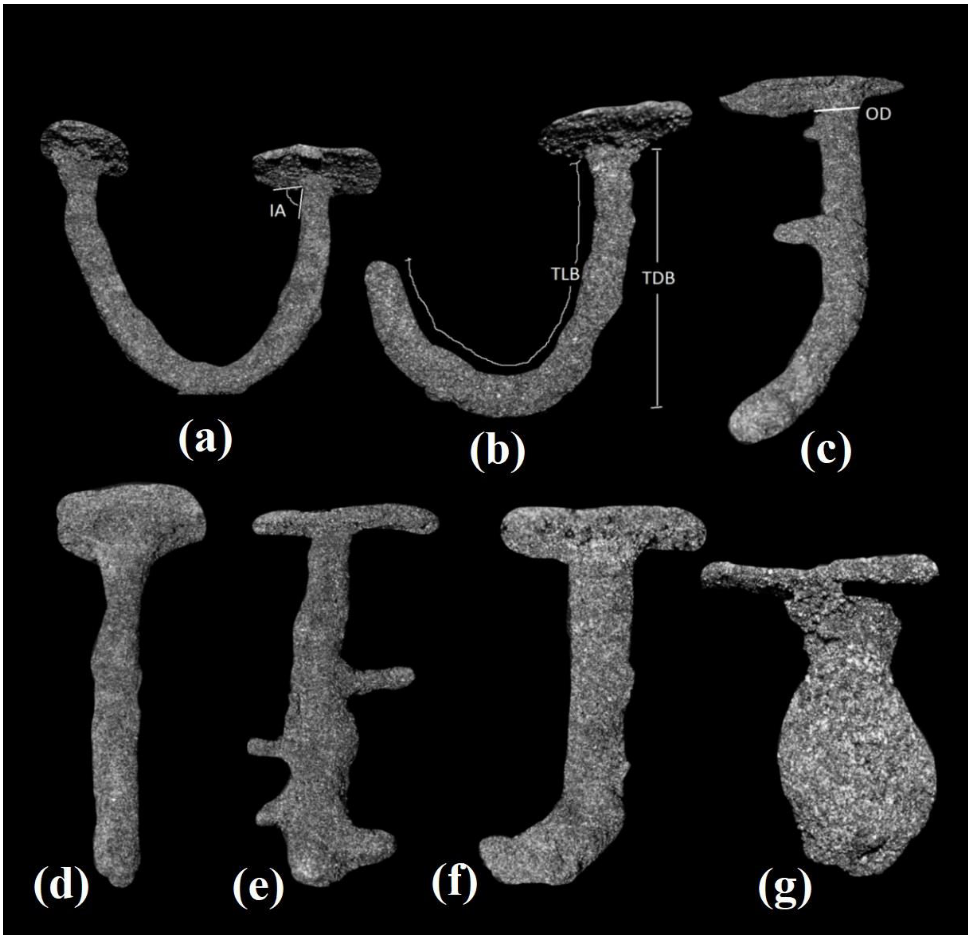

Fig. 2: Different burrow shapes made by *Dotilla blanfordi.* (a) U-shaped burrow with double opening burrow; (b) U-shape with single opening burrow; (c) J-shape with branch burrow; (d) Single tube burrow; (e) Single tube with branch burrow; (f) J-shape burrow; (g) Bulb shape burrow. TLB: Total length of burrow; TDB: Total depth of burrow; IA: Inclination angle; OD: opening diameter.

branch (one burrow cast), bulb shape burrow (two burrow cast), U shape with double opening (six burrow cast) and U shape with single opening (one burrow cast) (Fig. 2). Chan *et al*. (2006) and Trivedi and Vachhrajani (2016) studied burrow architecture of *Ocypode ceraptothelma* on sandy shores of Hong Kong and India, respectively. They have recorded different burrow shapes like Single tube burrow, J shape with branch at the base, J shape, Bulb shape, Y shape burrow, Multi branched burrow, Y shape with double opening and U shape burrow. The burrow constructed by *D. blanfordi* was diverse in terms of burrow shapes as compared to burrow shapes constructed by *D. fenestrate* (four shapes) (Gherardi and Russo, 2001) and *Uca annulipes, Uca chlorophthalmus* and *Uca sindensis* (six shapes) (Qureshi and Saher, 2012). The burrow shape is generally species-specific (Griffis and Suchanek, 1991; Wolfrath, 1992). However, due to varying physical and chemical differences in sediment type and vegetation, the burrow architecture might be modified to adjust according to the environmental parameters (Griffis and Chavez, 1988).

