Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer Reviewed Journal

Open Access
Research Article

Res. Agric. Livest. Fish.
Vol. 4, No. 2, August 2017: 131-140

SHORE TO LANDWARD TRANSECT BURROW DIVERSITY OF FIDDLER CRAB IN A TROPICAL INTERTIDAL COAST OF CHITTAGONG IN BANGLADESH

Mst. Mansura Khan[1*] and Mohammad Sadequr Rahman Khan[2]

[1]Department of Fisheries Biology and Genetics, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh; [2]Department of Marine Bioresources Science, Chittagong Veterinary and Animal Sciences University, Chittagong-4225, Bangladesh

***Corresponding author:** Mst. Mansura Khan; E-mail: keya.3a@gmail.com

ARTICLE INFO

Received
12 August, 2017

Accepted
24 August, 2017

Online
30 August, 2017

Key words
Burrow characters
Saltmarsh
Mangrove
Mangrove pool

ABSTRACT

Burrows indicate the abundance and distribution of fiddler crab in an intertidal coast that varies with structure and morphology within intertidal habitats. We observed fiddler crab burrow density and characters (burrow length, depth, diameter and volume) within randomly selected six 1m^2 quadrate from three intertidal habitats: higher saltmarsh, mangrove pool (a small ditch distributed within mangrove) and mangrove land through field surveys in a coast of Chittagong, Bangladesh. Burrows were observed and counted for density estimation, and burrow characteristics were studied through excavating 10 representative burrows from each quadrate of each habitat. Spearman correlation was used to relate between the distances (from shore towards land) and burrow characters. Transect starting from saltmarsh as base towards mangrove land showed burrow density decreased from shore to higher intertidal habitat. Simultaneously, higher burrow length and diameter were observed landward and contrariwise shoreward. Burrow prevalence in mangrove pools represents fiddler crabs are abundant within land and shore interface presumably due to the dual privilege of easy burrowing and moist condition required for gill ventilation.

To cite this article: Khan MM and MSR Khan, 2017. Shore to landward transect burrow diversity of fiddler crab in a tropical intertidal coast of Chittagong in Bangladesh. Res. Agric. Livest., Fish., 4 (2): 131-140.

www.agroaid-bd.org/ralf, E-mail: editor.ralf@gmail.com

INTRODUCTION

Fiddler crabs of the genus *Uca* Leach, 1814 are variably distributed over tropical to temperate mudflats, salt marshes, mangrove swamps, and sandy beaches (Crane, 1975; Hodgson, 1987; Peer, 2015). This genus is noteworthy with sexual dimorphism with male having one astoundingly enlarged and one minor cheliped, whereas females possess two equally sized chelipeds (Peer, 2015). About 97 species of *Uca* were recorded in the tropical and temperate climates throughout the world (Rosenberg, 2001) and by and large they live in the intertidal zone, actively create burrows during low tide as they stay inside their burrows during high tide (Wolfrath, 1992). Burrowing begins when crabs are very small (Herrnkind, 1968) and is influenced by a variety of conditions, such as water availability, food availability, substratum, ground temperature, tidal periodicity, reproductive activity, threat by potential predators, seasons and mate activities (Bertness, 1985; Genoni, 1991).

Burrows are exigent to fiddler crabs that support to adapt in a semi-terrestrial life to get rid of excessive wave action and environmental stresses to relief from harsh ambient temperatures and desiccation (Bertness and Miller, 1984; Lim and Diong, 2003). Burrows provide a shelter and escape route from terrestrial predators during exposed at low tide and from aquatic predators during at high tide, water for physiological processes, sites for molting and reproductive needs (Hyatt and Salmon, 1979; Christy, 1982; Thurman, 1984; Christy, Backwell *et al.*, 2001; and Milner *et al.*, 2010).

Fiddler crab creates burrows in intertidal zone with patchiness in distribution and diversity in burrow morphology. Within intertidal zone, salt marsh and mangrove habitats are the most productive ecosystems in tropical and subtropical regions lying between land and sea (Chowdhury *et al.*, 2011) and these habitats provide shelters for fiddler crabs. By means of burrow creation, fiddler crab work for nutrient recycling and energy flow in coastal ecosystem (Qureshi and Saher, 2012), translocate oxygen into the anoxic layers and promote aerobic respiration, iron reduction and nitrification thus play an important role in biogeochemical cycle of mangrove sediments (Mokhtari *et al.*, 2016). Likewise, they convert organic matter into small sized packs for others organisms and being preyed upon by predators and transfer energy both in terrestrial and marine environment (Skov and Hartnoll, 2001; Tina *et al.*, 2015).

