STUDIES ON HERMIT CRABS ALONG THE GOAN COAST AND THEIR SHELL SELECTION BEHAVIOR

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"Studies on Hermit crabs along the Goan coast and their shell exchange behavior"** is based on the results of investigations carried out by me in the Zoology Discipline at the School of Biological Sciences and Biotechnology, Goa University under the supervision of Dr. Preeti Pereira and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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<u>**COMPLETION CERTIFICATE**</u>

This is to certify that the dissertation report **"Studies on Hermit crabs along the Goan coast and their shell exchange behavior"** is a bonafide work carried out by **Ms. Anjelica Maria Dmello** under my supervision in partial fulfilment of the requirements for the award of the degree of **Master's of Science in Zoology** Discipline at School of Biological Sciences and Biotechnology, Goa University.

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PREFACE

Hermit crabs are anomuran decapod crustaceans belonging to the superfamily Paguroidea. These unique creatures have adapted to occupy empty scavenged mollusc shells to protect their fragile exoskeleton. Ecologically, hermit crabs play a crucial role as scavenging omnivores that contribute to the decomposition of organic matter in marine intertidal environments. They are attracted to decaying as a food source, which has significant implications for nutrient cycling in tide pool ecosystems.

In the present study, the hermit crabs were selected as a study organism because, despite their widespread presence, there hasn't been any research done specifically in the state of Goa. The topic was chosen to understand their general morphology and shell exchange behavior.

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ABSTRACT

The present study reports the presence of six species of hermit crabs distributed among two genera and a family Diogenidea, from the intertidal area along the Goan coast. All the recorded species were found inhabiting rocky and sandy habitats. The species *Diogenes avarus* and *Diogenes custos* were often observed in shallow sublittoral areas along sandy shores. This study also deals with the shell exchange behavior in the hermit crabs *Clibanarius infraspinatus* and *Diogenes avarus* in captive conditions. It was seen that hermit crabs choose shells with less weight and larger aperture size. The two hermit crab species- *Clibanarius infraspinatus* and *Diogenes avarus* were able to successfully occupy the shell in the captive environment.

Keywords: Anomura, Diogenidea, Rocky shores, Sandy shores, Shell switching, intertidal.

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1. INTRODUCTION

1.1 Background

As one of the largest and most varied groups of invertebrates on the planet, crustaceans are among the oldest arthropods. They are found in both terrestrial and aquatic habitats; however, marine habitats are where they are most diverse (Roy & Nandi, 2008). India's coastline stretches to 7516,06 km (Kumar et al., 2006), and is home to approximately 4,258 species of crustaceans from 22 orders. (Roy, 2015). Decapod crustaceans play a crucial role in marine ecosystems due to their diverse ecological functions and interactions. These crustaceans, which include shrimps, crayfish, lobster, hermit crabs, and crabs are essential components of marine food webs, serving as herbivores, detritivores, carnivores, and omnivores. They are involved in complex symbiotic relationships with other species and are integral to maintaining ecosystem balance and biodiversity (Fourzan & Hendrickx, 2022).

The state of Goa with a coastline of 105 km is home to an astounding diversity of marine life (Usmani & Ansari, 2020). The present study is focused on the distribution of hermit crabs along the coast of Goa. Hermit crabs are important to marine biology for several reasons, for example, hermit crabs are ecosystem engineers, affecting the abundance and distribution of other invertebrates by using gastropod shells as protection (Pretterebner et al., 2012). Hermit crabs play a significant role in nutrient cycles and seed dispersal in coastal forests, contributing to the acceleration of the decomposition of organic substances in terrestrial ecosystems (Hsu et al., 2019). They also serve as active carrion scavengers in intertidal ecosystems, playing an essential role in the removal of dead organisms and maintaining the balance of the ecosystem (Laidre & Greggor 2015). Also, hermit crabs are resilient to anoxia and hypoxia events, making them suitable for understanding post-disturbance community recovery in “dead zones” such as the Northern Adriatic Sea (Pretterebner et al., 2012). Hermit crabs are important model species for studying behavioral ecology, particularly in the context of risk and reward assessment, information acquisition, decision-making, and shell fighting (Briffa et al., 2024). Their small size and amenability to manipulative experiments make them valuable for investigating various classes of behavior related to shell use.

The morphology of hermit crabs is characterized by their unique adaptations to using gastropod shells as their homes. They have a soft, coiled abdomen that fits tightly inside the borrowed shell, and the tip of the abdomen is adapted to clap strongly onto the columella of the snail shell (Anusha & Roopavathy, 2021). Most hermit crabs are nocturnal and have two pairs of walking legs. Hermit crabs can be divided into two groups: Aquatic and terrestrial hermit crabs. The aquatic hermit crabs have gills that are adapted to extract oxygen from water, while terrestrial hermit crabs have gills adapted to extract oxygen from air.

In terms of their anatomy, hermit crabs have a hard shield called the carapace, which covers the cephalothorax. They have two pairs of sensory organs called antennae, with the longer outer pair to touch and feel the surroundings and the inner pair used to taste and smell. The larger claw is primarily used for defence, while the smaller right claw is used in feeding and scooping water up to the mouthparts. The fourth pair of legs are stubby and used to move in and out of the shell, while the fifth pair are gill grooming appendages that end in pinschers for cleaning the gills and removing the debris from the shell. The abdomen of hermit crabs is the soft portion of the crab protected within the shell and contains the digestive and reproductive organs. Female hermit crabs have feathery-looking appendages located on the left side of the pleopods, which are used for carrying eggs. The appendages located at the tip of the abdomen are called uropods, which are used to secure the crab within its shell (Brian, 2021).

Taxonomically, Hermit crabs are categorized into five groups, land hermit crabs (Coenobitidae), left-handed hermit crabs (Diogenidae), Right-handed hermit crabs

(Paguridae), deep-water hermit crabs (Parapaguridae), and non-gastropod hermit crabs as (Pylochelidae). A total of 114 species of hermit crabs from 27 taxa and 6 families were found to be present along the India coast (Behera et al., 2021). The west coast of India has a higher diversity of hermit crabs (73 species) as compared to the east coast (65 species) (Behera et al., 2021). Hermit crabs are one of the most attractive, distinctive, and ecologically important group of animals extensively spread across the intertidal, subtidal, estuarine, mangrove, and coral reef areas of tropical countries and are typically sublittoral rather than littoral in sandy environments (Reese, 1969).

The shell selection behavior of hermit crabs is a fascinating aspect of their ecology and adaptation. Hermit crabs exhibit a unique behavior where they carefully choose and occupy gastropod shells to protect themselves from predators, competitors, and desiccation. This behavior is crucial as their soft abdomens lack protective cover, making the selection of an appropriate shell vital for their well-being. In environments where empty, undamaged gastropod shells are scarce, hermit crabs face challenges in finding suitable shells, which can influence shell selection. Factors such as size, weight, species of gastropod, and shell condition play a significant role in their decision-making process (Kakui, 2019).

1.2 Aim and Objectives

The purpose of the research is to study the hermit crabs along the Goan coast and their shell exchange behavior.

