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Distribution Patterns of Key Gastropods (Mollusca) Species Along the Intertidal Zone of Adri Coast, Kathiawar Peninsula, India

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ABSTRACT

Distribution patterns of key gastropod species were studied on a rocky-sandy intertidal zone of Adri coast of Kathiawar peninsula. The studied coast has an ideal habitat for intertidal ecological studies. It has rich marine faunal and floral diversity devoid of any anthropogenic pressure. The present study was focused on distribution pattern of dominating intertidal gastropods species that considered as the most communal inhabitants of the intertidal zone worldwide. The coast has both rocky and sandy intertidal area with rock crevices and small to large pools and puddles. Physico-chemical parameters of seawater and ecological attributes like density, abundance, and frequency of five gastropod species *Astralium semicostatum, Cerithium caeruleum, Gyrenium natator*, *Nerita albicilla* and *Onchidium verruculatum* have been studied. Result indicates that all the species have their distinct preference for intertidal microhabitats like rocks, puddles, crevices and different substrata. The species has different strategies for the selection of microhabitat for their survival particularly in extreme environment of low tide when desiccation is at maximum.

Keywords Gastropoda, Diversity, Distribution, Physico-chemical parameters, Intertidal zone

INTRODUCTION

Mollusca are the second largest animal phylum on Earth after arthropods that encompasses around 50,000 to 55,000 marine, 25,000 to 30,000 terrestrial and 6,000 to 7,000 freshwater species (Mollusca Base 2023). The total diversity of molluscs from India comprises 5,169 species (MoEF 2014) while marine mollusan diversity of India include 3,400 species (Rao and Dey 1984, 1986, Rao and Rao1993, Rao 2003, Ramkrishna and Dey 2010, Venkataraman and Wafar 2005). More than a half of all living mollusc species live in oceanic environment, inhabiting every depth from the intertidal and splash zones to the bottoms of marine trenches (Leal and Harasewych 1999). Phylum Mollusca includes familiar invertebrates such as snails, clams, chitons, tusk shells, bivalves, octopuses and other cephalopods. Amongst them, Gastropoda is one of the largest and most diverse groups of Mollusca in forms of habit, habitat and species diversity, that comprise about 80% of living molluscs. Gastropods are the most common inhabitants of the marine ecosystem with wide range of distribution in the rocky intertidal zones, sea grass beds, coral reefs, mangroves and sandy beaches. It creates diverse morphologies

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depending on their environment. Individuals of the same species living on the same rocky shore may have varying morphologies due to various microhabitats (DeWolf *et al.* 1997). The gastropod fauna of Gujarat coast has been thoroughly researched and a total of 188 species have been reported (Apte 1998). The coastal region of Kathiawar peninsula, Gujarat, has diverse intertidal microhabitats that supports rich marine biodiversity (Mishra and Kundu 2005, Gohil and Kundu 2013, Bhadja *et al.* 2014, Poriya *et al.* 2014, Poriya *et al.* 2015, Beleem *et al.* 2019). Diversity and ecology of molluscs along the Kathiawar peninsular coastline was extensively studied from last few decades that explained vertical distribution of some molluscs like : Ecology of *Cerrithium caerulum* and *Clypeomorus monoliferus* (Patel 1985), ecology of *Turbo coronatus* and *Turbo intercoastalis* (Malli 1993), *Cellana radiata* and *Siphonaria siphonaria* (Prasad 1984), *Cellana karachiensis* (Vakani *et al.* 2013, Faladu *et al.* 2014), some studies focused on ecology and distribution of key intertidal mollusc in context of environmental factors : Vaghela (2010), Gohil *et al.* (2011), Gohil and Kundu (2011). Gastropods are an important and representative component of rocky shore ecosystem that found distributed in various intertidal microhabitats. Habitat structure and its complexity plays key role in shaping of faunal communities in such ecosystem. The present research conducted to explore such ecological phenomenon by focusing on distribution patterns of key gastropod species. Ecological attributes like density, abundance, and frequency of five gastropods species were studied along the Adri coast of Gujarat, India to characterize microscale ecological processes.

