Synopsis of the Thesis Entitled

ECOLOGICAL STUDIES OF INTERTIDAL BRACHYURAN CRABS IN GULF OF KHAMBHAT, GUJARAT, INDIA

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By

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❖ INTRODUCTION:

Oceans and major seas constitute approximately 71% of Earth's surface, with a coastline of approximately 1.6 million km. Coastal and marine ecosystems occur in 123 countries which include estuaries, lagoons, sand dunes, near shore coastal areas and open marine areas. The Indian Ocean ranks 3rd largest ocean that covers approximately 29% of total ocean area (Venkatraman & Raghunathan, 2015). India – a mega biodiverse nation is an integral and largest part of the Central Indian Ocean Marine Region (CIOMR) along with other countries like Bangladesh, Indonesia, Maldives, Malaysia, Myanmar, Thailand and Sri Lanka (Gopi & Mishra, 2015). India is surrounded by three distinct marine ecosystem zones of the central Indian ocean marine region: the Arabian Sea on West, the Bay of Bengal on East and the Indian Ocean on South (Gopi & Mishra, 2015). In terms of coastal habitat, India has a coastline of approximately 8000 km including Andaman-Nicobar and Lakshadweep Islands (Venkatraman & Raghunathan, 2015).

Coastal and estuarine ecosystems provide important ecosystem services like food provision and water filtration (Granek *et al*., 2010) and that's why it is among the world's most productive ecosystems (Berger *et al*., 1989; Costanza *et al*., 1995). They are hot spots of environmental variability, biogeochemical transformations, and biological interactions, where dynamic exchanges of energy, mass, and nutrients occur between various habitats via diverse pathways. These transitional ecosystems between land and sea are often densely populated and experience multiple anthropogenic pressures including climate change, nutrient loading, and fishing (Cloern *et al*., 2016). Marine ecosystem can be divided into benthic zone and pelagic zone on the basis of depth of sea water and distance from sea surface (Levinton, 2001). Among these, benthic zone is highly diverse and most important part of marine ecosystem. The benthic zone is rich in term of nutrient content, primarily influenced by both terrestrial and aquatic phytoplankton growth (Sinha, 2015). The essential ecosystem functions, such as production and energy transfer in food webs, biogeochemical cycling, and provisioning of fish nursery areas (Granek *et al*., 2010) are mainly supported by the interaction of benthic and pelagic coupling processes.

The intertidal zone is an important area of benthic ecosystem that lies between high-tide mark and low-tide mark. The intertidal area represents both marine as well as terrestrial habitat during high-tide and low-tide respectively and because of that, fluctuation in physical and chemical properties is commonly recorded in the intertidal area (Newell, 1979; Denny, 1988). In the intertidal zone, marine organism can be directly encountered during low-tide without special kind of equipment. Out of different types of marine organisms found in the intertidal zone, crustacea is one of the most prominent groups belongs to the largest and dominant phylum Arthropoda (Sinha, 2015). In crustaceans, brachyuran crabs are highly abundant and most diverse group of fauna inhabiting in wide range of habitats like rocky, mangrove forest, mudflats, coral reefs, sandy shores, estuaries etc. (Levinton, 2001; Gohil & Kundu, 2012). Brachyuran crabs inhabiting in the intertidal area develops different types of adaptation to get protection from adverse environmental conditions, such as temperature fluctuations, aerial penetration, salinity and hydrodynamic forces (Newell, 1979; Denny, 1988). Nature of the intertidal system and the distribution of sediments are depended on tidal wave action. Due to this the intertidal population is a key target during harsh environmental condition (Ribeiro *et al*., 2005).

The information regarding species composition and habitat preference of marine invertebrates including brachyuran crabs provides base line information for successful conservation of the habitat and benthic fauna. Besides that, the studies on the distribution and diversity of local fauna are of great importance as these studies lead to the comprehension of structure, function and problems of the local animal community (Trivedi & Vachhrajani, 2012). Tremendous work has been carried out on the diversity and distribution of brachyuran crabs in India (Alcock, 1896, 1901; Kemp, 1919; Chhapgar, 1957 a, b; Deb, 1992, 1998; Ng & Kumar 2015a, b, 2016; Trivedi *et al*., 2016; Ng *et al*., 2017) while, ecological studies on brachyuran crabs are quite less. Few studies are available in which different ecological aspects like distribution pattern (Ravichandran *et al*., 2001), habitat preferences (Khan *et al*., 2005; Trivedi *et al*., 2012; Devi *et al*., 2013), distribution and abundance (Chakaraborty & Choudhary, 1992; Pandya & Vachhrajani, 2010; Bandekar *et al*., 2011) of brachyuran crabs have been studied.

In Gujarat, the coastal region of Gulf of Khambhat is having wide variety of intertidal habitats like mudflats, sandy shores, rocky-muddy shores, estuaries and mangroves (Pandya & Vachhrajani, 2010). Some studies are available on the diversity of mudflat inhabiting brachyuran crabs of Gulf of Khambhat (Pandya & Vachhrajani, 2010; Shukla *et al*., 2013; Trivedi *et al*., 2015) but very less studies are available on ecology of brachyuran crabs of Gulf of Khambhat (Pandya & Vachhrajani, 2010). So, present work was designed to study the ecological aspects of the resident brachyuran crabs in mudflats of Gulf of Khambhat.

❖ OBJECTIVES:

1. To study the diversity and distribution pattern of brachyuran crabs.
2. To study the burrowing behavior of the dominant brachyuran crabs (*Austruca sindensis* (Alcock, 1900), *Ilyoplax sayajiraoi* Trivedi, Soni, Trivedi & Vachhrajani, 2015 and *Dotilla blanfordi* Alcock 1900.
    a) to study the burrow architecture,
    b) to study the effect of lunar phases on burrowing activity.
3. To study the foraging behavior and bioturbation activity of three dominant species.

❖ MATERIAL AND METHODOLOGY:

➢ *Study area:*

Gulf of Khambhat is one of the three Gulfs of India and having largest tidal amplitude on the West Coast of India (Unnikrishnan *et al*., 1999). Gulf of Khambhat owes its own peculiarity in terms of its geomorphology, hydrodynamics and high tidal amplitude. Gulf, being funnel shaped with wide mouth and narrow head (width 200 km at mouth of Gulf terminating to 6 km at the extreme end of Gulf *i.e.* mouth of Mahi estuary), provides geo assistance to the tidal amplitude and turbulence. The coastal area of Gulf of Khambhat is having wide variety of intertidal habitats like mudflats, sandy shores, rocky-muddy shores, estuaries and mangroves (Pandya & Vachhrajani, 2010). Kamboi coast is one of the important habitats located on the narrow head region of Gulf of Khambhat, which is reach in diversity of brachyuran crabs. The study on ecological aspects of brachyuran crabs was carried out on intertidal mudflats of Kamboi coast (Fig. 1). The upper intertidal zone of Kamboi coast is rich in silt and clay which is dominated by *Austruca* sps., the middle zone contains undulating muddy area which is dominated by *Ilyoplax sayajiraoi* Trivedi, Soni, Trivedi & Vachhrajani, 2015 and lower intertidal zone is made up of sand which is dominated by *Dotilla blanfordi* Alcock, 1900 (Pandya & Vachhrajani, 2013).

