International Journal of Ecology and Environmental Sciences 42(4): 341-348, 2016
ISSN: 2320-5199 (Online);   (Print)

Spatio-temporal Variations in the Distribution Pattern of Key Molluscs in a Rocky Intertidal Habitat Along South Saurashtra Coastline of Gujarat

[1] Bhavik Vakani,[2] Paresh Poriya and [3] Rahul Kundu*

[1, 3]Department of Biosciences, Saurashtra University, Rajkot 360 005, Gujarat, India
[2] Department of Lifesciences, M.K. Bhavnagar University, Bhavnagar 364002, Gujarat, India
E-mail: [1]-bhavik.vakani@gmail.com, [2]-pareshporiya@gmail.com, [3]-rskundu@sauuni.ernet.in
* Corresponding author

ABSTRACT

We studied the distribution and population ecology of seven gastropod molluscs in the intertidal areas of Veraval coast off Arabian Sea, Gujarat, India. About three km long rocky intertidal at Veraval was divided into two sampling sites. A total of 38 molluscan species belonging to four different classes, including two species of Bivalvia, one species of Cephalopoda, 32 species of Gastropoda and one species of Polyplacophora were recorded. Seven dominant gastropod species were studied for their spatio-temporal distribution. *Cellana karachiensis* was dominant in the spray zone, *Siphonaria* sp. and *Cerithium scabridum* dominated the upper zone while middle and lower zones were dominated by *Turbo coronatus* and *Onchidium verruculatum* respectively. Significant spatio-temporal variations in the population were observed at both the sites. Population abundance and frequency were high in the upper littoral but low in the lower littoral zone during the study period.

Key Words: Assemblage; Intertidal Zone; Gastropods; Population Dynamics; Rocky Shore; Saurashtra Coast; Vertical Zones

INTRODUCTION

Intertidal ecosystems have high variability of biological structure which is reflected in the variety and peculiarities of their diversity and functioning (Malli et al. 1982). The benthic communities can be used as bio-indicator of environmental coastal ecosystems (Underwood 2002). Intertidal habitats are normally complete with many assemblages and different parameters of population dynamics help to understand the distribution pattern of various constituent groups or species in the littoral zones (Underwood and Chapman 1996). In any ecological study, environmental factors are vitally important because these factors significantly affect the particular biomes (Connell 1983). The environmental conditions of the intertidal zones are continuously changing with tidal current determining the geographical distribution of the fauna (Prasad and Mansuri 1982). Intertidal rocky shores are heterogeneous environment supporting variable assemblage of sessile and mobile organisms which can be found along the shoreline throughout the world (Underwood 2002). These organisms are distributed in a particular way, occurring with the strong vertical pattern or zonation which is strongly influenced by tidal and wave actions (Little et al. 2009). Availability of food and impact of different physical, environmental and biological factors on the distribution and habitat preference of gastropod molluscs have been described earlier (Faladu et al. 2014). Quinno (1988) reported that the growth and biomass of individual gastropod species often decline when the population densities are high. This reduced growth and biomass are most likely from a change in the pattern of survival, rate of reproduction or migration. The population density has been described as one of the factors controlling the growth and biomass in gastropod snails (Prasad 1984, Patel 1984). It is reported that the competition for limited resources, like space and food, influences the structure of rocky shore communities and is thereby responsible for the modification in the dynamics of some littoral populations (Connell 1983).

Human activities in the coastal area are a matter of concern as they cause rapid deterioration in the marine ecosystems and resources in many parts of the world. The development of industries in coastal areas and pollution created by these coastal industries are a major problem these days (Misra and Kundu 2005). Rapid industrialization and consequent pollution on the Saurashtra coastline has resulted into deterioration of the intertidal macrofaunal community influencing their ecological attributes with respect to varying environmental conditions (Faladu et al. 2014). Different species of intertidal macrofauna in the littoral areas of the Veraval coast are in association with one another in various ways. For example, several intertidal macrofaunal groups use algal community as shelter to avoid predators. In a rocky shoreline, the intertidal area harbours different groups of animals in small to large patches. This format of the inhabited animal or plant community helps them in better survival against environmental stresses like wave action, emergence of the littoral area, fishing etc. Most of the studies of the area were aimed to identify and evaluate the ecological status of the constituent species, while few studies aimed to understand the assemblage structure of the particular area (Vakani et al. 2014). Samantaray (1979) has reported the role of reproduction in the population of *C. radiata* at Veraval coast. Prasad and Mansuri (1982) reported the anthropogenic influence on the density of *C. radiata* at Porbandar, West coast of India. Appukuttan (1977) documented the fishery of *Trochus* and *Turbo* in the form of shell and meat resources. In India *Turbo* fishery at Andaman and Nicobar has been described by Rao (1939). Sarvaiya (1977) described the distribution of two Turbinids, *T. intercostalis* and *T.coronatus* at Okha and nearby islands. Kawalramani and Kadri (1972) reported the economic importance of *Turbo* sp. from Saurashtra coast in food and craft industry. However, except for few studies on certain limpets (Prasad 1984), Turbinids (Malli 1982) and Cerithids (Patel 1984), no report is available on the macrofaunal resources of this region (Misra and Kundu 2005). Therefore, the present report was aimed at the study of distribution pattern and population ecology of a few gastropod molluscs in the intertidal areas of Veraval coast off Arabian Sea, Gujarat, India.