MATERIALS AND METHODS

The present work was carried out at the Adri coast

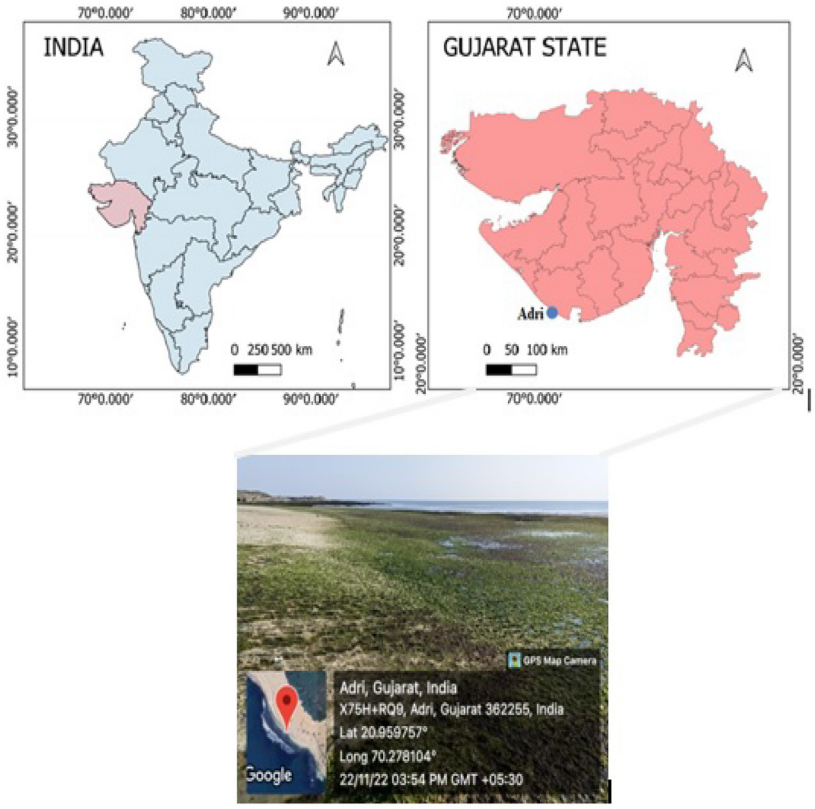

Fig. 1. Map of the study site - Adri coast, Gujarat.

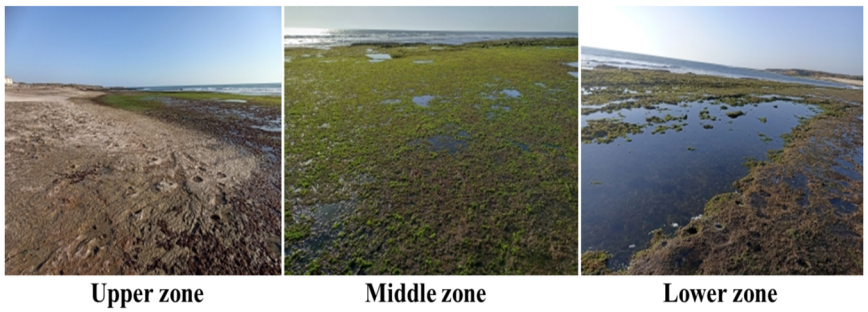

Fig. 2. Intertidal zones with different microhabitats.