Spatial distribution of fiddler crabs was studied in different coast of the world depends on the availability of vegetation, substratum, food, salinity, tide, and presence of other animals (Icely and Jones, 1978; Nobbs, 2003; César *et al.*, 2005). Despite of huge ecological significance in intertidal habitat and large coastal region, research regarding spatial distribution, burrow characteristics of fiddler crab are scanty and infancy in Bangladesh. Therefore, with a view to understanding burrow distribution pattern in intertidal habitats of Bangladesh, we surveyed a coast of Chittagong for the first time, which will be an effigy of other coasts and will open a horizon for future research.

MATERIALS AND METHODS

Sampling area

Sampling took place in a tropical intertidal coast during low tide at South Kattoly sea beach (Figure 01), locally known as Dakshin Kattoly sea beach, Salimpur, Chittagong (Latitude 22^{0}35'50" N, Longitude 91^{0}75'40" E) along the Bay of Bengal. This coast was planted by mangrove forest under the Asian Development Bank green belt project on 1997-1998 and characterized by a long intertidal salt marsh merged with mudflat and mangroves stretches about 200 m from the shore line. Tides are semi-diurnal with high tide and low tides in every 6 hours interval.

The characteristic of the coast is muddy or sandy coast dominated by saltmarsh *Porteresia coarctata* (Aysha *et al.*, 2015), and mangrove was dominated by *Avicennia spp.* Fiddler crab was found in higher marsh but not in lower saltmarsh. A special feature of around 1ft deep irregular shaped ditch (round or oval or L-shaped,), mangrove pool was observed within mangrove land adjacent to salt marsh (Fig. 3A). Pools remain water logged as it receives water during spring tide, but usually get dry when normal tidal water cannot reach.

Sampling method and data collection:

Sampling was followed by transect from saltmarsh towards mangrove by selecting three habitats (saltmarsh, mangrove pool and mangrove) and data were collected from November 2015 to February 2016. As burrow count provide quick and reliable estimate (Warren, 1990), burrow abundance and burrow characteristics (diameter, length, depth, volume and shapes) were determined in three intertidal habitats from shore towards land viz. higher saltmarsh, mangrove pools and mangrove higher intertidal land. In each habitat, we selected six 1 m^2 (1 m ×1 m) quadrates randomly to count burrows visually. But three quadrates in saltmarsh were chosen intentionally along the same line to consider them as base point to measure landward distance of other quadrates. Burrow length, depth and shape were measured with measuring tape after excavating 10 representative burrows from each quadrate using soil corer up to 30 cm depth. Burrow diameter was measured by digital venire calipers. Burrow volume was calculated using the formula ($\pi r^2 h$, where π = 3.1416, r = radius, h = length) assuming a cylindrical hole. The distance of each quadrate was measured from the first three quadrates which were situated in saltmarsh. In order to find correlations between distances (shores to landward) and burrow characters, each quadrate distance was measured from the quadrate positioned in salt marsh considering as the base point (0 m) towards mangrove, so that we can understand sea to landward burrow characters.

Data Analysis

Data were checked for homogeneity with Levine's test and for normality with Shapiro-Wilk test. We compared means of burrow characters among three habitats using one-way ANOVA through SPSS version-16.0. Significance was assigned at the 0.05% level. Bivariate Pearson correlation analysis (2-tailed) was used to find correlation between shore to landward distance and burrow characters.

RESULTS

Fiddler crab burrows were diversely distributed among three habitats in the intertidal zone, and the burrow characters differed considerably (Table 1). Considering burrow density, significantly higher ($P<0.05$) number of burrows (83.67±16.33) was found in mangrove pool and the highest abundance was 115 (Table 1). Within other habitats, relatively higher amount of burrows were observed in saltmarsh areas (76.67±6.67) than in mangrove intertidal high land (42.00±3.79). And, the highest number of burrows was 90 and 49 in those two habitats, respectively.