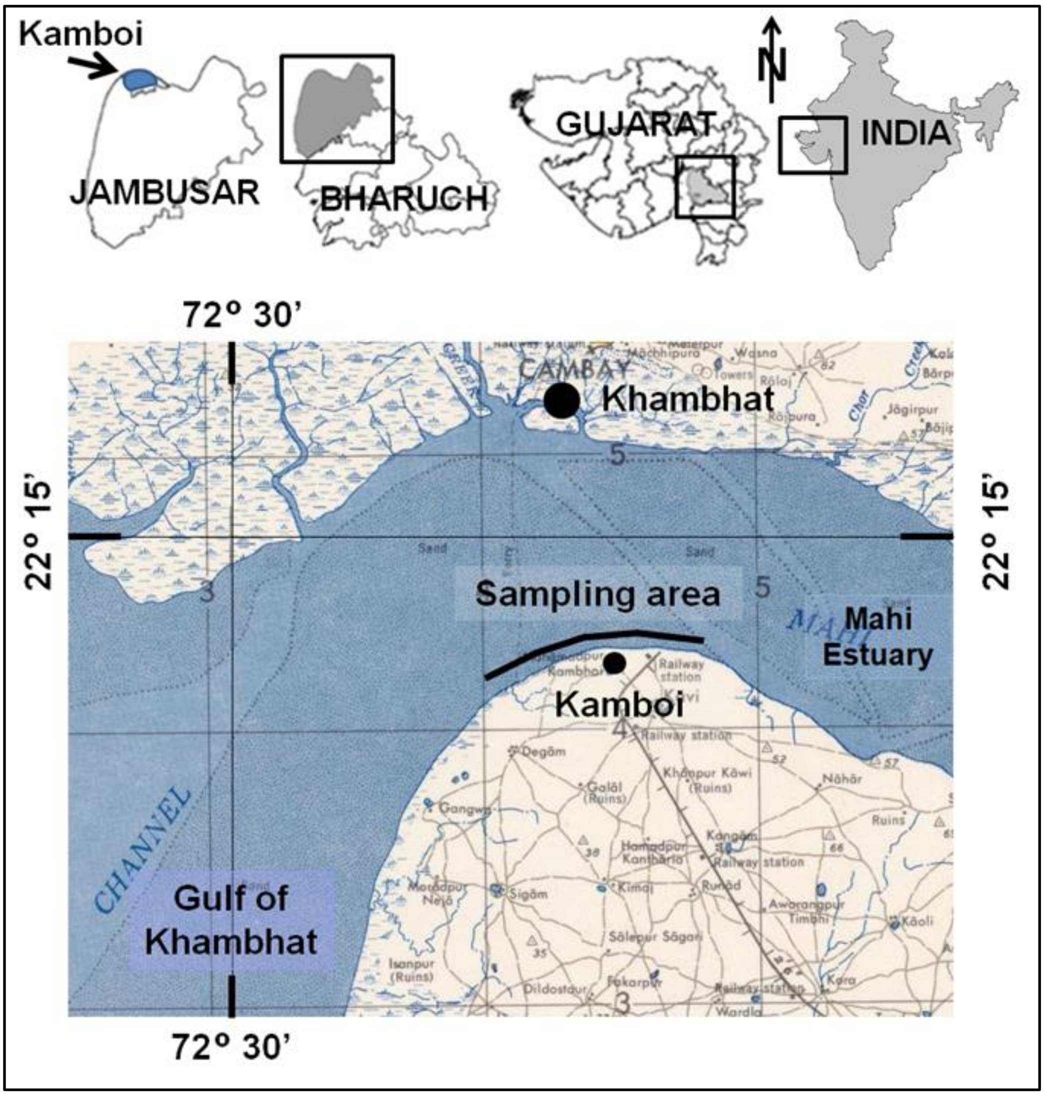

Figure 1: Location of the study site: Kamboi Coast, Gulf of Khambhat, Gujarat, India.

➢ ***Field methodology***

Extensive field work was carried out at Kamboi coast, Gulf of Khambhat from June 2020 to October 2022 for the collection of the data for the above-mentioned objectives.

- ***Diversity of brachyuran crabs*:**

For the collection of brachyuran crab species, extensive field surveys were carried out during January 2021 to October 2022, the hand-picking method was opted. On field, the visible characters were noted and photography was done of the freshly collected specimens for coloration. Later, the collected specimens were preserved in 70% ethanol and brought to the Marine Biodiversity and Ecology Laboratory (MBEL) at the Department of Zoology, The Maharaja Sayajirao University of Baroda (MSU), Vadodara. All the specimens were sorted out according to their sex. The specimens were identified up to species level by comparing morphological characters with available illustrative keys, research papers and monograms. For further confirmation of species, all the specimens were examined and compared with the images and identification characters available on Marine Species Identification Portal Website (http://species-identification.org/). The recent classification of crabs was adopted from the WoRMS website (www.marinespecies.org). Morphometric studies such as carapace length, carapace width, frontal length, cheliped length etc. of collected specimens were carried out.

- ***Distribution pattern of brachyuran crabs*:**

During April 2021 to June 2021, the initial field surveys were carried out to check the distribution status of brachyuran crabs in the study site. To study seasonal variation in distribution pattern of brachyuran crabs, monthly surveys were conducted during low-tide from October 2021 to September 2022. For the data collection, three transects were laid perpendicular to shore length and 100m apart from each other. Each transect was intercepted with $0.25m^2$ quadrates and laid 5m apart from each other for the entire length of the transect. A total number of burrows of different brachyuran crab species present in the quadrate area were counted and their opening diameter were recorded with the help of digital vernier caliper (Yuri YUR01). The quantified monthly quadrate data of burrows were integrated for different seasons like winter (November to February), summer (March to June) and monsoon (July to October) because climatic conditions of the study area do not change much in the successive months (Pandya & Vachhrajani, 2010). The quantitative seasonal burrow data was then analyzed for three different ecological attributes like density, abundance and frequency using following formulas.

$$\text{Density} = \frac{\text{Number of species recorded from all the quadrates}}{\text{Total number of Quadrates}}$$

$$\text{Abundance} = \frac{\text{Total number of species recorded}}{\text{Total number of Quadrates where the species recorded}}$$

$$\text{Frequency (\%)} = \frac{\text{Number of Quadrates where the species recorded x 100}}{\text{Total number of quadrates}}$$

- ***Burrow architecture of Austruca sindensis and Ilyoplax sayajiraoi*:**

Burrow casting of *A. sindensis* and *I. sayajiraoi* was performed from March 2021 to January 2022. For that, burrows of *A. sindensis* and *I. sayajiraoi* were selected randomly from upper intertidal zone to lower intertidal zone and their opening diameter was recorded with the help of digital vernier calipers (Yuri YUR01). After that, mixture of unsaturated resin, cobalt and catalyst (5:1:1) was poured into the burrows until the burrows were totally filled. Meanwhile, emerged crabs from the burrows were collected, sexed and the carapace width and length were measured using a digital vernier caliper (Yuri YUR01). Once, the burrow casts were solidified (~2 h), they were dug up for subsequent measurement of burrow dimensions (Fig. 2). The volume of the burrows was determined by weighing the burrow cast (±0.01 g) and dividing it by the density of unsaturated resin (0.96 g/cm3) (Trivedi & Vachhrajani, 2016). Besides that, variation in the sediment temperature was measured along the depth of the burrow at 5 cm interval using digital thermometer (Eurolab ST9269B, ± 0.1°C). For statistical analysis, regression was done to find out the relationship between carapace length of the crab and different morphological parameters of the burrow cast.