(20˚96′07″ N latitude, 70˚27′94″ E longitude) of Kathiawar peninsula, Gujarat, India from August 2021 to July 2022 (Fig.1). Based on previous studies and preliminary survey, five key intertidal gastropods species have been selected for the present study. Ecological attributes like density, abundance and frequency of species have been measured with stratified random sampling by laid down a 0.25 m² quadrate at uniform interval in the upper, middle and lower intertidal zones. Physico-chemical parameters like temperature, pH and salinity were measured by calibrated digital instruments. The coastal area of Adri has a mixed type of intertidal habitats having rocky outcrops studded with sand. The supratidal zone is covered with sand and the upper, middle and the lower intertidal zone is rocky-sandy (Fig. 2). The upper zone is dominated by gastropods and green seaweed *Ulva lactuca*, the middle zone comprises many small tide pools and crevices that predominated by sponges, zoanthids, gastropods, other molluscs, crabs, barnacles, worms and green and brown seaweeds. The lower zones include big tide pools and flat substratum with zoanthus colonies, gastropods, barnacles, worms, brittle stars and other macrofauna inhabited in algal cover.

RESULTS AND DISCUSSION

Spatiotemporal distribution pattern of five key gastropods species *Astralium semicostatum*, *Cerithium caeruleam, Gyrenium natator, Nerita albicilla* and *Onchidium verruculatum* have been studied in present study. Ecological attributes like density, abundance, and frequency were measured by quadrate methods. In case of seawater temperatures, temperature range from 27.2 ˚C to 34 ˚C, pH ranges from 7.2 to 8.5 and salinity range from 28 to 35.2 for a year from Aug-2021 to July-2022 (Fig. 3). These common gastropod species were found as being associated with seaweed during the current study. The distribution pattern of the gastropod species reveals that *Nerita albicilla* and *Gyrenium natator* were mostly observed in the upper littoral zone, while *Astralium semicostatum*, *Cerithium caeruleum* and *Onchidium verruculatum*

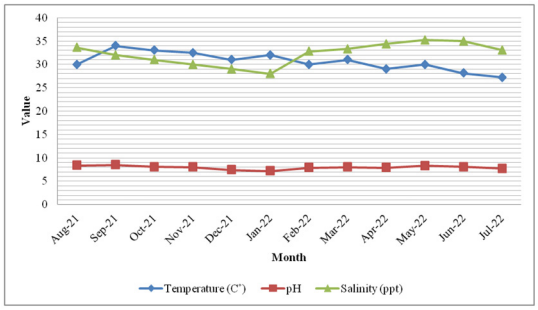

Fig. 3. Monthly variations of physio-chemical parameters at studied coast.

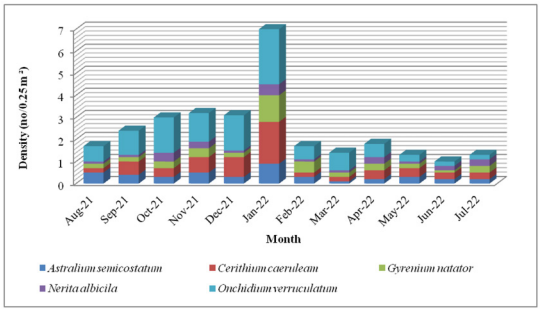

Fig. 4. Monthly variations in density (no/ 0.25 m²) of studied gastropod species along Adri coast.

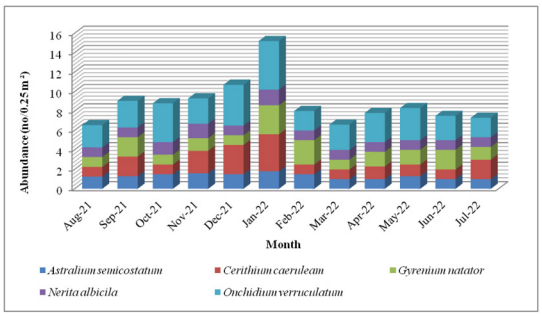

Fig. 5. Monthly variations in abundance (no/ 0.25 m²) of studied gastropod species along Adri coast.