MATERIALS AND METHODS

Present study was conducted at Veraval (20° 54' N and 70° 22' E) on the north-western coast of India (Figure 1) from September 2012 to March 2013. The rocky-sandy coastline of Veraval is about 5 km long which was divided into two sampling sites, Site - 1 (Light House) and Site - 2 (Jaleshwar Reef). These two sites were distinctly different in terms of their coast characteristics. Site -1 has flat and continuous substratum with less pools and puddles whereas the substratum of Site -2 is uneven with more and large pools and puddles. The tidal amplitude were 65 ± 5 cm in the post-monsoon, 75 ± 5 cm in winter and 80 ± 5 cm in the summer season.

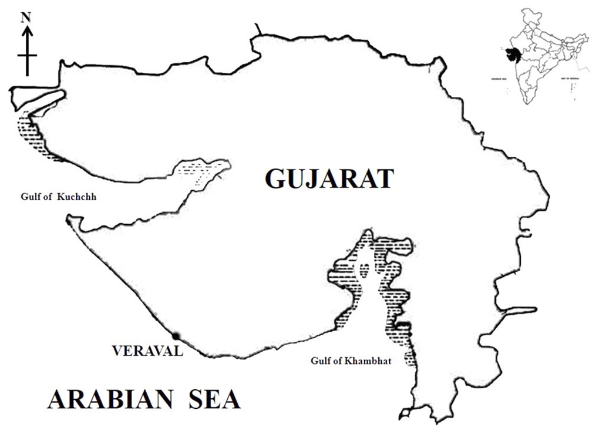

Figure 1. Map showing the location of study sites along the South Saurashtra coastline off Arabian Sea.

During the study, samples were collected along transects across the vertical zones of the intertidal area, for measuring the structural attributes of the intertidal molluscs. Quadrats (50 cm x 50 cm) were laid randomly at every 3 m interval along the transect (Misra 1968). Transect was laid from spray zone to lower littoral zone to cover the entire intertidal area. In each zone of a sampling site, a minimum of ten quadrats were laid once every month. The number of all gastropod molluscs in a quadrat was counted. The data was statistically analysed for their cumulative acceptability. Significance of spatial and temporal variations was compared by using single factor ANOVA. All statistical analyses were done as per Sokal and Rohlf (1987).

RESULTS AND DISCUSSION

We observed that mollusca was the dominant group among all other macrofaunal groups at both the sampling sites. A total of 38 species belonging to four different classes were recorded from the four vertical zones (Table 1). Out of these, seven molluscan species were selected for the population ecological studies (Figure 2), on the basis of their occurrence throughout the year and being a non-migrant species (Vaghela 2010, Vakani 2013).

Figure 2. The two sampling sites and their seven prominent species

Table 1. Molluscan Species diversity of Veraval coast off Arabian Sea at both sampling sites. Species names are updated as per WoRMS (Nov. 2016).