The crab carapace width showed significant relationship with crab carapace length ($R^2 = 0.954$, $p < 0.001$), burrow opening diameter ($r^2 = 0.668$, $p < 0.001$), burrow volume ($R^2 = 0.520$, $p < 0.001$), total depth of burrow ($R^2 = 0.58$, $p < 0.001$) and total length of burrow ($R^2 = 0.56$, $p < 0.001$) showing that the burrow morphology is closely associated with the size of the resident crab. However, the crab carapace width did not show significant correlation with the burrow inclination angle ($R^2 = 0.007$, $p = 0.89$) (Fig. 3).

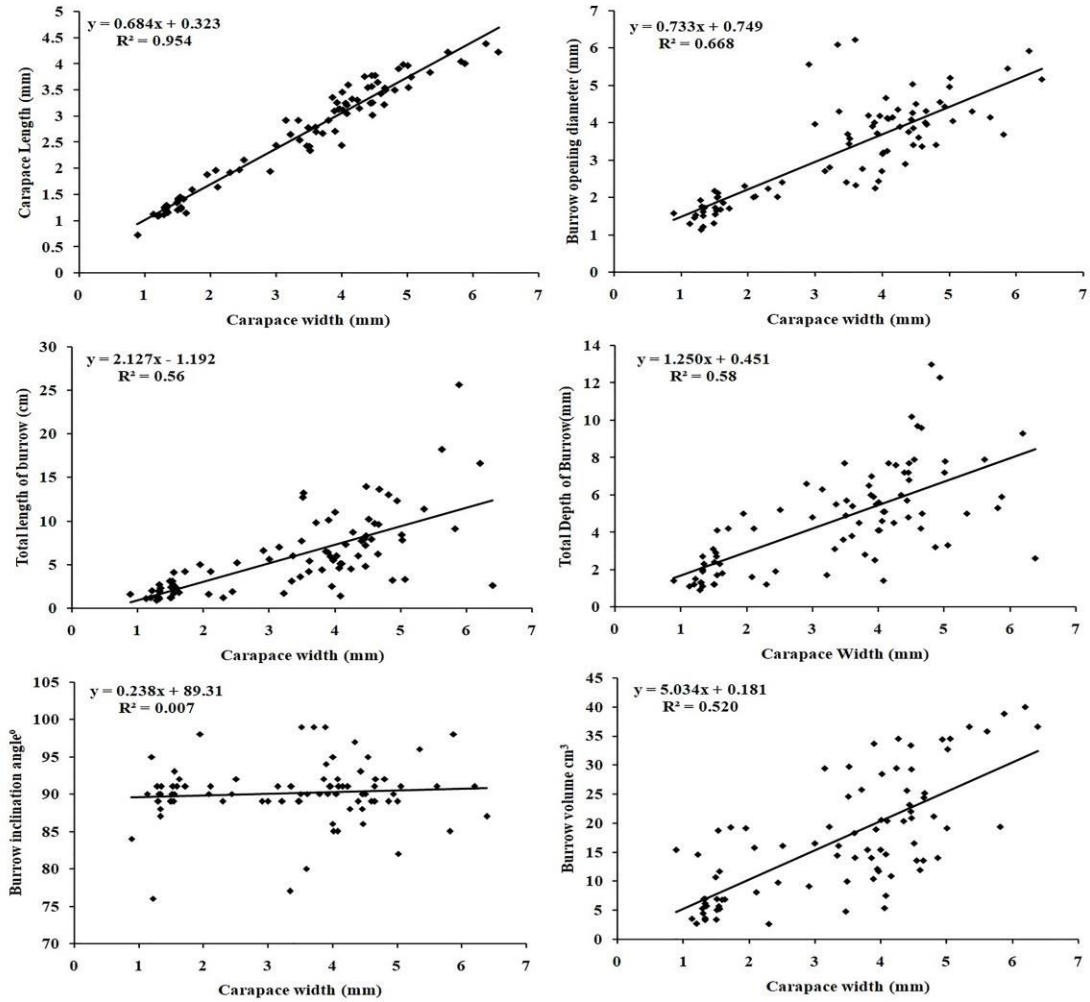

Fig. 3: Regression analysis of carapace width of *Dotilla blanfordi* and different morphological parameters of crab and burrow casts.