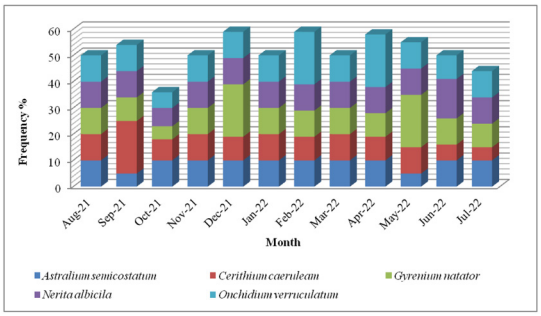

Fig. 6. Monthly variations in frequency (%) of selected gastropod species along Adri coast.

were mostly observed in the middle littoral zone during the study period.

The temporal and spatial variability in species abundance in biological groups has been suggested due to interactions between biotic and abiotic variables (Danielson 1991). The studied coast has rocky intertidal region with small to large tide pools, rock crevices and tiny creeks, all of which may be suitable habitats for gastropod species (Raghunathan *et al.* 2004).

The most abundant species in the present study was *Onchidium verruculatum.* Onchidids are found across the globe, with the exception of the Arctic and Antarctic and mainly live in the upper intertidal zone in muddy, rocky and sandy habitats while only three species are known to live on land (Dayrat 2009). *O. verruculatum* distributed across all three zones of the intertidal area of studied coast. On wide-raised intertidal limestone platforms, they can also be found on limestone bluffs, located in the middle and higher littoral zone (Joshi 2010). It was observed individually or in cluster form during the study period with the density value ranged from 0.2 no/ 0.25 m² to 2.5 no/ 0.25 m² and abundance of 2.0 no/ 0.25 m² to 5.0 no/ 0.25 m² (Figs. 4–5). It hides in rock crevices or holes when the water is covering them. They don't occur in large groups like *O. floridanum* (Arey and Crozier 1921). Compared to all other species, it shows higher abundance, density and frequency with most abundant and dense during the month of January and least during the month of March. Its distribution patterns reflect clump distribution along the coast. When the tide is strong, *Onchidium* communities' groups of up to or more individuals take refuge in cracks in the eroded shore rock (Leslie *et al.* 1918). However, the low-frequency range indicates that the species distribution was not uniform throughout the coast (Fig. 6).

Neritidae is creatures that eat plants and the middle to the higher intertidal zone is typically where Neritidae lives and is known to congregate there (Tan and Clements 2008). It was primarily found in tiny puddles, rock platforms and crevices of upper intertidal zones. Its abundance and density declined in the mid and lower intertidal zones. The animals were mostly distributed at random distribution in areas with greater cover of green algae on the Veraval coast (Vaghela 2010).

Maximum density (0.1 no/0.25 m²) was reported in August, September, December, February and May, while minimum density (0.5 no/0.25 m²) was noted in January. Lowest abundance (1.0 no/0.25 m²) was found in August, September and February to July month and high abundance (1.6 no/0.25 m²) was reported in January month. (Figs. 4–5). When compared to density, abundance was high, showing the clump distribution. Frequency (7% to 10%) varied more or less between various months (Fig. 6), which indicates that species dispersion is not uniform.

Gyrenium natator is third key species reported commonly from the west coast of India (The Gulf of Cambay, Mumbai, Deogad) and east coast of India (Pamban, Madras, Adyar, Visakhapatnam and the Andaman and Nicobar Islands) (Mookherjee 1985). In the upper and middle intertidal zone of the central

Table 1. Correlation of key gastropods species density with abiotic parameters (Temperature, pH and Salinity).

