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Burrow Construction Morphology of Ocypode Rotundata Miers 1882 (Ocypodidae: Brachyura) from the Sandy Coastal Areas of Karachi, Pakistan

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Abstract

Burrow morphology of ghost crab *Ocypode rotundata* was studied at two stations of Sandspit beach, Karachi. A quadrate method Two-meter square (2m2) was used for burrow cast profiling. Burrow casts were shaped by pouring plaster of Paris (liquified 2:1 ratio) into the ghost crab burrows. The Burrow casts and sediment samples were collected monthly from the studied site from Jan 2012 to Dec 2013. Besides this effect of human trampling on the sandy beach was also studied. Total Six types of burrow structures were observed (I, Y, C, L, J and multiple branched (M-type)), with burrow depth between 460 mm to 1300 mm. The most common casts collected were straight I- shaped (36.8%), while M- type casts were the rarest (5.7%). All the burrow openings were found positively correlated with carapace length (r2 = 0.81). The fine grain found dominated during grain size analysis from both stations. During anthropogenic survey, the effect of human trampling was less due to private huts as compared to the control area where a smaller number of burrows were found. Current study revealed strong relationship of ghost crabs with environment, therefore, may be useful to study as ecological indicators for sandy beaches.

Keywords: Anthropogenic impact; Burrow morphology; Ghost crabs; Grain size analysis; Human trampling; Sandspit; Sediment analysis

Abbreviations: OD: Opening Burrow Diameter; TL: Total Length; TD: Total Depth; CL: Carapace Length; CW: Carapace Width; Ch L: Chela Length; TBL: Total Burrow Length

Introduction

Ghost crabs are semi-terrestrial Brachyura from the genus *Ocypode Weber*, 1795 *(Family: Ocypodidae)* [1-5]. These crabs are frequently found in tropical to sub-tropical areas along the sandy coasts of the world, including the Atlantic, Pacific, and Indian Oceans, as well as major seas such as the Mediterranean and Red Sea. [5-8]. *O. rotundata Miers* 1882 is abundant in the Indo-Pacific region, found in large quantities above the high tide mark on sandy shores [5,8-12]. This species is the most conspicuous macroscopic invertebrate inhabiting the sandy beaches found along the coasts of Pakistan [6].

Ghost crabs are relatively large and mostly observed during dawn and dusk, but juveniles may also be seen during the daytime because they cannot spend as much time inside their burrows as adults. Ghost crabs usually feed during the night and are considered omnivorous scavengers, feeding on macroscopic, microscopic, live or dead animal or plant materials [13].

Marine invertebrate organisms living in the soft sediments of marine coastal area have developed burrowing adaptability [14]. Burrow construction behaviour is predominantly species specific, but individuals of some species may alter burrow structure when encountering variation in sediment properties to better regulate their activities in the transformed environment [14-18]. Ghost crabs can construct deep and complex burrows up to two meters [11] which provide shelter against both climatic extremes and predators and serve as sanctuaries during moulting and while gravid [4,18]. Crabs in the family *Ocypodidae* show significant intraspecific variation during construction of burrows in response to different individual and environmental conditions, such as sediment structure, vegetation forms, coastal height, tidal difference, gender, and age of individual [4,19-21]. The burrow openings of ghost crabs are circular with neighbouring accumulated sand mounds and are generally surrounded by intense feeding lines [22]. There are clearly visible entrances to ghost crab burrows on the surface of sandy beaches maintained as territory [23] and counting these burrows serves as a measure of local ghost crab density [8,18,24-26].

Coastlines of the world are dominated by sandy beach ecosystems [27,28], but increasing human population is destroying natural sandy beach habitats at an accelerating rate [8,29]. Because ghost crabs are a key component of the sandy beach food chain, they can be used for the assessment of human impact on the beach environment [8,30]. In Pakistan, the significance of ghost crab burrow morphology and relative growth analysis on beaches has yet to be explored. In this study, we examined burrow structure morphology of *O. rotundata* from two stations of Sandspit coast of Karachi, Pakistan and the influence of human impact on burrow density.

