Ecological studies on Hermit crab *Clibanarius rhabdodactylus* Forest, 1953 in Rocky Intertidal zone of Saurashtra coast, Gujarat

Abstract of Thesis submitted to

The Maharaja Sayajirao University of Baroda

For the award of

Doctor of Philosophy

In

Zoology

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The intertidal region is the most diverse and productive zone as it is a transitional zone between terrestrial and ocean ecosystems (Underwood, 2000). The environmental factors here fluctuate drastically as a result of periodic exposure and submergence of the habitat due to tidal action. Hence, the organisms in this particular habitat have to adapt themselves to survive in such harsh conditions. Information on the ecology of the commonly occurring species in a habitat is of great importance; as such studies provide the best understanding of how the species is affected by the interaction of the physical or biological components of its nearby environment. Such a study increases our understanding of the species and its connection with nearby habitat and helps in the successful management of the species as well as the habitat where it is found.

Around 2934 crustacean species have been reported from India (Venkataraman and Wafar, 2005), with the number steadily increasing as new records and species are discovered. Recently, a few groups of scientists have started preparing a taxonomically valid checklist of Indian crustaceans, revealing the Indian diversity as follows: 231 species of Anomuran crabs (58 genera, 15 families and 05 superfamilies) (Patel et al., 2022a), 144 species of barnacles (75 genera, 19 families) (Trivedi et al., 2021), 72 species of Stomatopods (35 genera, 10 families and 5 superfamilies) (Trivedi et al., 2020), 910 species of brachyuran crabs (361 genera and 62 families) (Trivedi et al., 2018), and 437 species of prawn (30 families and 131 genera) (Radhakrishnan et al., 2012). The hermit crab fauna of Indian waters is one of the most scarcely studied groups of decapod crustaceans. Total 115 species (26 genera) of hermit crab are reported from Indian waters (Trivedi and Vachhrajani, 2017; Patel et al., 2022a) out of which maximum species belongs to family Diogenidae (81 species, 11 genera) followed by Paguridae (20 species, 7 genera), Parapaguridae (6 species, 3 genera), Coenobitidae (6 species, 2 genera) and Pylochelidae (2 species, 2 genera).

Genus *Clibanarius* Dana, 1852, comes under the family Diogenidae of superfamily Paguroidea of infraorder Anomura, which currently comprises 60 species worldwide (McLaughlin et al., 2010). The species of the genus *Clibanarius* are mainly found in various types of tropical or subtropical intertidal habitats,

including mangrove forests, coral reefs, rocky substratum, sand and mud flats, etc. (Ismail, 2010). In India, taxonomic studies suggest that genus *Clibanarius* represents one of the diverse genera of hermit crabs, comprising 18 species, of which 11 are found on the coast of Gujarat (Trivedi and Vachhrajani, 2017; Patel et al., 2020a, 2022a). Although *Clibanarius* is one of the most commonly occurring genera, there is currently very little information available regarding the ecology of hermit crabs as a result of a lack of ecological studies focused on hermit crabs.

The present study was carried out on the commonly occurring hermit crab species, *Clibanarius rhabdodactylus*, on the Saurashtra coast of Gujarat state, India. Gujarat is the westernmost state of the country and has the longest coastline (1600 km), comprising 21% of the Indian coastline. Saurashtra has a west ward facing coastline which is majorly composed of rocky intertidal region supporting very rich diversity of marine organisms, Crustaceans in particular. *Clibanarius rhabdodactylus* is a species of hermit crab that is commonly occurring in the intertidal region of the entire Saurashtra coast, with maximum occurrence recorded from three sites: Veraval, Sutrapada, and Dhamlej, where the entire study was carried out.

Hermit crabs need to constantly protect their soft abdomen, for which they occupy empty gastropod shells that are not developed by themselves. During the course of their development, hermit crabs need to occupy the shells that fit them better, and therefore, in their lifetime, hermit crabs have to constantly search for a suitable shell. As a result, all aspects of the hermit crab's life, including body size, survival, mating success, population size, etc., are governed by the gastropod shells. Moreover, the exploitation of shell resources differs between male and ovigerous female individuals of the same species, leading to sexual dimorphism. In the present study, the population ecology of *C. rhabdodactylus* on the rocky intertidal region of the Saurashtra coast was studied in detail.

- It was observed that the males were significantly larger than non-ovigerous females as well as ovigerous females. It could be due to several possible reasons, like males using more energy for somatic growth, which benefits them in terms of their shell and mate choices. Females devote the majority of their energy to gonadal development and incubation, preventing them from growing to larger sizes; additionally, shell availability is a limitation factor for larger individuals, which females avoid.