There was no significant difference among the shelters regarding burrow length and depth. Minimum and maximum length was 26.0 and 58.2 mm in saltmarsh areas, 44.80 and 89.60 mm in mangrove pool, and 55.0 and 112.0 mm in mangrove high land. In these sites, average burrow length was 43.4±9.4, 69.5±13.1, and 90.0±17.7 mm, respectively (Table 1). Burrow length increased with increasing closeness to high intertidal land, and reciprocal observation in seawards boundary towards saltmarsh (Figure 3). Likewise, depths of the burrows were recorded lowest 38.0±8.1 mm in saltmarsh, highest 76.7±13.6 mm in mangrove land and 60±10.1 mm in mangrove pool. Similarly, burrow diameter was significantly higher ($P<0.01$) in mangrove land (24.0±2.1 mm) and mangrove pool (18.9±2.0 mm) than in higher saltmarsh (12.3±0.3 mm). Therefore, burrow lengths, depths and diameters were higher in mangrove higher intertidal land than the other habitats.

Burrows were also observed adjacent to a 2-5 feet water channel with patchy distribution that remains dry in low tide and drain tidal salt water upward during spring tide or downward during low tide. Four distinct shapes of burrows (I, J, C and L shaped) were observed with predominant 'I' shaped burrows in saltmarsh and, I, J and C shaped burrows in mangrove pool and mangrove higher intertidal habitat (Figure 4). Burrows with higher length had the enlarged ground in the bottom (Figure 4B and 4C).

Correlation

A Pearson product-moment correlation coefficient was computed to assess the relationship between shore to landward distances and burrow characteristics. Burrow lengths and burrow diameters were significantly positively correlated with landward distance ($r=0.774$, $p=0.014$, and $r= 0.811$, $p= 0.008$, respectively). Contrarily, negative relation was found between distance and burrow length (Table 2). Both the burrow length and burrow diameter were negatively related with burrow numbers.

Figure 1. Geographical location of the sampling site with map from Google earth and Asiatic Society of Bangladesh

Table 1. Burrow characteristics (Mean ± SE) in salt marsh, mangrove pool and mangrove land. The range of observed values is given in the parentheses. Means with the superscripts are significantly different (P<0.05) based on Duncan's test. N=6 quadrates (10 burrows from each)

Characters	Saltmarsh	Mangrove pool	Mangrove land	*p*-value
Number of burrows	76.67 ± 6.67^{ab}	83.67 ± 16.33^{a}	42.00 ± 3.79^{b}	0.062
Burrow length (mm)	43.4±9.4	69.5±13.1	90.0±17.7	0.135
Burrow depth (mm)	38.0±8.1	60±10.1	76.7±13.6	0.114
Burrow diameter (mm)	12.3 ± 0.3^{b}	18.9 ± 2.0^{ab}	24.0 ± 2.1^{a}	0.007
Burrow volume (cm^3)	5.08 ± 0.91^{b}	19.77 ± 5.66^{ab}	43.97 ± 13.91^{a}	0.051
Highest number of burrow (nos.)	90	115	49	
Characteristics	Underwater during high tide but exposed to sunlight during low tide. Extensive salt tolerant grass present.	Shallow intertidal or higher intertidal ditch within mangrove, contains salt water during spring tide, mangrove roots and sea weeds present.	Higher intertidal, inundation during spring tide. Mangrove plants, eg. *Avicennia spp.* and *Acanthus spp., roots of mangrove*	

Table 2. Bivariate analysis of Pearson correlation between sea to land ward distance and burrow characters (N=18 quadrates, 10 burrows from each quadrate)

Correlation		Distance from saltmarsh	Burrow number	Burrow length	Burrow Diameter
Distance from Saltmarsh	Pearson Correlation	1			
	Sig. (2-tailed)				
Burrow number	Pearson Correlation	-0.523			
	Sig. (2-tailed)	0.149			
Burrow length	Pearson Correlation	0.774*	-0.366		
	Sig. (2-tailed)	0.014	0.333		
Burrow Diameter	Pearson Correlation	0.811**	-0.119	0.782*	1
	Sig. (2-tailed)	0.008	0.761	0.013	

*Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed)

