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Correlation of limpet diversity with physico-chemical parameter at three different habitats along Saurashtra coast of Gujarat, India

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Abstract
The present study attempts to understand the correlation of ecological attribute (population density, abundance and frequency) of four limpet species *viz.*, *Cellana karachiensis* (Winckworth, 1930), *Siphonaria sp.*, *Scutus unguis* (Linnaeus, 1758) and *Diodora sp.* with physico-chemical characteristic at three different coastal habitats of Saurashtra *i.e.*, Veraval, Okha and Sikka. The samples collected through random quadrant method and mean values were taken to evaluate the density, abundance and frequency of limpet species. The various physico-chemical parameters *viz.*, temperature, salinity, pH and dissolved oxygen were analyzed. The highest density and abundance of limpet species were recorded during post-monsoon and winter months at all sampling sites. This may be because of migration of animals to avoid an influx of freshwater during monsoon and high temperature during summer months. The value of physico-chemical parameters shows a slight positive correlation with the density and abundance, while a strong positive correlation with frequency of limpet species. The present study confirmed that the environmental parameters cause subsidiary effects on population structure and distribution of limpets on the intertidal regime.

Keywords: Limpets, abundance, density, physico-chemical parameters, correlation

Introduction
The coastal environment is highly complex, productive, variable in space and time compared with the open-sea (Misra and Kundu, 2005; Pandit and Fulekar, 2017) [15, 16]. The fluctuations in environmental parameters associated with tide create the intertidal zone most vulnerable and extreme than any environment, because of this reason intertidal organisms encounter more rapid fluctuations in degree of physico-chemical factors (Dave and Chudasama, 2018; Rao and Ganpati, 1971) [4, 20]. The organisms inhabit different vertical heights on rocky shores according to their thermal niches, which set by tolerance limit of abiotic factors (Prusina *et al.*, 2014) [18]. Among the rocky intertidal inhabitants, one of the most prominent and successful groups are the limpets (Balamani, 1996) [1]. Since limpets are important part of rocky coast, most studies have been focused on the factors responsible to influence the seasonal changes on limpet population structure, which will be a beneficial indicator of threats to this species diversity (Branch, 1985; Khouw, 2006; Vaghela *et al.*, 2010) [3, 11, 29].
On the rocky coast, the temperature is a responsible factor in the vertical and horizontal distribution of intertidal animals has been studied by many researchers (Vermeij, 1971) [32]. Limpet growth and survival are completely depending on various physico-chemical stress, in which mainly temperature, desiccation shows more effect on the distribution of organisms (Balamani, 1996) [1]. According to Sukumaran and Krishnaswamy (1961) [26], *Cellana radiata* (Born) splashes seawater by raising its shell from the position in tight closure, which enables the animals to feed even during low tide. Hence, it is convenient to study the relationship between limpet distribution and environmental factors. The changes in composition, abundance and distribution of macrobenthos over a time provide an index of the ecosystem (Garg *et al.*, 2009) [7]. The basic aim of this work was to monitor the role of the physio-chemical parameters on population structure of four limpet species *viz.*, *Cellana karachiensis* (Winckworth, 1930), *Siphonaria sp.*, *Scutus unguis* (Linnaeus, 1758) and *Diodora sp.* at three different coastal habitats.

Materials and Methods

The present work carried out at three various coastal habitats *viz.*, Veraval (20^{0}54′ 35.31″N, 70^{0}21′7.72″E), Okha (22^{0}28′44.49″ N, 69^{0}4’43.81″E) and Sikka coast (22^{0}27′24″N, 69^{0}4′26″E) (fig.1) namely site-1, site-2, and site-3 respectively along the Saurashtra coast of Gujarat, India during September 2017 to April 2018. The randomly quadrant method was used to study the ecological attribute of limpet species in the intertidal zone. The quadrant of 1 m^2 size was placed at an interval to cover the maximum area of the intertidal zone during low tide. The limpet species samples were collected by handpicking and preserved in 5% formalin for further analysis. The physico-chemical parameter (temperature, salinity, pH and DO) were also taken to access the influence of abiotic factors on the population density, abundance and distribution of limpet species. The surface seawater temperature measured with mercury thermometer and seawater pH measured with pH meter on site. Salinity was estimated by Hand refractometer. Dissolved oxygen was determined by Winkler’s method (Trivedi & Goel, 1986) [28]. The collected data were analyzed by using Standard Deviation and Arithmetic Mean to come to a variable conclusion (Snedecor and Cochran, 1967) [25]. IBM: SPSS v.20 statistical packages were used to obtain Pearson’s correlation and multiple regressions values between limpet ecological attributes and physico-chemical parameters (Ragno *et al*., 2007; Joshi *et al.* 2018; Vase *et al.*, 2018) [10, 19,31]. The core objective of the present study was to investigate correlation of abiotic factors like water temperature, salinity, pH and dissolved oxygen (DO) with ecological attribute *i.e.*, population density, abundance and frequency of four limpet species at three studied sites.