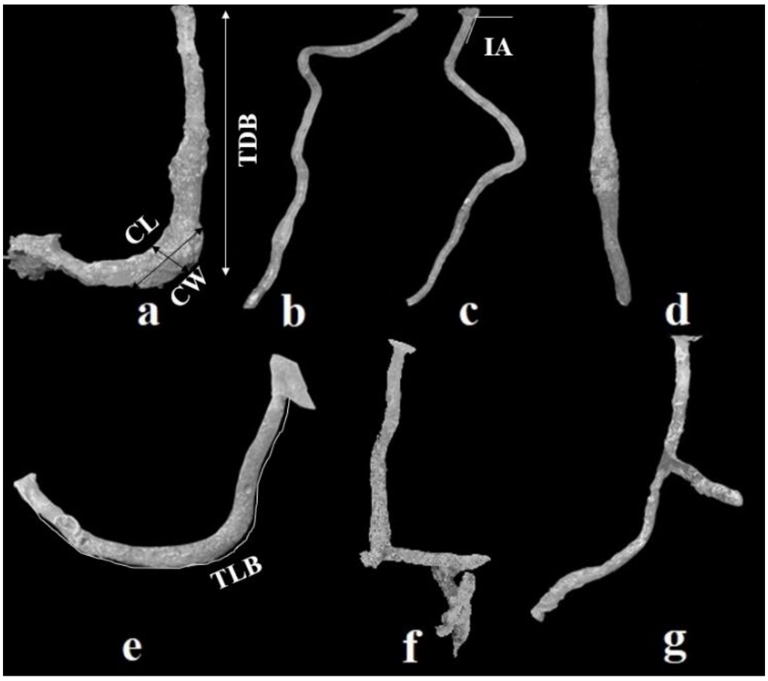

Figure 2: Shapes of burrows of *A. sindensis* with various measurements of burrow cast. a. J-shaped, b. Spiral, c. S-shaped, d. Single tube, e. U-shaped, f. Multi branched, g. J-shaped with Branch burrow. (TDB – Total depth of Burrow; TLB – Total length of burrow; IA – Burrow inclination angle; CL – Chamber length; CW – Chamber width)

- ***Effect of lunar cycle on burrowing activity of Austruca sindensis, Ilyoplax sayajiraoi and Dotilla blanfordi*:**

For the present study, three abundant burrowing crab species *i.e. A. sindensis*, *I. sayajiraoi* and *D. blanfordi* were selected. The sampling for the burrow density and its diameter for selected species was conducted for 6h during two full moon spring tides (28 March 2021; 19 November 2021), two new moon spring tides (12 April 2021; 4 December 2021), two waxing moon neap tide (22 March 2021; 11 November 2021), two waning moon neap tide (4 April 2021; 27 November 2021), two waxing crescent moon tide (17 March 2021; 4 November 2021), two waxing gibbous moon tide (26 March 2021; 15 November 2021), two waning crescent moon tide (1 April 2021; 23 November 2021) and two waning gibbous moon tide (8 April 2021; 1 December 2021). In each 6h sampling period, samples were taken every 1.30h interval from upper intertidal zone to lower intertidal zone. For that, three transects, 100m apart, were demarcated perpendicular to the waterline. Each transect was intercepted with 0.25m^2 quadrates which was laid 25m apart from each other. The burrows inside each quadrate were counted and their diameter was measured using a digital vernier caliper (Yuri YUR01). Crab density was calculated considering the number of burrows within each quadrat. The physical parameters (temperature and moisture content) were measured concurrently from the place where data for density and diameter were taken. For statistical analysis, the mean ± standard deviation value of the burrow opening diameter and density of each species from three transects was calculated. All the statistical analysis was performed using Statistical Package for the Social Sciences (version SPSS 22) software.

- ***Foraging range and pattern in Austruca sindensis, Ilyoplax sayajiraoi and Dotilla blanfordi*:**

The foraging range and pattern of *A. sindensis*, *I. sayajiraoi* and *D. blanfordi* were studied by taking scaled photographs. A total of 200 burrows of each species were selected randomly and their opening diameter were recorded using a digital vernier caliper (Yuri YUR01). The Photographs of selected burrow of each species were captured and total area of foraging was measured using DIGIMIZER Image Analysis Software (Fig. 3). Regression analysis was performed to check the relationship between opening diameter and total foraging area of selected burrows.

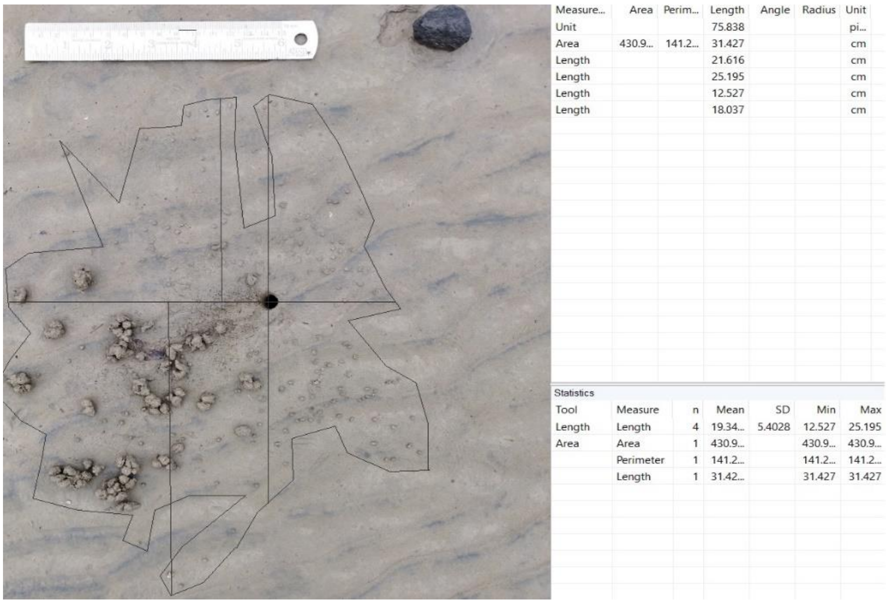

Figure 3: Representation of demarcation of total foraging range using DIGIMIZER Image Analysis Software

- ***Bioturbation potential of Austruca sindensis and Ilyoplax sayajiraoi*:**

These studies were not carried out for Dotilla blanfordi since it forms burrows in wet substratum therefore, the mudballing studies are not possible in this study area.

The preliminary survey was carried out in December 2021 to check the bioturbation potential of *A. sindensis* and *I. sayajiraoi*. For the data collection, a total of 50 quadrates were laid randomly from upper intertidal to lower intertidal zone. From each quadrate, a total number of burrows of individual species were counted and their opening diameters were recorded using digital vernier calipers (Yuri YUR01 Digital Vernier Caliper). After that, the mudballs of the individual burrow of each species were collected and labelled in separate zip-lock bags. Besides that, the sub-surface temperature data of each quadrate was taken with the help of digital thermometer (Eurolab ST9269B, ± 0.1°C). The zip-lock bags were brought to the MBEL at MSU and dry weight of the mudballs of each zip-lock bag were measured. Regression analysis was performed in SPSS 22 to check the relationship status of dry weight of mudballs with number and opening diameter of burrow of each species.