Materials and Methods

Study area

The Pakistan coastal belt covers about 990km from Ketibunder to Jiwani Bay. The Karachi coast, located in Sindh Province, is approximately 100km in length [31]. The Karachi coast comprises of many sandy beaches and is well known for its picnic spots. Sandspit beach is one of the more popular beaches of Karachi, with wide areas of mangrove on its backshore. The backshore and foreshore of Sandspit beach are separated by a wide strip of road which connects the Hawksbay coastline with Manora beach island over a distance of about 20km [32]. The study was carried out at two stations of Sandspit: (S1) Hawksbay (24°51’ N 66°53’ E): located on Hawksbay drive opposite to WWF wetland centre regional office, and (S2) Manora (24°50’24” N 66°54’36” E): located at the southwest of Karachi on Manora drive near leftover of CEMB shore lab. Both sites contain large population of ghost crabs. The S1 site is also famous as a nesting site of the green turtle Chelonia mydas [32]. Each station was divided into an upper tidal zone and a lower tidal zone. The upper zone ranges from splash zone to surf zone (approx. 38 feet), while the lower zone ran from the surf zone to the lowest tide level (approx. 38 feet).

Sampling methodology

The present study was carried out over two years from Jan 2011 to Dec 2012. Data was collected through line transect methods in four months (March, April, August and September) of each year. Four transects were placed in each zone for burrow count and cast filling. The measurement was taken from high tide zone to low tide zone with a line transect method. Total two quadrats ($2m^2$) were used in each tide level from high tide level to low tide level. Measurements included the diameter of burrow openings (OD), the distance of each burrow from the sea (DS) at low tide, and the total burrow count from each zone (TB). Burrow counts and cast filling were replicated during each visit, in order to search for any new form of burrow structure and examine human disturbance over time. An aqueous solution consisting of plaster of Paris and water with a 2:1 ratio was prepared in the field. This solution was emptied into the selected crab burrows until the burrows were filled completely with the solution and took 30 to 60 minutes to dry [4]. Few crabs emerged from burrows while filling with the solution; these crabs were tagged and placed into marked bags and brought to the laboratory for further analysis. On several occasions, crabs were trapped inside their burrows and could not emerge because of the depth, branching, or drying effect of the cast. The casts were excavated carefully as they become solidified and carefully taken to the laboratory for measurement of burrow proportions related with opening burrow diameter.

In the laboratory, casts were cleaned prior to measurement with a moderate size paint brush to remove dust. Measurements of each cast were recorded, including opening burrow diameter (OD), total length (TL), and total depth (TD), and associated captured crabs were measured for carapace length (CL), carapace width (CW) and enlarged chela length (Ch. L).

Sediment analysis

Sediment samples were collected near casting areas from a depth of 30cm for each quadrate replicate. Sediment samples were analyzed for sediment structure and morphology, including percent organic matter and grain size analysis [18]. For percent organic matter, 200g of sediment were placed into pre-weighted well labelled crucibles, placed into an oven at 70°C for 5hrs, weighed again, and then placed into a furnace at 400°C for 24hrs. After 24 hours, the crucibles were weighed a final time.

For grain size analysis, sediment was dried at room temperature and treated to have a permanently crumpled appearance. About 100g of sediment sample were taken from the dried sample and sieved through a sediment shaker machine with a standard mesh sized sieve for 15 minutes. Sediments retained on each sieve were collected, weighed, and analyzed to determine percent grain size.

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Anthropogenic impact

A 20m^2 area at a reference site and each station were chosen to estimate anthropogenic impact at each site. The reference site was a popular beach regularly visited for picnics. Ghost crab densities were calculated twice a month by counting the number of active burrows on the beach surface at each site. Burrows were counted by the line transect method. Four transects were positioned in each of the upper and lower shoe zones and burrow densities were observed as the number of burrows per transect. These counts were replicated during each visit, with counts carried out 8 times each year, twice a month in March, April, August, and September.