The present study was undertaken to achieve the following objectives:

- To study the Taxonomy of Hermit Crabs in the coastal areas of Goa.
- To understand how Hermit Crabs behave on sandy and rocky coastlines.
- To analyze the shell exchange behavior among different species of Hermit Crabs.

1.3 Scope of the work

Studying hermit crabs is broad and encompasses various aspects of their biology, ecology, and behavior. Taxonomy plays a crucial role in the study of hermit crabs by providing a systematic framework for classifying, identifying, and understanding the diversity of these crustaceans. Documenting new records of hermit crab species in different regions of Goa to expand the existing knowledge of hermit crab diversity and distribution. Hermit crabs are also used as model organisms for studying various biological processes, such as animal personality, behavioral ecology, and effect of pollution on behavior. Overall, the scope of work in studying hermit crabs is vast and includes various aspects of their biology, ecology, and behavior, making them a valuable subject of study for understanding the complex interactions between organisms and their environment.

2. LITERATURE REVIEW

The ecology of hermit crabs encompasses various of their behavior, habitat, and interactions within their environment. Hermit crabs are anomuran crustaceans that have adapted to occupying empty snail shells and other types of cavities. They play a critical role in terrestrial ecosystems, such as coastal forests, where they contribute to nutrient cycles and seed dispersal (Hazlett, 1981). Hermit crabs are known to be omnivorous detritivorous, feeding on a variety of organic matter and detritus. They are also important as seed dispersers and debris scavengers in coastal forests, accelerating the decomposition of organic substances (Hsu et al., 2019). In India the semi-terrestrial hermit crabs *Coenobita cavipes* and *Coenobita rugosus* are highly abundant in the supra-littoral zone, highlighting their adaptability to different ecological niches (David & Barnes, 1997). Understanding the behavioral ecology of hermit crabs, including their shell exchange behavior, mating success, and population consequences of shell utilization, provides insights into their social structure and reproductive strategies (Hazlett, 1981).

The shell exchange behavior of hermit crabs is a complex process that involves various behaviors such as they select based on several factors, including size, weight, species of gastropod and shell condition (Bulinski, 2007), also hermit crabs explore many gastropod shells by touching, rolling and probing them before choosing one of their home (Mesce, 1982). Hermit crabs rely on empty gastropod shells for protection, and they must continuously search for larger shells as they grow (Miele, 2021).

The shell-exchange behavior in the hermit crab-like tanaidacean *Macrolabrum* sp. (Pagurapseusisae: Pagurapseudinae) under captive conditions. The behavioral sequence of shell exchange in this species involves a shell-carrying tanaidacean grasping the edge of the aperture of an empty gastropod shell, inspecting the anterior portion of its body into the shell, and moving into the shell, posterior end (pleotelson) first (Kakui, 2019).

Hermit crabs may engage in shell fights to determine who gets a particular shell, and they may also use chemical cues to locate new shells, in some cases, hermit crabs may even cooperate to exchange shells, with larger hermit crabs helping smaller ones to find new shells. The shell exchange process is crucial for the survival and reproduction of hermit crabs. The social hierarchy among hermit crabs is influenced by the availability and quality of shells that possess better-fitting and higher-quality shells that have an advantage in the hierarchy, as they are better protected and more successful in resource competition in contrast, hermit crabs with inadequate or damaged shells which may be vulnerable to predation and environmental stress (Peres et al., 2018).

An annotated checklist of hermit crabs found in Indian waters has been prepared (Trivedi & Vachhrajani, 2017). With 81 species, the east coast of India has a greater diversity than the west coast (73 species). The coastal regions of Tamil Nadu state recorded the highest number of species (50 species), while Maharashtra recorded the lowest number of species (7 species). The diversity of hermit crabs in Odisha coast was investigated and a revised checklist of Indian coast hermit crabs was compiled (Behera et al., 2021). The annotated checklist showed that 114 species of hermit crabs from six groups and 27 taxa have been recorded along the Indian coast. The family Diogenidae has been reported frequently. Compared to the east coast, which has 65 species of hermit crabs, the West Coast has 73 species, which is a higher diversity, since diversity can be attributed to environmental factors including, habitat variation, water temperature, salinity levels, and food availability, which can influence the distribution and abundance.

The species *Calcinus morgani* and *Diogenes klaasi* have been reported from the Andaman and Nicobar Islands (Reshmi & Kumar, 2011). Frequent new reports of hermit crabs in recent years have contributed to the growing knowledge of hermit crab biodiversity in India, with a total of 114 species recorded in India (Paul & Thiruchitrambalam, 2022). Additionally, hermit crabs have been documented along the Maharashtra coast of India, further expanding the understanding of hermit crab distribution in the west coast of India (Nirmal et al., 2017). These additional records highlight the importance of ongoing research to document and understand the diversity, distribution, and behavior of hermit crabs in India.

The taxonomy of hermit crabs is still an evolving field, and DNA barcoding has been used to facilitate the identification and classification of hermit crabs (Landschoff & Gouws, 2018). A study on South African hermit crabs found that DNA barcoding can achieve nearly 100% success in identifying hermit crabs in an integrated taxonomic framework. However, morphological examinations are still necessary for accurate identification and classification

3. METHODOLOGY

3.1 Materials and Methods

In the present study, thirteen sampling locations comprising both sandy and rocky shores were selected along the Goan Coast from September 2023 to January 2024 (Table 3.1). Hermit crabs were collected by hand-picking from intertidal areas during low tide. The hermit crabs were stored in the refrigerator for 24 hours and later were removed from their shell and preserved in 70% ethanol. The specimens were observed under a stereomicroscope (WESWOX OPTIK SZN- 100). Shield length and width (SL, SW) were recorded using digital vernier calipers (WEN), photographs and video recordings were also done by an iPhone 14 plus. The species of hermit crabs were identified by using standard identification (Siddiqui et al., 2004, Thomas, 1989, Modayil, 2007). The scientific names of the hermit crabs as well as the gastropod shells were verified using the World Register of Marine Species (WoRMS, 2024) database for preparing the checklist of hermit crabs of Goa.

Table 3.1: Showing the GPS Coordinates of the selected sites.

