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Studies on the Interplay between Environmental Parameters and Behaviour of Ghost Crabs, *Ocypode* Sp. in the Coastal Ecosystem of India: A Mini-Review

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ABSTRACT

The semi-terrestrial ghost crabs of genus Ocypode are nocturnal scavengers, who occasionally feed upon bivalve mollusks. They dwell in the littoral fringe of sandy shores that are very close to the sea. Ghost crabs construct deep and complex burrows, where each species exhibits a certain range of burrow morphologies. Based upon the review made by Vannini in 1980, the burrows of juveniles were either I, J, or U-shaped whereas the adults show higher variability in burrow architecture which includes Y-shaped and spiral configuration in addition to those burrow shapes created by juveniles. The importance of burrows in protecting the ghost crabs and its other aspects which play an immense role in this regard is vividly elucidated in this review. Ocypode's digging behavior increases the oxygenation of ground soil and promotes the decomposition of organic materials, nutrient recycling, entrapping of the sediments, and mangrove seedlings and aids in the process of bioturbation. Generally, four types of burrow patterns were spotted - 'J,' 'I', 'U', semi 'U' Types with varying sizes as revealed by studies through the plaster of Paris (POP) casting. Significant physico-chemical parameters like air temperature, the salinity of water, and water temperatures are noticeably varied throughout the Ocypode zone. During summer daytime periods, the burrows protect the crabs from heat and prevent the chances of desiccation stress. Several studies have come up with the fact that the sand surface temperature at the burrow opening was measured about 48ºC but temperatures inside the burrows can drop to 32ºC at a depth of 250 mm. Variation in the burrow architecture with crab age seems to be associated with the crab's behaviour. From several studies, it has been pointed out that the burrow shape is directly correlated with tidal action, and the metabolic activities of crabs are intimately associated with burrow microenvironment. They adapt themselves to varying sediment conditions, different salinity gradients, air and water temperatures, and fluctuations in other environmental parameters.

Keywords: Burrow Architecture, Feeding habit, Ocypode, Juvenile Crabs, Adult Crabs, Mating Behavior

1. Introduction

Crustaceans are a diverse group of organisms that include- crabs, lobsters, crayfish, shrimp, krill, and many other species that are known to play a crucial role in marine ecosystems. Sometimes they are considered good indicators of environmental stress and pollution in the ecosystem and frequently have commercial and cultural significance(Barros, n.d.). The FAO statistics denote that the landings of freshwater and marine crustacean species were about 5,840,082 metric tons (6.5% of the total world catch of 90,063,851 metric tons)(Chan, Chan, and Leung, 2006a).

Behaviour can be designated as the sum of responses of an organism to internal and external stimuli. The behaviour of an organism is correlated to the functional integrity of the central nervous system, whereas the activity of the Central Nervous System cannot be assessed independently of behavioral analysis(Patra et al., 2019). The coastal areas are a refuge for diverse benthic fauna among which fiddler crabs (*Uca* spp., Ocypodidae) act as the representative of the bioenergetically significant microbenthic faunal group having ecological and economic significance. The semi-terrestrial crabs of the genus *Ocypode* (Brachyurans) are typical macro-faunal components of tropical and sub-tropical sandy beaches of the world (Dahl 1953)(Barros, n.d.). Analyzing the burrowing behavior in the specific ecosystem from the ecological perspective has received great importance in recent days and crab burrowing is regarded as one of the major bioturbations influencing the physical and chemical processes in the ecosystem. Being the most significant biotic components of aquatic and terrestrial ecosystems, soil organisms are multipurpose workers, for instance, consumers, litter decomposers, and habitat modifiers can affect the substrate either actively or passively(Mandal et al., 2015). Bioturbation can be defined as the biological restructuring of soils and sediments through animal activities like burrowing and feeding – it is mainly referred to as the natural outcome of the adaptation of organisms to live, forage, and respire in sediments(*Front Matter*, 2017). Darwin was the first to praise Animal Bioturbation and its ecological role in maintaining the soil ecosystem which was depicted in his last book *On the Formation of Vegetable Mounds through the Action of Worms with Observations on their Habits*(Wang et al., 2010). *Ocypode* is addressed as a proficient environmental engineer for its excellent engineering skill in tunneling and regulating the nutrient availability for other organisms by influencing sediment biogeochemistry and microbial decomposition(Dubey, n.d.). Crab Burrowing is one of the most dominant bioturbations prevalent in coastal ecosystems which can transport sediments, modify sediment texture, and enhance ecosystem nutrient cycling(Dubey, n.d.).

The semi-terrestrial Ghost crabs of the genus *Ocypode* exhibit dual activities since they can opt between surface activity at night and a fossorial lifestyle inside their burrows during the daytime(Srinivasan et al., 2017). Burrows they construct are generally deep and complex by nature which protects them from environmental adversities and predator attacks and functions as refuges during the time of molting and maternity. The population density of ghost crabs can be reduced to several extents under the influence of anthropogenic factors and the burrow density of crabs can be the indicative factor reflecting the recreational impacts on the sandy shores. These crabs are known to facilitate their burrowing behavior in a particular ecotype based on varying degrees of substratum conditions, salinity, temperature, tidal periodicity, anthropogenic disturbances, predators, etc(Srinivasan et al., 2017). To this end, the current study aims to enumerate the several aspects of the burrow morphology of Ocypode and its complexity from a structural perspective, and it has been pointed out whether any variations in juvenile and adult behavior may lead to the heterogeneity of the burrow architectures.