Statistical analysis

Linear regression was used to examine the relationship between the morphometric and burrow measures, with Student's t-test used to compare the two sites. A one-way ANOVA was employed to test differences among the sampling locations and the control location.

Results

Burrow morphology

In total, 65 complete burrow casts of *O. rotundata* were collected. Male crabs were more common burrow occupants, with 46 males (70.77%) vs. 14 females (21.54%), with an additional five (7.69%) empty burrows (Table1). The casts included six types of burrow structures: J-, L-, C-, Y-, I-, and multiple branched (M-) (Figure 1). The most common casts collected were straight I- shaped (36.8%), while M- type casts were the rarest (5.7%) (Figure 2).

Linear regression analysis revealed positive allometric relationships between both burrows opening diameter (BOD) and total burrow length (TBL) with carapace length (CL) (R2= 81.2% and 80.7%) respectively (Figure 3).

Figure 1: Burrow structures in Ocypode rotundata are generally labelled by letters that represent their shape. From left to right to top to bottom: L, M, I, C, Y, and J shaped burrows.

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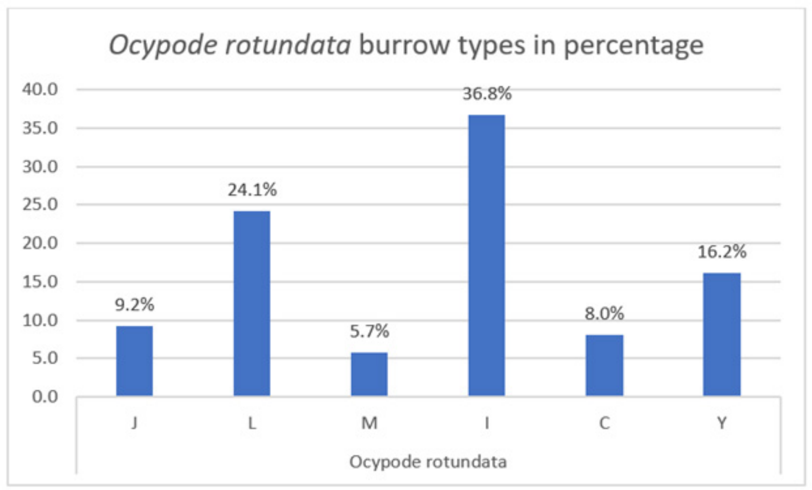

Figure 2: Percentage of different burrow structures in Ocypode rotundata.