Site	Location	GPS Coordinates		Tidal Exposure (m)
		Latitude	Longitude	
1	Vagator	15° 35' 36.9924" N	73° 44' 5.8128" E	0.41
2	Anjuna	15° 35' 4.0956" N	73° 44' 12.9912" E	0.11
3	Vainguinim	15° 27' 15.9768" N	73° 48' 51.5736" E	0.24
4	Odxel	15° 27' 13.284" N	73° 49' 48.9864" E	0.16
5	Siridao	15° 25' 46.146" N	73° 51' 56.1816" E	0.17
6	Hollant	15° 22' 11.6436" N	73° 51' 45.7056" E	0.55
7	Velsao	15° 21' 17.5356" N	73° 53' 1.1076" E	0.25
8	Arossim	15° 20' 5.8668" N	73° 53' 33.216" E	0.22
9	Betalbatim	15° 18' 26.9532" N	73° 54' 7.8948" E	0.58
10	Benaulim	15° 15' 25.6608" N	73° 55' 7.716" E	1.17
11	Palolem	15° 0' 41.3748" N	74° 1' 10.038" E	0.37
12	Talpona	14° 58' 57.0972" N	74° 2' 17.6208" E	0.37
13	Galgibaga	14° 57' 43.4376" N	74° 2' 41.3556" E	0.37

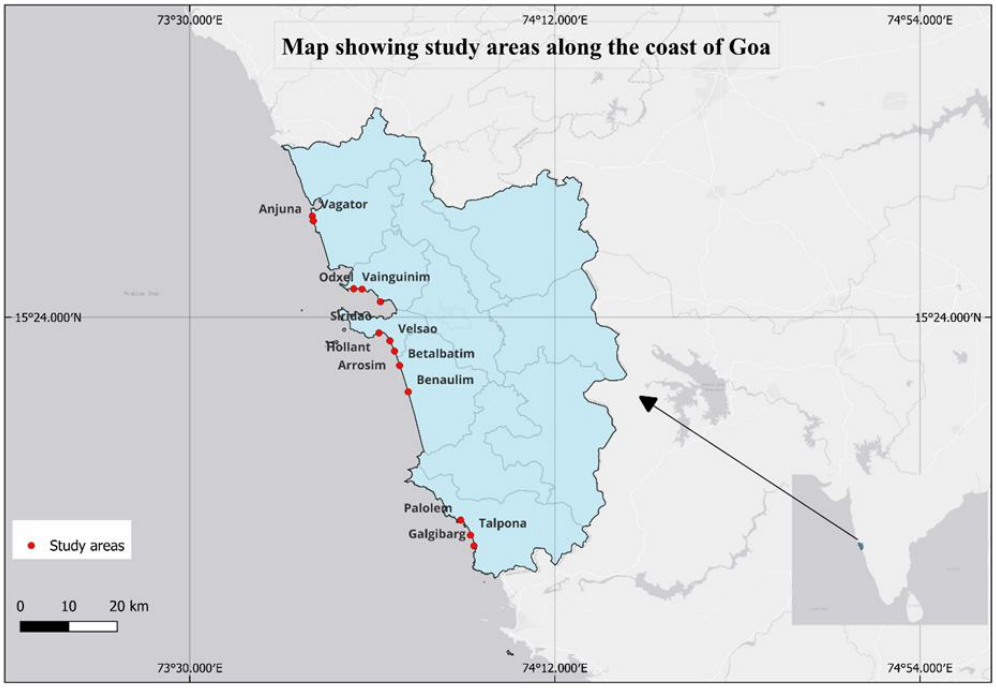

Figure 3.1: Map of Goa depicting study locations. Closed red circle denotes study sites as per table No- 3.1

3.2 Experimental Setup:

Two species of live hermit crabs (*Clibanarius infraspinatus* and *Diogenes avarus*) were placed in a container containing one litre of seawater and acclimatized for 24 hours (Plate 3.1). Two distinct species of gastropod shells- 4 of *Turritella duplicate* and 5 of *Babylonia spirata* with varying aperture diameters were utilized to study the shell selection behavior of hermit crabs (Plate 3.2). For every hermit crab, observations were made in 5-minute intervals. The observations were recorded as soon as a shell was occupied and described which of the two types of shells was occupied. The hermit crabs were successfully maintained by feeding algae and changing of water in the laboratory.

Figure 3.2.1 : Acclimatization Process

Figure 3.2.2: Shells selected

Figure 3.3.3: Shells exposed

4. ANALYSIS AND CONCLUSIONS

4.1 Results:

Taxonomic studies on anomuran crabs of the Goa coast revealed the presence of six species of Hermit crab belonging to one family and two genera. Hermit crab's behavior varied according to the kind of shore they lived on. Hermit crabs were more likely to be found in ankle-deep waters, according to the observations made on sandy shores. Hermit crabs were frequently observed on rocky coasts, emerging from tidal pools onto rock surfaces at low tide. *Diogenes* species were found to be more common than *Clibanarius* species on sandy shores. Additionally, it was observed that the majority of the hermit crabs were living in *Turritella duplicata* shells.

The shell selection behavior was conducted under laboratory conditions. Two distinct gastropod shells were selected ie. four specimens of *Turritella duplicata*, and five specimens of *Babylonia spirata*, which varied in terms of aperture and weight of the shell. As soon as the gastropod shells were introduced, the observation was noted down. The hermit crabs began exploring the shell and were increasingly active. It was soon noticed that the *Clibanarius infraspinatus* species of hermit crabs residing in *Turritella duplicata* weighing the weight of 23g and an aperture of 9.9mm exchanged to *Babylonia spirata* with 8.8g, and with an aperture of 21.9mm (Plate 4.1), it was quickly observed that the hermit crab chose a different shell of *Babylonia spirata* with 6.2g, and with an aperture of 17.9mm. The hermit crab instantly offered the first shell, which weighed 8.8g, it then switched the shell three more times, but eventually, the hermit crab retained a constant 8.8g *Babylonia spirata* shell. Similarly, *Clibanarius infraspinatus* species residing in *Turritella duplicata* weighing 36.5g and with an aperture of 17.9mm were exchanged to 23g of *Turritella duplicata* species, an aperture of 9.9mm. The *Diogenes avarus* species of hermit crabs were initially seen to occupy the *Turritella duplicata* shell weighing 17g and an aperture of 6.36 mm which changed to

Babylonia spirata with 10g and an aperture of 9.9mm (Figure 4.2). It was concluded that hermit crabs choose shells with less weight and larger aperture size. The two hermit crab species- *Clibanarius infraspinatus* and *Diogenes avarus* were able to successfully occupy the shell in the captive environment (Figure 4.1).