❖ <u>RESULT & DISCUSSION:</u>

- ***Diversity of brachyuran crabs*:**

In the present study, a total of 10 species belonging to 7 families and 9 genera were recorded from the study site. Out of these, families Ocypodidae Rafinesque, 1815 (1 genera), Dotillidae Stimpson, 1858 (2 genera) and Pilumnidae Samouelle, 1819 (2 genera) have contributed two species. Whereas, Matutidae De Haan, 1835, Sesarmidae Dana, 1851, Macrophthalmidae Dana, 1851 and Portunidae Rafinesque, 1815 have contributed one species of brachyuran crab (Table 1).

Table 1: List of the brachyuran crab species recorded.

Family	Species
Dotillidae	*Dotilla blanfordi* Alcock, 1900
	Ilyoplax sayajiraoi Trivedi, Soni, Trivedi & Vachhrajani, 2015
Macrophthalmidae	*Macrophthalmus sulcatus* H. Milne Edwards, 1852
Matutidae	*Ashtoret lunaris* (Forskål, 1775)
Ocypodidae	*Austruca iranica* (Pretzmann, 1971)
	Austruca sindensis (Alcock, 1900)
Pilumnidae	*Eurycarcinus orientalis* A. Milne-Edwards, 1867
	Heteropanope glabra Stimpson, 1858
Portunidae	*Scylla serrata* (Forskål, 1775)
Sesarmidae	*Parasesarma persicum* Naderloo & Schubart, 2010

- ***Distribution pattern of brachyuran crabs*:**

For the distribution pattern of brachyuran crabs on study site, initially three-month survey (April-June, 2021) was carried out and in each month distribution of brachyuran crabs was observed for three consecutive low tide. In that survey, distribution of seven different species of burrowing brachyuran crabs *i.e*. *Austruca sindensis*, *A. iranica*, *Ilyoplax sayajiraoi*, *Dotilla blanfordi*, *Macrophthalmus sulcatus*, *Eurycarcinus orientalis* and *Scylla serrata* were observed. *A. sindensis*, *I. sayajiraoi*, *D. blanfordi* and *M. sulcatus* were commonly recorded throughout the duration of initial field survey. While *A. iranica*, *E. orientalis* and *S. serrata* were observed one or two times during initial phase of field survey (Fig. 4). Form the outcome of the initial field surveys, monthly analysis of brachyuran crab distribution on Kamboi coast was carried out. Burrow distribution data for the resident brachyuran crabs were collected form the study site. Data analysis for the monthly collected data will be completed before the submission of the thesis.

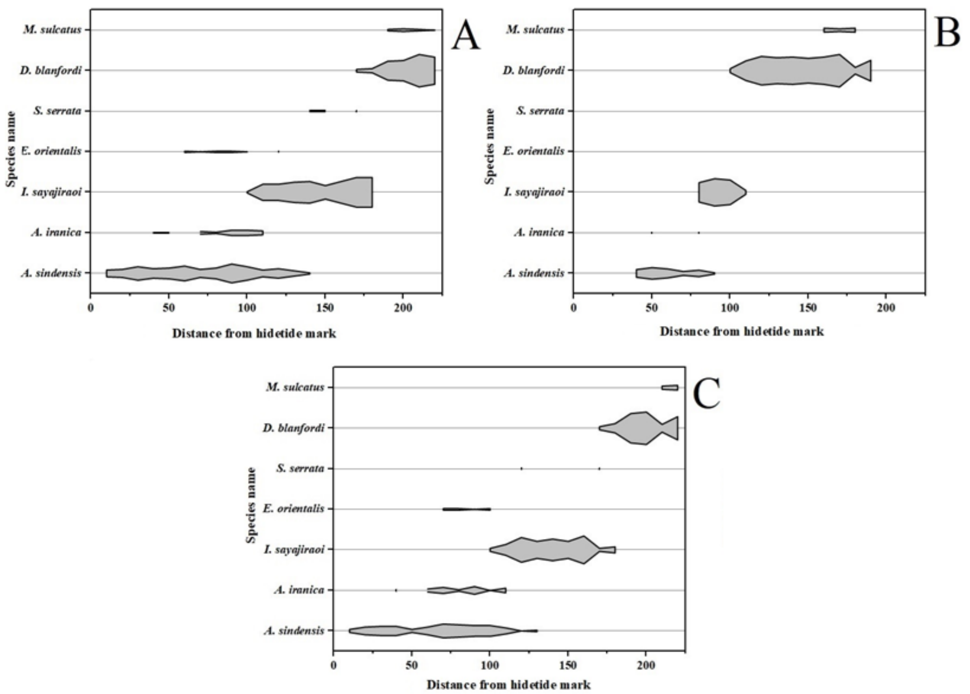

Figure 4: Representative kite diagram of brachyuran crab distribution with respect to the distance from the shoreline at Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India; A. April; B. May; C. June

- ***Burrow architecture of Austruca sindensis and Ilyoplax sayajiraoi*:**

In the present study, burrow architecture of above mention species was carried and for that a total of 94 burrow casts for *A. sindensis* and 59 burrow cast for *I. sayajiraoi* were obtained. Here, representative data for the burrow architecture of *A. sindensis* have been given in detail. Similar kind of work have been carried out for *I. sayajiraoi* also.

Burrow architecture of *A. sindensis*:

A total of 94 burrow casts were obtained, of which the 46 host crabs were captured (29 males and 17 females). A total of 7 different burrow shapes were recorded including J-shaped burrow (28), Single tube burrow (27), S-shaped burrow (21), Spiral burrow (10), J-shaped burrow with branch (5), U-shaped burrow with single opening (2) and Multiple branched burrow (1) and the relationship between various parameters was studied in three seasons (Fig. 5). During winter, summer and monsoon respectively, crab carapace length showed positive correlation with carapace width (R^2=0.90; 0.93; 0.92), burrow opening diameter (R^2=0.82; 0.96; 0.91), total burrow length (R^2=0.57; 0.74; 0.64), total burrow depth (R^2=0.56; 0.57; 0.57) and burrow volume (R^2=0.49; 0.63; 0.44). The crab carapace length did not show significant correlation with burrow inclination angle in all three seasons (R^2=0.06, 0.01, 0.01 respectively for winter, summer and monsoon) (Fig. 6, 7, 8).