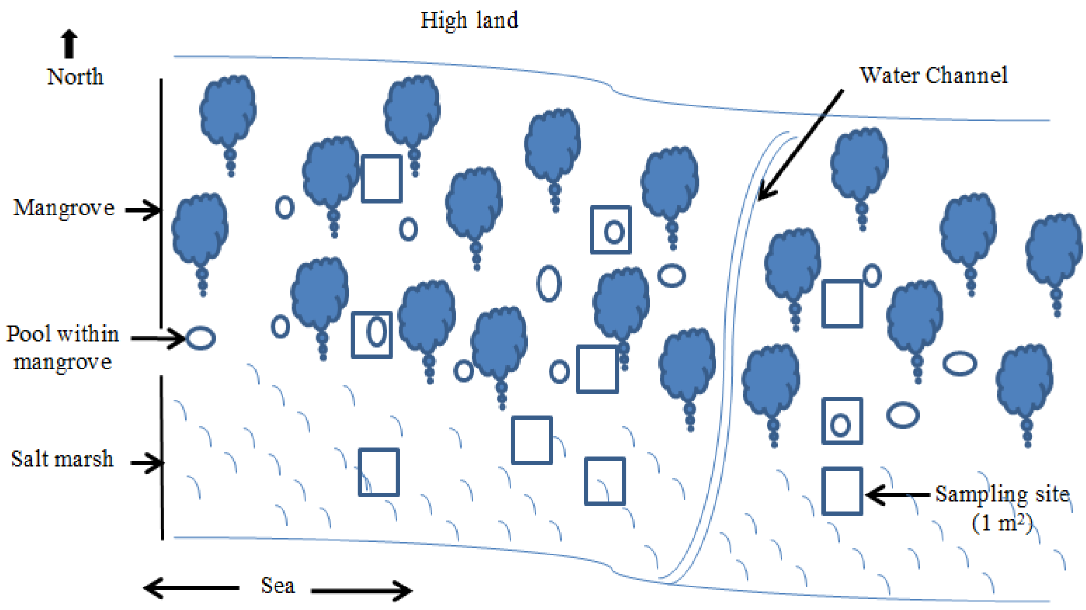

Figure 2. Schematic diagram of sampling sites in the saltmarsh, mangrove and mangrove pool. First three quadrates in saltmarsh were intentionally selected along the same line. Circle indicates pools intermingled with mangrove forest and squares ($1m^2$) are randomly chosen quadrates