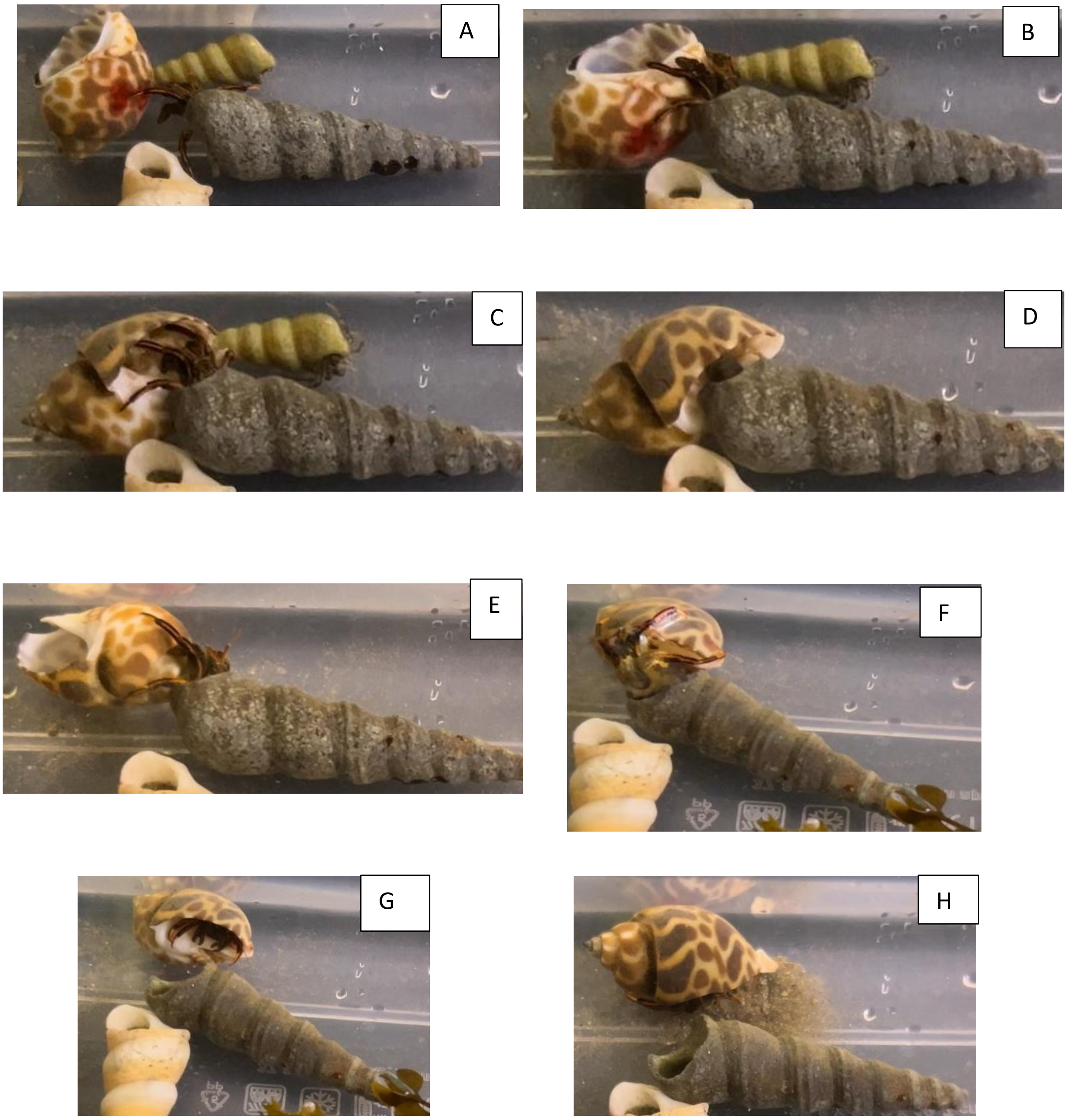

Figure 4.1: A behavioral sequence of shell exchange *in Clibanarius infraspinatus*. **(A)** Hermit crab moving towards a new shell. **(B)** New shell grasped by left cheliped. **(C-D)** Checking

inside of the new shell. **(E)** examining the external surface of the new shell. **(F)** Moving to the new shell. **(G)** entire body deeply retracted into the new shell. **(H)** Cleaning the sand from inside the shell.

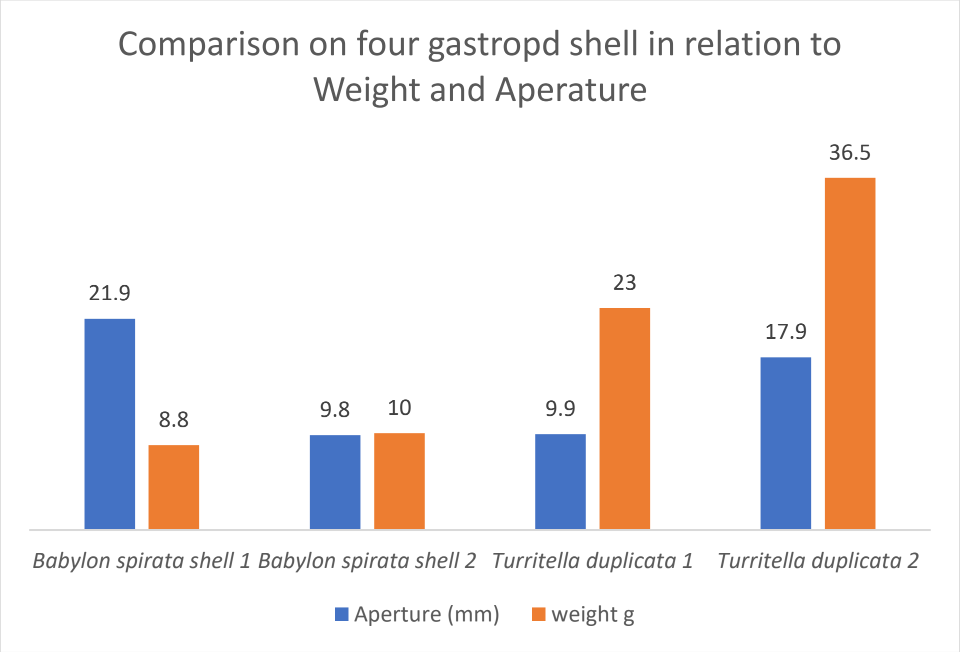

Figure 4.2: Comparison of gastropod shells in relation to weight and aperture

Figure 4.3: *Diogenes avarus* exchanged from *Turritella* to *Babylon*

Taxonomic Account

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Clibanarius* Dana, 1852

Clibanarius infraspinatus (Hilgendorf, 1869) (Figure 4.4)

Synonyms: *Pagurus (Clibanarius) infraspinatus* Hilgendorf, 1869: 97. *Clibanarius infraspinatus* Yap- Chiongco, 1938: 194, pl. 2, fig. 4;. Fize & Serene, 1955: 77, fig. 10. Tirmizi and Siddiqui, 1982: 26, Fig. 20.

Materials examined:

2 specimens, collected from the intertidal areas of Vainguinim (15˚27'15.976''N., 73˚48'51.5736''E.), and Odxel (15˚27'13.284''N., 73˚49'48.9864''E).

Description:

The carapace is longer than broad, with tufts of long, bristly hair. The rostrum is more prominent than anterior angles with two spines, and nearly reaching the base of the ophthalmic scale. Long eyestalks that are shorter than the antennal peduncle and carapace's anterior width. Distal four spinules on antennal scale and a longer antennal flagellum than carapace. The distal superior margin of merus is serrated. Carpus with three strong spines in a row on the upper inner margin and scattered few on rest on the upper surface. Propodus with tubercles on the upper and outer surface and well-developed spines on the inner edge, scattered, less acute spines. Tips of fingers spooned, corneous and black. Legs second and third are longer than the chelipeds. Dactyli and propodi have long tufts of bristles.

Color: Carapace color in live specimens is cream in the anterior region. Appendages with a ground color of dark ash on the second and third legs have orange-yellow longitudinal stripes surrounded by red or brown lines. Fingers spooned, tips black, abdomen dark on the dorsal side.