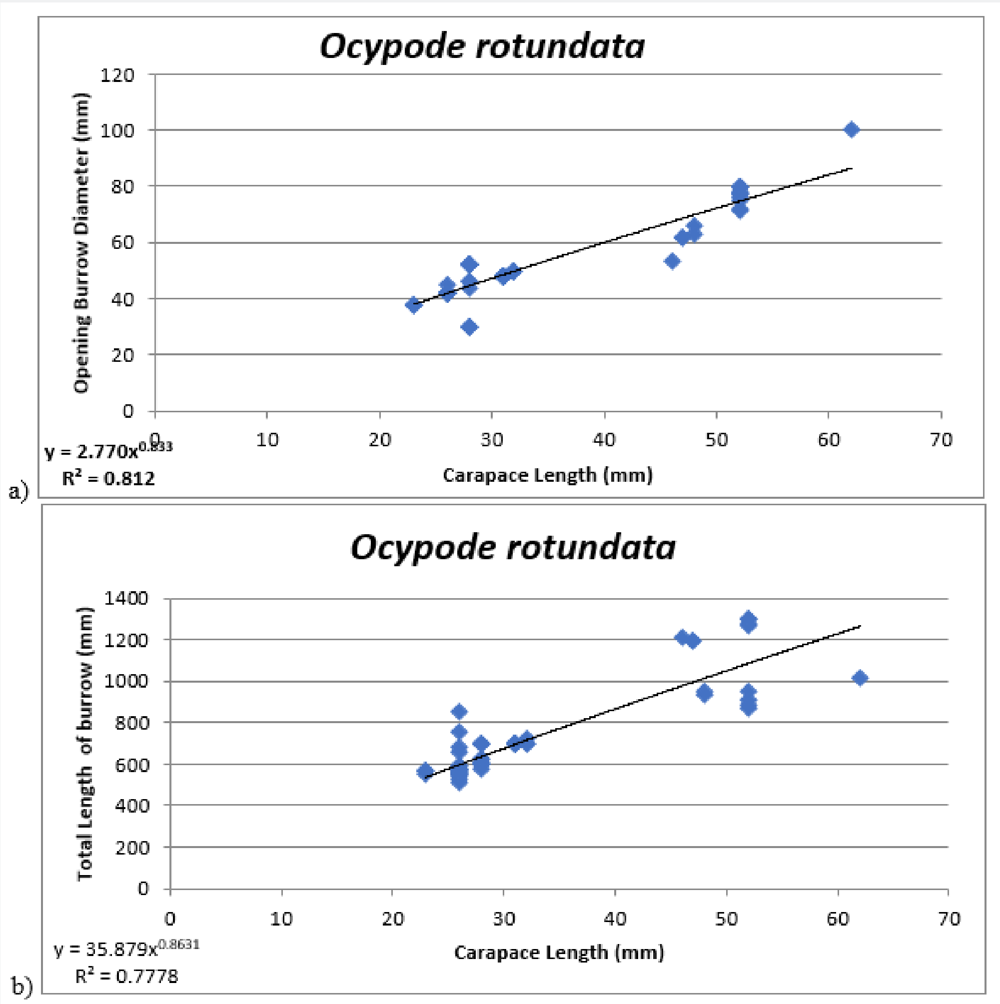

Figure 3: Relationship between carapace length vs. opening burrow diameter (a) and capace length vs. total length of burrow (b) in O. rotundata.

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Table 1: Gender wise percentage of *Ocypode rotundata* during burrow cast collection.

Species	Sex	Total Number	Percentage (%)
Ocypode rotundata	Male	46	70.77
	Female	14	21.54
Unknown	???	05	7.69
Total		65	100

Using Student's t-test, no significant differences were observed in crab size between the two study sites, whether measured by carapace length (p=0.58) or width (p=0.30). J-shaped burrows had the smallest volume with a mean opening diameter (OD) of 38.31mm (Table 2). The primary and secondary arms of Y shaped burrows joined together into a straight shaft and ended up in a chamber at the base (Figure 1). All the primary arms were found to be oriented towards seaside, with the secondary arms opposite the sea and not opened at the surface. The multiple branched burrow structure (M) had the largest OD (87.0 ± 67.7mm) despite containing the smallest size crabs (CL = 26.00mm (Table 2). The largest crabs tended to be found in I-shaped burrows (Table 2).

Table 2: Descriptive analysis of burrow cast structure of *Ocypode* species along the coast of Karachi.

Variable	CS	N	Mean±SD	Minimum	Maximum
CL (mm)	J	12	26.33±2.462	23	31
	L	13	33.62±10.63	26	52
	M	3	26.00±0.051	26	26
	I	32	35.94±11.35	26	62
	C	15	37.60±12.56	26	56
	Y	14	28.00±12.71	23	58
OD (mm)	J	13	38.31±8.900	30	60
	L	13	63.10±36.20	30	170
	M	5	87.00± 67.70	30	200
	I	37	70.46±48.67	30	205
	C	15	59.87±12.56	40	80
	Y	14	52.21±13.90	46	85
TL (mm)	J	13	630.0±74.00	550	770
	L	13	693.8±138.1	540	950
	M	5	786.0± 275.0	580	1240
	I	37	770.5±294.7	300	1300
	C	15	702.7±82.10	540	820
	Y	14	610.0±104.9	550	680
TD (mm)	J	13	576.9±79.70	480	710
	L	13	631.3±123.8	500	840
	M	5	582.0±141.7	460	820
	I	37	767.8±296.0	300	1300
	C	15	596.7±73.40	500	720
	Y	14	540.0±91.60	490	760
DS (cm)	J	13	3596.5±293.4	3383.3	4236.7
	L	13	3762±8310	2591	5608
	M	5	4504±6390	4115	5639
	I	37	4107.1±565.2	2590.8	5516.9
	C	15	3700.3±177.7	3322.3	3962.4
	Y	14	3601.1±102.1	3413.8	3659.6