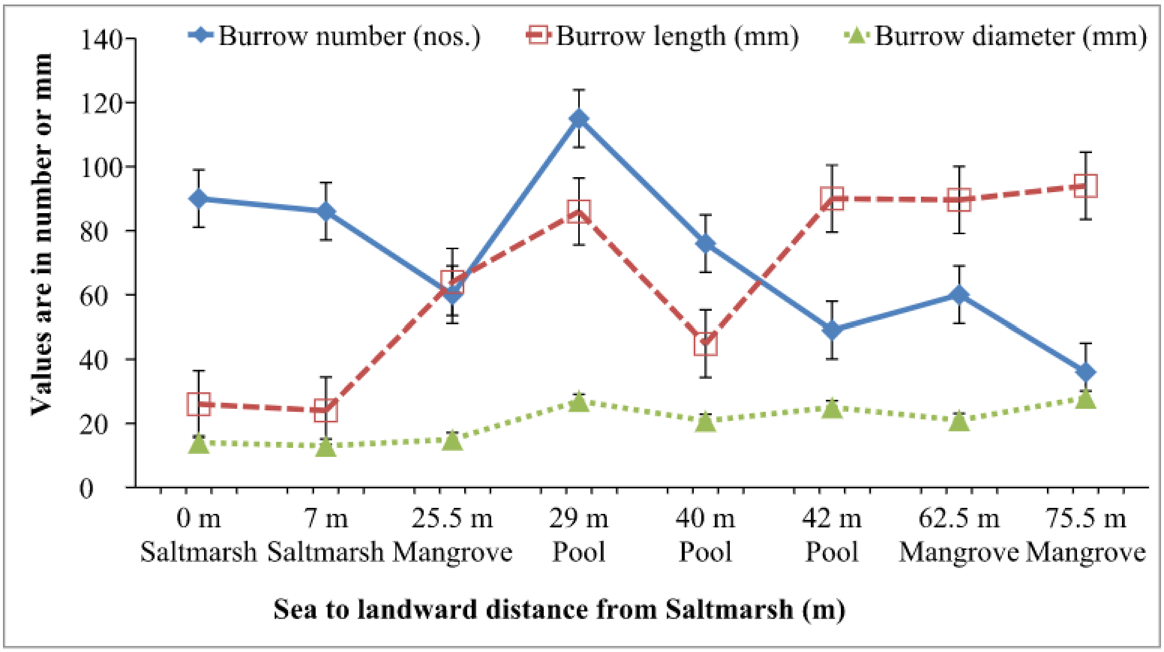

Figure 3. Comparison of Burrow characteristics along transect from saltmarsh (0 m) towards mangrove (every point indicates mean with error bar). Burrow density (blue) and burrow length (red) decreased with increasing distance, but burrow diameter (green) increased with increasing distance

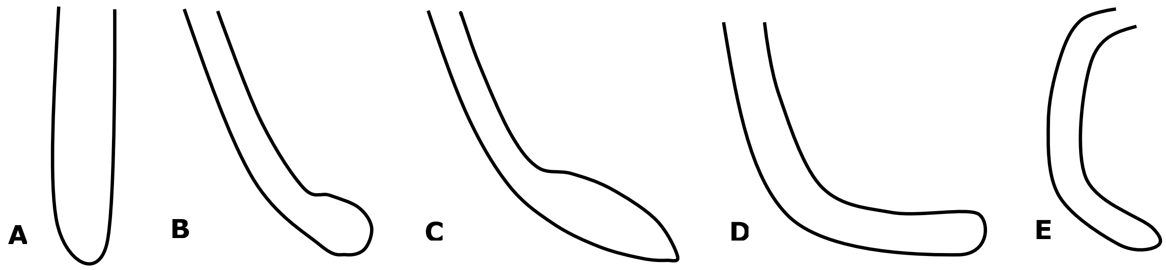

Figure 4. Burrow shapes: (A) I-shape, (B and C) J-shape, (D) L-shaped (E) C- shaped

DISCUSSION

Burrow abundance

Fiddler crab burrows were found in all the three sampling areas viz. saltmarsh, mangrove pool and mangrove highland with variable densities. Burrow distribution showed higher density (nos.) in mangrove pool and in saltmarsh than in mangrove high land (Table 1). Highest number of burrows (115 burrows m^{-2}) was found in mangrove pool (Table 1), where soil was relatively wet due to regular tidal splash and water containment, therefore, was soft for burrowing. Similarly, higher burrow density was also found in salt marsh which is relatively unstable area in terms of sedimentation due to regular tidal action. This area was usually occupied with early aged smaller fiddler crabs with higher density. In contrast, low burrow density was found in mangrove high land where soil was harder to make burrows. Mangrove high land is usually dried place inundated only in spring tide or highest high tide. So, fiddler crab distribution showed higher burrow prevalence in moist areas possibly due to the privilege of easy burrowing and wet condition required for gill moisture (Wolfrath, 1992; Lim and Diong, 2003). Soil characteristics (sediment) have important influence regarding burrow creation. Burrow density matches with the observation of Zeil and Hemmi (2006) who found fiddler crab live in large colonies that of all ages and sexes can reach densities of 50–100 individuals per square meter.

Burrow characters and morphology

Burrows in the saltmarsh are characterized by lower depth and smaller diameter. On the contrary, burrow depth and burrow length increased towards mangrove pool and mangrove high land (Figure 3). In mangrove high land, burrow length was higher (90 mm) with significantly higher burrow diameter, but burrow density was lowest among the studied habitats. Qureshi and Saher (2012) reported burrow length 105.4±45.9 mm and mean burrow diameter 13.7±3.0 mm for *U. annulipes*, which is similar with the present study. Therefore, with closeness to land, water availability decreased as this area is inundated only in spring tide and the soil become harder to burrow. In contrast, burrow depth increased with decreasing burrow density (Edmond *et al.,* 1996; Qureshi and Saher, 2012; Tina *et al.,* 2015). It reflects larger holes are relatively in highlands towards land (Lim and Diong, 2003) and perhaps burrows were created by larger individuals for breeding purpose (Hyatt and Salmon, 1979). Breeding burrows are relatively large and with hoods (Christy, 1982). Deeper burrows in high shores might be a way of maintaining lower burrow temperatures in areas that are exposed to sunlight for greater periods of time (Wolfrath, 1992; Lim and Diong, 2003). Reciprocally, in salt marsh (lower shore), burrow depth was lower along with significantly smaller burrow diameter which indicate smaller individuals were distributed close to the shore with higher densities. Therefore, these smaller burrows in anoxic sediments are significantly shorter in depths, which would help to improve aeration after every tidal flushing (Lim and Diong, 2003). Similar to mangrove land, mangrove pool was dominated with burrows with higher burrow length and diameter due to availability of water and easy burrowing. Therefore, water and sediment characteristics influence burrow density (Genoni, 1991).

