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BURROW ARCHITECTURE OF RED GHOST CRAB *OCYPODE MACROCERA* (H. MILNE-EDWARDS, 1852) : A CASE STUDY IN INDIAN SUNDARBANS

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ABSTRACT: A study on burrow architecture and burrow morphology of the red ghost crab (*Ocypode macrocera*) was carried out at the southern proximity of the Sagar island (21°37.973' N, to E 88° 04.195'), western sector of Indian Sundarbans that faces the regular tidal influences of Bay of Bengal. *Ocypode macrocera* constructs burrows that are highly species specific and used by single individual. Four types of burrow patterns were observed like 'I', 'J' 'U' and 'semi-U' type with different sizes as revealed by POP casting. Important physic-chemical parameters like air temperature, temperature and salinity of the water were significantly varied ($P < 0.05$) throughout seasons in the *Ocypode* zone. Burrow sand column temperature were also significantly varied from ambient air temperature thus exhibiting preference for cooler subterranean residential compartment. The digging behaviour of *Ocypode*s enhances oxygenation in the ground soil and facilitates decomposition of organic materials, nutrient recycling, entrapping the sediments and mangrove seedlings and helps the process of bioturbation. As per the preliminary observations it was suggested that burrow shape is directly related to tidal action and metabolic activities of the crab are strongly correlated with burrow micro-environment. They are adapted to the different sediment conditions, tidal fluctuations, varying salinity gradients, air and water temperatures and other environmental fluctuations.

Key Words: Burrow, Indian Sundarbans, *Ocypode macrocera,* POP casting

INTRODUCTION

The semi-terrestrial crabs of genus *Ocypode* (Brachyurans) are typical macro-faunal components of tropical and sub-tropical sandy beaches of the world (Dahl 1953). The red ghost crab *Ocypode macrocera* is the predominant residential burrowing brachyuran crab species found in Sundarbans estuarine sand flat where they occupy conspicuous burrows. Ecological functions of burrowing behaviour in specific ecosystem have received increasing attention over the recent decades, and crab

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burrowing has been considered as one of the major bioturbation affecting the physical and chemical processes in ecosystems (Wang *et al*. 2010). The term "bioturbation" is generally used to describe how living animal affects the substratum in (or an) which they live (Kristensen *et al*. 2012). *Ocypode* is exhibiting its engineering skill during tunnelling and considered as a meticulous environmental engineer.

The numerous aspects of burrow structure, digging behaviour, burrow morphology of *ocupodid* crabs and related burrowing arthropods have been explored by several workers (Kristensen *et al*. 2012, Qureshi and Saher 2012, Strachan *et al*. 1999, Griffis and Suchanek 1991, Atkinson and Taylor 1988, Crane 1975). In Indian Sundarban mangrove complex, several taxonomic works on estuarine and mangrove brachyuran crabs have been reported (Dev Roy and Das 2000, Chaudhuri and Choudhury 1994, Chakraborty and Choudhury 1992, Mandal and Nandi 1989, Chakraborty *et al*. 1986) but comparatively less attention have been concentrated on biogenic structure of *Ocypode macrocera*. 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*. The architecture of the burrows plays an important ecological role in the life history and helps to maintain semi-terrestrial mode of habit. There has been no previous study on burrow morphology of *Ocypode macrocera* were reported in the coast of Indian sundarbans. In continuation to this fact, several aspects of the structural burrow morphology and complexity of *Ocypode macrocera* were hypothesised in present study. As they prefer in a particular ecotope with varying degree physico-chemical compositions, relationship of biogenic structure with environmental condition were also examined in this study.

MATERIAL AND METHODS

Site of the study

The study site, Gangasagar (21°37.973' N to E 88° 04.195') is located in the extreme southern part of the Sagar island of Indian Sundarbans with the confluence of Bay of Bengal (Fig.1). This sand flats of the mixed and open sea inter tidal zone consists of 96% of fine to very fine sand with good sorting. Sagar island, mostly reclaimed from mangrove swamps, has triangular outline with a length of 30 km North-South and a maximum width of 10 km of East-West towards South. The northern extremity is only 5 km South-West of Kakdwip point of the mainland and is separated from the mainland by the Hoogly river. On the East and West of the island are respectively Muriganga and Hoogly tidal river. The southern margin of the island faces the tidal action of Bay of Bengal which is fully disturbed due to almost all sorts of direct and indirect anthropogenic stresses. Most part of the island is occupied by human habitation.