Species	Site 1	Site 2
Aplysia oculifera (A. Adams & Reeve, 1850)	+	+
Astralium semicostatum (Kiener, 1850)	+	+
Bursa granularis (Röding, 1798)	-	+
Cellana karachiensis (Winckworth, 1930)	+	+
*Cerithium morus (*Bruguière, 1792)	+	+
Cerithium columna (Sowerby I, 1834)	+	+
Cerithium scabridum (Philippi, 1848)	+	+
Chiton peregrinus (Thiele, 1909)	+	+
Clanculus ceylonicus (G. & H. Nevill, 1869)	+	+
Conus cumingii (Reeve, 1848)	-	+
Conus figulinus (Linnaeus, 1758)	-	+
Orania subnodulosab (Melvill, 1893)	-	+
Cypraea (Mauritia) grayana (Schilder, 1930)	+	+
Cypraea (Lyncina) lynx (Linnaeus, 1758)	+	+
Cypraea (Mauritia) maculifera (Schilder, 1932)	-	+
Cypraea (Erosaria) ocellata (Linnaeus, 1758)	-	+
Cypraea (Talparia) talpa (Linnaeus, 1758)	-	+
Drupe (Ergalatax) heptagonalis (Reeve, 1846)	-	+
Echinolittorina malaccana (Philippi, 1847)	+	+
Gibbula sp. (Risso, 1826)	+	+
Mitra guttata (Swainson, 1824)	-	+
Mitra scutulata (Gmelin, 1791)	+	+
Murex (Chicoreus) brunneus (Link, 1807)	+	+
Murex ternispina (Lamarck, 1822	-	+
Neocancilla antoniae (H. Adams, 1870)	+	+
Nerita albicilla (Linnaeus, 1758)	+	+
Octopus vulgaris (Cuvier, 1797)	-	+
Onchidium (Peronia) verruculata (Cuvier, 1830)	+	+
Ostrea sp. (Linnaeus, 1758)	+	+
Planaxis sulcatus (Born, 1778)	+	+
Purpura panama (Röding, 1798)	+	+
Pyrene sp. (Röding, 1798)	-	+
Siphonaria sp. (G. B. Sowerby I, 1823)	+	+
Sunetta scripta (Linnaeus, 1758)	+	+
Tibia insulaechorab (Röding, 1798)	-	+
Turbo bruneus (Röding, 1798)	+	+
Turbo intercostalis (Menke, 1846)	+	+
Turbo (Lunella) coronata (Gmelin, 1791)	+	+
Total	25	38

Spray zone

The spray zone is the uppermost area of the intertidal reached by the sea only during highest of the high tides, usually associated with gale or during monsoon season. Limpets and barnacles were usually found on the lower end of this zone. Among the selected seven species, most thrived and sturdy species was *Echinolittorina malaccana*. *E. malaccana* was most abundant during the transition period between winter and summer (February-March) and post-monsoon period (Figures 3a and 4a). *E. malaccana* showed different distribution ranges and displayed clear patterns of vertical distribution which are possibly their adaptations to adjust in different thermal regimes available in the spray zone (Faladu et al. 2014). Williams and Reid (2004) and Reid (2007) have reported that *E. pascua* that inhabits the littoral fringe of the upper littoral zone on the artificial seawalls at Pantai Tungku coastal area in Darussalam, Brunei, can aestivate for more than 60 days (Marshall et al. 2010). At Veraval, *E. malaccana* were mostly observed in a clumped distribution on the open rock or in the shaded spots including crevices, pits, or in the shaded and humid microhabitats in upper fringe of the spray zone. Interestingly, a limpet, *Cellana karachiensis* was found to be another dominant species of the spray zone.

However, the abundance and frequency values of this species were less compared to *E. malaccna* possibly due to the fact that this limpet species was present in patches in the entire intertidal area. The clustering habit is a homoeostatic adaptive mechanism of certain gastropods in tropical waters, to avoid desiccation and adhesion to preferable substratum (Fischer 1966). *Chiton peregrinus* was another species reported from both the sites during winter months. Similarly, *Lunella coronata* and *Cerithium scabridium* were recorded only in the transitional period between post-monsoon and winter season. However, these three species were observed in the rocky pools which were formed in areas where the upper littoral zone has overlapped into a portion of the spray zone. In this habitat, *C. karachiensis* was observed in large numbers during post monsoonseason at both the sites. In case of *Siphonaria* sp., population abundance showed an increasing trend at both the sites in winter followed by decreasing trend in summer (Figure 3a). *Peronia verruculata* was totally absent in this zone at both the sites. No significant spatio-temporal difference in the population abundance was observed between the sampling sites (Table 2). *C. karachiensis*, showed higher population frequency (60% to 100%), than *Siphonaria* sp. (25% to 60%). The other five species showed moderate to low frequency levels (25 to 33.33%). The observed results clearly indicated that *C. karachiensis* dominated the spray zone since this species is highly tolerant to the harsh environment conditions like high temperature, desiccation, salinity changes and splashing wave action than the other limpet species *Siphonaria* sp. (Vakani et al. 2014). *Siphonaria* sp. rather inhabits wetter areas with more algal growth which helps species to settle themselves on the substratum (Eaton 1968,Cook and Cook 1978) (Figure 4a).