Shape observation revealed *Uca* produce nearly vertical and straight and unbranched, mostly typical I-and J-shaped burrows (Tina *et al.*, 2015) and few L and C-shaped burrows with lower region enlarged (Montague, 1980). Similar burrow shapes were also observed in vertical and complex branching morphologies with a single and multiple entrances by Qureshi and Saher (2012). Different species of fiddler crab produce simpler L or J-shaped (Katz, 1980; Genoni, 1991, and Montague, 1980) burrow or even U-shaped (Montague 1980) and Y-shaped (Qureshi and Saher, 2012) complex burrows. Saltmarsh had the most I and J shaped burrows with simple structure possibly for easy burrowing by smaller fiddler crabs and short time availability within tidal action. Mangrove pool and high land had mostly I, and J-shaped burrows with few L and C-shaped burrows. Complexity of burrow structure were found in mangrove high land with higher burrow length and diameter represents larger fiddlers make deeper burrow in firm soil.

Burrow diversity along transect

Considering transect from salt marsh to mangrove land, burrow density decreased with increasing distance from shore toward mangrove (Edmond *et al.*, 1996). Reversely, burrow length and diameter increased landward, presumably larger individuals create stable burrows for breeding purpose in the higher intertidal zone and smaller individuals dominate in saltmarsh near water area. Moreover, burrows were deeper in drier upper shore land than in moist lower shore sediment (Takeda and Kurihara, 1987; Wolfrath, 1992; Lim and Diong, 2003). Burrow diameter increased with increasing distance and correlation analysis between burrow diameter and landward distance showed strong relationship ($R=0.771$, $y = 0.1157x + 12.06$). So, closer to saltmarsh, lower the burrow diameter and reciprocally near the land, higher the burrow diameter. Likewise, borrow length increased with increasing distance from shore showed positive correlation (Table-2). Thurman (1984) also showed that burrows of *U. subcylindrica* increase in depth with increasing distance from low water mark in Laguna Salado, Mexico. Therefore, shore to landward distance comparison explicit positive relation among distance, burrow length and burrow diameter. Contrarily, correlation between burrow number (density) and distance was negative. Therefore, higher number of burrows in saltmarsh was closer to sea water that decreased toward mangrove land. But, the higher numbers of burrows were abundant in mangrove pools. Pools are characterized by a small ditch contains salt water after being inundated with flood tide. Therefore, fiddler crab burrows were dominated in the margin of salt marsh and mangrove pool. So, water content (Frith and Brunenmeister, 1980; Ewa-Oboho, 1993) salinity and substratum (MacIntosh, 1989; Frusher *et al.*, 1994) of habitat have role in the distribution of fiddler crab burrows. Costa (2000) found positive correlations with water content and distribution of burrows for *U. thayeri* and Tina *et al.* (2015) observed burrows were shorter in length, shallower in depth, and smaller in volume at 2 m distance, but these measures increased with increasing distance from the river edge. In fine, it reflects complex interaction of multiple factors play role in burrow structuring, ie. soil texture sediment characteristics, water availability and burrowing individuals size (Thurman, 1987; Costa, 2000).