Single tube burrows (N = 53) had the mean burrow volume of 13.45 ± 1.38 cm^3 with an average burrow opening diameter of 2.77 ± 1.20 mm. The burrows were constructed by the crabs with mean carapace length of 2.95 ± 1.44 mm. The burrows were inclined vertically with an average inclination angle (IA) of 88.88 ± 12.14°. The mean burrow length (MBL) and depth (MBD) of the burrows were 4.49 ± 3.31 cm and 4.18 ± 2.92 cm, respectively (Table 1).

Single tube with branch burrow (N = 1) had burrow volume of 15.43 cm^3 with opening diameter of 4.26 mm. This burrow was occupied by the crabs with carapace width of 4.46 mm. Total length and depth of burrow was same 4.8 cm. The burrow was inclined vertically with the inclination angle of 90°. Branch length of single tube burrow was 0.9 cm and depth of branch was 0.7 cm (Table 1).

J-shape burrows (N = 20) had the mean burrow volume of 19.06 ± 6.89 cm^3 with an average opening diameter of 3.64 ± 1.25 mm. The burrows were constructed by the crabs with mean carapace length of 3.60 ± 1.24 mm. The burrows were inclined vertically with the average inclination angle 88.9 ± 4.98°. The mean burrow length (MBL) and depth (MBD) of the burrows were 6.5 ± 2.44 cm and 5.31 ± 2.01 cm, respectively (Table 1).

J-shape with branch burrow (N = 1) had the burrow volume of 8.5 cm^3 with the opening diameter of 3.2 mm. The burrow was constructed by the crab with carapace length of 4.02 mm. The burrow was inclined vertically with the average

Table 1 Value of different parameters of burrow morphology of *Dotilla blanfordi*.

Burrow shape	n	Host crab CW (mm)	MBOD (mm)	MBL (cm)	MBD (cm)	MIA	MBV $(cm)^3$
Single tube shape	53	2.95±1.44	2.77±1.20	4.49±3.31	4.18±2.92	88.88±12.44°	13.45±1.38
Single tube with branch	1	4.46	4.26	4.8	4.8	88°	15.43
J- shaped	20	3.60±1.24	3.64±1.25	6.5±2.44	5.31±2.01	88.9±4.98°	19.06±6.89
J-shape with branch	1	4.02	3.2	6	4.1	85°	8.51
U-shape	6	4.72±1.05	3.04±0.78	15.83±5.31	6.03±1.14	94±4.14°	33.51±14.36
U-shape with single opening	1	6.2	5.92	16.6	9.3	91°	38.04
Bulb shape	2	4.22±1.21	5.06±1.44	3.21±0.14	3.21±0.14	84±9.98°	13.39±1.56

n = total number of burrows; CW= carapace width; MBOD= mean burrow opening diameter; MBL= mean burrow length; MBD= mean burrow depth; MIA= mean inclination angle; MBV= mean burrow volume

inclination angle 85°. The burrow length and depth were 6 cm and 4.1 cm respectively (Table 1). The length of 1st branch and 2nd branch was 0.9 cm and 0.7 cm, respectively. Depth of 1st and second branch was 3 cm and 0.8 cm, respectively. Inclination angle of 1st and 2nd branch was 99° and 92°, respectively.

Bulb shape burrows (N = 2) had the mean burrow volume of 13.39 ± 1.56 cm^3 with an average opening diameter of 5.06 ± 1.44 mm. The burrows were constructed by the crabs with mean carapace length of 4.22 ± 1.21 mm. The burrows were inclined vertically with the average inclination angle 84 ± 9.98°. The mean burrow length (MBL) and depth (MBD) was similar of 3.21 ± 0.14 (Table 1).