2. Environmental Impacts on Crab Burrow Densities

The semi-terrestrial, supra-littoral, macrobenthic ocypodid prefers a solitary mode of habit and depends upon the self-constructed wide variety of burrows for shelter, life cycles, etc. Burrowing is executed with the help of the first pair of unequal chelipeds accompanied by the left chela. The second and third pairs of legs and dactyls of these appendages somehow act like trowels to pull the dirt loose and carry the mass before it to the outside of the burrow(Dubey, n.d.). Rows of setae present between the bases of the second and third pairs of legs are used for sorting sand particles(Dubey, n.d.). It has been noted from several studies that the area under analysis showed there is a connection between the maturity of crabs and varying distribution patterns of crabs up to the seashore. In general, from several studies, it has been noticed that juvenile crabs were more available near the sea during low tide, which might be due to feeding purposes, and larger adults were found at a distance from the sea. Burrow diameters were relatively less in the seaward margin, ranging between 2-3 cm, and it got broadened in landward zones, ranging between 5.5-6.5cm(Chakraborty, 2011).

Burrows tend to protect against dehydration, but the crabs are still dependent on water access to moisten their gill chamber(Chan, Chan, and Leung, 2006a). On the contrary, extreme dehydration can lead to the loss of body weight and significantly impaired locomotion. Generally, juveniles have the stringency to renew the water in the gill chambers more frequently than adults, as a result, their distribution is prone to extend further landward(Chan et al., 2006a). Again, on the other hand, the seaward limitation of crabs is favored by waves and swash as prolonged exposure to water can lead to osmotic stress(Chan et al., 2006b; *THE_CRABS_CRUSTACEA_DECAPODA_BRACHYURA_OF_THE_PACI*, n.d.). The primary role of the habitat is to keep them moist to avoid desiccation so that the internal fluid that is lost due to evaporation gets easily replaced which in turn ensures the easy removal of waste products of the crabs(*Atlantic Ghost Crab Ocypode Quadrata Taxonomy and Basic Description*, n.d.).

From studies carried out at Gangasagar, it has been observed that there exists a wide range of seasonal variations throughout the zone of Ocypode. Mean air temperature and salinity of water undergo fluctuations following the season. Differences in air temperatures were marked high between May and June (35–38 °C), and lowest in December (20°C) and January (21°C)(Chakraborty, 2011). Water Temperature was marked high attaining a peak in May (35°C) and a decline in December (18°C)(Chakraborty, 2011). Salinity is also not an exception in this category of Physico-chemical parameters since it exhibits a rapid decline (16 ppt ± 4.56) in the monsoon period followed by the gradual increase in post-monsoon period (20 ppt ± 2.29) with the highest peak in the pre-monsoon period. Generally, interior to the burrow there is 8°C - 9°C reduction in the temperature from the ambient air temperature(Srinivasan et al., 2017).

*Ocypode*s are generally considered meticulous and efficient diggers among the burrowing Crustaceans in Sunderbans Ecotope(Chakraborty, 2011). Ghost crabs are highly spontaneous during time of strong onshore winds since wind-driven onshore advection is the principal mechanism for delivering wrack and carrion to beaches. This event enhances the chances of resource availability for nocturnal ghost crabs(Chakraborty, 2011; Dubey et al., 2013).

3. Feeding Habit of Ghost Crabs

Ashley Jones, Mike Kowalski, and Evan Kuras conducted analytical studies on diurnal feeding behaviour in juvenile and adult crabs where they used the high-nutrient fish carcass to feed ghost crabs dominating in the intertidal zone of Pacific shores on the Western coast of South America and the Galapagos Islands(Lucrezi et al., 2009). During their studies, they placed one decomposing fish carcass at the middle intertidal zone and the other in the higher sand dunes. It was observed that just after the placement of fish carcass, it was first noticed by a juvenile crab twelve minutes after its placement. The first adult to feed arrived 19 minutes after placement of the fish, which was then followed by the arrival of small groups of crabs, both adult, and juvenile. In total, 39 crabs fed on the fish over an hour, consisting of 14 adults and 25 juveniles(Lucrezi et al., 2009).

It was expected that adult crabs would colonize the carcass first and outcompete juveniles for the food source(Zipser & Vermeij, 1978). But the scenario turned out to be reverse- since the higher frequency of juveniles were feeding on the carcass than adults(Robertson & Pfeiffer, 1982). On the contrary, it was pointed out that juveniles leave their food only when it is under the control of an aggressive adult ghost crab(Robertson & Pfeiffer, 1982; Zipser & Vermeij, 1978). Although all are opportunistic scavengers, juvenile crabs abandon a food source easily when challenged by a larger adult. However, juveniles may also be at lower risk for predation and have more affinity to feed despite the presence of an interspecific threat, including a human(Lucrezi et al., 2009; Robertson & Pfeiffer, 1982).