Upper Littoral Zone:

The inhabitants of upper littoral zone, which is flooded with water only during high tide, are also sturdy individuals tolerating harsh environmental conditions. This zone was populated with limpets *Siphonaria* sp. followed by *C. karachiensis*. However, *E. malaccana*, which was the dominant species of the spray zone, was observed only during winter season at the upper littoral zone. Significantly high abundance of these species were

Table 2. Results of the one way ANOVA for the spatial and temporal variations in the abundance and frequency of the species studied in each of the littoral zone of the two sampling sites. Species names are updated as per WoRMS (Nov. 2016).

Species	Abundance				Frequency			
	Spray	Upper	Middle	Lower	Spray	Upper	Middle	Lower
Spatial Variation (f-critical : 4.7472)								
Echinolittorina malaccana	0.0086	0.0895	-	-	3.502	0.0054	-	-
Chiton peregrinus	0.0945	1.2762	0.0023	1.7778	7.7279*	2.6457	2.2757	2.2727
Onchidium (Peronia) verruculata	-	1.3913	1.6053	2.5	-	1.5957	0.4502	0.3015
Turbo (Lunella) coronata	1.0338	-	0.0061	0.0198	0.1827	1.2395	1.218	1.9919
Cerithium scabridum	0.7126	0.0087	2.1192	2.4	0.3462	1.3892	1.5503	2.2997
Cellana karachiensis	0.0148	0.1923	0.5927	1	0.1636	3.4046	0.4967	1
Siphonaia sp.	0.4918	0.0008	1.9687	4.1013	0.03	0.0002	0.1832	3.5397
Temporal Variation (f-critical : 3.866)								
Echinolittorina malaccana	0.9588	30.128*	-	-	1.2899	82.128*	-	-
Chiton peregrinus	0.5162	0.332	3.6294	0.9	0.3141	1.0953	0.6637	0.8462
Onchidium (Peronia) verruculata	-	0.7346	0.7675	1.0303	-	0.344	1.4015	2.0266
Turbo (Lunella) coronata	2.5265	0.4581	0.6575	1.0326	16.279*	1.7342	0.6243	1.1264
Cerithium scabridum	0.5414	3.5063	0.7359	0.8333	0.3619	1.3744	2.6707	0.8434
Cellana karachiensis	2.4725	1.0947	0.9237	1	1.9023	0.4729	0.6725	1
Siphonaia sp.	1.033	1.6912	1.6224	0.693	1.4138	15.061*	25.721*	0.7338

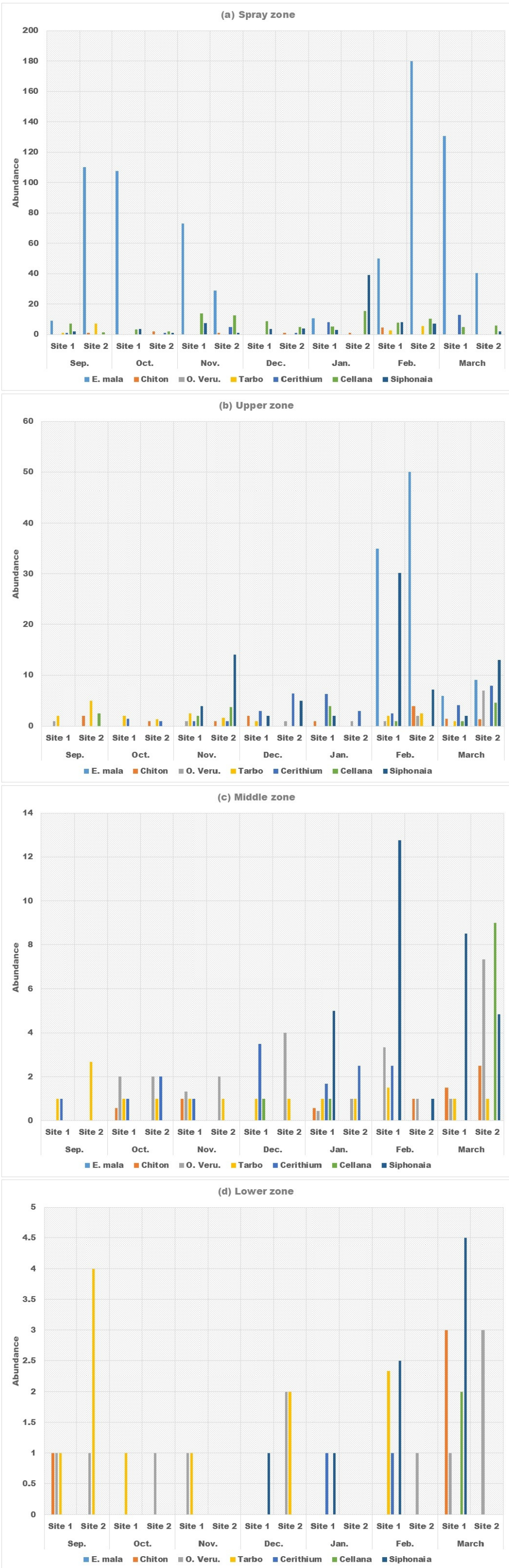

Figure 3. Spatio-temporal variation in abundance of selected molluscan species in vertical zones (a-d).