Distribution in India: Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, West Bengal.

Elsewhere: Red Sea, Indian Ocean, Thailand, Singapore, Philippine Islands, Vietnam, northern Australia, Taiwan, and Japan (Lemaitre 1999).

Remarks: *Clibanarius infraspinatus* is characterized by its orange-striped appearance. This distinct coloration sets it apart from other species within the same genus.

Figure 4.4: *Clibanarius infraspinatus*

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Clibanarius* Dana, 1852

Clibanarius longitarsus (De Haan,1849) (Figure 4.5)

Synonyms: *Clibanarius longitarsus* Dana 1852, p. 464; Fize and Serene 1955, pp, 83-90, fig. 11, A, B, C, pl. 3, 1, 7, 10, 13. *Clibanarius longitarsus* de Man 1902, p. 741; Sundara Raj 1927, p. 130; Sewell and Anandale 1928 p. 695; Reddi 1935, p. 562; Gravely 1941, p. 77; Lewinsohn 1969, 18-19.

Materials Examined:

5 specimens, collected from the intertidal areas of Vainguinim (15˚27'15.976''N., 73˚48'51.5736''E.), and Odxel (15˚27'13.284''N., 73˚49'48.9864''E).

Description:

The carapace is well developed, reaching the base of the ophthalmic scale. Eyestalks without color bands. Small ophthalmic scale with sharp points. The antennal acicles, which have serrated inner borders, extend somewhat beyond the final segment of the antennal peduncle. Propodus is shorter than the third leg dactylus. Ambulatory legs have a red border around a blue band.

Color: Bluish green body with a distinct red and blue band on ambulatory legs.

Distribution in India: Goa, Kerala, Tamil Nadu, Chilka Lake, Andhra Pradesh, Andaman and Nicobar Islands.

Elsewhere: Indian Ocean, northern Australia, Thailand, Indonesia, Taiwan and Japan.

Remarks: The color of *Clibanarius longitarsus* varies greatly, this species distinctive longitudinal blue stripe on the lateral aspect of its ambulatory legs remains constant, even after extended durations of alcohol storage (Rahayu, 2003).

Figure 4.5*: Clibanarius longitarsus*

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Clibanarius* Dana, 1852

Clibanarius Padavensis (De Haan,1888) (Figure 4.6)

Synonyms*: Clibanarius padavensis* de Man 1888, p. 242, pi. 16, fig 1. Alcock 1905b, pp. 44-46, pi. 4, fig. 2. Southwell 1906, p. 215. Sundara Raj 1927, p. 130. Panikkar and Aiyar 1937, p. 296.

Materials Examined:

One specimen was collected from an intertidal area of Galgibarg (14˚57'43.437''N., 74˚2'41.3556''E.).

Description:

Carapace longer than broad. Well-formed rostrum that extends beyond the level of the carapace's antennal angles and reaches the base of the ocular scales. Eyestalks are nearly as long as the antennal peduncle, and longer than the anterior carapace border. Antennal acicle with serrated borders that extend nearly to the antennal peduncle terminal joint. The flagellum is twice as long as the carapace. The distal and lower side of the merus has two spinules, with the lower inner edge being serrated. Carpus on the dorsal inner surface distally with a strong spine. Long setae and sparsely uniform.

Color: The color is yellowish with rows of straight red lines longitudinally on the second to fifth legs. Flagella are yellow, and the antennal peduncles have red bands. Carapace yellow. Chelipeds with fewer, irregular bands of the same color.

Distribution in India: Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil nadu, Chilka Lake, Andhra Pradesh, Orissa, West Bengal.

Elsewhere: Sri Lanka, and Mergui Archipelago.

Remarks: *C. padavensis* is a species found in marine, brackish, and freshwater environments. This species is also notable for its symbiotic relationship with sea anemones, which it uses for protection and as a source of food. In terms of its morphology, *C. padavensis* has a shield that is almost long and broad, and its ocular peduncles are stout and longer than those of other species in the genus (Trivedi, 2015).

Figure 4.6: *Clibanarius padavensis*

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Clibanarius* Dana, 1852

Clibanarius striolatus Dana, 1852 (Figure 4.7)

Materials Examined:

3 specimens, collected from the intertidal areas of Odxel (15˚27'13.284" N., 73˚49'48.9864" E.), Siridao (15˚25'46.146" N., 73˚51'56.1816" E.), and Talpona (14˚58'57.097"N., 74˚2'17.6208"E.).

Description: Short rostrum that does not extend to the base of the ophthalmic scale. The antennule is shorter than the eye length, antennal acicle just extends to the base of the antennal peduncle's last joint. Brown longitudinal stripes are absent for the eye. Legs with red stripes.

Color: Carapace crimson in fresh specimens with brown and white spots, with a brown blotch in the anterior median region. Chelipeds with dark tips and white spines. Legs with white dots scattered across reddish-brown crossbars. Legs have a dark color. The abdomen is white with reddish spots. Setae is also reddish brown with white tips.

Distribution in India: Goa, Lakshadweep Islands, Andhra Pradesh, Andaman and Nicobar Islands.

Elsewhere: Red Sea, Arabian Sea, Seychelles, South Africa, Sri Lanka, Mergui Archipelago.

Remarks: In *Clibanarius striolatus*, the legs have brown transverse bands whereas the other species in the genus *Clibanarius virescens* have dark green coloration on the chelipeds.

Figure 4.7: *Clibanarius striolatus*

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Diogenes* Dana, 1851

Diogenes custos (Fabricius, 1798) (Figure 4.8)

Synonyms: *Pagurus custos* Fabricius 1798: 412. Bosc 1802: 77. Cancer custos Herbst 1804: 27. *Diogenescustos* Dana 1851: 268. Stimpson 1858: 245. McLaughlin and Dworschak 2001: 142. SiddiquI and Kazmi 2003: 89. *Diogenes miles* Heller 1865: 83. *Diogenes affinis*: Henderson 1893: 415, pl. 39, figs 1-2. *Diogenes custos* var. affinis: Alcock 1905b: 66.

Materials Examined:

3 specimens, were collected from the intertidal areas of Odxel (15˚ 27' N., 73˚ 49' E.), Palolem (15˚ 0'41.374'' N., 74˚1'10.038'' E.), and Talpona (14˚ 58'57.097'' N., 74˚ 2'41.3556'' E).

Description: Eyestalks are shorter, only less than two-thirds anterior breadth of the carapace. Antennal and antennular peduncles of equal length. Antennal acicle with a well-defined fork reaching the middle of a penultimate segment of the antennal peduncle. The flagellum is slightly longer than the carapace. Dactyli are characterized by longitudinal grooves and ridges but fewer granules. Strong spines are grouped in a single row at the superior edge of the second and third segments. On the upper edge of the propodus, the granules are arranged in two rows, whereas on the sides, they are arranged in transverse rows.

Color: consistently yellow-brown. The same color is found on the seate, chelae, eyestalks, antennae, antennules, and the cephalic portion of the carapace. The ventral surface is lighter in color. Cream colored in the abdomen and other appendages.