CONCLUSION

Fiddler crab burrow distribution and characters differed in different habitats of the intertidal coast of Bangladesh with more burrow density in shoreward and contrariwise towards landward. The number of burrows reduced towards higher intertidal zone but burrows of this area had higher burrow depth and diameter which represents water availability, substrate characteristics and size of burrowing individuals determine the burrow characters. Contrarily, smaller and temporary burrows were denser in saltmarsh towards shore. Highest burrows in mangrove pool indicated crabs prefer to stay in moist condition, where water availability support burrowing and gill activity. Fiddler crabs are ecologically important bio-turbator contribute in nutrient replenishment and support for nutrient enrichment in the intertidal habitat. The current study focused on fiddler crab burrows at the scale of 1 m^2 sampling plots. For better understanding of burrow characters, a more detailed study with a finer sampling design and massive burrow observation along with more intensive ecological study is required.

COMPETING INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

The authors would like to thank Dean, Faculty of Fisheries, Chittagong Veterinary and Animal Sciences University to support grant for this research and the students who participated in burrow observation in the intertidal coast.

REFERENCES

1. Aysha A, Kamal AHM, Mishra M, Nesarul MH, Padhi BK, Mishra SK, Islam MS, Idris MH and MB Masum, 2015. Sediment and carbon accumulation in sub-tropical salt marsh and mangrove habitats of north-eastern coast of Bay of Bengal, Indian Ocean. International Journal of Fisheries and Aquatic Studies, 2: 184-189.
2. Bertness MD and T Miller, 1984. The distribution and dynamics of *Uca pugnax* (Smith) burrows in a New England saltmarsh. Journal of Experimental Marine Biology and Ecology, 83: 211–237.
3. Bertness MD, 1985. Fiddler crab regulation of *Spartina alterniflora* production on a New England salt marsh. Ecology, 66: 1042–1055.
4. César II, Armendariz LC and RV Becerra, 2005. Bioecology of the fiddler crab *Uca uruguayensis* and the burrowing crab *Chasmagnathus granulatus* (Decapoda, Brachyura) in the Refugio de Vida Silvestre, Bahía Samborombón, Argentina. Hydrobiologia, 545: 237-248.
5. Chowdhury MSN, Hossain MS, Mitra A and P Barua, 2011. Environmental functions of the Teknaf Peninsula mangroves of Bangladesh to communicate the values of goods and services. Mesopatamian Journal of Marine Science, 26: 20-27.
6. Christy JH, 1982. Burrow structure and use in the sand fiddler crab, *Uca pugilator* (Bosc). Animal Behaviour, 30: 687–694.
7. Christy JH, Backwell PRY and S Goshima, 2001. The design and production of a sexual signal: Hoods and hood building by male fiddler crabs *Uca musica*. Behaviour, 138: 1065-1083.
8. Costa TM, 2000. Ecologia de caranguejos semiterrestres do gênero *Uca* (Crustacea, Decapoda, Ocypodiae) de uma área de manguezal, em Ubatuba (SP). PhD thesis, University Estadual Paulista.
9. Crane J, 1975. Fiddler Crabs of the World (Ocypodidae: Genus *Uca*). Princeton University Press, Princeton, New Jersey, xxiii 736 pp.
10. Edmond C, Mouton Jr. and DL Felder, 1996. Burrow Distributions and Population Estimates for the Fiddler Crabs *Uca spinicarpa* and *Uca longisignalis* in a Gulf of Mexico Salt Marsh. Estuaries, 19: 51-61.
11. Ewa-Oboho IO, 1993. Substratum preference of the tropical estuarine crabs, *Uca tangeri* Eydoux (Ocypodidae) and *Ocypode cursor* Linne (Ocypodidae). Hydrobiologia, 271: 119-127.
12. Frith, DW and S Brunenmeister, 1980. Ecological and population studies of fiddler crabs (Ocypodidae: genus *Uca*) on a mangrove shore at Phuket Island, western Peninsular Thailand. Crustaceana, 39: 157-184.
13. Frusher SD, Giddings RL and TJ Smith III, 1994. Distribution and abundance of Grapsid crabs (Grapsidae) in a mangrove estuary: effects of sediments characteristics, salinity, tolerance and osmoregulatory ability. Estuaries 17: 647-654.
14. Genoni GP, 1991. Increased burrowing by fiddler crabs *Uca rapax* (Smith) (Decapoda: Ocypodidae) in response to low food supply. Journal of Experimental Marine Biology and Ecology, 147: 267-285.
15. Herrnkind WF, 1968. The breeding of *Uca pugilator* (Bosc) and mass rearing of the larvae with comments on the behavior of the larval and early crab stages (Brachyura, Ocypodidae). Crustaceana, 2: 214-224.