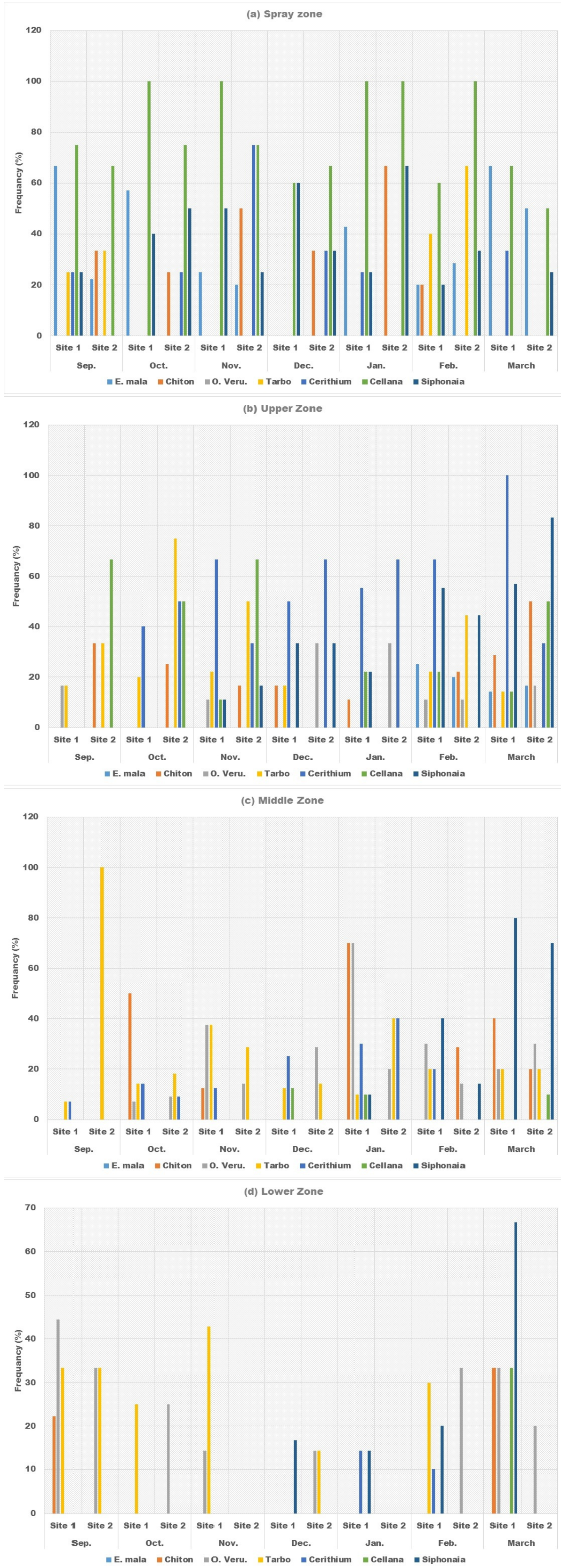

Figure 4. Spatio-temporal variation in frequency of selected molluscan species in vertical zones (a-d).

observed during winter season. Breaking waves create enormous force to shore surface and transmit destructive impact on inhabitants of this zone. Therefore, the surface inhabitants like limpets have great power of adhesion to resist dislodgement (Newell 1970). Further, animals that survive in this zone must overcome the problems of competition for space and food. Irregular pattern of population abundance was observed in *Chiton peregrinus* and *P. verruculata* at both the sampling sites (Figure 3b). Abundance value of *Lunella coronata* decreased in post-monsoon and winter seasons, whereas *Cerithium scabridium* showed high abundance compared to other species. It was observed that most Siphonarians grazed on thin film of microalgae that grows on rocks and this kind of feeding habit may also influence their distribution in particular littoral zone (Creese 1980).This variation in habitat and environment factors may be responsible for the distribution pattern of the inhabiting gastropod molluscs as the site 2 is more interrupted and having more pools and puddles than site 1 (Vakani et al. 2014). It has also been reported that fewer sharp edges and inclines create tough circumstances to survive (Branch 1981). Only those animals can survive which have the capacity to tolerate high desiccation, fluctuation in salinity and temperature (Branch 1981, Vakani et al. 2014). On the other hand, the irregular frequency of *C.peregrinus* and *P. verruculata* was observed during winter at site 2. *L. coronata* was sparsely seen at the edge of the spray and upper littoral zones at most of the time but found abundantly during post monsoon season. *Cerithium scabridium* was the dominant species in upper littoral zone followed by*C. karchiensis* and *Siphoneria.* sp., was found more in Site 1 with higher frequency compared to rest of the species (Figure 4b).