Distribution in India: Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Chilka Lake, Orissa, West Bengal, Andaman and Nicobar Islands.

Elsewhere: Gulf of Mannar, Palk Bay, Mergui Archipelago.

Remarks: *Diogenes custos* is a species of hermit crab that was first described by Fabricius in 1798. It is a member of the genus Diogenes, which is characterized by the possession of an intercalary rostriform process surrounded by ocular acicles, and long and slender antennae. The length of the carapace is between 20 to 30 mm.

Figure 4.8*: Diogenes custos*

Order: Decapoda Latreille, 1802

Infraorder: Anomura MacLeay, 1838

Superfamily: Paguroidea Latreille, 1802

Family: Diogenidae Ortmann, 1892

Genus: *Diogenes* Dana, 1851

Diogenes avarus, Heller 1865 (Figure 4.9)

Materials Examined:

5 specimens, collected from the intertidal areas of Velsao (15˚ 21' 17.535" N., 73˚ 53' 1.1076" E.), Arrosim (15˚ 20' 5.866" N., 73˚ 53' 33.216" E.), Betalbatim (15˚ 18' 26.953" N., 73˚ 54' 7.8948" E.), Benaulim (15˚ 15' 25.660" N., 73˚ 55' 7.716" E.), and Palolem (15˚ 0'41.374"N., 74˚ 1'10.038"E).

Description:

Moderately elongated carapace with finely serrated anterolateral edges. Rostrum thin, not extending to the end of the ocular scales. Large ophthalmic scales with teeth on the border of the anterior side. Antennal flagellum is less setose and shorter than the carapace. Chelipeds uneven, left one much longer than the right. Carpus is longer than the merus and palm. Presence of teeth on the inner edge of the dactylus, carpus, and merus. Dactylus shorter than the palm's length.

Color: The overall body color is either grey or pale yellow with orange or yellow spots distributed around the legs and the carapace.

Distribution in India: Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Chilka Lake, West Bengal, and Andaman and Nicobar Islands.

Elsewhere: Red Sea, Gulf of Mannar, Palk Bay, Mergui Archipelego, Malay Peninsula, Philipines, and Australia.

Remarks: *Diogenes avarus* species was described by Heller in 1865. The distribution of *D. avarus* in India is primarily concentrated along the coastal areas of both the western and eastern regions. *D. avarus* is a small species of soft hermit crab, with a carapace that is typically less than 10 mm in length. This species is characterized by its distinctive shield and cephalic appendages, as well as its left chelipeds covered with small spines. The species is also known for its left first ambulatory leg, which has a spine on the outer surface.

Figure 4.9: *Diogenes avarus*

4.2 Discussion:

The present study reports the presence of six species of hermit crabs distributed among 2 genera and a family Diogenidae, along the Goan coast. Thirteen sampling sites with rocky and sandy shores were sampled to investigate the diversity of hermit crabs. The distribution of these six species within India and their wider geographic distribution was studied based on the literature. These species have a wide distribution, including the Red Sea, Indian Ocean, Thailand, Indonesia, Singapore, Vietnam, Philippine Islands, Taiwan, and Japan to Northern Australia (Reshmi 2014, Thomas 1989). Within India, they have been reported from Gujarat, Maharashtra, Goa, Karnataka, Kerala in the West coast; Tamil Nadu, Andhra Pradesh, West Bengal, and Andaman and Nicobar Islands in the East coast (Trivedi & Vachhrajani, 2017; Thomas, 1989). The species *Diogenes avarus* and *Diogenes Custos* were often observed in shallow sublittoral areas along sandy coasts. Their submergence may be attributed to reduce the risk of desiccation during low tide and, need for suitable gastropod shells to protect them from predators (Teoh et al., 2014; Komai et al., 2012). On examining the shell preference, it was observed that the hermit crabs prefer *Turritella* shells in the sandy habitat. The *Turritella* shells are often larger, spirally shaped, and have a thicker, stronger wall than the shells of other gastropods. These characteristics of *Turritella* shells make a good shelter for hermit crabs, by providing protection to the soft-bodied crabs and are more resistant to being dislodged by strong wave currents, providing hermit crabs with a more secure habitat during high tide; the large shell volume also allows the hermit crabs to grow comfortably and reduce the frequency of shell swapping (Brusca et al., 2015). In the sandy habitat hermit crabs occupy heavy shells to protect them from damage from waves action and attack from predators (Reese, 1969). In rocky areas, hermit crabs may prefer shells that have a more secure grip or attachment to the rocks, as this can provide additional protection from predators and wave action. In the present report, it was observed that a hermit in the *Turritella* shell was completely trapped in a rock crevice. The chance of the *Turritella* shell being too heavy or large for the hermit crabs, facing difficulties moving around, especially in rocky areas where mobility is crucial (Michael, 2023; McLeod, 2022). In captivity, hermit crabs have been observed to select shells that are similar in size and shape to their own body, as this can provide optimal protection and mobility. However, the specific shell preferences of hermit crabs can vary depending on the species and the availability of shells in their environment (Teoh et al., 2014). The distribution of hermit crabs and gastropod shells used varied in different locations probably due to the variety and availability of gastropod shells. The availability and variability of gastropod shells may be a determining factor that can influence the diversity and abundance of hermit crab communities (Teoh et al., 2014).

Hermit crabs were also observed using damaged, drilled shells of *Babylonia spirata* during sampling. The shell selection could be attributed to lack of availability of better shells; the damaged shells would be lighter in weight and holes in the shell would provide more aeration and prevent risk of desiccation. When hermit crabs are unable to find a suitable shell, they are forced to occupy a damaged shell as a temporary solution until a better shell becomes available. (Lancaster, n.d. and Gorman et al., 2018).

The hermit crab's habit of shell selection was mostly determined by the availability of shells in the surrounding area. In the present study, the hermit crab *Clibanarius infraspinatus* and *Diogenes avarus* preferred *babylonia spirata* over *Turritella duplicata*. Nirmal (2018) reported that internal shell volume is the most crucial element of consideration while choosing a shell; it was reported that *Clibanarius infraspinatus* and *C. padavensis* mostly preferred *Tibia curta*.

Clibanarius infraspinatus and *Diogenes avarus* preferred *Babylonia spirata* over *Turritella duplicata* shells due to their specific shape and characteristics that better suit the needs of the hermit crabs, also *Babylonia spirata* have different shapes and openings compared to *Turritella* *duplicata*, which may provide a better fit for the hermit crabs body size and shape. Hermit crabs prefer shells that offer a good balance between aperture size and shell weight, as well as other factors such as shell shape and availability (Carranza et al., 2008). Some studies suggest that hermit crabs prefer shells with larger apertures, as this allows them to move easily in and out of the shell (Torjman & Iyengar, 2024).