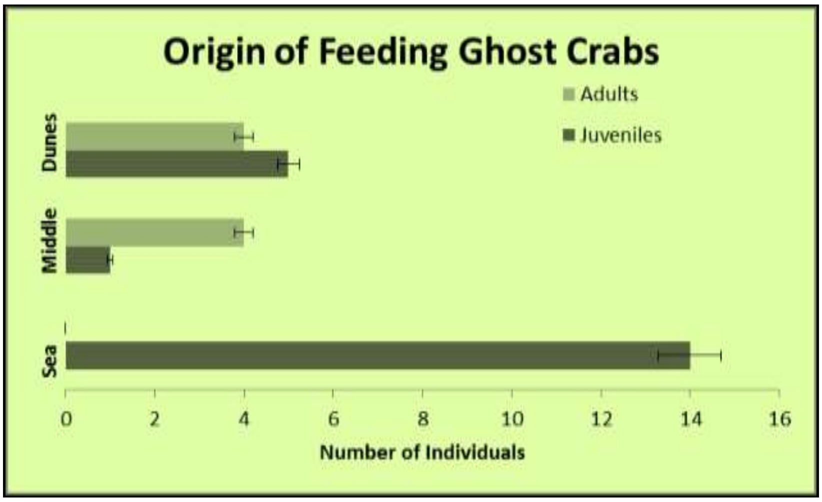

Figure 1: - Graphical Representation showing the direction of the burrow which are abandoned by adult and juvenile crabs relative to the position of fish. Although the number of adults and juveniles is equivalent in the dune and middle areas, only maximum number of juveniles are found in the burrows which are near the sea. (Source: - Jones, Ashley. (2013). Habitat and Feeding Behavior of the Ghost Crab *Ocypode gaudichaudii*.)

Figure 2: - A) *Ocypode macrocera* **B)** Burrow Pattern of *Ocypode macrocera* **C)** *Ocypode macrocera* Colony during low tide (Source: - Exploratory Animal and Medical Research, Vol.3, Issue 2, December 2013, p. 136-144)

Figure 2: Feeding behavior of O. rotundata in Qeshm Island, A: deposit-feeding, B: consuming of macroscopic plant detritus, C: scavenging on animal carcasses.

Figure 3: - The feeding behavior of *O. rotundata* divides into three classifications: A) deposit-feeding, B) consuming of macroscopic plant detritus, C) scavenging on animal carcasses (Source: - Mini Review Volume 11 Issue 4 - January 2020 DOI: 10.19080/OFOAJ.2020.11.555816)

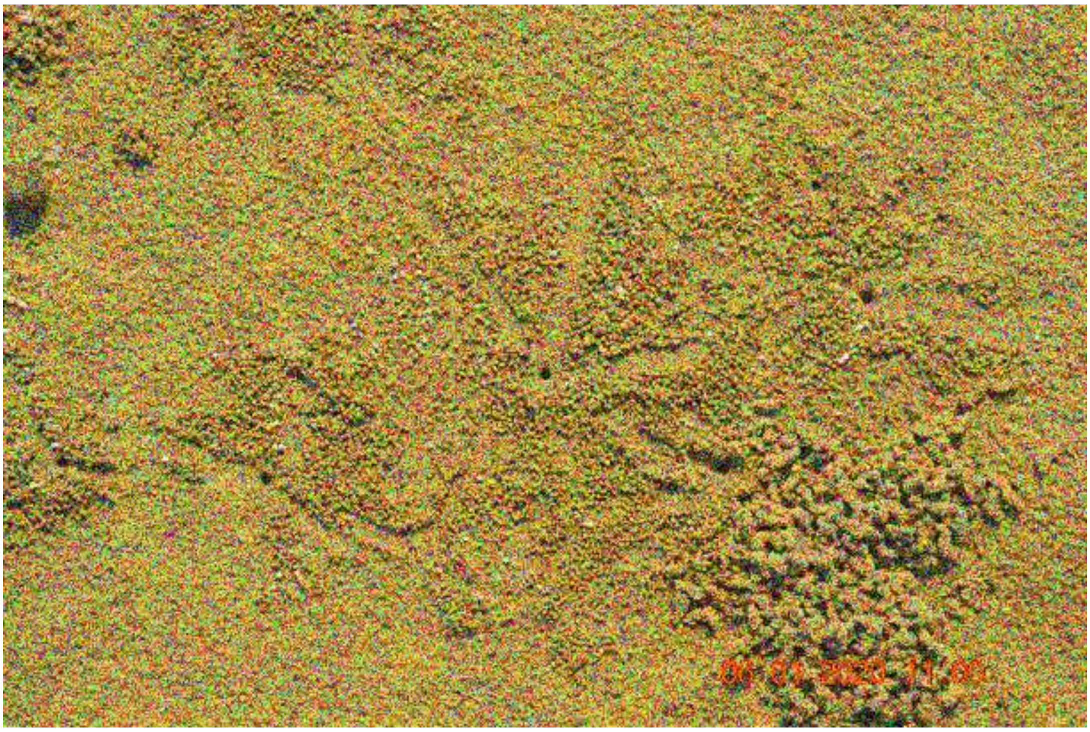

Figure 4: - An up-close look at the sand bubbling patterns at Mandarmani Sea Beach, West Bengal (photographed in January 2020). These patterns are created by sand bubbler crabs searching for food in the damp sand. They work at high-speed passing sand grains into their mouth, filtering out the nutrients, and kicking aside the waste rolled into little sand balls.