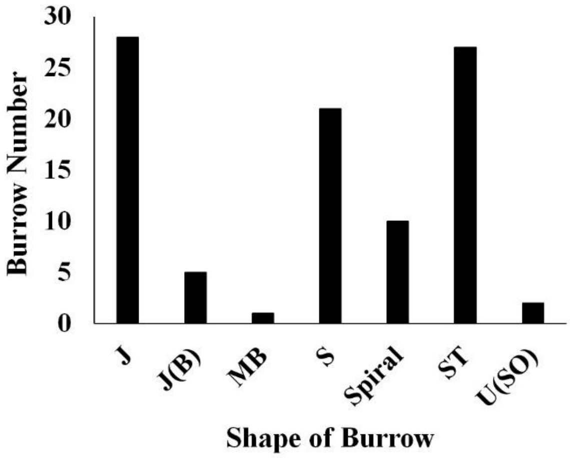

Figure 5: Indicates number of burrow count with respect to shape of the burrow at Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

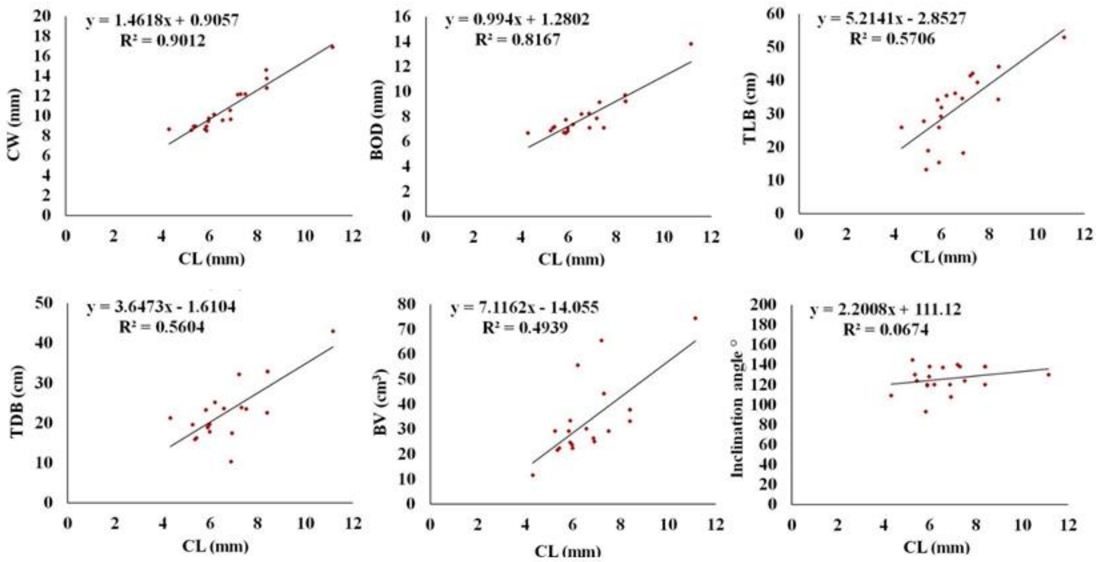

Figure 6: Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in winter season.

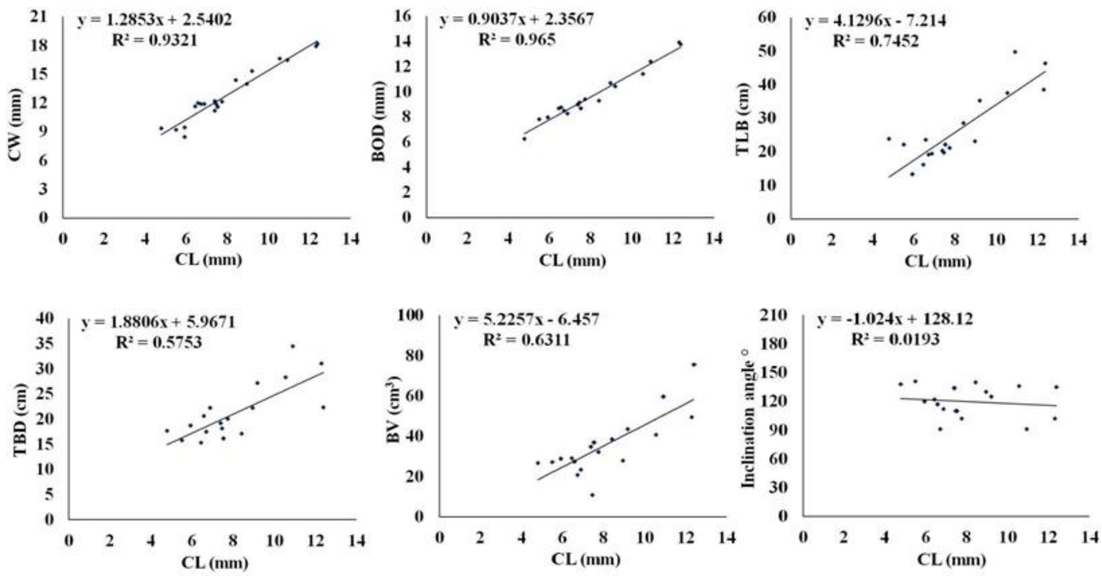

Figure 7: Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in summer season.

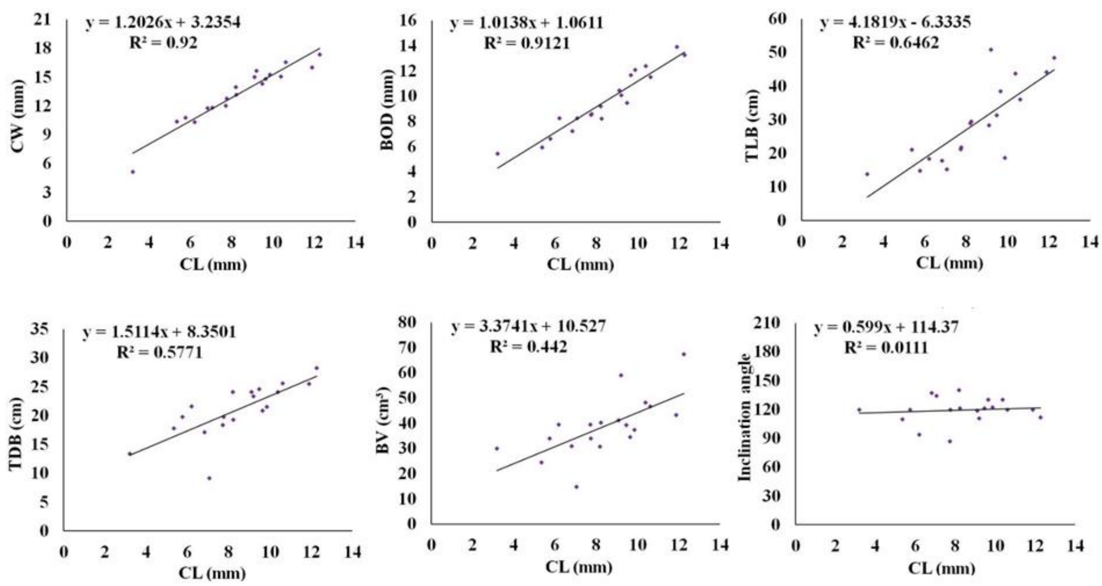

Figure 8: Regression analysis for the relationship between crab carapace length and different morphological measurements of burrows in monsoon season.

Depth wise variation in the burrow temperature for various burrow shapes was recorded in the present study. The results revealed similar pattern in temperature variation for all the burrow shapes. During winter, depth wise variation in the burrow temperature was studied in J-shaped, S-shaped, ST-shaped and Spiral burrow (Fig. 9).

