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Examining the Interrelationship between Physicochemical Properties and Brachyuran Crab Diversity in the Gulf of Kachchh, Gujarat, India: A Quadrat Sampling Approach for Ecological Assessment and Conservation Strategies

Tandel Lata [a++], Kardani Hitesh [b#*], Vijay Kumar [a++], Siddharth Kumar Jatav [a++] and Tandel Bhavika [a++]

[a] College of Fisheries Science, Kamdhenu University, Veraval- 362265, India.
[b] Fisheries Research Station, Kamdhenu University, Sikka- 361440, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] Research Scholar;
[#] Assistant Professor;
**Corresponding author: Email: hiteshkardani@gmail.com;*

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ABSTRACT

The study aims to examine the relationship between physicochemical parameters and the diversity of Brachyuran crabs in the Gulf of Kachchh, Gujarat, from November 2020 to April 2021. The research was conducted at two locations, Vador and GSFC (Gujarat State Fertilizer & Chemical Limited) Jetty near Sikka on the southern coast of the Gulf of Kachchh, using the quadrat method for sampling. Various species diversity indices and attributes were calculated, such as species diversity, richness, species evenness, density, abundance, and frequency. A total of 31 Brachyuran crabs belonging to 26 genera and 14 families were recorded, with 26 and 18 species reported from Vador and GSFC Jetty sites, respectively. The Portunidae family had the highest number of species, followed by the Xanthidae family. Brachyuran crab species were found in habitats including rocky areas, muddy areas, mangroves, sponge-associated areas, seaweed-associated areas, and coral reef-associated areas. During the study period, *Thalamita crenata* showed the highest average density (no/m^2) and abundance along the Sikka coast. An analysis of physicochemical parameters, including air and water temperature, pH, salinity and dissolved oxygen, revealed positive correlation with temperature and salinity and a negative correlation with dissolved oxygen. These findings provide crucial baseline data that can inform the development of conservation and biodiversity management strategies in this region, emphasizing the importance of protecting coastal ecosystems.

Keywords: Brachyuran crab; diversity index; physicochemical parameter; correlation; Sikka.

1. INTRODUCTION

Biodiversity, a multidimensional trait of natural systems, is challenging to quantify because of many proposed indexes. These indexes aim to describe the overall attributes of communities, allowing us to compare different areas, taxa, and trophic levels. They are crucial for environmental monitoring and conservation, even though there is no consensus about the most appropriate and informative (Morris et al., 2014). The composition of species is fundamental to understanding the number of species in a community. Studies on the diversity of local fauna are important as they reveal various ecological processes and environmental issues. These investigations enable the development of adequate protection and preservation measures for the marine environment and its diverse flora (Saher et al., 2018).

Brachyuran crabs belong to the Decapoda, infraorder Brachyura (Ponnada et al., 2019). Brachyuran crabs are well-known for their vast diversity, comprising about 1,271 genera and 6,793 species in 93 families worldwide (Ng et al., 2008). Trivedi et al. (2018) listed 361 genera and 62 families containing 910 brachyuran species from India. A checklist of 152 species belonging to 87 genera and 29 families of marine brachyuran crabs, including four new records and two revisions with their distribution status in Gujarat waters, was provided by Beleem et al. (2019). Lata et al. (2021) listed 31 brachyuran crab species from the Sikka coast belonging to 26 genera and 14 families, with the maximum number of species reported in the family Xanthidae. From an ecological perspective, crabs are significant faunal communities in the marine ecosystem. They serve as carrion eaters, filter feeders, sand cleaners, mud cleaners, parasites, predators, and commensal organisms. Additionally, they create burrows, allowing oxygen to pass below the surface and oxygenate the deposited organic material. They also prey on fish, turtles, squid, and other marine mammals (Josileen, 2011, Sen et al. 2014).

The distribution of crustaceans is significantly influenced by physicochemical factors and is affected by pollution. Excessive nutrients in coastal waters lead to environmental issues such as the extinction of benthic animals, crabs, algal blooms, and the loss of seagrass and mangroves (Varadharajan et al., 2013). Crab diversity varies across intertidal zones. In the high tide zone, there is less crab biodiversity due to inadequate ecological conditions like light, temperature, increased evaporation, dry weather, and low humidity during ebb tide. Temperature is a key factor affecting both abundance and diversity. High temperatures in intertidal zones result in dry areas, reducing the variety and number of organisms (Fatemi et al., 2012). A meta-analysis indicated a positive relationship between dissolved oxygen concentration and taxonomic richness. On the other hand, although there was a negative relationship with temperature, adding

temperature to a model that already included dissolved oxygen content did not significantly improve the model (Croijmans et al., 2021).