Figure 5: - A- The entry point of the ghost crabs' burrows is very steep but they possess an almost horizontal room at the bottom end of the tunnel. Mainly, the water content of beach sands allows crabs to build a stable tunnel at any depth. **B**: - A close-up of the ghost crab basking in the sun. Generally, they stay hidden in the complex deep burrows during the hottest time of the day and step out to forage when the sun's rays are not sharp.

4. Mating Behaviour in Ocypode sp.

Mating can take place all year round. Unlike other crab species, ghost crabs can mate even if the female's integument becomes hard, i.e., they can mate any time after sexual maturity. It is an example of terrestrial adaptation(Yosef, Korkos, et al., 2021). Mating occurs while both males and females have hard shells (*THE_CRABS_CRUSTACEA_DECAPODA_BRACHYURA_OF_THE_PACI*, n.d.). Usually, mating takes place somewhere in or near the male's burrow. The male releases a seminal fluid along with his sperm which ultimately gets hardened and prevents rival sperm from reaching the female's ova. The precopulatory courtship ritual is highly significant in this case since male ghost crabs can build sand

Figure 6: - A typical Red Sea Ghost Crab (*Ocypode saratan*) burrow entrance with a sand pyramid on the outside. (Source: - Yosef, R.; Korkos, M.; Kosicki, J.Z. Does Size Matter? The Case of the Courtship Pyramids in Red Sea Ghost Crabs (*Ocypode saratan*). Animals 2021, 11, 3541. https://doi.org/10.3390/ ani11123541)

structures near the entrance to their burrows. Males attempt to display to maximize fitness by attracting reproductive females to mate to drive speciation by sexual selection(Mokhlesi et al., 2011; Yosef, Korkos, and Kosicki, 2021). Sand pyramids act as the sign stimulus for attracting females, opponent males are fought off by the owner and males generally guard their pyramids for 4-8 days, during which it does not feed. When the female is present nearer to the pyramid, males exhibit vibration signals to convince females to enter the burrow(Naderi et al., 2018). To attain maximum fitness, males would try to attract females from greater distances and display their size concerning their competitive neighbours by enhancing the size of their pyramids and taking advantage of their large body size to build higher and more distinct pyramids(Naderi et al., 2018).

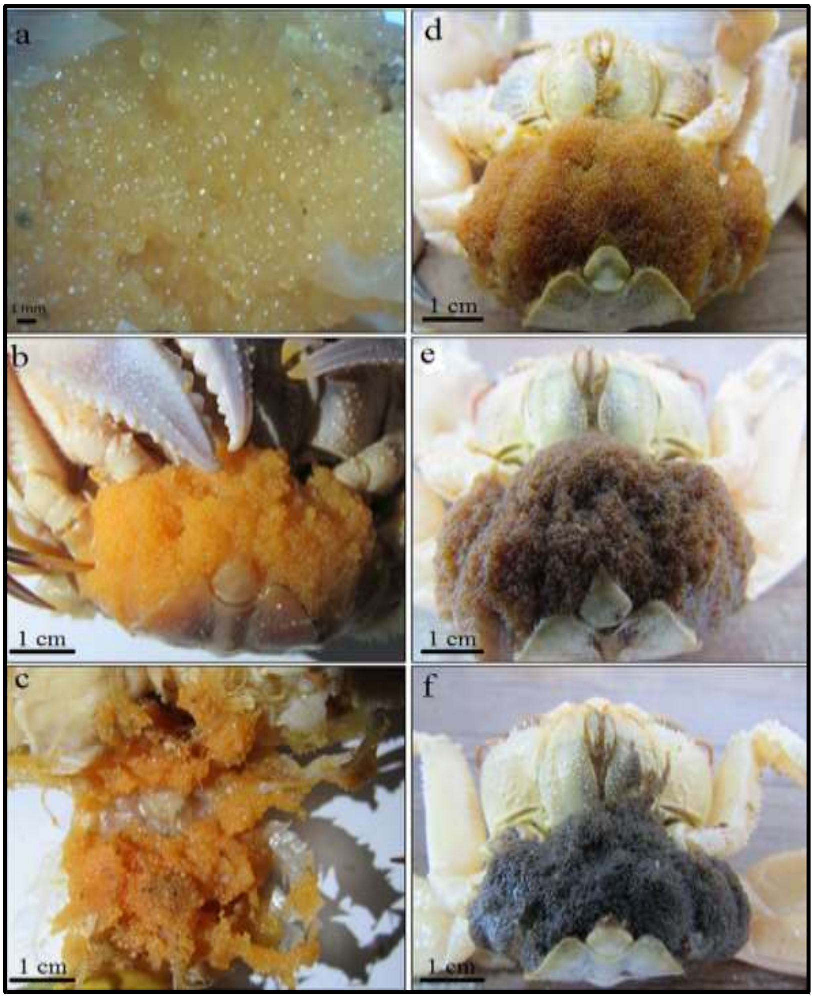

Figure 7: - Egg-colour variation in ovigerous females of *Ocypode rotundata* Miers, 1882, as observed in the population at Qeshm Island: a, yellow; b, light orange; c, orange; d, dark orange; e, brownish; f, brown (Source: - REPRODUCTIVE BIOLOGY OF THE GHOST CRAB, OCYPODE ROTUNDATA MIERS, 1882 (DECAPODA, OCYPODIDAE) AT QESHM ISLAND, PERSIAN GULF, Crustacean 91 (9) 1039-1059, DOI 10.1163/15685403-00003804)