	A. semicostatum	*C. caeruleum*	*G. natator*	*N. albicilla*	*O. verruculatum*	Tem (C˚)	pH	Salinity (ppt)
A. semicostatum	1							
C. caeruleum	0.821	1						
G. natator	0.807	0.821	1					
N. albicilla	0.491	0.583	0.672	1				
O. verruculatum	0.731	0.841	0.691	0.541	1			
Temperature (C˚)	-0.720	-0.673	-0.559	-0.395	-0.760	1		
pH	-0.095	-0.128	-0.056	-0.392	0.161	0.138	1	
Salinity (ppt)	0.408	0.333	0.237	0.028	0.710	-0.600	0.639	1

west coast of India, it is the most abundant and lived in the intertidal zone and are typically found under rocks and boulders (Vishwakiran *et al.* 2006). During the study period, *G. natator* was found in the upper and middle zone and rarely in lower zone of the study site. Abundance values were very high compared to its density, and as a result, the species distributed in clumps on the intertidal area. Minimum abundance (1.0 no/0.25 m^2) was recorded in the months of August, October, December, and March while its minimum density (0.1 no/0.25 m^2) was reported in the month of June (Figs. 4–5). The range of frequency (5% to 20%) of the *G. natator* species that has not existed in uniform showed more or less fluctuation during all months (Fig. 6).

The Cerithiidae is one of the 19 recognized families of the Cerithioidea and with 219 species officially accepted; it is one of the most varied families (Bouchet *et al.* 2017, Mollusca Base 2018). Distributions of rocky intertidal gastropods like cerithiids and littorinids frequently congregate (Chapman and Underwood 1996, Denadai *et al.* 2004, Moulton 1962, Rohde and Sandland 1975). In the present study *Cerithium caeruleum* is another key species with maximum density of 1.9 no/0.25 m^2 in January and a minimum density of 0.2 no/0.25 m^2 in August, February and March (Fig. 4). It was more abundant (3.8 no/0.25 m^2) in January than it was in August, October, and December, or in February, March and June (Fig. 5). The values of abundance were noted to be extremely high when compared to the density, which depicts the species distribution in clumps at the study site. In some cases, intertidal cerithiids do not congregate while feeding at high tide, cluster formation takes place right before low tide (Moulton 1962). The frequency range (5% to 20%) measured across different months indicate that the species has not been dispersed uniformly along the intertidal zone (Fig. 6). The distributions of cerithiid gastropods, which are frequently rather patchy are notably common on the rocky beaches of North and West India. This is true for large-scale distributions, where species densities per m^2 30 to 279 depending on the location and time of year (Thivakaran and Sawale 2016). The high, middle and lower intertidal zones of the intertidal area were mostly occupied by clusters of *C. caeruleum* species. The upper middle littoral

Table 2. Correlation of key gastropods species abundance with abiotic parameters (Temperature, pH and Salinity).

	A. semicostatum	*C. caeruleum*	*G. natator*	*N. albicilla*	*O. verruculatum*	Tem (C˚)	pH	Salinity (ppt)
A. semicostatum	1							
C. caeruleum	0.606	1						
G. natator	0.386	0.365	1					
N. albicilla	0.742	0.587	0.327	1				
O. verruculatum	0.611	0.638	0.197	0.558	1			
Temperature (C˚)	-0.839	-0.623	-0.334	-0.590	-0.609	1		
pH	-0.236	-0.169	-0.146	-0.001	-0.030	0.138	1	
Salinity (ppt)	0.744	0.309	-0.050	0.454	0.384	-0.600	0.639	1

Table 3. Correlation of key gastropods species frequency with abiotic parameters (Temperature, pH, and Salinity).

	A. semicostatum	*C. caeruleum*	*G. natator*	*N. albicilla*	*O. verruculatum*	Tem (C˚)	pH	Salinity (ppt)
A. semicostatum	1							
C. caeruleum	0.682	1						
G. natator	0.368	0	1					
N. albicilla	0.044	-0.189	0.152	1				
O. verruculatum	0.137	-0.017	-0.024	0.055	1			
Temperature (C˚)	-0.255	-0.006	-0.028	0.172	0.247	1		
pH	-0.050	0.379	0.144	-0.355	0.370	0.138	1	
Salinity (ppt)	0.126	0.401	-0.014	-0.505	-0.044	-0.600	0.639	1

zone and lower middle littoral zone of the intertidal substratum of the Dwarka coast are habitats for the dominant molluscan species *C. caeruleum* (Gohil and Kundu 2013). Cerithiids were typically seen in clusters in areas of around 0.1 m², where the majority of the individuals were in contact with one another (Jethwa *et al.* 2022).