4.3 Conclusion:

The goal of the present study was to study the taxonomy of hermit crabs along the Goan coast and to understand the shell selection behavior of hermit crabs (*Clibanarius infraspinatus and Diogenes avarus*) given the choice of two distinct species of gastropod shells. It may be concluded that *Clibanarius infraspinatus* and *Diogenes avarus* utilized shells having less weight and more aperture size in captivity. This could be because of the unavailability of gastropod shells from the natural habitat, where the demand for gastropod shells is high. Understanding the species composition of any biogeographic region is imperative for devising conservation and monitoring programs. The knowledge of hermit crab's diversity and distribution in Goa and the West coast of India continues to increase. The future studies may be focused on the diversity and zoogeographical distribution of hermit crab species inhabiting the diverse habitats of Goa’s coastline, ranging from sandy to rocky shores and mangrove forests.

References:

Alam, N., Chakraborty, S., Hossain, M., Baki, M. A., Alam, S. M. I., & Li, C. (2020). Brachyuran Crab Fauna Character Estimated from Marine Water of Bangladesh and Noted New Record (Crustacea: Decapoda) as Distribution. *Open Journal of Marine Science* (Print), 10(04), 218–232.

Alcaraz, G., Toledo, B., & Burciaga, L. M. (2020). The energetic costs of living in the surf and impacts on zonation of shells occupied by hermit crabs. *Journal of Experimental Biology*.

Anusha, M., & Roopavathy, J. (2021). A survey on the species composition of decapod Crustaceans in Dharmadam coast, Kannur District, Kerala. *In International Journal of Creative Research Thoughts*, 9.

Asakura, A. (2021). Crustaceans in changing climate: Global warming and invasion of tropical land hermit crabs (Crustacea: Decapoda: Anomura: Coenobitidae) into temperate areas in Japan.

Briffa, M., Arnott, G., & Hardege, J. D. (2024). Hermit crabs as model species for investigating the behavioural responses to pollution. *Science of the Total Environment*, 906.

Bulinski, K. V. (2007). Shell selection behavior of the hermit crabs *Pagurus granosimanus* in relation to Isolation, Competition, and Predation, *Journal of Shellfish Research*, 26(1), 233-239.

Behera, A., Padhi, S. K., Roy, S., Patro, S., & Mitra, & S. (2021). Biodiversity of hermit crabs in Odisha, east coast, and their distribution in other coastal states of India. *In Indian Journal of Geo-Marine Sciences*.,50(5).

Brusca, R. C., Lindberg, D. R., & Ponder, W. F. (2015). Phylum Mollusca. B&B, 3.

Bundhitwongrut, T. (2014). Population ecology of the land hermit crab *Coenobita rugosus* (Anomura, Coenobitidae) at Cape Panwa, Phuket Island, Andaman coast of Thailand., 60(1): 34-51.

Brian, K. (2021). Infraorder Anomura mole crabs, hermit crabs, king crabs, Porcelain crabs, and Squat lobsters of British Columbia. E- Fauna BC: Electronic Atlas of the Fauna of British Columbia.

Conover, M. R. (1978). The importance of various shell characteristics to the shell-selection behavior of hermit crabs. *Journal of Experimental Marine Biology and Ecology*, 32(2), 131–142.

Carranza, a., c., segura, á., lópez, j., & rubio, l. (2008). Shell use patterns of the hermit crab *Loxopagurus loxochelis* (decapoda: diogenidae) in cerro verde-la coronilla (rocha-uruguay). Comunicaciones de la sociedad malacológica del uruguay, 9(91), 139–145.

David, K. A., Barnes. (1997). Ecology of tropical hermit crabs at Quirimba Island, Mozambique: a novel and locally important food source. In Marine Ecology Progress Series, 161: 299-302.

Danin, A. P. F., Pombo, M., Martinelli-Lemos, J. M., Santos, C. R. M. D., Aviz, D., & Petracco, M. (2020). Population ecology of the hermit crab *Clibanarius symmetricus* (Anomura: Diogenidae) on an exposed beach of the Brazilian Amazon coast. Regional Studies in Marine Science, 33, 100944.

Fourzán, B. P., & Hendrickx, M. E. (2022). Ecology and diversity of marine decapod crustaceans. Diversity, 14(8), 614.

Gravel, B. E., Wong, P. Y., Starks, P. T., & Pechenik, J. A. (2004). The use of artificial shells for exploring shell preference in the marine hermit crab *Pagurus longicarpus* (Say). In Ann. Zool. Fennici., 41.

Gorman, D., Ragagnin, M. N., McCarthy, I., & Turra, A. (2018). Risk-taking and risk-avoiding behaviors by hermit crabs across multiple environmental contexts. *Journal of Experimental Marine Biology and Ecology*, 506, 25–29.

Hazlett, B. A. (1981). The Behavioral ecology of hermit crabs. *Annual Review of Ecology and Systematics*, 12(1), 1–22.

Hendrickx, M, E. (1995). Checklist of brachyuran crabs (Crustacea: Decapoda) from the eastern tropical Pacific. Bulletin de I' Institut Royal des Sciences Naturelles de Belgique, Biologie., 65: 125-150.

Hsu, C, H., Liang, Y, B., Li, J, J., Liu, C, C. (2019). Ecological information of land hermit crabs (Crustacea: Decapoda: Anomura: Coenobitidae) and a new record in Dongsha Atoll, National Park Taiwan. Taiwania, 64(3): 299-306.

Kachiiya, P., Ravel, J., Poriya, P., Kundu, R. (2017). Diversity and new records of intertidal Hermit Crabs of the Genus Clibanarius (Crustacea: Decapoda: Diogenidea) from Gujarat coat off the Northern Arabian Sea, with two new records for the mainland Indian Coastline. *Journal of Threatened Taxa*, 9(6), 10334-10339.

Kakui, K. (2019). Shell-exchange behavior in a hermit-crab-like tanaidacean (Crustacea: Malacostraca). *Zoological Science*, 36(6), 468–470.

Komai, T., Liang, J., & Tingbao, Y. (2012). Records of four species of the shallow water hermit crab genus Diogenes (Crustacea: Decapoda: Anomura: Diogenidae) from southern China, with description of a new species. *Journal of Natural History*, 46(19–20), 1219–1248.

Kumar SV, Pathak KC, Pednekar P, Raju NSN, Gowthaman R. (2006). Coastal processes along the Indian coastline. *Current Sciences*: 91(4): 36-53.

Lemaitre, R. (1999). Crustacea Decapoda: A review of the species of the genus Parapagurus Smith, 1879 (Parapaguridae) from the Pacific and Indian Oceans, 303–378.

Landschoff, J., & Gouws, G. (2018). DNA barcoding as a tool to facilitate the taxonomy of hermit crabs (Decapoda: Anomura: Paguroidea). *Journal of Crustacean Biology*, 38(6), 780–793.

Lancaster, I. (n.d.). Optimisation in the life history of the hermit crab Pagurus Bernhardus. pp 5-190.

Mesce, K. A. (1982). Calcium-Bearing objects elicit shell selection behavior in a hermit crab. Science, 215(4535), 993–995.

Martin, J. W., & Davis, G. E., An updated classification of the recent Crustacea. (2001). Los Angeles: Natural History Museum of Los Angeles County, p. 129.