Middle Littoral Zone

The middle littoral zone is less exposed than the spray or upper littoral zones. In the present study most of the species observed in the middle littoral zone showed low abundance values. In this zone, *L. coronata* and *C. scabridium* was found throughout the year at both the sites while *P. verruculata*was more abundant in the winter may be due to the characteristics of middle littoral zone, which harbours more diverse animal groups and complex animal-algal communities (Faladu et al. 2014). *Siphonaria* sp. and *Chiton peregrinus* were rarely observed in the middle zone while L.*coronate,*closely followed by *P. verruculata* and *C. scabridium* were the most abundant molluscan species of this zone with frequency values ranging from 7% to 40% (Figure 3c). Interestingly, most of the limpet species like *Chiton peregrinus,* C. *karachiensis* and *Siphonaria* sp. were present in this littoral zone in moderate frequency only during the winter season (Figure 3c). This may be due to the fact that these animals usually move to the place where the temperature and tidal force are less (Creese 1980, Branch 1981).

Lower Littoral Zone

The lower intertidal zone totally emerges during the lowest tide. In this zone, moderate population abundance of *Chiton peregrinus* was reported during post-monsoon and winter months. Most of the species like *Cerithium scabridum* and *C. karachiensis* were observed with very low abundance value during the last month of winter and the beginning of summer season. *T. coronatus* was observed with less abundance throughout the study period. *Siphonaria* sp. and *P. verruculata* were also observed with very low abundance while *Chiton peregrinus, C. scabridum* and *C. karachiensis* exhibited low frequency during the summer season. In this zone, the frequency of *P.verruculata* and *Siphonaria* sp. was low and was observed less in winter and summer, while *E. malaccana* was totally absent in this zone (Figure 3d). Though the lower littoral zone is always flooded with water, it encounters continuous wave action. It also has a number of algal communities covering most of the available space of this littoral zone, leaving very little space for inhabiting animals to attach themselves with the exposed rocks (Faladu et al. 2014).

It was observed that most of the molluscan species exhibited cluster formation in the spray and upper littoral zones, a phenomenon rarely seen in the middle and lower littoral zones. It was reported earlier that the clustering habit is a homoeostatic adaptive mechanism of certain gastropods in tropical waters, to avoid the desiccation which was observed in spray and upper littoral zone (Branch 1981). Fisher (1966) gave an idea that adhesion to preferable substratum by the snails may also be a factor in the clustering behaviour. Many intertidal limpets and littorinid gastropods exhibit homing behaviour after grazing and restrict movements during the exposure to avoid water loss and subsequent desiccation. Faladu et al. (2014) observed that these animals perform this action typically just before emersion in the low tide and thus, can survive harsh and difficult condition facing at upper and spray zone during the exposure. Clustering or aggregation behaviour have also been useful to thrive environmental conditions like temperature, salinity and desiccation. Patel (1984) studied the locomotion rates and shell forms in various gastropods and classified them in various groups with slow or fast movement in relation to tidal rhythm. It is generally recognized that competition for limited resources of space and food is a widespread feature influencing the structure of rocky shore community (Gohil and Kundu 2013a,b). In the present study, therefore, *Chiton peregrinus* was found inhabiting from spray zone to the lower littoral zone of the intertidal, but preferred the upper littoral zone where its frequency and abundance were high (Hyman 1967). Food in the form of algae, more space for settlement on the rocks and low tearing wave action in the middle and upper littoral zones are suitable for this kind of species (Slieker 2000, Eernisse et al. 2007). Similar observations were reported on the *Chiton* assemblages of the Mexican Pacific coast (Keen 1971, Ferreira 1983, Reyes-Gómez 2004). On the other hand, the distribution of family Certhiidae is widespread ranging from western to southern Indian Ocean (Gohil and Kundu 2011). In the present investigation, *Cerithium scabridium* was observed in all the intertidal zones but dominated in the upper and middle littoral zones. This is possibly due to the availability of major source of food like planktonic larvae (Vaghela et al. 2010) and abundant algal community as shelter (Gohil and Kundu 2013a,b). *P. verruculata* showed the typical habitat preference by conspicuous absence from the lower littoral zone. This species, being a voracious grazer on algae, showed greater density and abundance in middle littoral and lower part of the upper littoral zone during post-monsoon and winter seasons. The present study clearly indicates that the upper and middle littoral zones are the preferred habitats of many species. The intertidal zone of Veraval is mostly flat with some pools and puddles with abundent vegetation on which these species can feed (Mishra and Kundu 2005). The statistical analyses showed no significant temporal variations (Table 2) which may be due to the movement of the animals to the deeper regions to avoid exposure to temperature and desiccation. This trend was reflected by the reduced density and abundance during the summer months. *C. karachiensis* showed habitat preference mostly in the pools and puddles of the upper littoral zone during the low tide and feeds on the encrusting algae on rocks. The abundance and frequency values of *C. karachiensis* were higher in the spray and upper zones (Figure 4).