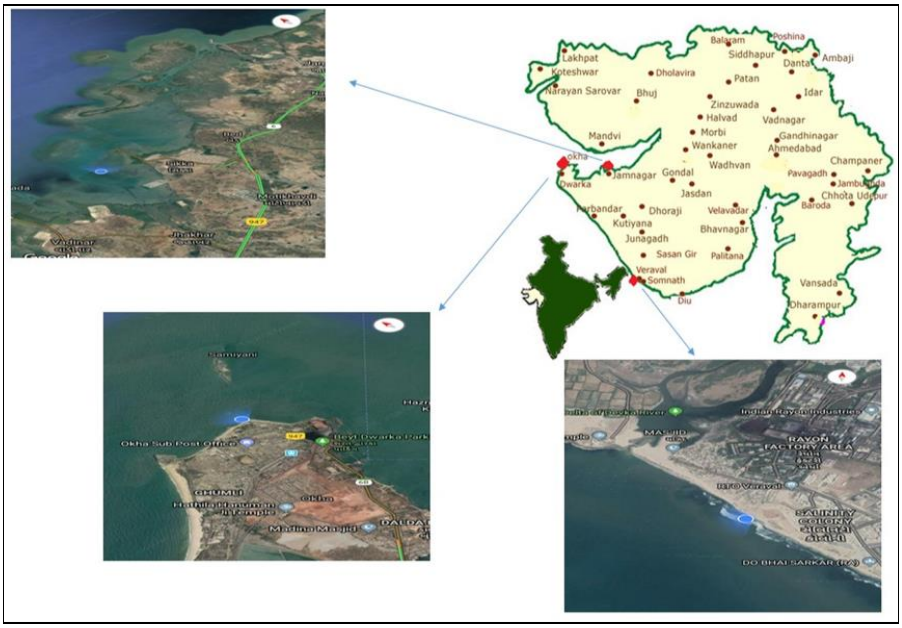

Fig 1: Satellite overview of three sampling site. (Source: google map)

Results and Discussions

During study, four limpet species vi., *C. karachiensis* (Winckworth, 1930), *Siphonaria sp., S. unguis* (Linnaeus, 1758) and *Diodora sp.* were recorded from studied site. The correlation between the ecological attribute (density, abundance and frequency) value of these four limpet species with physico-chemical factors shown in table 1. The population density and abundance of limpet shows a slight positive correlation with temperature (r = 0.32), salinity (r = 0.32), pH (r = 0.31) and DO (r = 0.31), while frequency shows strong positive correlation with all abiotic factor as shown in table 1. The density and abundance describe a strong positive correlation (r = 0.99) with each other. A strong positive correlation (r = 0.99) of temperature with salinity shows that increasing seawater temperature also leads to increase salinity. All abiotic parameters positively correlated with each other.

Table 1: Correlation of the density, abundance and frequency distribution of limpet with abiotic parameter (Temperature, Salinity, pH and DO) at three different sites (* indicate p value).