U-shape with double opening burrows (N = 6) had the largest mean burrow volume of 33.51 ± 14.36 cm^3 with an average opening diameter of 3.04 ± 0.78 mm. The burrows were constructed by the crabs with mean carapace length of 4.72 ± 1.05 mm. The burrows were inclined vertically with the average inclination angle 94 ± 4.14°. The mean burrow length (MBL) and depth (MBD) of the burrows were 15.83 ± 5.31 cm and 6.03 ±1.14 cm, respectively (Table 1).

U-shape with single opening burrow (N=1) had burrow volume of 38.04 cm^3 with largest burrow opening diameter of 5.92 mm. This burrow was occupied by the crabs with carapace width of 6.2 mm. The burrow was inclined vertically with the average inclination angle of 91°. The total length and depth of burrow was 16.6 cm and 9.3 cm, respectively (Table 1).

The single tube and bulb shape burrow were constructed by the juvenile and adult individuals. Similar kind of burrow were also reported in some other studies carried out on the crab species like *Uca pugilator* (Christy, 1982), *Cradisoma carnifex*, *Macrophthalmus parvimanus* and *Ocypode ceratophthalmas* (Trivedi and Vachhrajani, 2016). Such type of burrows is suggested to be built temporarily in order to get refuge during the high tide or get protection from the predator (Braithwaite and Talbot, 1972; Christy, 1982). It was also observed that single tube with branch and J shape with branch type of burrows were constructed by adult crabs only. The function of the branch of single tube and J shape burrows is still unknown but it has been proposed that the branch may provide shelter to the crab individuals from the splash of the waves and predators (Chakrabarti, 1981).

In the present study out of 84 captured host crab individuals, 31 individuals were juvenile and 53 individuals were adult. Juveniles constructed burrows of only three shapes (Single tube, J-shaped and Bulb shape) while adults have constructed burrows of all the seven different shapes. The carapace width, carapace length,