ACKNOWLEDGEMENTS

This paper was presented at the International Conference on Tropical Ecosystems in a Changing World, organized by the International Society for Tropical Ecology, during 10 -12 December 2014 at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi. We are thankful to the University Grants Commission (UGC), Govt. of India, New Delhi, for supporting this study through its Centre of Advanced Studies (CAS, Phase-I) programme. UGC is also thankfully acknowledged for a BSR-Research Fellowship awarded to BV and PP. Various Govt. and non-Govt. organizations of the Gujarat State are thankfully acknowledged for their help during the coastal surveys.

REFERENCES

Appukuttan, K.K.1977. *Trochus* and *Turbo* fishery in Andamans. Seafood Export Journal 9 (12): 21-25.

Branch, G.M. 1981. The biology of limpet. Oceanography and Marine Biology: An Annual Review 19: 235-380.

Connell, J.H.1983. On the prevalence and relative importance of inter specific competition, evidence from field experiments. American Naturalist 12: 661-696.

Cook, S.B. and Cook, C.B. 1978. Tidal amplitude and activity in the pulmonate limpets *Siphonaria normalis* (Gould) and *S. alternata* (Say). Journal of Experimental Marine Biology and Ecology35: 119-136

Creese, R.G. 1980. An analysis of distribution and abundance of populations of the high-shore limpet, *Notoacmea petterdi* (Tenisonwoods). Oecologia (Berlin) 45: 252-260.

Eaton, C.M. 1968. The activity and food of the file limpet *Acmaea limatula*. Veliger, Supplement 11: 5-12.

Eernisse, D.J.; Clark, R.N. and Draeger, A. 2007. *Polyplacophora.* Pages 701-713, In: Carlton, J.T. (Editor). Light and Smith Manual: Intertidal Invertebrates from Central California to Oregon. 4th edition. University of California Press, Berkeley.

Faladu, J., Vakani, B.; Poriya, P. and Kundu, P. 2014. Habitat preference and population ecology of limpets *Cellana karachiensis* (Winckworth) and *Siphonaria siphonaria* (Sowerby) at Veraval coast of Kathiawar Peninsula, India. Journal of Ecosystem Article ID 874013, 6 pages, DOI: 10.1155/2014/874013.

Ferreira, J.A. 1983. The genus *Chaetopleura* Shuttleworth, 1853 in the warm temperate and tropical Eastern Pacific, Southern California to Peru, with the description of two new species. Veliger 25: 203-224.

Fischer, P.1966. Disposition gregaire chez um *Cerithium* Indo-Pacifique. Journal de Conchyliologie, Paris 105: 49-52.

Gohil, B. and Kundu, R.2011. Ecological status of *Rhinoclavis sinensis* at Dwarka Coast, Gujarat (India). The Ecoscan.5 (3 & 4): 131-134.

Gohil, B. and Kundu, R. 2013a. Ecological status of *Cerethium caeruleum* at Dwarka coast, Gujarat (India). Indian Journal of Geo-MarineScience 42(4): 481-486.

Gohil, B. and Kundu, R. 2013b. Ecological status of *Cellana radiata* at Dwarka Coast, Gujarat, India. Research Journal of Recent Sciences 2(5): 1-5.

Hyman, L.H. 1967. Mollusca. I. The Invertebrates 4: 1-792.

Kawalramani, K.M. and Kadri, E.S.1972. Shell fisheries of India. Seafood Export Journal 4(12): 1-9.

Keen, M.A. 1971. Sea shells of Tropical West America. Marine Mollusks from Baja California to Peru. Stanford University Press, Stanford, USA. 1065 pages.