Architecture of burrow

Burrow entrances were measured by side to side with the help of scale and verniar caliper (nearest precession of 0.1 mm). Burrow casting were made by pouring Plaster of Paris (POP) slurry (water : POP = 1:2) into each burrow entrance randomly selected burrows within 18 m^2 quadrat and were allowed to dry for 30 minutes as described by Qureshi and Saher (2012). Dried casts were carefully excavated with the help of spade from all sides and measurement of burrow diameter (BD), Total

Table 1: Details of the burrow architectural patterns.

Appearance	BD (cm)	TBL (cm)	TBD (cm)
'J'	4.56 ± 0.92	45.72 ± 9.67	36.83 ± 6.77
'I'	4.62 ± 2.04	36.40 ± 11.65	29.17 ± 10.84
'Semi-U'	3.81 ± 1.81	41.05 ± 19.07	29.04 ± 12.71
'U'	4.69 ± 1.89	36.53 ± 16.89	25.53 ± 8.35

Values are expressed as Mean ± standard deviation (SD)

burrow length (TBL) and total burrow depth (TBD) were recorded using measuring tape (Fig. 2). Burrow casting pattern and shape were demonstrated through visual observations.

Physico-chemical parameters

The important physico-chemical parameters of the study site *viz.*, air temperature, temperature and salinity of the water was measured fortnightly in every month during the year 2012 using Hanna Multi-parameter kit (Model No: HI 929828). Seasons of the year were established in pre-monsoon (March-June), monsoon (July-October) and post-monsoon (November- February) as noted by Vyas (2012). Burrow sand column temperature was measured by digital thermometer.

Statistical analysis

The data were analyzed by one way analysis of variance (ANOVA) using statistical software Medcalc ® version 12.7.0. (MedCalc Software bvba, Ostend, Belgium). In all cases data were tested normality of variance homogeneity before analysis. All numerical data are represented as the mean ± standard deviation (SD) unless otherwise stated. Statistical differences were considered significant when P = 0.05.

RESULTS AND DISCUSSION

Habitat preference and behaviour

The semi-terrestrial supra-littoral macro-benthic ocypodid in-fauna meticulously preferred coastal, estuarine, sand flat. They enjoy detritus based tidal influences and the abundance is directly related to tidal action. It is commonly burrowing a deep hole to keep them cool during the hottest part of the day. *Ocypode macrocera* constructs species specific burrow and single individual was entrapped from burrow, exhibiting intra-specific behaviour. The burrowing activity of *Ocypode macrocera* were reported maximum in day time (Fig.3).

Burrowing behaviour and burrow architecture

Ocypode macrocera is bearing solitary mode of habit and relies on self constructed wide variety of burrows for shelter, life cycles *etc*. The animal burrows with the first pair of unequal chelipeds with major involvement of left chela. The second and third pairs of legs

