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INTRODUCTION:

The Earth's oceans and seas, covering approximately 71% of the planet's surface with a coastline spanning 1.6 million km, host a diverse array of plant and animal species. The marine environment is home to around 1,78,000 species, classified into 34 phyla, emphasizing its rich biodiversity. The Indian Ocean, the third-largest ocean, constitutes approximately 29% of the total ocean area, and India boasts an 8000 km coastline, including islands. Coastal areas feature diverse habitats like estuaries, lagoons, mangroves, and coral reefs, with estuaries serving as unique ecosystems bridging marine and freshwater environments. Recognized for their contributions to ecosystem services, coastal and estuarine habitats support food provisioning and water filtration.

Estuaries, partially enclosed coastal bodies of water with varying salinity due to the mixing of sea and freshwater, exhibit unique characteristics derived from both terrestrial and marine influences. India hosts 14 major and 228 minor estuaries, contributing to a hinterland of approximately 2000 km2. Estuarine ecosystems are highly productive, featuring abundant autotrophs, high oxygen levels from tidal currents, and a complex food chain supporting rapid nutrient conversion and regeneration. Crustaceans, particularly Brachyura, are vital components of macrobenthic fauna, constituting a majority of the documented 2934 crustacean species, with adaptability and significant roles in ecosystems. Brachyuran crabs, with around 1439 genera and 7400 species worldwide, are integral to estuarine, marine, and mangrove ecosystems, contributing to biomass and community structure. Species diversity serves as a crucial metric for assessing community health and stability.

The marine ecosystem, renowned for its diversity, supports a wide array of floral and faunal communities across various habitats. The coastal environment, with its diverse ecosystems like estuaries, lagoons, mangroves, and more, plays a crucial role in sustaining high biodiversity. Among the marine fauna, crustaceans, particularly brachyuran crabs, are significant contributors to the macrobenthic fauna, showcasing adaptability and evolutionary diversity. The taxonomical study of brachyuran crabs in India has a rich history, with recent efforts contributing to records and new species documentation. In Gujarat State, researchers have studied the brachyuran fauna, revealing diverse species compositions. The Gulf of Khambhat, with its mangroves,

estuaries, and intertidal mudflats, exhibits rich ecosystem diversity. This study focuses on estimating the species diversity of intertidal brachyuran crabs in the Gulf of Khambhat, providing insights into their distribution, families, and genera across established zoogeographical provinces and sub-provinces.

The study on the distribution pattern of the brachyuran crabs explains the field of organismal ecology, focusing on the abundance and distribution of organisms within a specific geographic area over time. The study emphasizes the importance of understanding biogeography and distribution patterns to integrate responses to global environmental changes, considering both biotic and abiotic factors. To comprehensively understand ecological dynamics, factors such as water temperature, salinity, organic matter, and sediment texture are investigated. These elements play a crucial role in influencing primary and secondary productivity in coastal regions and shaping habitat characteristics. Niche partitioning of macrofaunal organisms, especially crabs, is attributed to sediment zonation in coastal environments, with sediment properties influencing the dispersal of macrobenthos. The vertical distribution patterns of intertidal organisms are highlighted for assessing biodiversity. Factors influencing the distribution of brachyurans, such as substrate characteristics, feeding preferences, life cycle, and mobility, are discussed. Burrowing crustaceans, particularly crabs, are identified as key contributors to modifications in sediment properties on estuarine mudflats. The study also touches upon the challenges of quantifying population densities of soft-sediment infauna due to inconspicuous burrowing behaviours. The impact of environmental factors, including temperature, light intensity, water availability, and nutrient levels, on the presence or absence of species is explored. Studies on sessile invertebrates in the intertidal zone and mobile animals, particularly crabs, reveal insights into their ability to mitigate unfavourable environmental conditions. The focus is on how certain crab species regulate body temperature and exhibit zonation patterns that are harder to observe. The investigation of crab burrow distribution patterns in different environments is outlined, emphasizing the influence of factors like water depth, plant communities, soil water content, light, salinity, food resources, tides, and sediment characteristics. The study underscores the need for population studies in specific areas to understand the complex relationships between invertebrates and environmental conditions. The study concludes by highlighting the observed shifts in species distribution in response to global warming

and their implications for marine ecosystems. The primary objective of the described study is to analyse and describe the geographical distribution patterns and habitat preferences of brachyuran species in the Gulf of Khambhat's intertidal mudflats. The research aims to enhance comprehension of species distribution, abundance, density, and niche partitioning among beach crabs, particularly focusing on the Kamboi Coast. The study utilizes quantitative transect and quadrate sampling methods to measure burrow density and abundance, with a specific focus on the influence of temperature variations.