The middle of the intertidal zone is home to various crabs. This area has a low slope and high humidity, providing an ideal environment for crab growth. Algae, which are essential for crab nutrition, thrive in this zone. The low tide area of the intertidal zone is permanently submerged in water, making it more vulnerable to erosion. It is also less sloped and has fewer holes, making it less suitable for crabs. The low zone has lower species diversity than the high and mid-tide zones. According to Fatemi et al. (2012), this environment has a weak relationship between pH, temperature, and salinity. The varying physicochemical characteristics of coastal environments, including temperature, salinity, pH, dissolved oxygen, and nutrients, significantly impact crustaceans' abundance and life cycles (Varadharajan et al., 2013). In this context, the study aims to correlate the physicochemical parameters and brachyuran crab diversity at two selected locations along the Sikka coast in Gujarat's Gulf of Kachchh region by conserving and managing the ecologically important species to sustain the ecosystem.

2. MATERIALS AND METHODS

The current study took place at two specific locations, Vador (22.455322°, 69.804308°) and GSFC jetty (22.459104°, 69.805923°), along the Sikka coast in the Gulf of Kachchh (Fig 1). Sampling was carried out during low tide once a month. The Vador site is muddy at high tide zone while rocky at low tide zone while GSFC jetty consist of mangrove, sandy, rocky substratum. The vador is approximately 4.5 Sq km while GSFC is nearly 6 sq km. We covered atleast 10% of the area from both site. The belt transect method was used to study brachyuran crabs' diversity, density, and frequency (Krebs, 1989). Ecological values of the brachyuran crab species were calculated and recorded at the sampling site. Each species was photographed and characterized morphometrically after being hand-picked. Collected crab samples were kept in plastic containers and brought to the laboratory for species-level identification. Species identification was conducted using standard literature, including the Marine Species Identification Portal (www.speciesidentification.org), the FAO species identification guide, and a manual on the taxonomy and identification of commercially

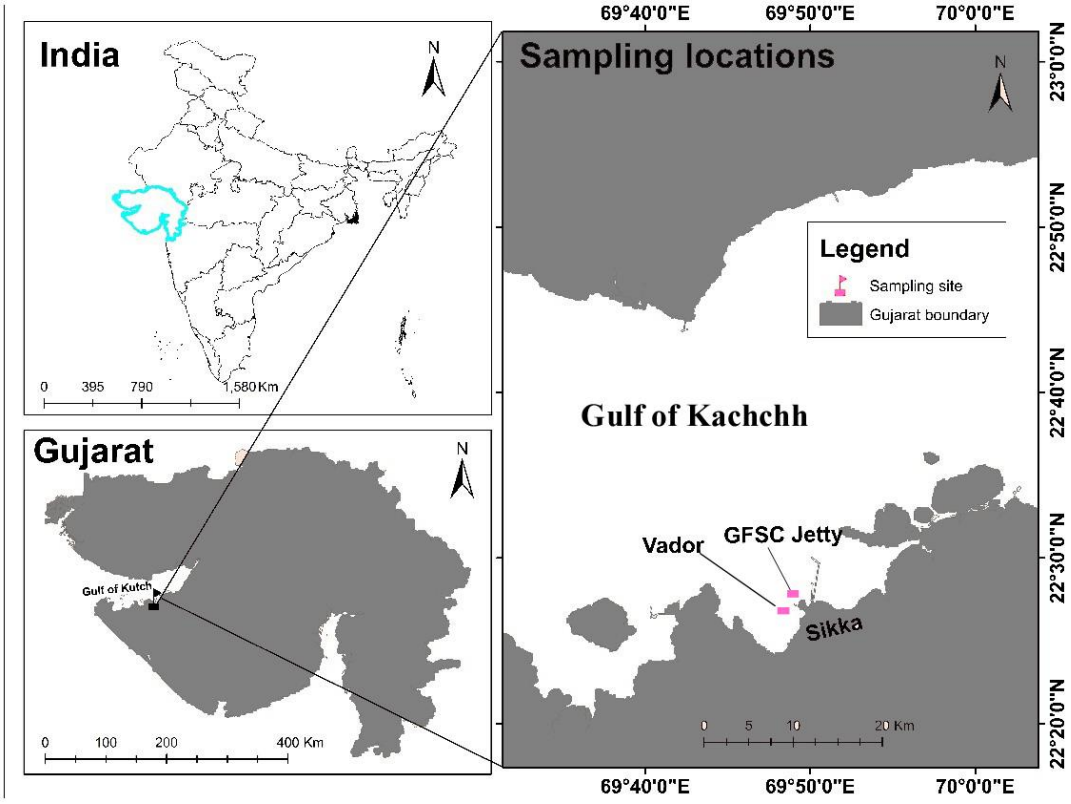

Fig. 1. Map showing the sampling sites along the Sikka coast

important crustaceans of India. Collected samples were preserved in 70% ethyl alcohol and stored at ambient temperature.