(OR: *O. rotundata*; CL: Carapace Length; OD: Opening Burrow Diameter; TL: Total Length of Burrow; TD: Total Depth of Burrow; CS: Cast Shape).

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Sediment analysis

The yearly grain size analysis revealed that fine grain dominated the sediment composition from both stations (Table 3). The coarse silt sand was consistently less than 2% in any core, site, or year (Figures 4 & 5).

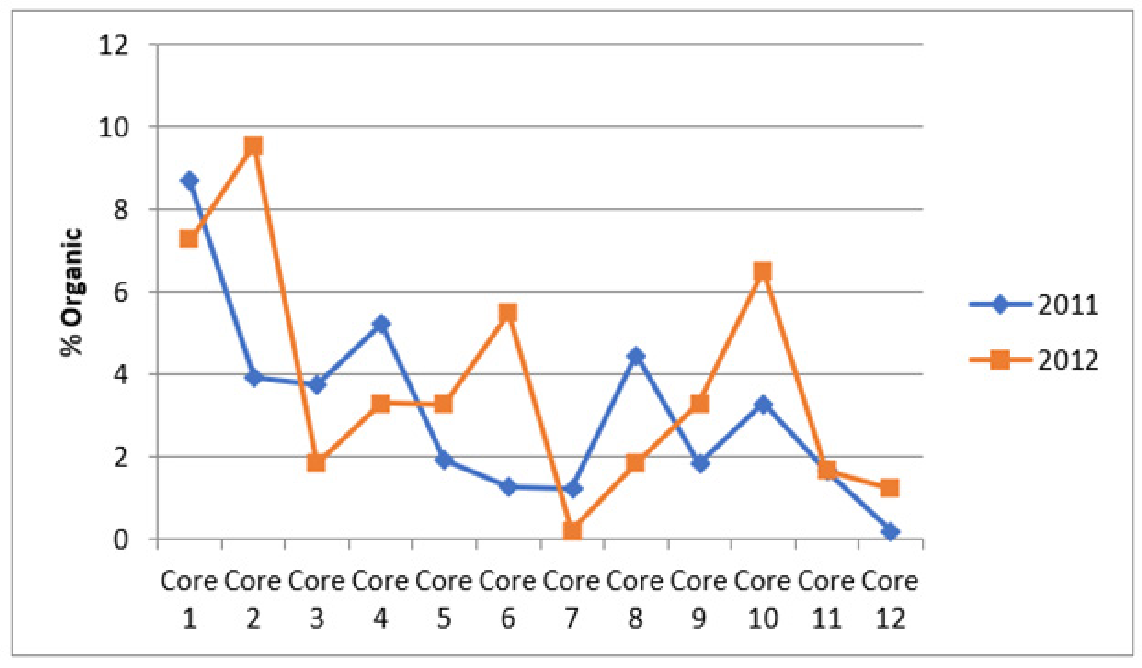

Figure 4: Two-year difference of percent organic matter (POM) in sediment from Sandspit area.