Another distinguishing behavioural characteristic that has been noted in several studies is Cradle Carrying – this is a pre-copulatory mate-guarding behavior that is needed to assure a successful mating and to convince paternity and poses a great ecological significance. Male mate-guarding is energetically expensive and is recognized as a measure of male fitness(Soundarapandian P & Soundarapandian, 2013). During this position, both animals are facing the same direction. Several studies on sand crab have revealed that males only initiate the cradle carry position by approaching the pupertal females and the pupertal females have not exhibited any means of approach towards the males(Soundarapandian P & Soundarapandian, 2013). Male provides chivalry and protection to the females before and after her pubertal moult with their first pair of walking legs grasping the females and holding them in the right-side cradle carry position under them. Mating was initiated whenever the female exoskeleton becomes soft(*Atlantic Ghost Crab Ocypode Quadrata*, n.d.). At that moment, the male crab becomes active and rotates the female by using his walking legs, and by using chelate, he turns over her. The female crab meticulously positions herself upside down beneath him and elongates her abdomen to expose her gonophores which in turn allows the male to insert his paired gonopods into her genital pores. Eventually, male and female crabs are facing in opposite directions. During the time of copulation, the male often walked around with the female attached to its ventral surface, holding her with third and fourth walking legs(Soundarapandian P & Soundarapandian, 2013).

After the copulation has been completed, the male crabs release the female from the mating position embrace in a short while to form the cradle-carrying position that continued for only a few hours. The female remains inactive until her exoskeleton regains hardness in texture(Soundarapandian P & Soundarapandian, 2013). During mating, males deposit spermatophores within the female's spermatheca and it is stored until the female is prepared for extrusion(Naderi et al., 2018; Soundarapandian P & Soundarapandian, 2013). During the time of extrusion or spawning, ovaries release the eggs through the seminal receptacles(Soundarapandian P & Soundarapandian, 2013). In the seminal receptacles, the stored sperms were liberated from the spermatophores to fertilize the eggs and fertilized eggs are extruded through the gonophores present in the sternites of the sixth thoracic segments of the third pair of legs, and these eggs become attached to the smooth setae present in the endopodites of the four pairs of pleopods in the abdominal flab(Soundarapandian P & Soundarapandian, 2013). The segregated egg mass was carried on the abdominal flab- this is known as berry or sponge(Soundarapandian P & Soundarapandian, 2013). The females bearing eggs were called berried crabs(Soundarapandian P & Soundarapandian, 2013).