While in summer and monsoon, depth wise variation in burrow temperature was studied in J-shaped, S-shaped and ST-shaped (Fig. 10, 11). In winter, the sand surface temperature recorded 26-30°C which remained similar for all the burrow types (Fig. 9). While during summer and monsoon, the surface temperature was recorded 38-44°C and 32-40°C respectively (Fig. 10, 11). The temperature declined to 2 to 2.5°C at a depth of 5 cm. After the depth of 5 cm the rate of temperature drop decreased to 1 to 1.5°C at every 5 cm. The temperature recorded at the deepest part of the burrow (up to 25 cm) was 22-27.5°C, which was cooler than the surface temperature in all the season.

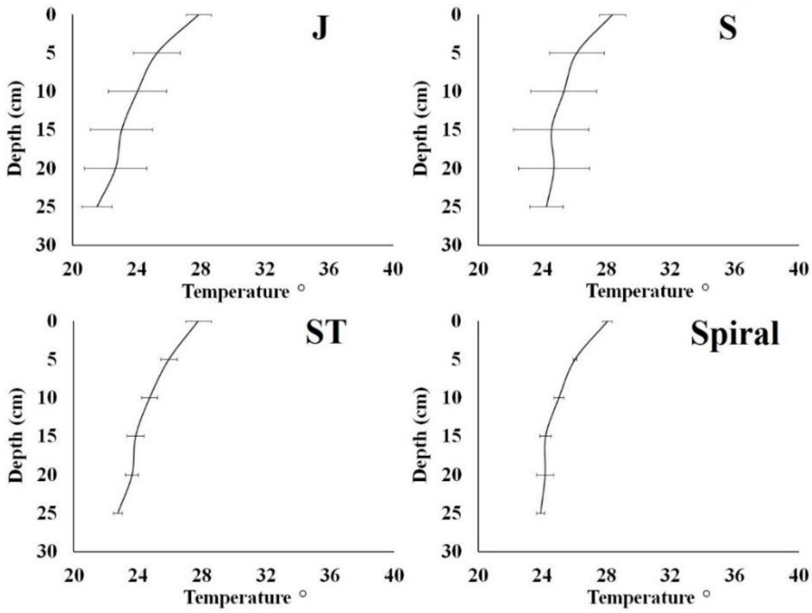

Figure 9: Vertical temperature profiles with the burrow depth for different shapes of the burrows during winter season.

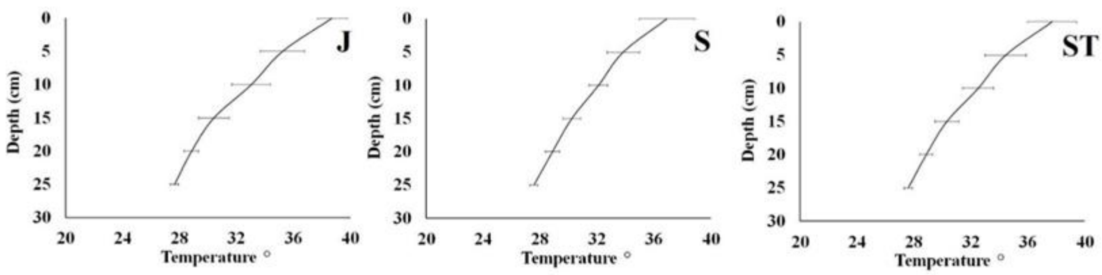

Figure 10: Vertical temperature profiles with the burrow depth for different shapes of the burrows during summer season.

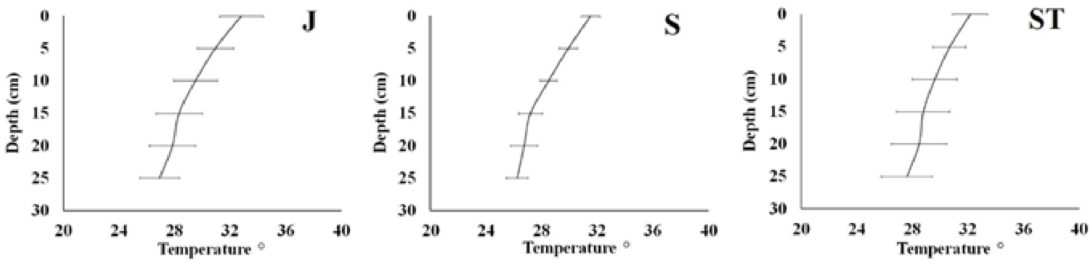

Figure 11: Vertical temperature profiles with the burrow depth for different shapes of the burrows during monsoon season.

- ***Time lapse study of burrowing activity of Austruca sindensis, Ilyoplax sayajiraoi and Dotilla blanfordi:***

In present study, effect of lunar phases on the burrowing activity was studied on above mention crab species. In present study, density of burrows varied significantly between lunar phases. In *A. sindensis*, highest mean burrow density was recorded during waning gibbous moon day and lowest mean burrow density was recorded on new moon day (Fig. 12). Maximum mean burrow density for *I. sayajiraoi* was recorded during waning crescent moon day while minimum mean burrow density for the same species was recorded on new moon day (Fig. 14). In *D. blanfordi*, maximum burrow density was recorded on full moon day and minimum mean burrow density was recorded on waning gibbous moon day (Fig. 16). Maximum mean burrow opening diameter was recorded on new moon day while minimum mean burrow opening diameter was recorded on waning gibbous moon day for *A. sindensis* (Fig.13). In *I. sayajiraoi*, maximum and minimum mean burrow opening diameter was recorded on waning gibbous and waning crescent moon day respectively (Fig.15). While in *D. blanfordi*, maximum mean burrow opening diameter was recorded on waning crescent moon day and minimum mean burrow opening diameter was recorded on full moon day (Fig.17).

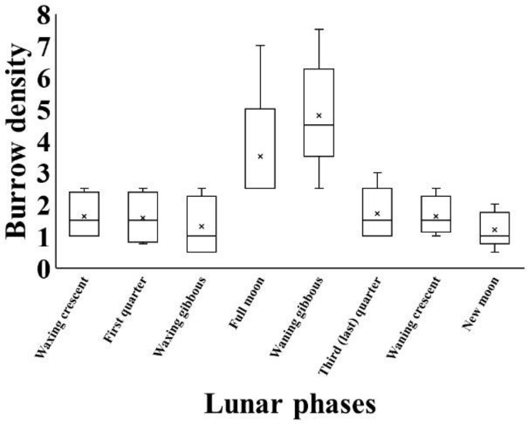

Figure 12: Average densities of *A. sindensis* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

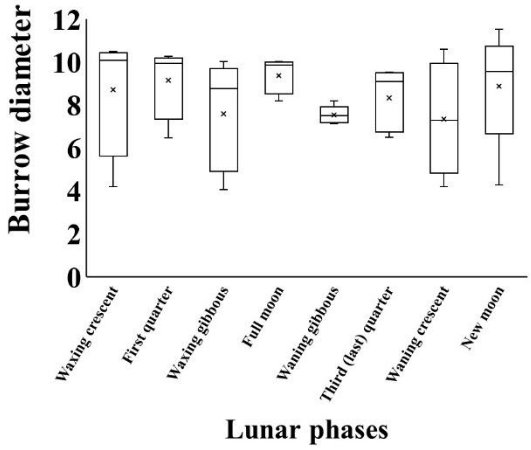

Figure 13: Average opening diameter of *A. sindensis* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