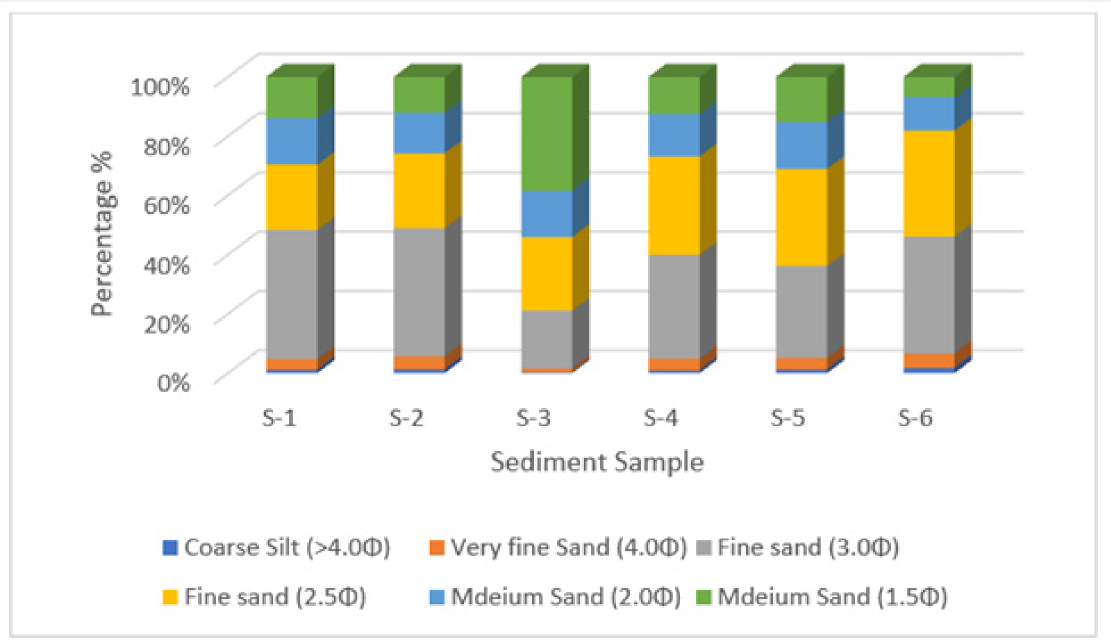

Figure 5: Bar chart shows sediment grain size in percentage where different colors represent percentage of various type of sand.

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Table 3: Detailed descriptive analysis of the annual percentage of organic matter and sediment structure in the form of grain size analysis from sandspit study.

Core	Year	Station	Organic Matter (%)	Coarse Slit (>4.0/230)	Very Fine Sand (=4.0/230)	Fine Sand (=3.0/120)	Fine Sand (=2.5/80)	Medium Sand (=2.0/65)	Medium Sand (=1.5/45)
Core 1	2011	Shore Lab	8.68	1.25	3.52	43.62	22.11	15.73	14
	2012		7.23	1.15	2.98	44.62	21.3	14.63	15.32
Core 2	2011	Shore Lab	3.93	1.36	4.37	43.02	25.07	13.67	12.03
	2012		9.55	1.46	4.88	41.44	29.56	11.33	11.33
Core 3	2011	Shore Lab	3.74	0.34	1.28	18.92	24.34	15.35	37.45
	2012		1.86	1.14	2.18	38.22	18.66	17.66	22.14
Core 4	2011	Shore Lab	5.21	1.07	3.99	35.84	33.85	14.75	12.7
	2012		3.3	1.34	4.8	28.99	32.55	19.88	12.44
Core 5	2011	Shore Lab	1.91	1.29	4.01	31.23	33.03	16.01	15.35
	2012		3.28	0.66	3.55	38.55	24.78	14.99	17.47
Core 6	2011	Shore Lab	1.26	1.9	5.03	40.27	36.58	11.43	7.12
	2012		5.49	1.99	4.66	41.29	33.76	10.44	7.86
Core 7	2011	WWF	1.23	1.75	4.52	42.62	21.11	14.73	15.21
	2012	Site	0.21	1.2	4.38	43.22	20.2	15.1	15.9
Core 8	2011	WWF	4.47	1.56	3.37	41.02	22.07	16.67	15.03
	2012	Site	1.86	1.26	3.25	40.44	23.66	15.1	16.29
Core 9	2011	WWF	1.86	1.34	2.28	35.92	29.34	15.35	16.45
	2012	Site	3.3	1.15	1.98	34.29	28.66	16.63	17.29
Core 10	2011	WWF	3.3	2.07	2.99	31.84	30.85	16.75	15.7
	2012	Site	6.5	1.98	3.5	30.22	29.88	17.88	16.54
Core 11	2011	WWF	1.65	1.9	4.01	36.23	28.03	16.01	13.35
	2012	Site	1.65	2.14	3.7	38.44	25.77	14.66	15.29
Core 12	2011	WWF	0.21	0.9	3.03	40.27	36.58	15.43	4.12
	2012	Site	1.23	1.25	2.78	39.55	33.27	14.28	8.87