- In the current study, the overall and monthly sex ratios of male and female individuals were skewed towards female. Moreover, it was also observed that the sex ratio was female-biased in the smaller and intermediate size classes (1 to 5 mm SL), whereas in the largest size classes it was male-biased (5 to 8 mm SL).

- There were significant seasonal differences observed in the size-frequency distribution of the *C. rhabdodactylus* population. Monthly size–frequency distributions in the male population of *C. rhabdodactylus* showed a bimodal pattern of distribution during the majority of the months of the year (January, February, April, June, July, September, October, and November); however, a unimodal pattern of distribution was observed in a few months (March, May, August, and December).

- On the other hand, the monthly size–frequency distributions in the female population of *C. rhabdodactylus* showed a unimodal pattern of distribution during the majority of the months of the year (January, March, April, May, June, July, August, September, October, November, and December); however, a bimodal pattern of distribution was observed only in February month.

- In the present study, ovigerous females occurred throughout the year, with two peaks in their frequency of occurrence during January to June and September to October, suggesting that *C. rhabdodactylus* is a continuously breeding species.

- It was also observed that the occurrence of juvenile individuals was throughout the year with highest incidence of occurrence in the February, April and July to October.
- The timing of peak breeding and juvenile recruitment shows that the breeding season is immediately followed by the juvenile recruitment season.
- The number of eggs, weight of egg mass, and size of eggs all had positive correlations with the size and weight of the ovigerous female, suggesting that fecundity is greatly influenced by the size of the ovigerous female.

The environmental conditions of the intertidal region are very unstable, as the region is submerged and exposed periodically. Moreover, certain abiotic factors like temperature, salinity, and pH, along with the periodic tidal water influx, make the environmental conditions in the intertidal region too harsh to survive. Although hermit crabs have evolved to occupy gastropod shells to obtain protection from such abiotic factors, some behavioural adaptations include migrating along the different zones of the intertidal region in response to different environmental or physiological factors. The intertidal distribution of hermit crabs is governed by abiotic factors as well as different reproductive and life stages.

- The upper intertidal zone experiences the highest exposure to sunlight, leading to increased water temperature during low tide time, followed by middle and lower intertidal regions.
- The seawater temperature of the upper intertidal zone was reaching its maximum in the summer season as a result of the highest exposure to sunlight during low tide, when water does not replenish.
- In the present study, *C. rhabdodactylus* individuals were observed forming aggregations on the raised surface in the nearby area of the intertidal region when the water receded during low tide, which led to a patchy distribution in the study area.

- Such aggregations are termed "clustering" (Barnes, 1997) and are formed for the purpose of shell exchange between individuals of the same species.
- *Clibanarius rhabdodactylus* individuals were most abundantly found in the upper intertidal zone during most of the year since the species had a specific microhabitat preference (tide pools and crevices), which was maximum in the upper intertidal zone.
- Moreover, it was observed that *C. rhabdodactylus* mostly uses *Cerithium caeruleum* shells. *Cerithium caeruleum* was found most abundantly in the upper intertidal zone, which could be another reason governing the distribution pattern of *C. rhabdodactylus* individuals.
- Variations in the abundance of *C. rhabdodactylus* individuals were observed between different genders and different seasons.
- It was observed that the *C. rhabdodactylus* individuals were distributed in the intertidal region where the water temperature was ranging between 30–35°C considering it as the optimum temperature preferred by *C. rhabdodactylus*.
- During winter, the temperature of the upper intertidal region falls in an optimum range, and the species are distributed in the upper intertidal region, with their abundance recorded at its maximum in this region.
- During summer, the water temperature of the upper intertidal increases drastically, hence the *C. rhabdodactylus* individuals shifted from the upper intertidal region and were distributed in the middle intertidal and lower intertidal zones having optimum temperatures (34.63 ± 0.37 °C and 31.09 ± 0.48 °C respectively).
- The temperature remains almost similar in all the intertidal zones during the monsoon, and hence the *C. rhabdodactylus* individuals were distributed in all the intertidal zones. However, greater abundance was observed in the upper intertidal region since wave action in the lower intertidal region was greater, which can lead to shell breakage.

Hermit crabs have evolved and adapted successfully to thrive in the harsh conditions of the intertidal zone. They are one of the most common species found in the intertidal region, and this is possible due to their behavioural adaptation of occupying empty gastropod shells. These occupied shells protect them from various environmental factors like desiccation and wave action as well as biological factors like predation. During the present study, along with *C. rhabdodactylus*, another hermit crab species, C. ransoni was also occurring abundantly in the study site and hence the shell utilization pattern of the hermit crab species was studied and compared.