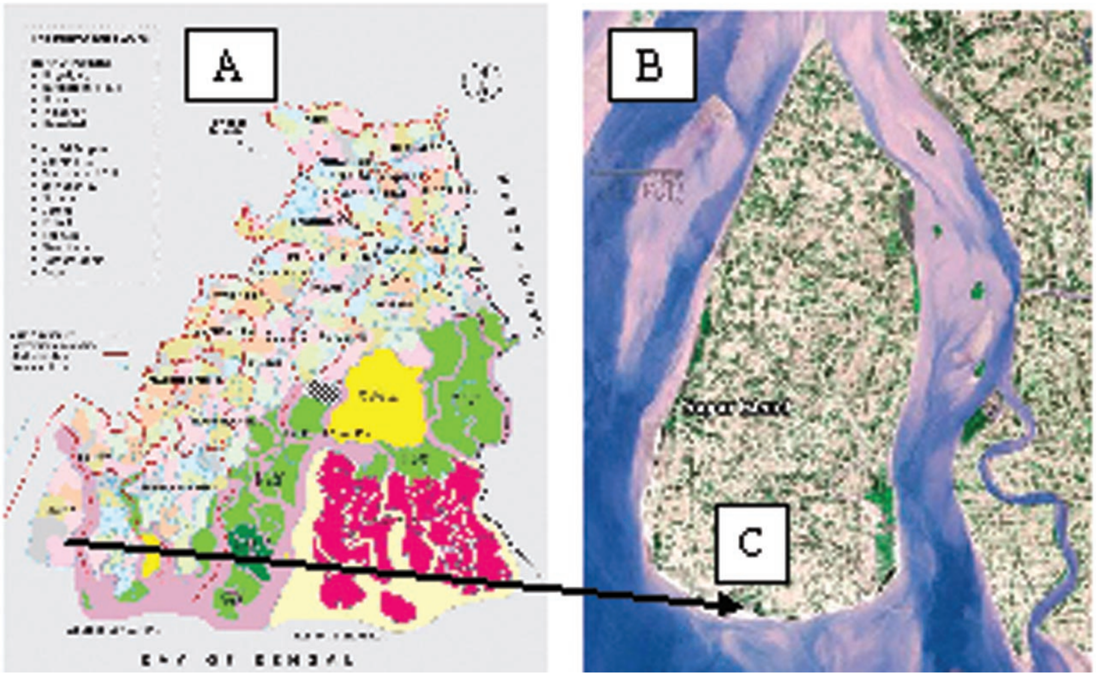

Fig. 1: The study site (A = Indian Sundarbans eco-region; B = Sagar island; C = Gangasagar)

and dactyls of these appendages are being used somewhat like trowels to pull the dirt loose and carry the mass before it to the outside of the burrow. Various rows of setae present between bases of second and third pairs of legs are involved in sand sorting.

Out of 20 burrow casts, 15 intact burrow casts were recovered. Burrow architecture patterns is given in Table 1. Burrow casts generally varied in length and in shape of closed ends encompassing four distinct types shape *viz.* 'I' , 'J' , 'U' and 'semi-U' in vertical, single entrance with no shaft or branching (Fig.4). Burrow entrances were oriented sea-wards but ended opposite direction of the sea. The maximum burrows found to be 'J' shaped *i.e* 'horizontal' section slightly re-curved distally.

Physico-chemical parameters

The seasonal variations of environmental parameters were significantly varied ($P < 0.05$) throughout the *Ocypode* zone. Mean air temperatures, temperatures and salinity of water fluctuated according to the season. Significant differences of air temperature were observed ($F_{11-12} = 8.42$; $P = 0.05$) with highest occurring between the months of May and June (35–38 °C), and lowest in December (20°C) and January (21°C). Water temperature also differed significantly ($F_{11-12} = 24.05$; $P = 0.05$) with a peak in May (35°C) and decline in December (18°C) (Fig. 5). Salinity also significantly varied throughout the seasons ($F_{11-12} = 14.95$; $P = 0.05$) with a trend of gradual decline during monsoonal period (16 ppt ± 4.56) due to

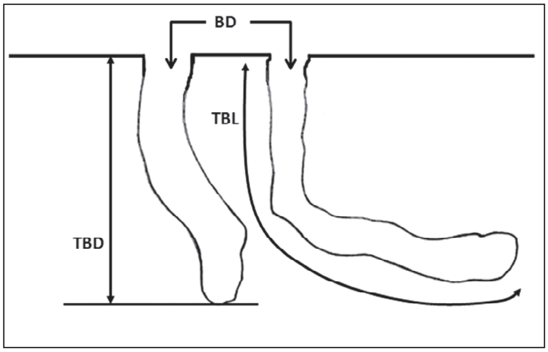

Fig. 2: Burrow architecture parameters selected for analyses [BD = Burrow diameter (cm), TBL = Total burrow length (cm) and TBD = total burrow depth (cm)].

precipitation and slowly increasing in post-monsoon (20 ppt ± 2.29) with a highest pick (27 ppt ± 1.3) in pre-monsoon period (Fig. 6). About 8°C - 9°C temperature reduced in the burrow from the ambient air temperature (Fig.7).

Ocypodes are the most extraordinary and proficient diggers among the burrowing crustaceans found in Sundarban ecotope. Within the study area, the distribution of the crabs up to the sea shore was found to vary with maturity of crabs. Juvenile crabs were found nearer to the sea during low tide may be due to feeding and larger adults being located distance from the sea. Burrow diameter were found to be less (2-3 cm) in sea-ward margin which become broaden (5.5-6.5 cm) in land-ward zones. Shuchman and Warburg (1978) demonstrated similar types of relationship between species abundance and beach position of *Ocypode cursor* at Northern Israel. The burrow shape of