The burrow architecture study provides an overview of the ecological significance of burrow structures created by various burrowing macro-organisms in marine sediments near the beach. The text emphasizes the stages of burrow development, from excavation to disrepair, and highlights the variability in burrow shape and purpose among different macro-faunal groups. Biologists have shown a persistent interest in studying burrow architecture due to its role as a morphological window into an organism's life. Understanding burrow characteristics enhances our knowledge of species' reproductive, behavioural, and physiological activities. The ecological importance of burrow architecture is particularly emphasized for maintaining a semi-terrestrial mode of habit. The study delves into the diverse functions of burrows, such as providing protection against environmental conditions, refuge during high tides, escape from predators, and facilitating reproductive activities. Burrows also play a crucial role in retaining water during low tide, serving as a habitat for invertebrates to fulfil their physiological needs. The impact of burrowing activities on sediment dynamics, nutrient cycling, and mangrove regeneration is discussed, highlighting the ecological significance of burrow construction by macrobenthic invertebrates. The study addresses the variation in burrow morphology within and between species, influenced by factors like sediment composition, substrate hardness, vegetation type, and tidal variation. The role of environmental conditions, including temperature fluctuations, is explored in affecting the feeding, physiology, growth, and reproduction of resident fauna. The study employs various methods, such as resin casting and archaeological techniques, to identify morphological patterns and environmental influences on burrow architecture. Crabs, recognized as ecological engineers, are acknowledged for their role in regulating estuarine communities and influencing material cycles in mangroves and salt marshes. Specifically, the study focuses on the burrow architecture of the fiddler crab *Austruca sindensis* and the recently

discovered species *Ilyoplax sayajiraoi* in the Gulf of Khambhat coastal region. The research aims to enhance understanding of the structural characteristics of these crab burrows and their ecological functions in the specified ecosystem.

The significance of biological rhythms in various species and their implications for effective management and conservation efforts. The lunar synodic cycle, spanning approximately 29.53 days, is introduced as a key factor influencing tidal amplitudes and, consequently, the behaviour of intertidal animals such as terrestrial crabs. The interplay between lunar cycles and tidal patterns is emphasized, noting the alignment and deviation between the moon, sun, and earth during the lunar synodic cycle, which affects tidal amplitudes. The text explains the behavioural patterns of terrestrial crabs, such as feeding during low tide and retreating to burrows during high tide, underlining the crucial role of tidal cycles in shaping their activities. Environmental factors, including the lunar cycle, are identified as influencing the ecological activities of brachyuran crabs, particularly in terms of variations in tidal range and nocturnal illumination. The Ocypodidae and Dotillidae families, belonging to macro-benthic fauna in tropical and subtropical regions, are highlighted for their reliance on burrows as sanctuaries for protection and various life processes. The study by Lucrezi and Schlacher (2014) is referenced to underscore the consistent pattern of alternating activities observed in burrowing crabs between the surface of the beach and their underground microhabitat. The diurnal activity patterns of burrowing crabs are explored, with heightened activity during daylight hours, influenced by environmental variables such as temperature, tides, wind intensity, and wave levels. Overall, the text provides insights into the intricate interactions between biological rhythms, lunar cycles, and environmental factors that shape the behaviours of diverse crab species in intertidal ecosystems.