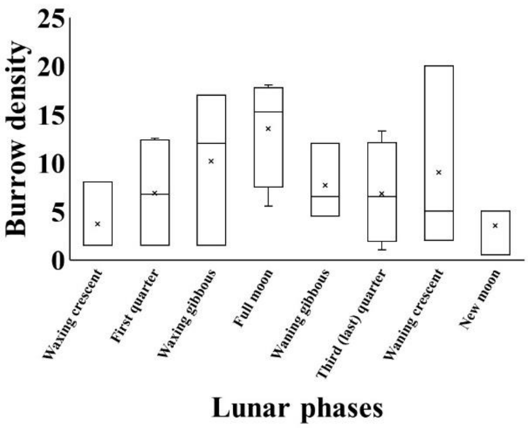

Figure 14: Average densities of *I. sayajiraoi* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

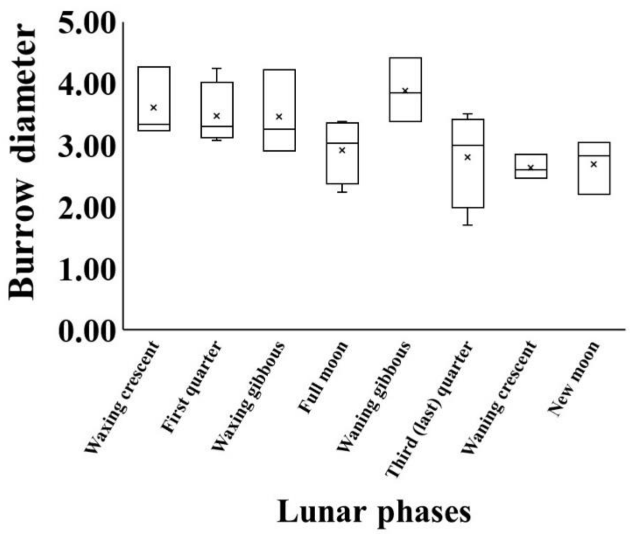

Figure 15: Average opening diameter of *I. sayajiraoi* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

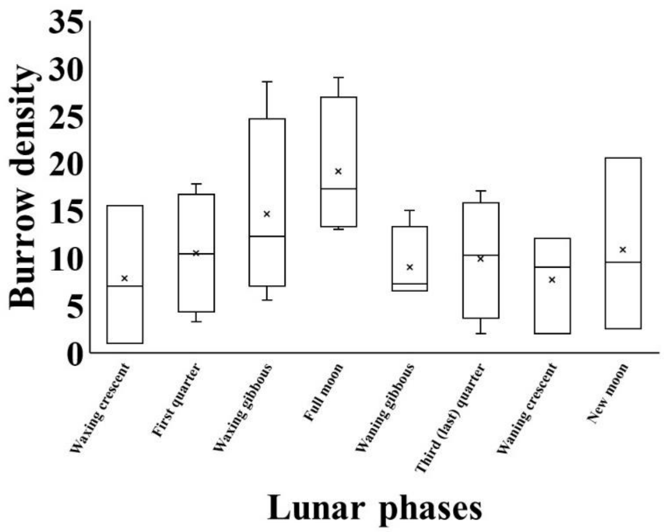

Figure 16: Average densities of *D. blanfordi* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

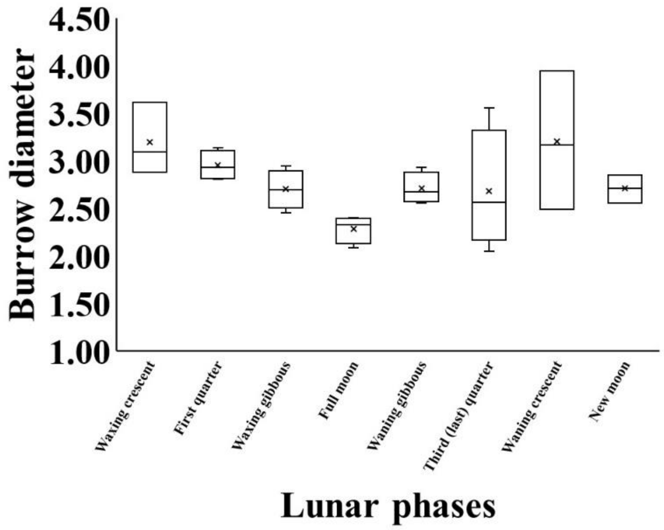

Figure 17: Average opening diameter of *D. blanfordi* burrows during the lunar cycle on Kamboi Coast - Gulf of Khambhat, Bharuch, Gujarat, India.

- ***Foraging range and pattern in Austruca sindensis, Ilyoplax sayajiraoi and Dotilla blanfordi*:**

The present study was carryout to mark total foraging area of above mentioned three species. In the present study, significant positive correlation was recorded between the total foraged area and opening diameter of *A. sindensis* (R^2=0.53), *I. sayajiraoi* (R^2=0.32) and *D. blanfordi* (R^2=0.34) (Figure 18, 19 and 20 respectively).

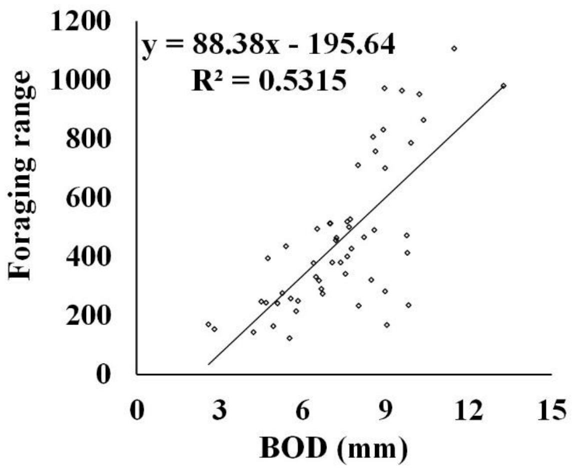

Figure 18: Regression analysis for the relationship between Burrow opening diameter and total foraging range of *A. sindensis*.

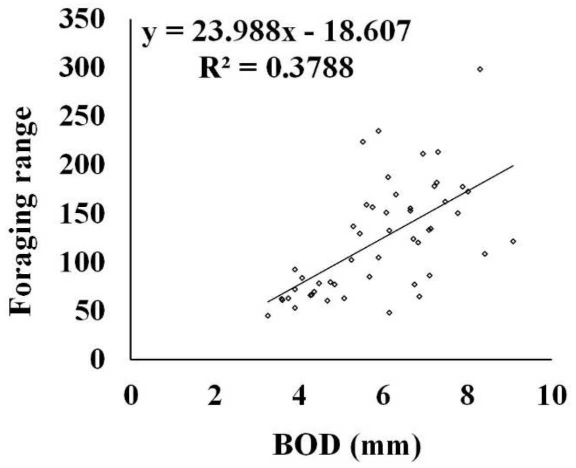

Figure 19: Regression analysis for the relationship between Burrow opening diameter and total foraging range of *I. sayajiraoi*.