Mukhopadhyay, S. K., CR, S., Raghunathan, C., & Sen, A. (2022). First report of a hermit crab Clibanarius longitarsus (De Haan, 1849) (Crustacea: Anomura) from Sunderbans, India. *Journal of Entomology and Zoology Studies*, 10(1), 220–223.

Miele, H. (2021). Cost Functions of Crabs: Applications of Hermit Crab Shell Exchange Behavior to Vacancy Chain Modelling.

Minsky, M. (2018, July 31). DinaCrab: Hermit Crab Behavior – The Digital Naturalism Conference. https://www.dinacon.org/2018/07/31/dinacrab-hermit-crab-behavior/. Accessed on 1 March 2024.

McLeod, L. (2022, April 7). Shell evacuation in Hermit Crabs. The Spruce Pets. https://www.thesprucepets.com/what-to-do-if-hermit-crab-is-out-of-shell-1239085. Accessed on 1 March 2024.

Michael. (2023, September 12). Is hermit crab dead or molting? - Shrimp and Snail breeder. Shrimp and Snail Breeder. https://aquariumbreeder.com/is-hermit-crab-dead-or-molting/. Accessed on 1 March 2024.

Nirmal, T., Jaiswar, A. K., Chakraborty, S. K., Kumar, A. P., Kantharajan, G., & Nuzaiba, P. M. (2017). New Records of Hermit Crab (Crustacea: Decapoda: Anomura) From Maharashtra Coast of India. *International Journal of Current Microbiology and Applied Sciences*, 6(8), 2871–2878.

Paul, P., & Thiruchitrambalam, G. (2022). New Records of Hermit Crabs (Crustacea: Decapoda: Anomura: Paguroidae) from the Andaman and Nicobar Archipelago in India. Research Square (Research Square).

Peres, P. A., Ferreira, A. P., & Leite, F. P. P. (2018). Expanding the "shell exchange market" hypothesis for clustering behavior in intertidal hermit crabs: Mating and tide as proximate factors. *Journal of Experimental Marine Biology and Ecology*, 500, 100–104.

Pretterebner K, Riedel B, Zuschin M, Stachowitsch M. (2012). Hermit crabs and their symbionts: Reactions to artificially induced anoxia on a sublittoral sediment bottom. *Journal of Experimental Marine Biology and Ecology*, 411, 23-33.

Patel, P., Patel, K., & Trivedi, J. (2020). First record of Hermit crab Clibanarius ransoni Forest, 1953 (Crustacea: Anomura: Diogenidae) from India. *Journal of Biological Studies*, 3(1), 19–23.

Reese, E. S., (1962). Shell selection behaviour of hermit crabs. *Animal Behavior.*, 10, 347-360.

Reese, E. S. 1969. Behavioral Adaptations of Intertidal Hermit Crabs. *American Zoologist*, 9(2): 343-355.

Reshmi, R., & Kumar, A. B. (2011). New records of hermit crabs, Calcinus morgani Rahayu & Forest, 1999 and Diogenes klaasi Rahayu & Forest, 1995 (Crustacea: Anomura: Diogenidae) from India. *Journal of Threatened Taxa*, 3(5), 1771–1774.

Rahayu, D. L. (2003) Hermit crab species of the genus Clibanarius (Decapoda, Anomura, Diogenidae) from mangrove habitats in Papua, Indonesia, with description of a new species. Memoirs of the Museum Victoria, 60 (1): 99 - 104.

Roy, D. M. K. (2015). Conservation concerns on Crustacean Fauna of India. *Journal of Environment and Sociobiology*, 12(1): 77-98.

Reshmi. R. (2014). Taxonomy and diversity of anomuran crabs (Decapoda: Anomura) of Kerala coast. PhD Thesis submitted to University of Kerala, India.

Reese, E. S. (1969). Behavioural adaptations of intertidal hermit crabs. *American Zoologist*, 9 (2): 343–355.

Strasser, K. M., & Price, W. W. (1999). An annotated checklist and key to hermit crabs of Tampa Bay, Florida, and surrounding waters. Gulf Research Reports, 11.

Tricarico, E., & Gherardi, F. (2006). Shell acquisition by hermit crabs: Which tactic is more efficient? *Behavioral Ecology and Sociobiology*, 60(4), 492–500.

Trivedi, J. N., & Vachhrajani, K. D. (2017). An annotated checklist of hermit crabs (Crustacea, Decapoda, Anomura) of Indian waters with three new records. *Journal of Asia-Pacific Biodiversity*, 10(2), 175–182.

Trivedi, J. N., Osawa, M., & Vachhrajani, K. D. (2016). A new species of the genus Diogenes Dana, 1851 (Crustacea: Decapoda: Anomura: Diogenidae) from Gujarat, northwestern India, *Zootaxa*, 4208(2), 189–197.

Trivedi, J. N., Soni, G., Trivedi, D., Purohit, B., Trivedi, J. N., Soni, G. M., Trivedi, D. J., & Vachhrajani, B. D. A. (2015). On new records of Hermit Crabs (Anomura: Paguroidea: Diogenidae) from Gujarat state of India. *Electronic Journal of Environmental Sciences*, 8, 33–42.

Thomas, M. M. (1989). On a collection of hermit crabs from Indian waters. *Marine Biology Association India*, 31(1&2): 59-79.

Trivedi, J., & Vachhrajani, K. D. (2017). An annotated checklist of hermit crabs (Crustacea, Decapoda, Anomura) of Indian waters with three new records. *Journal of Asia-Pacific Biodiversity*, 10(2), 175–182.

Teoh, H. W., Hussein, M. a. S., & Chong, V. C. (2014). Influence of habitat heterogeneity on the assemblages and shell use of hermit crabs (Anomura: Diogenidae). *Zoological Studies*, 53(1).

Torjman, B. Z., & Iyengar, E., V. (2024). Hefting Heavy Shells: Sustenance Demands Caused by Various Abodes of the Hermit Crab *Pagurus granosimanus*. *Multidisciplinary Digital Publishing Institute*.

Usmani, S. M. P. A., & Ansari, Z. (2020). Status of Coastal Marine biodiversity of Goa and Challenges for Sustainable Management - An overview. *Journal of Ecophysiology and Occupational Health*, 20(3 & 4), 222–231.

Vance, R. R., & Vance, R. R. 1972. The Role of Shell Adequacy in Behavioral Interactions Involving Hermit Crabs. In Source: *Ecology*, Vol. 53(6).

Williams, J. D. 2005. The not-so-lonely lives of hermit crabs: studies on hermit crabs symbionts, *Journal of Crustacean Biology*.

World Register of Marine Species (WoRMS). (n.d.). Retrieved April 2, 2024, from https://www.marinespecies.org/taxonomy/Paguroidea/index.php

Ye, W. 2019. Shell Selection of the Hermit Crab, *Pagurus longicarpus* Say (Crustacea: Decapoda: Paguroidea), in Response to Acid-Treated Shells: A Laboratory Study. Life: *The Excitement of Biology,* 6(3), 108–121.