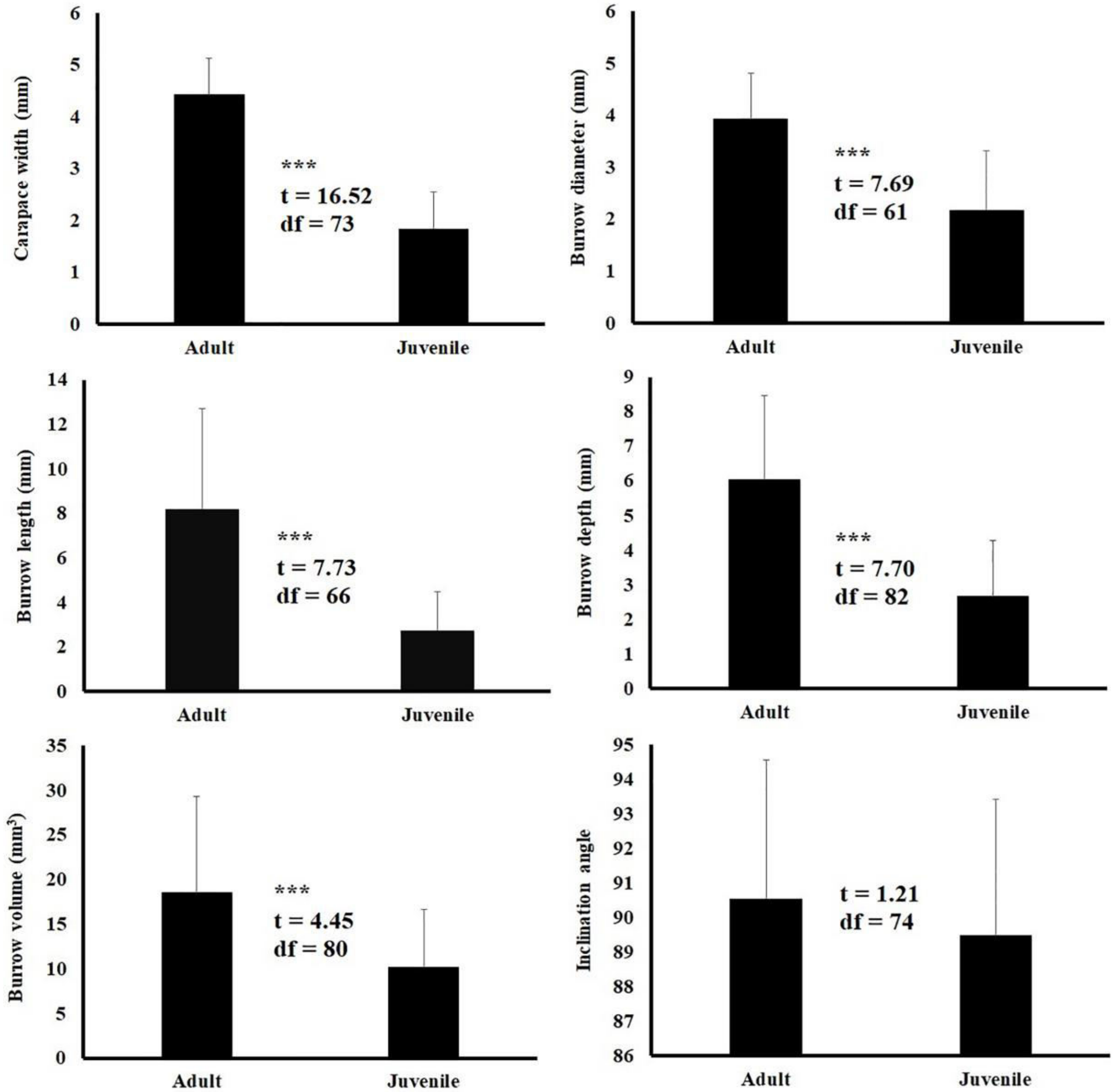

Fig. 4: Mean variation in different morphological parameters in burrow between adult and juvenile host crab individuals of *Dotilla blanfordi*.

burrow opening diameter, inclination angle, burrow depth and burrow volume showed significant variation between juvenile and adult individuals. However, there was no significant variation in the burrow inclination angle (Fig. 4). The burrows like J shape and single tube burrow of juvenile crab were shallow in depth with narrower opening diameter and lesser volume. Some previous studies also found similar kind of trend in burrow architecture (Chakrabarti, 1981, Chan *et al*., 2006; Trivedi and Vachhrajani, 2016). It is suggested that the juvenile individuals have smaller gills surface area and hence they need to renew their respiratory water more frequently as a result of it they could not tolerate air or sunlight exposure for a longer period of time. Due to such condition, juveniles have to evacuate their borrow to reach to sea water for the purpose of renewing their respiratory water (Chen *et al*., 2006). Also, it is suggested that crabs with larger size construct burrow with larger burrow opening diameter which enables the species to move comfortably inside the burrow (Lim, 2006).

Out of 84 captured host crab individuals, 37 individuals were male and 47 individuals were female. Male and female crabs constructed five different shaped burrows among which bulb