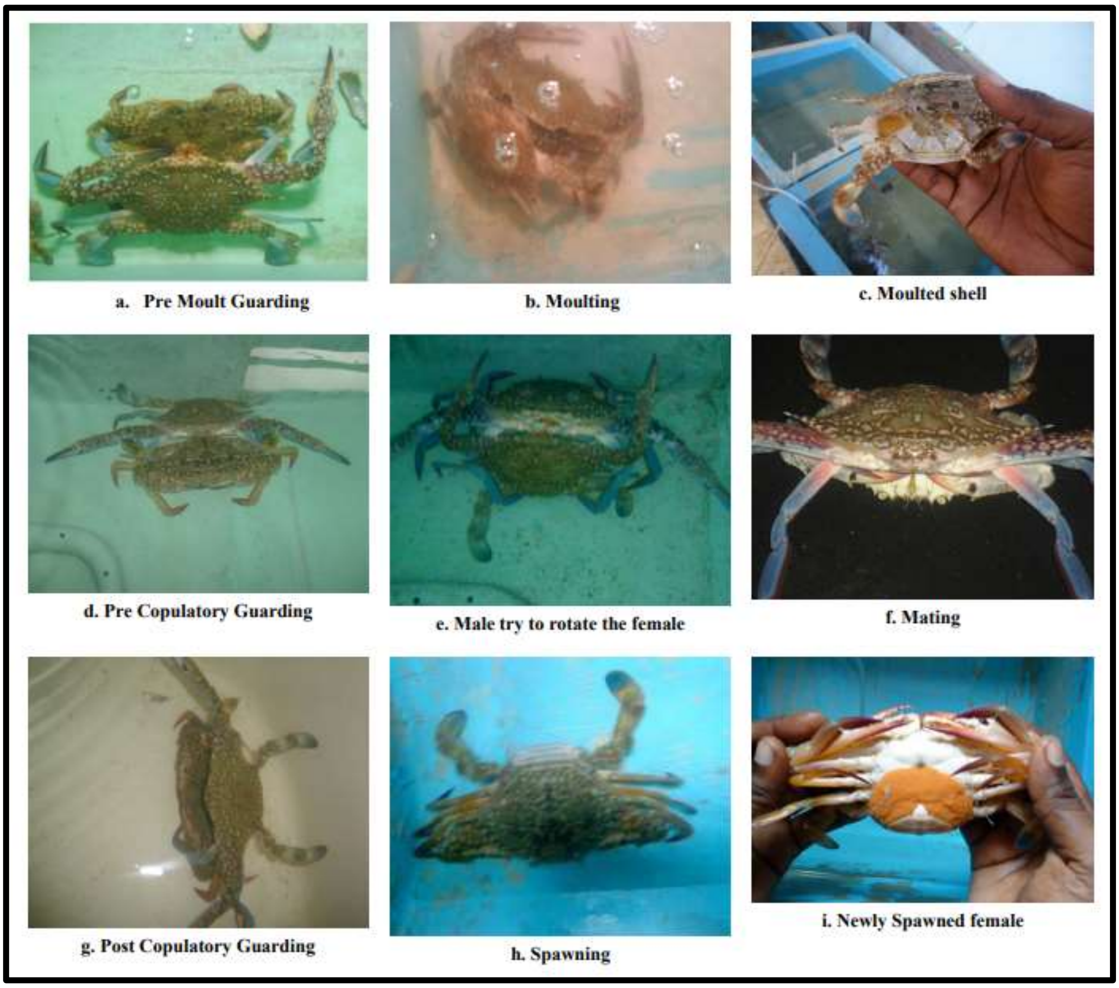

Figure 8: -Different positions of Mating Behavior (Source: Soundarapandian P, Varadharajan D, Anand T (2013) Mating Behaviour of Sand Crab, Portunus pelagicus (Linnaeus). 2: 685 doi:10.4172/ scientificreports.685)

5. Burrow Architecture on Ghost Crabs

Ocypode constructs a wide variety of burrow architectural types. Juvenile crabs had J-shaped burrows, whereas larger crabs made Y-shaped, spiral burrows and single tube burrows(*THE_CRABS_CRUSTACEA_DECAPODA_BRACHYURA_OF_THE_PACI*, n.d.). In this regard, Frey (1970) opined that Y-shaped and U-shaped are usually constructed by intermediated aged crabs, whereas young crabs construct single tube burrows that are oriented vertically in the substrate. Burrows made by old crabs are larger but not usually branched(Chan, Chan, and Leung, 2006b; Seike and Nara, 2008). Barrass (1963) differentiated two types of burrows based upon the presence or absence of piles of sand near the opening of the burrows indicating whether the burrow would be used as an entrance (called true burrows) or exit (called emergency holes), respectively. Ghost crab burrows also show differential patterns of distribution according to their age group(Seike & Nara, 2007). Adult ghost crab burrows are uniformly distributed, whereas juvenile crab burrows show an aggregated pattern of distribution. This difference in distribution between age groups may reflect the physiological competence of young and old crabs to resist desiccation (Fisher and Tevesz, 1979) (Seike & Nara, 2008).