16. Hodgson AN, 1987. Distribution and abundance of the macrobenthic fauna of the Kariega estuary. South African Journal of Zoology, 22: 153–162.
17. Hyatt GW and M Salmon, 1979. Comparative statistical and information analysis of combat in fiddler crabs, *Uca pugilator* and *U. pugnax*. Behaviour, 68: 1-23.
18. Icely JD and DA Jones, 1978. Factors affecting the distribution of the genus *Uca* (Crustacea: Ocypodidae) on an East African shore. Estuarine, Coastal and Shelf Science, 6: 315-325.
19. Katz LC, 1980. The effects of the burrowing of the fiddler crab *Uca pugnax* (Smith). Estuarine, Coastal and Shelf Science, 4: 233–237.
20. Lim SSL and CH Diong, 2003. Burrow-morphological characters of the fiddler crab, *Uca annulipes* (H. Milne Edwards, 1837) and ecological correlates in a lagoonal beach on Pulau Hantu, Singapore. Crustaceana, 76:1055-1069.
21. MacIntosh DJ, 1989. The ecology and physiology of decapods of mangrove swamps. Proceedings of the Zoological Society of London 59: 325-341.
22. Milner RNC, Booksmythe I, Jennions MD and PRY Backwell, 2010. The battle of the sexes? Territory acquisition and defence in male and female fiddler crabs. Animal Behaviour, 79: 735–738.
23. Mokhtari M, MA Ghaffar, G Usup and ZC Cob, 2016. Effects of fiddler crab burrows on sediment properties in the mangrove mudflats of Sungai Sepang, Malaysia. Biology, 5: 7.
24. Montague CL, 1980. A natural history of temperate western Atlantic fiddler crabs (genus *Uca*) with reference to their impact on the salt marsh. Contribution in Marine Science, 23: 25-55.
25. Nobbs M, 2003. Effects of vegetation differ among three species of fiddler crabs (*Uca* spp.). Journal of Experimental Marine Biology and Ecology, 284: 41-50.
26. Peer N, Miranda NAF and R Perissinotto, 2015. A review of fiddler crabs (genus Uca Leach, 1814) in South Africa. African Zoology, 50: 187-204.
27. Qureshi NA and NU Saher, 2012. Burrow morphology of three species of fiddler crab (*Uca*) along the coast of Pakistan. Belgium Journal of Zoology, 142: 114-126.
28. Rosenberg MS, 2001. The systematics and taxonomy of fiddler crabs: a phylogeny of the genus *Uca*. Journal of Crustacean Biology 21: 839–869.
29. Skov MW and RG Hartnoll, 2001. Comparative suitability of binocular observation, burrow counting and excavation for the quantification of the mangrove fiddler crab *Uca annulipes* (H. Milne Edwards). Hydrobiologia, 449: 201-212.
30. Takeda S and Y Kurihara, 1987. The distribution and abundance of *Helice tridens* De Haan (Crustacea, Brachyura) burrows and substratum conditions in a north eastern Japan salt marsh. Journal of Experimental Marine Biology and Ecology, 107: 9–19.
31. Thurman CL, 1984. Ecological notes on fiddler crabs of south Texas, with special reference to *Uca subcylindrica*. Journal of Crustacean Biology, 4: 665-681.
32. Thurman CL, 1987. Fiddler crabs (genus Uca) of eastern Mexico (Decapoda, Brachyura, Ocypodidae). Crustaceana, 53: 94-105.
33. Tina FM, Jaroensutasinee M, Sutthakiet O and K Jaroensutasinee, 2015. The fiddler crab, *uca bengali* crane, 1975: population biology and burrow characteristics on a riverbank in southern Thailand. Crustaceana, 88: 791-807.
34. Warren JH, 1990. The use of open burrows to estimate abundances of intertidal estuarine crabs. Australian Journal of Ecology, 15: 277-280.
35. Wolfrath B, 1992. Burrowing of the fiddler crab *Uca tangeri* in the Ria Formosa in Portugal and its influence on sediment structure. Marine Ecology Progress Series, 85: 237–243.
36. Zeil J and JM Hemmi, 2006. The visual ecology of fiddler crabs. Journal of Comparative Physiology, 192: 1–25.