A comprehensive exploration of the ecological significance of bioturbation, particularly the impact of Grapsid and Ocypodid crabs, known as ecosystem engineers, on sediment dynamics and ecosystem functioning was carried out. These crabs play a vital role in forming habitats for diverse organisms, including microbial communities and macrobenthic populations. The study investigates the various biogenic structures constructed by different organisms and emphasizes the role of crabs in building mud and sand formations such as hoods, pillars, pyramids, mounds, chimneys, and mudballs. The feeding and burrow maintenance behaviours of crabs are intricately linked to sediment

dynamics, influencing microbial, faunal, and plant communities. The rates of these activities are influenced by abiotic conditions, including sediment grain size, cohesiveness, vegetation cover, and sewage influent. The text underscores the importance of understanding these factors in shaping individual crab species' behaviour and their interactions within ecosystems. The role of crabs in nutrient recycling through burrowing, bioturbation, and mudball construction. Fiddler crabs and ghost shrimp are recognized as significant bioturbators with crucial roles in nutrient recycling, organic matter breakdown, and primary productivity. Specific species within the Ocypodidae family, like ghost crabs, exhibit unique behaviours such as constructing sand pyramids or diverse structures using mud. The study focuses on the ecological importance of crab activities, including their influence on sediment reworking, nutrient cycling, and organic matter decomposition. It acknowledges the scarcity of research on mudball construction in India, emphasizing the need for further investigations into potential variations between genders and species. The historical lack of attention to the habits and behaviours of shore crabs in the Indian subcontinent is addressed, emphasizing the importance of the present study in enhancing comprehension of the behavioural characteristics exhibited by mud crabs and their ecological significance in the Indian coastal environment.

MATERIAL AND METHODOLOGY:

This research focuses on the mudflats of Kamboi (22° 12' 59.1444'' N, 72° 36' 54.7992'' E) in the upper reaches of the Gulf of Khambhat. Kamboi, strategically located at the estuary mouth, features extensive tidal mudflats with distinct zones characterized by vegetation, composition, and geomorphology influenced by marine forces. For Habitat Characterization, the study involves visual evaluation and PVC pipe coring to collect sediment samples from different zones. Sediment grain size analysis is conducted through wet sieving. The sedimentological and water quality characteristics are shaped by the hydrodynamics of the Gulf of Khambhat and the geomorphology of the Mahi estuary. For the diversity of brachyuran Crabs, field surveys from January 2021 to October 2022 using hand-picking method are employed to collect brachyuran crab species. Morphological identification, morphometric measurements, and classification are performed, referencing illustrative keys, research papers, and monographs. The World Register of Marine Species and Marine Species Identification Portal Website are consulted for species

confirmation. The distribution of six brachyuran crab species is assessed through field surveys, with seasonal variations analysed. Density, abundance, and frequency of burrows are calculated for ecological assessment. Data is categorized into winter, summer, and monsoon based on climatic conditions. Burrow architecture variation is studied for *Austruca sindensis* and *Ilyoplax sayajiraoi* across seasons. Burrows are cast, measured, and analysed for parameters such as Inclination Angle, Total Depth, Length, and Volume. Regression analysis establishes relationships between crab carapace lengths and burrow morphological parameters. Principal Component Analysis is conducted for *A. sindensis*. The burrowing activity of three crab species is studied during different lunar phases. Sampling during specific tide events is conducted, and burrow density and diameter are measured. Physical parameters like temperature and moisture content are concurrently recorded. Foraging range and pattern of *A. sindensis* and *I. sayajiraoi* are investigated using photographs of selected burrows. Mudball characteristics, including number, size, and weight, are measured. Regression analysis examines the relationship between crab carapace length and foraging parameters. Preliminary survey explores the bioturbation potential of *A. sindensis* and *I. sayajiraoi*. Burrow count, opening diameter, and mudball characteristics are recorded. Regression analysis assesses the relationship between mudball weight and burrow diameter for each species.

RESULTS:

The study conducted in the mudflats of Kamboi, Gulf of Khambhat, Gujarat, India, revealed a rich diversity of brachyuran crabs, with a total of 10 species representing 7 families and 9 genera identified in the study area. Families Ocypodidae, Dotillidae, and Pilumnidae contributed two species each, while Matutidae, Sesarmidae, Macrophthalmidae, and Portunidae each contributed one species. The identified species include *Dotilla blanfordi*, *Ilyoplax sayajiraoi*, *Macrophthalmus sulcatus*, *Ashtoret lunaris, Austruca iranica*, *Austruca sindensis*, *Eurycarcinus orientalis*, *Heteropanope glabra*, Scylla serrata, and *Parasesarma persicum*. The habitat characterization of the Coast of Kamboi revealed distinct zonation patterns influenced by sedimentological characteristics, microhabitat variations, and hydrodynamic processes. Four identified zones displayed unique features from the upper to the lower intertidal line. Zone I, subjected to periodic flooding, exhibited loose silty/clayey sand eroded by wind. Zone II, with a predominantly muddy composition, showed high biodiversity and population density. Zone III displayed