Little, C.; Williams, G.A. and Trowbridge, C.D. 2009. The Biology of Rock Shores. Oxford University Press, New York. 356 pages.

Malli, P.C.; Prasad, M.N. and Mansuri,A.P. 1982. The response of the limpets *Cellana radiata* (Born) and *Siphonaria siphonaria* (Sowerby) of Saurashtra coast to desiccation and waters of different salinity. Journal of Animal Morphology and Physicology 29 (1-2): 71-77.

Misra, R. 1968. Ecology Work Book. Oxford and IBH Publishing, Calcutta. 242 pages.

Misra, S. and Kundu, R. 2005. Seasonal variations in population dynamics of key intertidal molluscs at two contrasting locations. Aquatic Ecology 39: 315-324.

Newell, R.C. 1970. Biology of Intertidal Animals. Elek Books, London. 555 pages.

Patel, A.N.1984. Ecological Studies on Two Cerithiid Gastropods, *Cerrithium caerulum* (Sowerby) and *Clypeomorus monoliferus* (Miener) from Saurashtra Coasts, India, Ph.D. Thesis, Saurashtra University, India. 184 pages.

Prasad, M.N. and Mansuri, A.P. 1982. Population density of the Limpet, *Cellana radiata* (Born) in polluted waters at Porbandar, West coast of India. Indian Journal of GeoMarine Science11: 180-181.

Prasad, M.N.1984. Ecological Studies on Two Limpets *Cellana radiata* (Born) and *Siphonaria siphonaria* (Sowerby) from Saurashtra Coast, India. Ph.D. Thesis, Saurashtra University, Rajkot, India. 305 pages.

Quinno, G.P. 1988. Ecology of the intertidal pulmonate limpet *Siphonaria dimenensis* Quoy et Gaimard. I. Population dynamics and availability of food. Journal of Experimental Marine Biology and Ecology 117: 115-136.

Rao, H.S. 1939. Consolidated Report on the Shell Fisheries in Andaman During the Year 1930-35. Zoological Survey of India, Calcutta. 130 pages.

Reid, D.G. 2007. The Genus *Echinolittorina* Habe, 1965 (Gastropoda: Littorinidae) in the Indo-West Pacific Ocean. Zootaxa 1420: 1-161.

Reyes-Gómez, A. 2004. *Chitons* in Mexican waters. Bollettino Malacologico 5: 69-82.

Samantaray, K.C. 1979. Edible Limpet *Cellana radita* (Born) (Mollusca: Patellidae) at Veraval Coast of Saurashtra. M. Sc. Dissertation, Saurashtra University, Rajkot, India.

Sarvaiya, R.T. 1977. Studies on Mollusca of Saurashtra Coasts-l. Fish Technology 1: 27-32.

Slieker, F.J.A. 2000. *Chitons* of the World: An Illustrated Synopsis of Recent Polyplacophora. L'Informatore piceno, Ancona, Italy. 154 pages.

Sokal, R.R. and Rohlf, F.J. 1987. Introduction to Biostatistics., Dover Publications.San Francisco. 260 pages.

Underwood, A.J. 2000. Experimental ecology of rocky intertidal habitats: what are we learning? Journal of Experimental Marine Biology and Ecology 250: 51-76.

Underwood, A.J. and Chapman, M.G. 1996. Scales of spatial patterns of distribution of intertidal invertebrates. Oecologia 107: 212-224.

Vaghela, A., 2010, Spatial and Temporal Variations in Population Dynamics of Few Key Rocky Intertidal Macrofauna at Anthropogenically Influenced Intertidal Shoreline. Ph.D. thesis, Saurashtra University, Rajkot.

Vakani, B., 2013. Study on the Structure of a Rocky-Muddy Intertidal Assemblage. M. Phil. Thesis, Saurashtra University, Rajkot.

Vaghela, A.; Bhadja, P.; Ramoliya, I.; Patel, N. and Kundu, R. 2010. Seasonal variations in the water quality, diversity and population ecology of intertidal macrofauna at an industrially influenced coast. Water Science and Technology 61(6): 1505-1514.

Vakani, B., Poriya, P. and Kundu, R. 2014. Spatio-temporal variations in the population ecology of two limpets in a rocky intertidal shore of South Saurashtra coast (Gujarat: India). The Ecoscan 8(1&2): 71-75.

Williams, S.T. and Reid, D.G. 2004. Speciation and diversity on tropical rocky shores: A global phylogeny of snails of the Genus *Echinolittorina*. Evolution 58: 2227-2251.

Received 1 May 2016;
Accepted 19 November 2016