The study measured key physicochemical parameters such as temperature (°C), salinity (ppt), dissolved oxygen (mg/l), and pH to understand how abiotic factors influence the population density, diversity, abundance, and distribution of brachyuran crab species. The measurements were taken in the morning following the standard laboratory procedures, with water samples collected in clean plastic bottles from each site monthly and analysed in the laboratory.

For statistical analysis, the monthly physicochemical data was correlated with the total number of species and their occurrences. Biodiversity indices such as the Shannon Wiener diversity index (H'), Margalef diversity index (D), and Pielou's evenness index (J') were calculated using Past software (v. 4.03) (Hammer et al., 2001) and Microsoft Office Excel (v. 2007) to assess species diversity, richness, and evenness.

3. RESULTS

A total of 31 species of brachyuran crabs, belonging to 26 genera and 14 families, were identified in the study area. Specifically, 26 species were found at Vador and 18 at GSFC Jetty. Among the 14 families, Portunidae and Xanthidae were the most prominent, with seven and six species, respectively.

3.1 Biodiversity Assessment

Biodiversity indices such as the Shannon Wiener diversity index (H'), Margalef diversity index (D), and Pielou's evenness index (J') calculated for both locations from November 2020 to April 2021 reveal spatiotemporal variations as follows. The Shannon Wiener diversity index *(H')* ranges from 0.4634-2.32 (Vador) and 0.2868-1.989 (GSFC jetty), respectively. Among the Vador and GSFC jetty, the highest *H'* was observed in February, while the lowest was in November. The Margalef diversity index *(D)* ranges from 0.7213–3.631 (Vador) and 0.4024–2.832 (GSFC jetty). The highest (D) was observed at both sites during March and February, while the lowest was in November. The Pielou's evenness index (*J'*) ranges from 0.3919–0.783 (Vador) and 0.5386–0.817 (GSFC jetty), respectively. The highest J' was observed in February for Vador and April for GSFC jetty, with the lowest in December for both locations.

3.2 Physicochemical Parameter of Vador and GSFC Jetty Site of Sikka

Table 2 shows the monthly variation in the seawater quality parameters from the Vador and the GSFC jetty site on the Sikka coast. Fig 2 shows the graphical representation of monthly variation of water quality parameters and indices.

3.3 Correlation of Total Number of Occurrences and Total No. of Species with Physio-Chemical Parameters

A study investigated the relationship between water quality, the number of occurrences, and the number of species reported. This information is presented in Table 3. At the Vador site, the analysis showed a positive correlation between species occurrence and air and water temperature and salinity. The pH exhibited a positive association with the total number of occurrences but a negative link with the total number of species recorded. Additionally, dissolved oxygen showed a negative relationship between the total number of occurrences and the total number of species recorded at this site. On the other hand, at the GSFC jetty site, a positive association was found between species occurrences and air and water temperature, pH, and salinity. An analysis of the association between recorded occurrences of species and dissolved oxygen at this site revealed a negative correlation.

Environmental parameters are key factors for the diversity and distribution of the crustacean. The relationship or correlation between environmental parameters and the Shanon diversity indices of brachyuran crab species is presented in Table 4, which shows the influence of environmental conditions on crab diversity. The independent variables are the pH, dissolved oxygen, air temperature, water temperature, and salinity, and crab species' diversity indices (Shannon) are observed as the dependent variable. Partially, the pH variable's correlation has a t-value of 1.317 < 2.0201, with the significance level obtained by the equation 0.236 > 0.05. The dissolved oxygen variable has a t-count value with the equation of -1.566 < 2.0201 and a sig

value of 0.168 > 0.05. For the air temperature, the equation for the t value is 2.887 > 2.0201, and the sig value for the equation is 0.028 < 0.05. For the water temperature, the equation for the t value is -1.954 < 2.0201 and the sig value for the equation is 0.099 < 0.05. For the Salinity, the equation for the t value is -0.091 < 2.0201 and the sig value for the equation is 0.931 < 0.05. For all the independent variables *viz.,* air temperature, water temperature, dissolved oxygen salinity, and pH based on both the t- and sig value obtained on both station lines, the hypothesis is rejected, which means that such environmental parameters had no significant effect on the diversity of crab at Vador and GSFC jetty site.