a noticeable beach slope with a muddy and sandy habitat mosaic, while Zone IV, the lowest intertidal zone, was primarily composed of fine sand with intermittent hard substratum and intertidal pools. The study provides valuable insights into the ecological characteristics and diversity of brachyuran crabs in the Kamboi mudflats, contributing to the understanding of the complex interplay between sediment dynamics, hydrodynamics, and microhabitat variations in estuarine ecosystems.

Distribution of Sediment Temperature:

Sediment temperature in the upper intertidal zone (Zone I) exhibited significant seasonal variations, with the highest recorded during summer (40.48±1.66°C), followed by monsoon (36.09±1.25°C) and the lowest in winter (31.28±1.21°C). Similarly, sediment temperature in the middle intertidal region (Zone II and III) and lower intertidal region (Zone IV) also displayed distinct seasonal patterns.

Burrow Density, Abundance, and Frequency:

Burrow density, abundance, and frequency were assessed for six brachyuran crab species. *Austruca sindensis*, *Ilyoplax sayajiraoi*, and Dotilla blanfordi were abundantly distributed, with varying densities across seasons. *A. sindensis* exhibited maximum density and abundance in winter, *I. sayajiraoi* in the monsoon, and D. blanfordi in summer. No significant seasonal variations were observed for Macrophthalmus sulcatus, Eurycarcinus orientalis, and Scylla serrata.

Burrow Occurrence Variation:

Frequency of burrow occurrence varied across seasons. *A. sindensis* showed higher frequency in summer, *I. sayajiraoi* in winter, and D. blanfordi in winter. The overall burrow distribution study revealed distinct preferences and patterns for each brachyuran crab species across different zones.

Seasonal Fluctuations in Burrow Distribution:

The study demonstrated seasonal fluctuations in the distribution of *A. sindensis*, *I. sayajiraoi*, and D. blanfordi. *A. sindensis* had a distribution range of 0-100m during monsoon and summer, reducing to 75m in winter. *I. sayajiraoi* ranged from 60-170m in

monsoon, 60-125m in winter, and D. blanfordi showed a range of 160-200m in monsoon and 125-190m in winter. These findings provide insights into the dynamic ecological preferences and behaviours of these crab species in response to seasonal changes in the intertidal zones of Kamboi.

Overall, the results contribute valuable information to the understanding of the ecological dynamics and adaptive behaviours of burrowing brachyuran crabs in estuarine ecosystems.

Burrow Architecture:

In this comprehensive exploration titled "Exploring the Intricacies of Burrow Architecture in *Austruca sindensis*: A Comprehensive Morphometric Analysis," our study undertook an exhaustive examination of the burrow architecture of *Austruca sindensis*, a captivating intertidal crab species. Our investigation was grounded in the meticulous collection of 94 burrow casts from two distinct intertidal zones, Zone I and Zone II, strategically chosen to represent the diverse burrow structures within the population. The foundation of our research comprised 46 host crabs, including 29 males and 17 females, each subjected to precise measurements of carapace length and width. The methodology unfolded in several key steps, starting with the detailed collection of burrow casts to ensure a representative sample. Subsequently, the demographic details of host crabs were recorded, followed by the identification and classification of seven distinct burrow shapes, ranging from classic J-shaped formations to multi-branched structures. Rigorous morphometric analyses were then conducted on each burrow type, measuring parameters such as opening diameter, volume, inclination angle, length, and depth with precision. Our findings were multifaceted, revealing sexual dimorphism in burrow characteristics, with notable differences in opening diameter, length, and volume between male and female crabs. The study also uncovered intriguing seasonal variations in burrow architecture during winter, summer, and monsoon seasons, providing insights into the seasonal adaptability of *Austruca sindensis*. Temperature profiles within various burrow shapes were analysed, highlighting consistent patterns across different seasons and contributing ecological understanding to the observed structures. Utilizing Principal Component Analysis (PCA), our research discerned variations in burrow morphology between the two intertidal zones, providing a comprehensive overview of factors

contributing to observed differences. Furthermore, we extended our study to explore the burrow architecture of *Ilyoplax sayajiraoi* during pre-monsoon and post-monsoon periods. Comparative analyses were conducted, encompassing burrow shapes, morphometry, and temperature profiles. In conclusion, our research significantly advances the understanding of the intricate burrow architecture of *Austruca sindensis* and *Ilyoplax sayajiraoi*. The detailed analyses offer valuable insights into the ecological adaptations of these crabs in diverse intertidal environments. This study serves as a foundational contribution to marine ecology and crustacean behaviour, paving the way for further investigations into the intricacies of burrow structures in intertidal crab species.