Anthropogenic impact

Both selected stations were observed to have less impact from human intervention than the control area. Both sites are usually used by a few people for bathing and picnicking due to access to private huts throughout the study area. Occasionally the number of people increased during weekends and holidays. Both stations are similar in topography; burrow density was compared using ANOVA (Table 4). Burrow density was substantially smaller at the control site than either of the two study sites, but also differed significantly at the control site between the two years, but not at either of the two study sites.

Discussion & Conclusion

Smaller crabs and juveniles construct smaller burrows closer to the sea than larger, adult crabs. Adult ghost crabs have a larger gill surface area which helps them maintain respiratory water for a longer period, allowing them to construct burrow further away from the sea, whereas juveniles with their smaller gill surface areas, cannot tolerate as long a period away from the water [4]. Chan et al. [4] stated that burrows which are shallow with a single tube structure are considered to be temporary burrows. Such behaviour was also observed in other species of crabs such as *Ocypode ceratophthalmus (Pallas), Austruca iranica (Pretzman), Austruca annulipes (H Milne Edwards) and Austruca sindensis (Alcock), Leptuca pugilator (Bosc), Sesarma longipes (Krauss), Carisoma carnifex (Herbst), and Macrophthalmus parvimanus (Gurin)* [4,31,33,34].

Increasing gill surface area and constructing deeper, more complex burrows help protect ghost crabs from predators, mainly shore birds and wandering animals (i.e., cats, dogs); dogs have been observed to dig up ghost crab burrows on Sandspit beach (S.O., personal observation). Crabs are cold blooded, and harsh environmental conditions may directly influence burrow density as extreme temperatures (below 15˚C or above 30˚C) induces them to hide inside burrows for protection [15,25,18,26,35-37].

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Table 4: Descriptive analysis of total number of burrows showing anthropogenic impact. Minimum number of burrows, maximum number of burrows and One-way ANOVA P-value of two selected sites along with Picnic site.

Site	Year	Total	Mean±SD	Minimum	Maximum	P
Picnic site	2011	103	12.88±4.70	8	21	0.008
	2012	60	7.500±1.773	5	10	
Shore Lab	2011	1320	165.0±47.0	69	188	0.128
	2012	987	123.4±38.5	78	226	
WWF Site	2011	1161	145.1±32.1	103	192	0.671
	2012	1400	175.0±41.2	83	210	

The air temperature in Karachi rises to more than 40˚C during summer (April-June) and drops below 15˚C during winter (December and January); at these times burrow density increases, and crabs remain inside their burrows all day. The deeper parts of the burrows remain moist, preventing crabs from suffering from desiccation [13,18]. Similar patterns were observed by Takahashi [38] from Taiwan and India.

The present study revealed that the opening burrow direction was tilted towards the sea, regardless of the structure. When the burrow structure is complex with many branches, secondary arms face landward. Similar results of burrow opening direction were observed from Hong Kong and India [4,22], whereas Hayasaka [39] reported secondary shafts opened at the surface like primary shafts. The secondary arm provides additional protection from predators [22]. Larger crabs protect themselves by constructing deeper burrows with single tube [4], as was found in the current study.

Ghost crabs are considered ecological indicators of anthropogenic impact in urban areas; this impact can be evaluated through burrow counts [24,30,40-42]. Urbanization and human use can have a major impact on the ghost crab burrow density [30,43,44], as human use of beaches lowers ghost crab burrow density [26,40,45-62].

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