Table 1. Comparison of various indices observed at Vador and GSFC Jetty

Locations	INDICES		
	Shannon Wiener diversity index (*H'*)	**Margalef diversity index (*D*)**	**Pielou's evenness index (*J'*)**
Vador	1.46	2.24	0.53
GSFC jetty	1.50	2.01	0.71

Table 2. Monthly variations in the water quality parameters of seawater from sampling sites (Vador and GSFC jetty of Sikka coast) from November 2020 to April 2021

Months	Sampling site	Parameters				
		Air temp (^{0}C)	**Water Temp (^{0}C)**	**pH**	**Salinity (ppt)**	**Dissolved oxygen (ppm)**
Nov-20	Vador	20	23	8.1	35	8.7
	GSFC jetty	21	24	8	35	8.5
Dec-20	Vador	18	21	8.3	35	8.9
	GSFC jetty	18.5	21.3	8.1	37	8.8
Jan-21	Vador	18.3	22.2	8.1	35	8.7
	GSFC jetty	27..3	26.1	8.3	38	8.1
Feb-21	Vador	28.8	24.4	8	35	8.4
	GSFC jetty	29	25	7.9	36	8.3
Mar-21	Vador	30	28.8	8.1	36	7.7
	GSFC jetty	31	29.4	8.2	36	7.6
Apr-21	Vador	32	30.2	8.3	35	7.6
	GSFC jetty	33	30.5	8.2	36	7.6

Table 3. Correlation of the total number of occurrences and total no of species with physio-chemical parameters at the Vador and GSFC jetty site

Sites		Air Temp. (^{0}C)	Water Temp. (^{0}C)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)
Vador	Against a total number of occurrences	0.77	0.91	0.57	0.28	-0.93
	Against a total no. of species recorded	0.81	0.74	0.67	-0.27	-0.79
GSFC	Against a total number of occurrences	0.79	0.60	0.38	0.34	-0.59
	Against a total no of species recorded	0.69	0.40	0.52	0.23	-0.45

Table 4. Correlation analysis of environmental parameters with the Shannon diversity indices crab

Coefficients[a]						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	46.779	35.530		1.317	.236
	pH	0.369	1.053	0.071	0.350	.738
	DO	-4.075	2.601	-3.020	-1.566	.168
	Air. Temp.	0.164	0.057	1.425	2.887	.028
	Water. Temp.	-0.721	0.369	-3.700	-1.954	.099
	Salinity	-0.013	0.144	-0.019	-0.091	.931