The Effect of Lunar Cycle:

The study on effect of lunar cycle on burrowing brachyuran crabs, investigates the influence of lunar cycles on the nocturnal luminosity, temperature variations, and burrowing behaviour of three common crab species—*Austruca sindensis*, *Ilyoplax sayajiraoi*, and Dotilla blanfordi. Nocturnal luminosity exhibits distinct patterns across lunar phases, with the highest values during full moon (93-100%), intermediate values during waning gibbous to third quarter moon (36-71%), and a near absence of light during new moon (0-5%). Significant temperature differences were observed throughout lunar cycles (ANOVA test: $p < 0.005$). The study focused on the density and diameter of burrow openings, revealing species-specific variations. *A. sindensis* displayed the highest burrow density on full moon days, contrasting with *I. sayajiraoi* and D. blanfordi, which exhibited peak densities on waxing gibbous and full moon days, respectively. Mean burrow diameters varied with lunar phases, and while *A. sindensis* and D. blanfordi showed little diameter variation on full moon days, *I. sayajiraoi* burrows displayed less variance on waxing gibbous days. Hourly variation in burrow density highlighted distinct burrowing patterns. *A. sindensis* actively burrowed over a 6-hour period, with the highest density on full moon days and the lowest on new moon days at specific hours. *I. sayajiraoi* burrowed for up to 4.5 hours, with maximum density on full moon and waxing gibbous days. D. blanfordi engaged in burrowing for around three hours, with the highest density on full moon days. Overall, the findings underscore the intricate relationship between lunar cycles and the ecological behaviour of these crab species, shedding light on how environmental factors, such as light conditions and tidal phases, influence their

burrowing activities. This research contributes valuable insights into the broader understanding of lunar-mediated ecological dynamics in coastal ecosystems.

Foraging and Bioturbation:

A study on the foraging behaviour and bioturbation activities of two crab species, *Austruca sindensis* and *Ilyoplax sayajiraoi*, shedding light on their intricate ecological dynamics. For *A. sindensis*, a thorough examination of 200 burrows revealed positive correlations between carapace length (CL) and various mud balling metrics, including burrow opening diameter (BOD), total foraging area (TFA), total number of mudballs (TNM), total weight of mudballs (TWM), average mudball size (AMS), and average distance between mudballs (ADM). Males exhibited a more dispersed mud balling pattern, whereas females displayed a denser arrangement. In the case of *A. sindensis*, the foraging rate showed no significant difference between males and females, with both genders creating mudballs from surrounding sand and depositing them around their burrows. Female individuals constructed more mudballs, albeit smaller in size, than males. Male and female burrows exhibited variations in the number, diameter, and weight of mudballs, indicating gender-specific foraging strategies. For *I. sayajiraoi*, a difference in foraging rate was observed between male and female individuals, with females exhibiting a greater foraging area. The study detailed the CL, foraging areas, and mudball-related metrics for both genders. Females of *I. sayajiraoi* displayed a diverse foraging range compared to males.

Bioturbation analysis, involving the correlation between opening diameter and dry weight of mudballs, revealed a strong positive relationship in both *A. sindensis* and *I. sayajiraoi*. The study assessed the daily bioturbation rate per square meter for each species, with *A. sindensis* exhibiting a higher turnover rate (126g/m^2/day) compared to *I. sayajiraoi* (45g/m^2/day). Bioturbation, assessed through burrow excavation, emerges as a crucial aspect of these crab species' ecological contributions to their habitat. The findings underscore the nuanced foraging strategies and ecological roles of *A. sindensis* and *I. sayajiraoi*, contributing valuable insights into the complex interactions within coastal ecosystems.