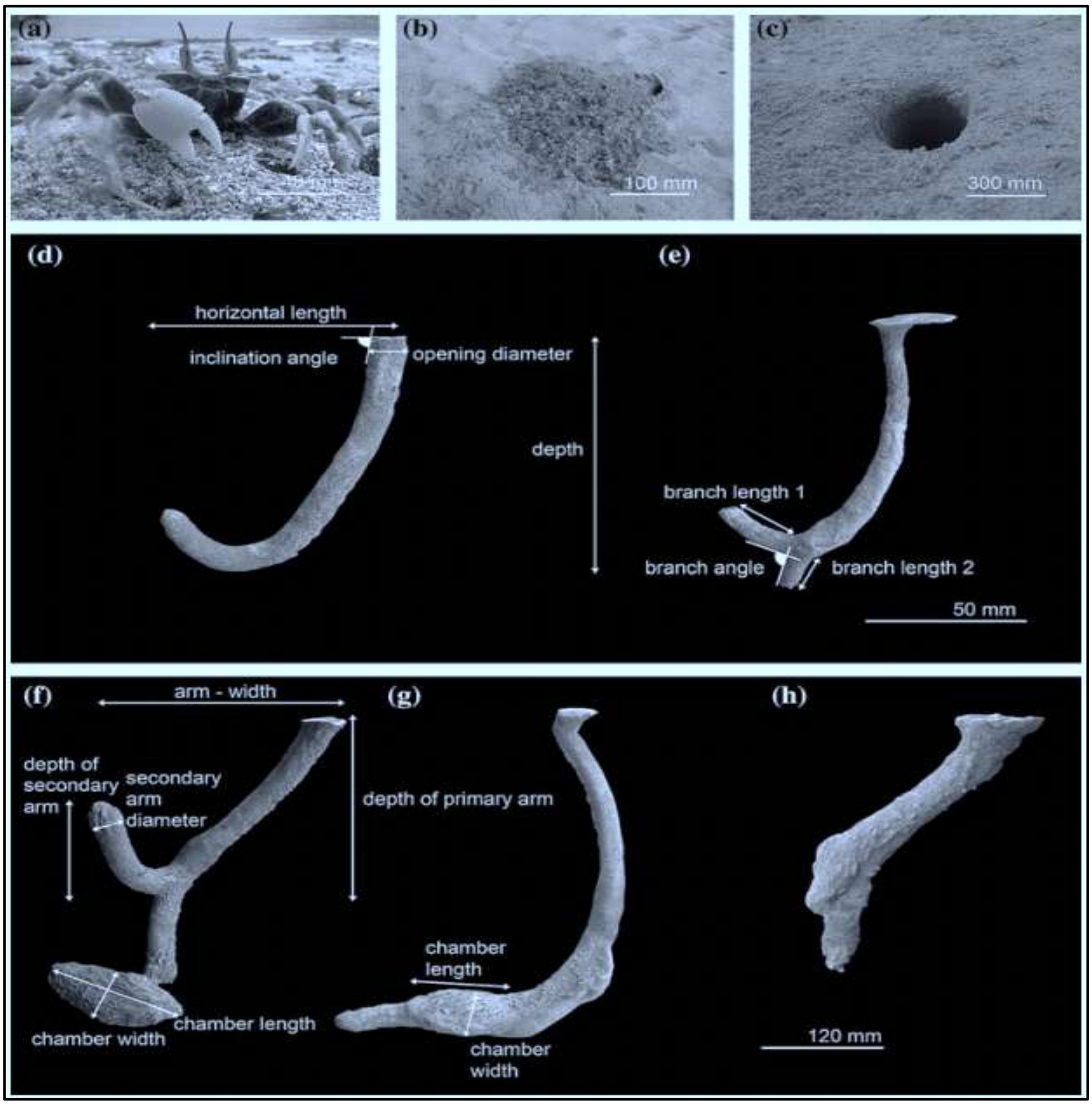

Figure 9: - (a) Adult male of *Ocypode ceratophthalma*; **(b)** External view of the burrows of *O. ceratophthalma* showing the sand mounds at the burrow opening; **(c)** Close-up view of a spherical burrow opening; (d–h) Typical burrow architecture with the corresponding parameters which were measured. Horizontal length, inclination angle, opening diameter, and depth were measured for all burrows. Additional measurements on branch angle, and branch lengths 1 and 2 were made on J-shaped burrows, which had a branch at the base. Arm width, depths of primary and secondary arms and secondary arm diameter were measured on Y-shaped burrows. Chamber length and width were measured on Y-shaped, spiral, and single-tube burrows**. (d)** J-shaped burrows; **(e)** J-shaped burrows with a branch at the base; **(f)** Y-shaped burrows; (g) Spiral burrows and **(h)** Single tube burrows. (Source: - Burrow architecture of the ghost *crab Ocypode ceratophthalma* on a sandy shore in Hong Kong, Hydrobiologia (2006) 560:43–49, Springer 2006, DOI 10.1007/s10750-005-1088)

The structure of sandy shoreline can be altered by ghost crabs as the burrow protects the ghost crab from predation by shorebirds during daytime(Seike & Nara, 2008). Ghost crab burrow abundance is also used to evaluate the impact of human disturbance on the coastal sandy beach. Ghost crab burrowing can enhance sediment drainage, and soil oxidation-reduction potential, improve sediment aeration, and increase substrate complexity. According to Chakrabarti (t981), ghost crab sex does not influence the burrow shape but according to Tureli et al. (2009), ghost crab anatomy and sex will influence the burrow shape. Burrow shape is widely determined by ghost crab species, ghost crab size, distribution pattern, beach slope direction, sandy beach grain size, duration of burrow building, and tidal range (Chakrabarti, 1981; Lim et al., 2011; Chan et aI., 2006; Shuchman and Warburg, 1978 cited from Tureli et al., 2009) (Chan et al., 2006b; Seike & Nara, 2008). The diameter range of the burrow does not reflect the burrow shape (Lim et al., 2011).

Bioglyphs are carving patterns that can be observed on a burrow wall due to the excavating activity of ghost crabs and are found on semi-consolidated sandy substrates (Seike & Nara, 2007). They are referred to as a group of small ridges at the burrow wall and are available at the lower zone of the burrow wall arranged parallelly(Branco et al., 2010; Seike & Nara, 2007). Generally, bioglyphs are present at the newly excavated burrow walls and over time, patterns gradually disappeared. Mostly bioglyphs are thus obliterated and retained only at relatively newly excavated parts, i.e., near the burrow end(Seike & Nara, 2007). This arrangement has also been reported in *Thalassinoides* in Cretaceous chalk sediments (Bromley, 1967)(Seike & Nara, 2007).

Laterality is one of the most distinct behavioral-physiological characteristics of organisms that has been observed in many systemic groups i.e., both invertebrates and vertebrates, it is suggested that bilateral symmetry indicates an evolutionary advantage like locomotion, sexual selection that has been developed in natural populations and possess systematic directional bias(Yosef, Daraby, et al., 2021). This behavioral lateralization (handedness) increases an individual's handling capabilities- this ecological advantage has been extensively studied by several scientists in Red Sea Ghost Crab. Many reported that there is temporal segregation between the right- and left-clawed crabs(Yosef, Daraby, et al., 2021). The right-handed crabs resume activity just after sunrise, whereas the left-handed crabs appear 40 mins after it. Ghost crabs always exit the burrow with the larger cheliped which is thought to be self-defence-related behaviour. The directional excavation of the burrow mediates the homoclawed females to choose males(Yosef, Daraby, et al., 2021).