a. Dependent Variable: Shannon

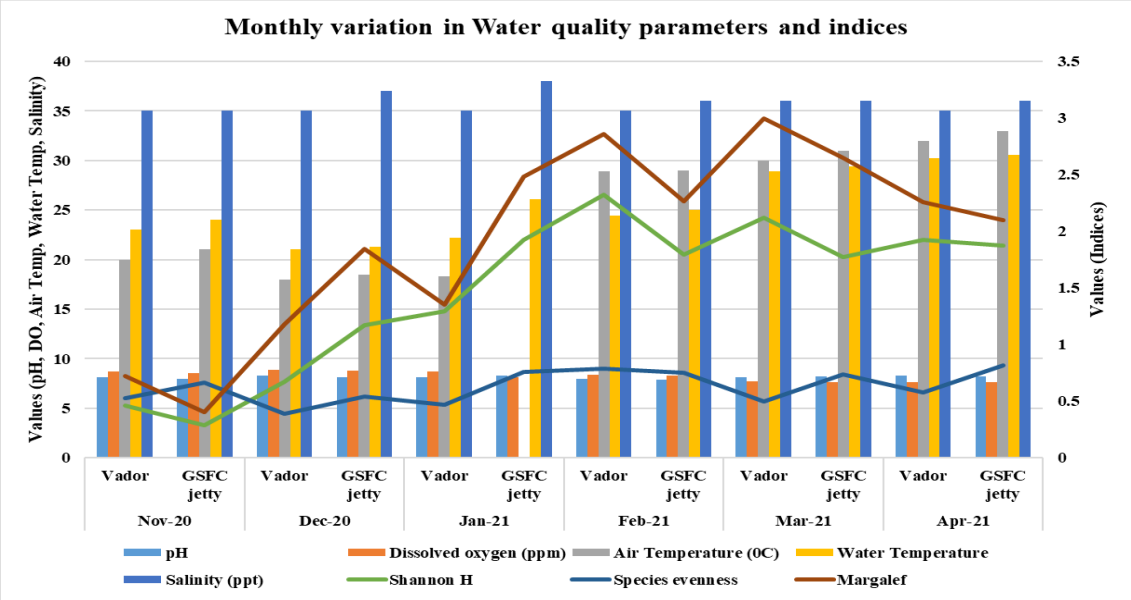

Fig. 2. Monthly Variations in the water quality parameters and various indices

3.4 Average Species Density, Abundance, and Frequency of Brachyuran Crabs

At the Vador site on the Sikka coast, the species *Thalamita crenata* had the highest average computed densities per square meter, followed by *Etisus laevimanus* (0.0361 no/m^2) and *Metopograpsus thukuhar* (0.022 no/m^2). The highest value was reported for *Thalamita crenata* (1.45), followed by *Etisus laevimanus* (1.25), with an average abundance value close to integrity. *Thalamita crenata* also had the highest average frequency (37.78%), followed by *Etisus laevimanus* (20%). Furthermore, at the GSFC jetty site on the Sikka coast, *Thalamita crenata* again had the highest average computed densities per square meter (0.0272 no/m^2), followed by *Metopograpsus thukuhar* (0.0078 no/m^2). The average abundance values were close to integrity, with *Pilumnus vespertilio* (1) and *Thalamita crenata* (1.24) having the highest values, respectively. Additionally, *Thalamita crenata* had the highest average frequency at this site (22.22%), followed by *Thalamita prymna* (6.67%).

4. DISCUSSION

4.1 Biodiversity Assessment

Measuring species diversity is important in assessing biological communities (Saher et al., 2018). In this study, the Shannon Wiener diversity index (H') ranged from 0.4634 to 2.32 at Vador and from 0.2868 to 1.921 at the GSFC jetty of the Sikka coast. The Margalef diversity index (D) ranged from 0.7213 to 3.631 at Vador and from 0.4024 to 2.832 at the GSFC jetty of

the Sikka coast. The Pielou's evenness index (J') ranged from 0.3919 to 0.783 at Vador and from 0.5386 to 0.817 at the GSFC jetty of the Sikka coast. Another study by Beleem et al. (2014) found that the maximum species diversity, species evenness, and species richness were 2.48, 0.91, and 3.33, respectively, while the minimum were 0.84, 0.76, and 0.65, respectively, at GOK, MNP. Sen et al. (2014) observed higher species evenness (J') during the pre-monsoon season than the post-monsoon and monsoon seasons. In the present study at Vador and GSFC jetty, the highest species evenness was observed in February and April, while the lowest was in December.

Contrary to the above result, Saher et al. (2018) found diversity ranging from 0.63 to 1.64, richness from 0.84 to 1.76, and evenness from 0.1 to 0.35 along the Sonmiani coast. Varadharajan and Soundarapandian (2014) discovered a maximum diversity index (5.9008), maximum richness index (14.0946), and maximum evenness (0.9775) at various sites from Arukkattuthurai to Pasipattinam on the southeast coast of India. Our findings fell within the range of these values. Kumar et al. (2007) recorded the Shannon diversity index (2.98), richness (43), and Pielou's evenness (0.79) for crustacean fauna from different fishing harbors on the Kerala coast. Haragi et al. (2010) studied species diversity, richness, and evenness for brachyuran crabs at four sites: Devabag and Mavinhole Creek, Kanasgiri, Sunkeri and Kadwad, and Hankon. The maximum Shannon diversity index, Richness index, and Evenness index were reported as 2.7165, 3.8618, and 0.9588, respectively, from Devbagh, while the minimum values, i.e. 1.8570, 2.7976, and 0.7473, were reported in Sunkeri from the Kali estuary.