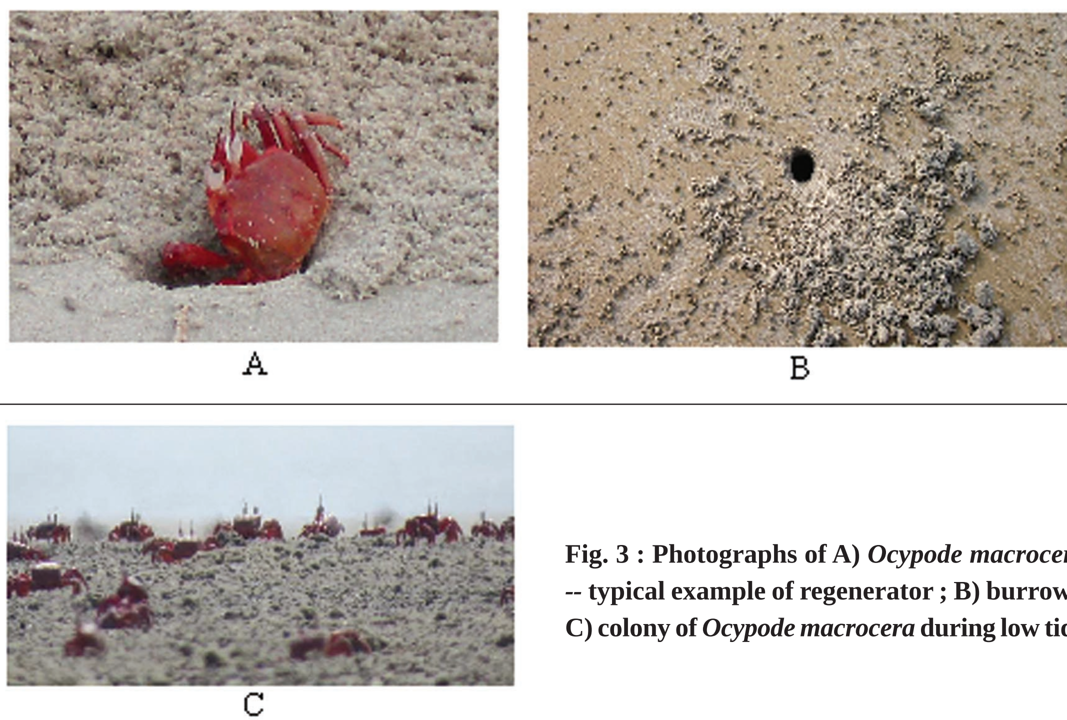

Fig. 3 : Photographs of A) *Ocypode macrocera* -- typical example of regenerator ; B) burrow ; C) colony of *Ocypode macrocera* during low tide

Fig.4: Photographs of POP casting of burrows (A = J shaped ; B = I shaped ; C = semi-U shaped

ghost crab species has been reported by Vannini (1980a, 1980b) were I, J or U shaped, which is very similar to the study. Sea-ward burrow opening of *Ocypode macrocera* were similar to other species like *O. ryderi*, *O. ceratopthalma* and *O. saratan* which has been reported by Vannini (1980b) and Fellows (1973). The maximum burrow architecture of *O. macrocera* found to be 'J' shaped. Similarly Katz (1980) and Montague (1980) also described that general burrow shape of *Uca* species is either L or J shaped. The air temperatures and burrow sand column temperatures exhibited characteristic variations. The air temperatures were seen to vary between 29ºC to 32ºC. The burrow sand column temperatures vary between 21ºC to 23ºC, thus exhibiting preference for cooler subterranean residential compartment. The importance of burrows in protecting high external temperatures and environmental extremes has been discussed by Vannini (1980a) and Atkinson and Taylor (1988). Furthermore, Lim and Diong (2003) working upon fiddler crabs hypothesized those high intertidal areas might help to maintain lower burrow temperature during ebb tides. Thus temperature and moisture levels in the substratum could influence the burrow depth architecture, playing an important ecological role in the life history and habitat dependency of *Ocypode macrocera*. Physic-chemical parameters monitoring was suggested that they are adapted to the varying salinity zonations, air and water temperatures and to the different sediment conditions, tidal fluctuations.

This preliminary study is an indicator of future work of *Ocypode* mediated bioturbation in Sundarbans ecosysytem. This faunally

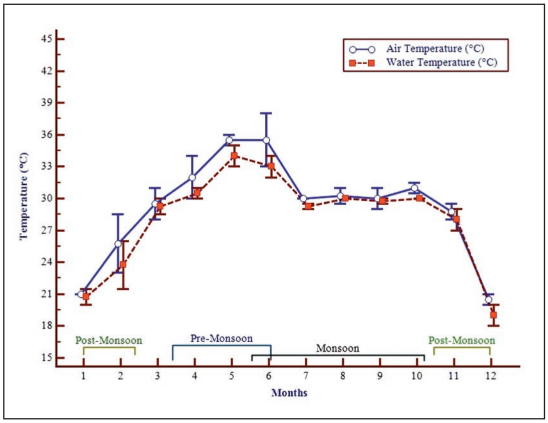

Fig.5: Monthly variation of surface water temperature and air temperature throughout the study period in the year 2012. The results are expressed as Mean ± SEM. In figure, 1-12 denotes January to December.