Astralium is sometimes referred to as star snails or turban snail (Bouchet 2012) and most common species of upper intertidal zone worldwide. On intertidal reefs, size and abundance of turbinid gastropod vary along environmental gradients related to elevation (Worthington and Fairweather 1989, Bruton *et al.* 1991). As a result of competing for food and space with other species and being relatively abundant in the rocky intertidal zone, species are distributed most widely in the upper littoral zone, followed by the middle littoral zone (Dayton 1971, Underwood 1981). The middle and lower intertidal zones of the studied intertidal are occupied by *A. semicostatum* with highest density (0.9 no/0.25 m²) during January and lowest density (0.1 no/0.25 m²) in March (Fig. 4). The abundance values decreased during the months of March, April, June, and July (Fig. 5). The frequency range (5% to 10%) indicates that species is not uniformly distributed (Fig. 6).

Table 4. Results of the one-way ANOVA for various ecological attribute at the sampling site. 4.30095 is the f-critical value, while * indicates significance at P < 5.

	Density	Abundance	Frequency
Astralium semicostatum	27.93*	13.68*	45.42*
Cerithium caeruleum	13.45*	7.69*	5.59*
Gyrenium natator	16.66*	6.21*	23.45*
Nerita albicilla	22.93*	6.55*	152.67*
Onchidium verruculatum	29.20*	17.93*	0.072

Correlation of key gastropods and physico-chemical parameters

The correlation analysis was represented to illustrate the interrelationship between the physico-chemical parameter and population attributes of key gastropod species. The correlation of different intertidal organisms with physico-chemical parameters provides information on the influencing capacity of abiotic factors on biological life. Significant monthly variations among gastropod species on the *Adri* coast was observed. Few physico-chemical parameters significantly impacted these gastropod species based on correlation analysis. The statistical analysis shows that correlations were entrenched between abiotic parameters *Astralium semicostatum*, *Cerithium caeruleum, Gyrenium natator, Nerita albicilla* and *Onchidium verruculatum* were negatively correlated with temperature and pH. A positive correlation was observed between studied gastropod species with salinity that indicates species herein can best survive in the reported range of salinity. Salinity has direct positive effect on the distribution and density, abundance and frequency of intertidal gastropod species (Tables 1–3). While a negative correlation was observed between temperature and pH which shows a moderate effect on the distribution pattern and diversity attributes. The community of gastropods can survive better at optimal concentrations. A negative correlation between temperature and pH was found, indicating that the distribution and abundance of intertidal gastropod species are directly impacted

by changes in the overall temperature (Vandarwala *et al.* 2020).

The density, abundance and frequency measured herein tested for its significant values using a one-factor ANOVA (Table 4). Frequency of *O. verruculatum* was not statistically significant that indicates its uniform distribution in all the three zones. The results show that the substratum structure and seasonal variation have a substantial impact. *Nerita albicilla* shows greater significant values that proves it as prime key species amongst all five. However, results of ANOVA depict that all key species has its own microsites combinations on the substratum including zones, pools, crevices and algal cover, which influence how these communities are distributed throughout the intertidal zones.

CONCLUSION

The present study focused on distribution of key gastropod species along the rocky intertidal zone of Adri coast of Kathiawar Peninsula, Gujarat. The selected coast was not thoroughly investigated earlier for species diversity and ecological studies. Both rocky and sandy substratum of intertidal zone along the coast offers favorable habitats for rich macrofauna and flora. The key gastropods have made the highest contribution compared to other species in studied coast. This indicates that the microscale habitat and conditions are suitable for maintaining the gastropod species in stable condition throughout seasons.

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