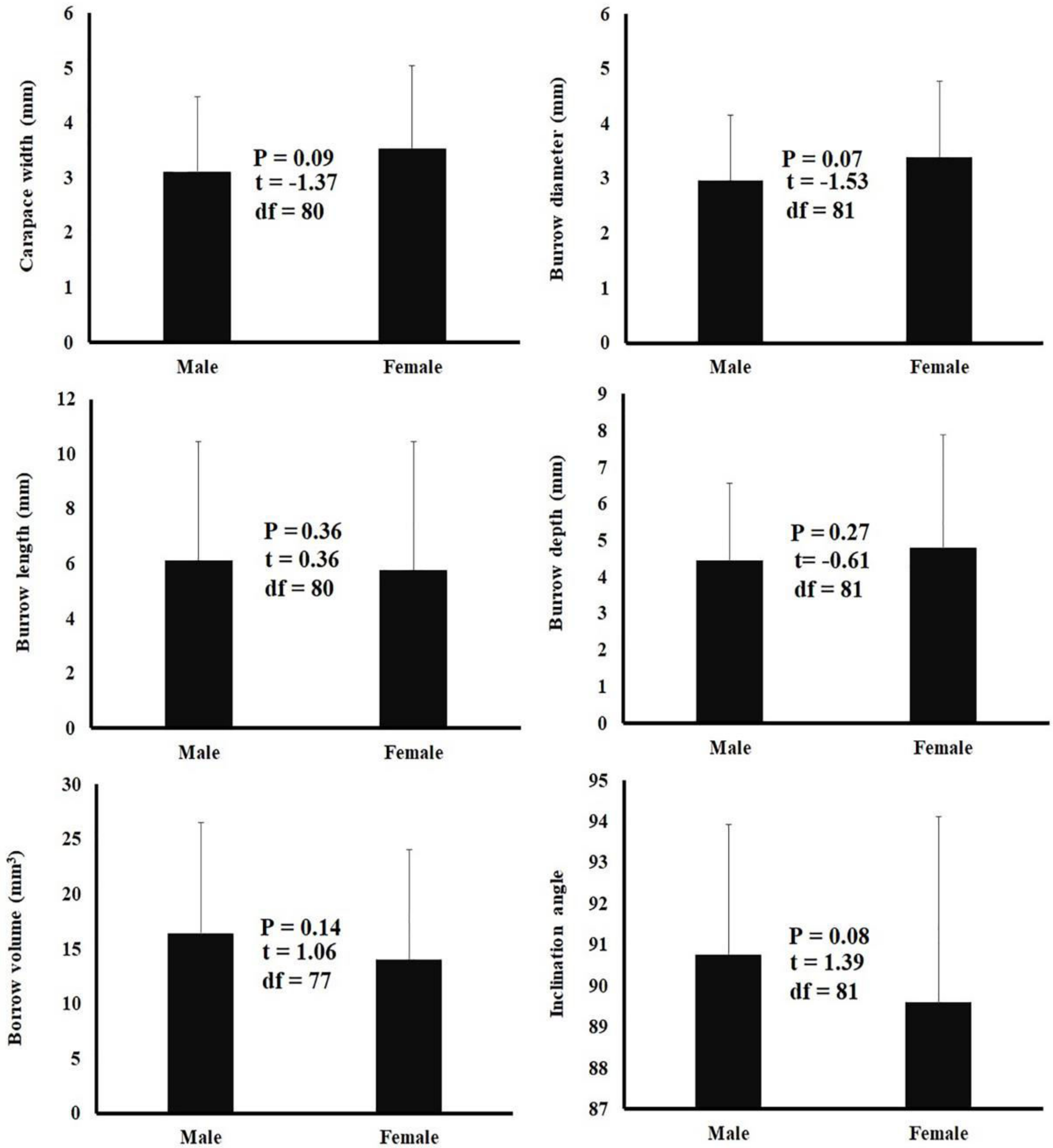

Fig. 5: Mean variation in different morphological parameters in burrow between male and female host crab individuals of *Dotilla blanfordi*.

shape and single tube with branch shape burrow were exclusively constructed by males while U-shape with single opening and J-shape with branch were exclusively constructed by females. The carapace width, carapace length, burrow opening diameter, inclination angle, burrow length, burrow depth and burrow volume did not show significant variation between male and female individuals (Fig. 5). Similar results were observed in a study carried out on *Ocypode ceratophthalma* where the burrow architecture did not differ between sexes (Chakrabarti, 1981). It was also observed that the bulb shape and single tube with branch shape burrow were constructed only by males while U-shape with single opening and J-shape with branch were constructed only by females. A study carried out on the *Ocypode ceratophthalmas* by Farrow (1971) also found that the male crabs constructed spiral burrow while female crabs constructed Y-shaped burrow. However, very few burrows were obtained of bulb shape (two burrows), single tube with branch shape (one burrow), U-shape with single opening (one burrow) and J-shape with branch (one burrow) and hence the effect of sex on the burrow architecture needs further investigations in future.

Conclusion

Dotilla blanfordi is commonly found on the mudflats of Dandi beach, Gujarat. The species is known for the construction of burrows in the mudflat habitat. Present study found that the species construct seven different types of burrows which differs in their complexity. The morphometry of the constructed burrow is highly influenced by the body size and different life stages of resident crab. It was also found that the sex of *D. blanfordi* crab does not have a significant effect on the burrow morphometry. The burrow has advantages for the crabs as it serves different function in the life of an individual and further studies should be conducted to estimate the effect of seasonal variation and sediment types on the burrow architecture of *D. blanfordi*.

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