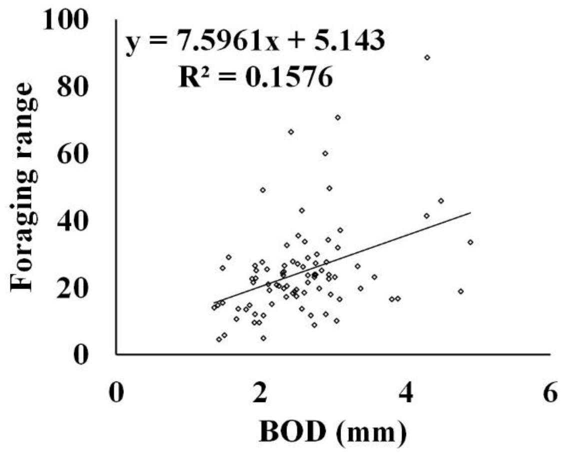

Figure 20: Regression analysis for the relationship between Burrow opening diameter and total foraging range of *D. blanfordi*.

- ***Bioturbation potential of Austruca sindensis and Ilyoplax sayajiraoi*:**

For the collection of data for the bioturbation potential for above mentioned species, a total of 50 quadrates were laid randomly during low tide. In the present study the correlation status was checked between opening diameter and dry weight of mudballs of individual burrow in *A. sindensis and I. sayajiraoi*. Strong positive correlation was recorded in both the species between the studied parameters (Fig. 21, 23). In both species, relationship status was checked between the total number of burrow and average dry weight of the burrow in individual quadrate area. Average dry weight of mudballs collected from the quadrates was negatively correlated to the total number of burrows present in that particular quadrate area (Fig. 22, 24).

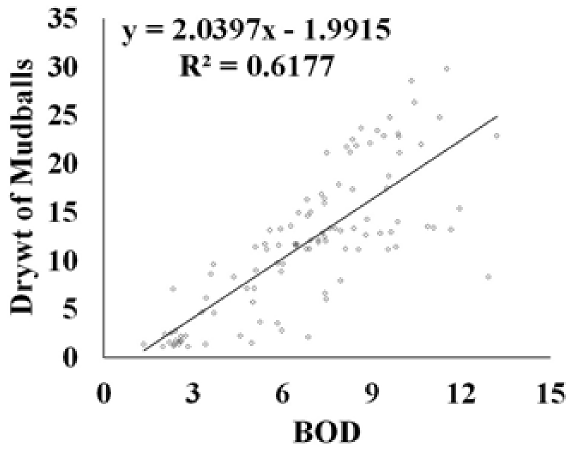

Figure 21: Regression analysis for the relationship between Burrow opening diameter and Dry weight of Mudballs of the individual burrow of *A. sindensis*.

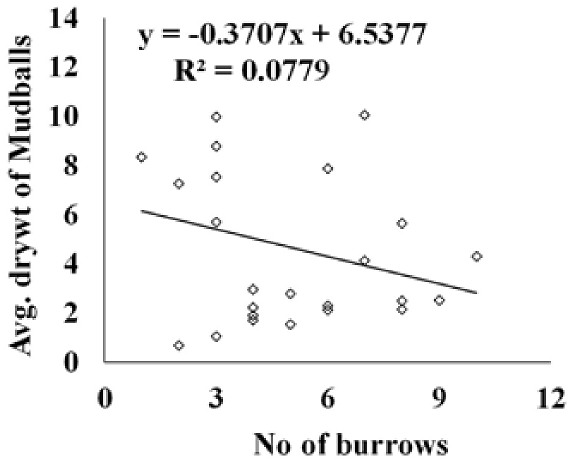

Figure 22: Regression analysis for the relationship between total number of burrows and average dry weight of Mudballs per quadrates area of *A. sindensis*.

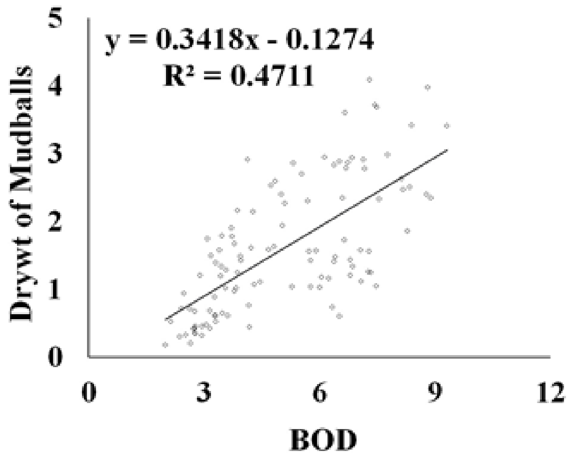

Figure 23: Regression analysis for the relationship between Burrow opening diameter and Dry weight of Mudballs of the individual burrow of *I. sayajiraoi*.

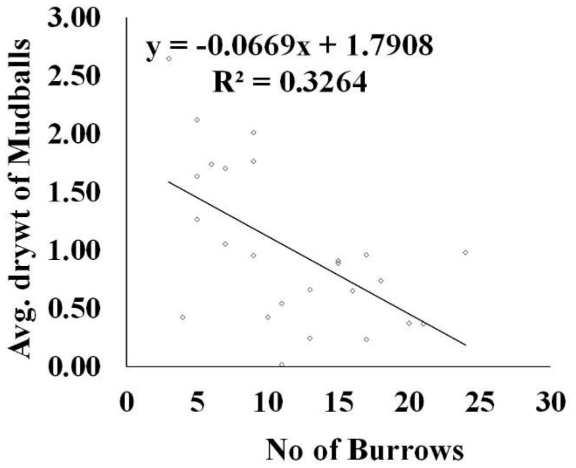

Figure 24: Regression analysis for the relationship between total number of burrows and average dry weight of Mudballs per quadrates area of *I. sayajiraoi*.

❖ **CONCLUSION:**

- A total of 10 different species of brachyuran crabs were reported from Kamboi which included seven burrowing species. Among these seven species, *Austruca sindensis*, *Ilyoplax sayajiraoi* and *Dotilla blanfordi* were highly abundant on the mudflats of Kamboi coast and these three were studies in detail.
- Analysis of burrow architecture showed that larger individuals excavate deeper and larger diameter burrows to minimize chances of desiccation.

- The analysis for crab's carapace width and burrow diameter implies that crab fit tightly in the respective chamber, which may prevent them from being displaced from larger crabs.
- The lunar cycles influence the activity of the *A. sindensis*, *I. sayajiraoi* and *D. blanfordi*, varying the density, diameter, and distribution of the burrows on Kamboi coast, Gulf of Khambhat due to changes in the tidal conditions.
- The occurrence of burrow construction and the distancing of larger animals from the sea were greater in the lunar phases that provided brighter nights. While, during dark nights, the density of burrows is reduced and larger organisms do not move much away from the sea.
- In foraging behavioral study, it was observed that as the diameter of burrow increases the total foraging range also increases. This might be because as the size of crab increase, their metabolic activities also increase and to fulfill that demand they require more food and due to that their foraging area also increases.
- The foraging range is also depended on the food availability in surrounding area. When food availability was lower, foraging range for the individual crab is wider. If, more organic matter is present in the sediment than foraging range will be smaller.
- Bioturbation by burrowing macrofauna has a major impact on the sediment. Their activities affect the environmental conditions within their burrows and the surrounding surface sediment.
- In the present study, results showed that as the opening diameter increase the bioturbation potential also increases which suggest that larger crabs required more food and bigger burrows as compared to smaller ones.
- From the present study, we can conclude that as the density of burrows increases in particular area, bioturbation potential decreases. This may be due to competition between crabs' increases for food and shelter in the available limited space.

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