- In the present study, it was observed that the males of both hermit crab species were reaching larger sizes, followed by ovigerous females and non-ovigerous females.
- It was observed that the male individuals were occupying larger shells as compared to non-ovigerous females and ovigerous females in both the species. Since male use most of their energy in physical growth as well as they are involved in male-male antagonism to get a female where a larger and robust shell helps in dominance.
- It was also found that the ovigerous females occupied larger and more voluminous shells as compared to the non-ovigerous females they need more internal space for accommodation and protection of their eggs from predators and desiccation.
- It was observed that *C. rhabdodactylus* and *C. ransoni* utilised 29 species and 28 species of gastropod shells respectively which is quite higher as compared to some other hermit crab species most probably because the rocky intertidal region supports rich diversity of gastropods and hence their empty shells provide huge options for shell selection.
- In the present study, it was observed that the gastropod shells occupied by the ovigerous female individuals of both species were significantly less as compared to the male and non-ovigerous female individuals of the same species. It is because the ovigerous females are choosy for the shells

as they have to accommodate and incubate their egg mass and hence require the shells with larger inner space.

- It was found that both the *Clibanarius* species were showing a high overlap in their intertidal distribution as well as gastropod shell use pattern.
- It was also observed that *C. caeruleum* was the most preferred gastropod species by the individuals of *C. rhabdodactylus* and *C. ransoni,* possibly due to the high abundance of *C*. *caeruleum* in the intertidal region of the study area.
- The availability and abundance of the gastropod shell is an important aspect governing the shell use pattern of the hermit crab species, which is also proved in the present study.
- However, shell availability and abundance are not the only factors affecting the shell use factor. Hermit crabs carry out a complex assessment of the shell before inhabiting it.
- In the present study, it was observed that all the morphological parameters of gastropod shells showed a significant relationship with the hermit crab's weight and shield length, suggesting that shell characters like shell total length, shell aperture length, shell aperture width, shell dry weight, and shell volume greatly affect the hermit crab's shell selection.
- The morphological analysis of most occupied shell species revealed that the *C. caeruleum* shells were more spired, elongated, had a narrow aperture, and were lighter in weight; the *P. undosa* shells were smaller in length, but their aperture was proportionately elongated; and the *T. granulata* shells were smaller in length and lighter in weight. The shells of *T. bruneus* and *L. coronata* were larger in size, with a wide aperture and more voluminous and heavier shells.
- It was observed that the smaller sized hermit crabs of both the species profoundly utilised the shell of *C. caeruleum* which are more spired with

smaller aperture which can conserve more water and hence it protects the occupant crab from desiccation.

- The larger individuals use a bigger, heavier, and more voluminous shell, which can protect from predators, protect from crushing wave actions, and aid in mating success.

Recommendations for future study

- The present study tried to gather some information on the breeding biology of the species; however, a detailed study focusing on the fecundity of the species can be carried out by studying different stages of eggs, the survival rate of the offspring, different larval stages, and their ecology.
- A study can be designed where another distinct study site having a higher abundance of *C. rhabdodactylus* can be selected for sampling, and the effect of shell abundance and size on the shell use pattern and growth rate can be studied and compared with the data of the present study.
- During the study, another hermit crab species, *C. ransoni,* was also found abundantly in the intertidal region of the Saurashtra coast. Ecological studies can be carried out on this species too.
- The present study can be used as baseline information, and on the basis of that, the ecology of other crustaceans can be studied for a better understanding of the species.
- As microplastics are a major environmental concern, future research can be conducted on the microplastic contamination in *C. rhabdodactylus* on the Saurashtra coast, as it is one of the most commonly occurring crustaceans in the intertidal region, where the most microplastic accumulation occurs.
- Several site of saurashtra coast have major industries releasing affecting the environment of the intertidal region. Studies on the effect of industrial

pollutants on the ecology of hermit crabs can be carried out to assess the impact of pollutants on the local environment.

- The coastal region of Gujarat possesses a rich diversity of coastal habitats, including mangroves, coral reefs, mudflats, sand/beaches, salt marshes, other vegetated areas, rocky areas, and salt pans as the major ecosystems. However, only 18 species of hermit crabs are known from Gujarat State, which is very little. Taxonomical studies can be carried out in the coastal regions of Gujarat to assess the diversity of hermit crabs in different coastal habitats.
- The information from the present study can be used as a baseline to study the ecological aspects of commonly occurring crustaceans in the coastal region of Gujarat state.
- The information from the present study can be used in the future to assess the effect of anthropogenic activities on the rocky shores of the Saurashtra coast.