4.2 Physicochemical Parameter of Vador and GSFC Jetty Site of Sikka

Water temperature is the most critical environmental factor that affects the activities, growth, oxygen consumption, reproduction, moulting, survival, distribution, and migratory behaviours of crustaceans (Le Moullac and Haffner, 2000; Varadharajan et al., 2013). The intensity of solar radiation, evaporation, freshwater inflow and cooling constantly influences the water temperature. In the present study, the water temperature of Vador and GSFC jetty at Sikka coast ranged between 21 ^{0}C to 30.24^{0}C and 21.3^{0}C to 30.56^{0}C, respectively; the highest temperature was observed in April (summer), and the lowest temperature was observed in December (winter). The air temperature of the Sikka coast ranges from 18 ^{0}C to 33 ^{0}C. Fatemi et al. (2012) concluded that temperature is a factor that can directly influence the distribution and abundance of organisms in an area. The high temperature at intertidal zones usually causes dry areas and decreases species diversity and abundance. During the present study, air and water temperatures positively correlated with the total number of occurrences and species recorded at both sites.

In the present study, the pH of seawater from the Vador and GSFC jetty areas at the Sikka coast ranged from 8.0 to 8.3 and 7.9 to 8.3, respectively. The pH is another important parameter that affects crab diversity and ecosystem distribution. The uptake of CO_2 by the photosynthesizing organisms, especially phytoplankton from the sea, could have increased the pH levels. It can be due to the influence of seawater penetration, high biological activity, and photosynthetic activity. The alkaline pH was found to be associated with several crab species. However, with increasing pH, the number of species has been reported to decrease (Das et al., 1997; Subramanian and Mahadevan, 1999; Varadharajan et al., 2013). A similar negative correlation of pH with the number of species has been observed at the GSFC site.

Salinity is an ecological factor that influences the distribution of marine organisms and larval development (Pittman and McAlpine, 2003; Kunsook and Dumrongrojwatthana, 2017). In the present study, the maximum salinity (38 ppt) was observed during January, whereas minimum salinity (35 ppt) values were reported in November. Dissolved Oxygen concentrations in seawater affect the behaviour of decapods and life strategies based on oxygen consumption and energy content (Varadharajan et al., 2013). In the present study, total dissolved oxygen fluctuated from 7.6 to 8.83 mg/L at both sites along the Sikka coast. During the present study, a positive correlation was observed between salinity, the number of species, and the total number of occurrences.

4.3 Species Abundance, Species Density and Species Frequency of Brachyuran Crab Species

Raval et al. (2020) reported that the highest number of species belongs to the Xanthidae

family, followed by Portunidae. During the present study, we recorded the highest number of species from the Portunidae family, followed by Xanthidae. The monthly mean density of brachyuran crab at the Vador site of the Sikka coast was recorded, and Thalamita crenata showed the highest density, followed by *Etisus laevimanus.* Similarly, at the GSFC jetty site on the Sikka coast, *Thalamita crenata* showed the highest density, followed by *Metopograpsus thukuhar*. *Thalamita crenata* was observed from both Vador and GSFC jetty sites in all months. Jeyabaskaran and Khan (2007) reported the highest density of *Chlorodiella nigra* followed by *Etisus laevimanus* in all seasons from the Gulf of Mannar at Island such as Manauli Island, Appa Island, Nallathanni Island and Karaichalli Island. *Etisus laevimanus* showed the highest abundance value in April, followed by Parasesarma persicum in March from the Vador site on the Sikka coast. *Metopograpsus thukuhar* showed the highest abundance value in April from the GSFC jetty site on the Sikka coast. Trivedi et al. (2012) recorded *Scylla serrata* and *Uca lactea annulipes* as the dominant species as they were found in all the sampling sites from the Gulf of Kachchh, Gujarat. Kunsook and Dumrongrojwatthana (2017) observed that temperature, turbidity, and salinity influenced the abundance and distribution of some species of marine crab. *Uca lactea annulipes* were found only in the mangrove areas in the upper intertidal zone, while the study sites during the present study were concentrated in the intertidal zone.

The highest frequency percentage of *Etisus laevimanus* was observed, followed by Thalamita crenata in March and December, respectively, from the Vador site at the Sikka coast. In contrast, *Thalamita crenata* showed the highest frequency percentage from the GSFC jetty site at the Sikka coast.

5. CONCLUSION

Studying the diversity of brachyuran crabs helps us better understand the structure, function, and challenges these species face. The intertidal zone, where a wide variety of plants and animals can be found within a small area, is considered the most diverse and productive region in coastal environments. The Sikka coast is home to a rich diversity of crabs. The study indicates fewer crab species, less richness, and lower abundance during winter, likely due to lower water temperatures. Conversely, higher values were observed during the summer, confirming the hypothesis that the crabs move to deeper zones in winter.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text to image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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