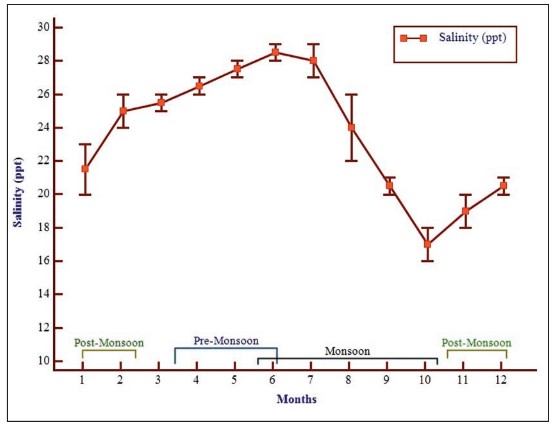

Fig.6: Monthly variation of water salinity throughout the study period in the year 2012. The results are expressed as Mean ± SEM. In figure, 1-12 denotes January to December.

mediated bioturbation as all transport processes carried out by animals that directly or indirectly affect sediment matrices. These processes include particle reworking & bio-mixing (bio-diffusers, bio-regenerators), and burrow ventilation & bio-irrigation. Regenerators are excavators that dig and continuously maintain burrows in the sediment and transfer sediment from depth to surface. The excavated sediment is replaced either by surface sediment through wind current and tidal action or by collapsing of burrow wall. Ghost crabs *Ocypode spp*. and fiddler crabs *Uca spp.* are the typical examples of regenerators (Kristensen *et al*. 2012). The crabs directly depend upon mangrove influenced areas for survival, feeding, predation and reproduction. It constructs unique burrows of extreme architectural and functional complexities which influence the whole sedimentology and geochemistry of mangrove shore bed. The digging behaviour enhances oxygenation in the ground soil and facilitates decomposition of organic materials, nutrient

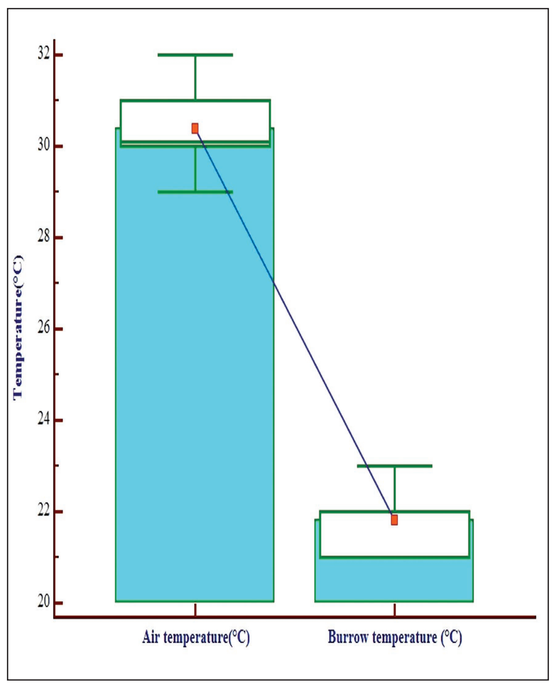

Fig.7: Differences between ambient air temperature and burrow temperature. The results are expressed as Mean ± SEM.

recycling, entrapping the sediments and mangrove seedlings. This is also documented by Atkinson and Taylor (1988) and other several workers. The biogenic structures (the burrows) can (may) provide refuse from predation; facilitate larval settlement etc. of various categories of macro-infauna inhabiting in the region (Dubey *et al.* 2012).

CONCLUSION

In conclusion, this study shows that *Ocypode macrocera* display varying degree of burrow morphology in relation to abiotic factors in a particular biotope. Further investigation is required to determine the exact influence of these environmental factors on burrow morphology. This preliminary investigation serves as primer for future works on structural bioturbation pattern of *Ocypode*. The biological monitoring of coastal sandy beaches using burrowing species can be of a tool for anthropogenic impact assessment. Periodic scientific assessment on the occurrence of *Ocypode macrocera* burrows in the study area can be considered as helpful matrix for determining pilgrimage impact upon Gangasagar sandy beaches for future.

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