6. Concluding Remarks

Beach and coastal dune systems are conspicuously exposed to a broad spectrum of anthropogenic disturbances such as vehicle traffic and human trampling(Defeo et al., 2009). In 1976, Berry reported that owing to crabs' burrowing and scavenging habits, ghost crabs might be seriously affected by increased oil tanker traffic which in turn leads to an increase in the amount of stranded oil on ocean beaches(Schlacher et al., 2011, 2016). When these crabs meet oil, either the breeding rate becomes severely reduced or enhanced rate of mortality during molting. In a recent study conducted in North Carolina, it had been reported by Peterson et al. (2000) significant deleterious effects on ghost crab populations owing to beach nourishment and bulldozing activities on eroding beaches(Barros, n.d.). In South Carolina, coastal regions claim a significant portion of the State's tourism; in 1996 these coastal areas accounted for 56% of the State's visitors (SCDNR and NOAA 2000)(Defeo et al., 2009). Spending time at the beach is a highly popular activity among tourists during their visit to the coast. Alterations to the upper intertidal zone caused by residential or commercial development of coastal areas and other beach construction may eliminate *Ocypode* from its natural habitat, either by direct mortality or by displacement to less optimal habitat(Schlacher et al., 2016). Such development, undertaken to accommodate increased recreational uses of the beaches, has been cited as the cause of the elimination of the ghost crab *O. stimpsoni* from the coastal Chinese region of Rizhao (Gao and Xu 2002).

Increasing temperatures associated with climatic alterations are predicted to cause a wide range of biological and ecological responses in marine organisms such as alterations in physiological processes, phenology, demography, behaviour, and modifications along with shifts in distributions and species ranges (Lucrezi et al., 2009; Xie et al., 2020). Humans emit a range of chemical and physical stimuli that can disrupt animals and interfere with the perceptual processing of important signals and cues, which in turn creates sensory pollution in several ecosystems. This altered acoustic landscape exerts many biological effects shifts in physiology (e.g., impaired hearing, elevated stress hormone levels), changes to key behaviors (e.g., foraging, mating, vigilance, movement), interference with the ability to detect important natural sounds (e.g.,vocalizations of conspecifics, acoustic signals of prey or predators), and direct fitness consequences (e.g., survival, reproduction)(Branco et al., 2010; Seike & Nara, 2008). Eventually, crabs are also sensitive to this noise pollution and become the victims of shifting in physiology, impairment of predator avoidance, altered development, and shifts in foraging behaviours (Gül & Griffen, 2018).

Man-made debris, mostly plastics, is now one of the most common, widespread, and persistent pollutants in marine waters and beaches worldwide which can act as anthropogenic stressors in marine ecosystems(Barros, n.d.).

Apart from all these aspects, introducing exotic vegetation, invasive species like exotic mammalian carnivores manipulate dune geomorphology and habitat quality for dune-associated species. Likewise, the effects of invasive species on ghost crabs have been documented in only a single study reporting a lower density of *O. cordimanus* in areas dominated by exotic vegetation(Defeo et al., 2009; Gül & Griffen, 2018).

From several reports, it has also been noted that the COVID-19 pandemic accompanied by its slowdown of human activity during the worldwide lockdown periods lead to the recovery of ghost crab metapopulations in the high-impact beaches where sand vegetation has been repressed for several years. So COVID-19 anthropause i.e., suppression of urbanization followed by recreational activities, litter pollution, artificial light, etc, leads to the passive restoration of the crab population in sea beaches but it is not a permanent solution(*Crab 456*, n.d.). So, it is better to focus on the implementation of nature-based tourism, scientific outreach, and environmental awareness projects are pivotal, providing a biocentric point of view for beachgoers and political support for beach wildlife conservation(*Crab 456*, n.d.).

From all aspects, it can be commendable that ghost crabs represent themselves to be powerful model organisms for the determination and evaluation of any sort of ecological impacts in warm-temperate to tropical coastal ecosystems(Chang et al., 2012). Ghost crabs are sentinel species for several reasons: i) they are widespread in the subtropics and tropics; ii) they occur on both the non-vegetated beaches and in the dunes backing beaches; iii) they are relatively large, often locally abundant, arguably charismatic, and require no specialized tools to sample; iv) their taxonomy is well known and identification not overly difficult; and v) they construct semipermanent burrows with clearly visible openings at the beach surface. So, ghost crabs also provide a strong indicator of impact from analysis and counting of burrows. These series of environmental fluctuations in marine ecosystems require manifolds of investigations based on the ghost crab population density. To mitigate impacts to ghost crabs associated with beach bulldozing practices, it is highly mandatory to encourage municipalities and private landowners to implement dune stabilizing techniques such as planting grasses and raise awareness among every tourist on how useful this species might be as an indicator of the overall "health" of the dune and fore-beach ecotone(Chang et al., 2012).

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