Parameter	Density	Abundance	Frequency	Temperature	Salinity	pH
Abundance	0.994					
	*0					
Frequency	0.577	0.55				
	*0	*0				
Temperature	0.323	0.324	0.655			
	*0.001	*0.001	*0			
Salinity	0.322	0.324	0.649	0.993		
	*0.001	*0.001	*0	*0		
pH	0.308	0.309	0.642	0.995	0.997	
	*0.002	*0.002	*0	*0	*0	
DO	0.307	0.309	0.627	0.984	0.979	0.985
	*0.002	*0.002	*0	*0	*0	*0

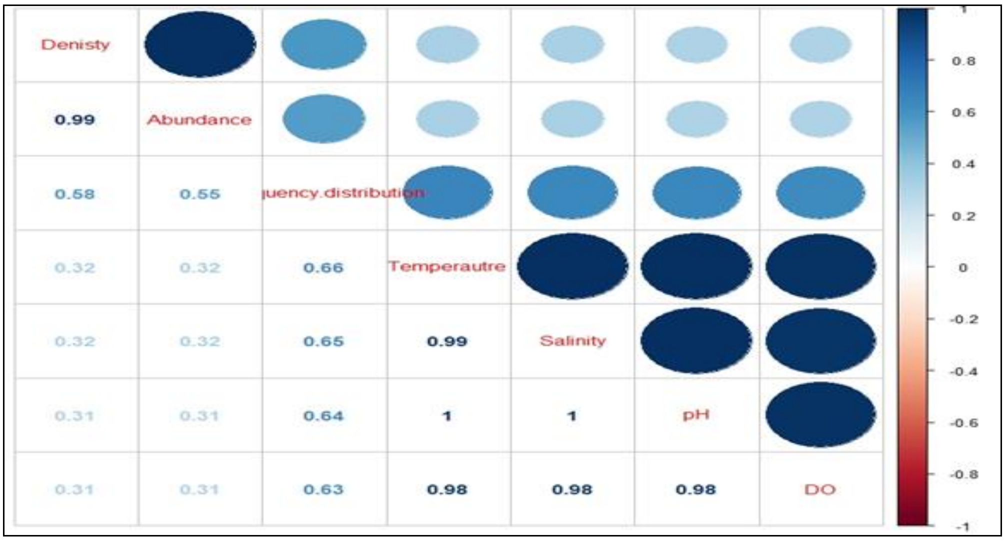

Fig 2: Correlation of the population density, abundance and frequency distribution of limpet with abiotic parameter at three different sites.

Temperature

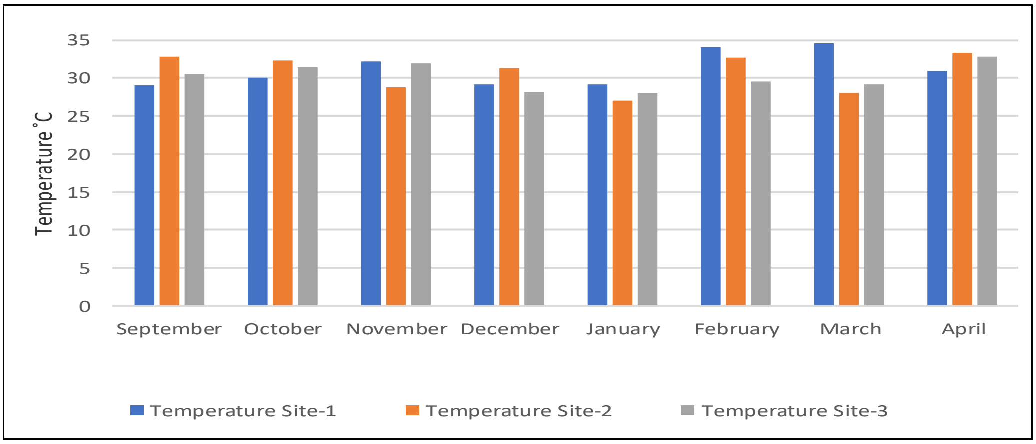

Fig 3: Monthly variation in temperature at each sampling site; x-axis: months, y-axis: temperature (°C).

Environmental factors such as temperature, salinity, wave action etc. directly influence the distribution patterns and population of limpets by imposing physical constraints on their living (Khouw, 2006) [11]. Among these, the temperature is a significant parameter influencing physiochemical characteristics of seawater and growth and development of macrobenthic organisms (Saravanakumar *et al.*, 2008, Smitha and Mustak, 2017) [23, 24]. Therefore, temperature analysis is crucial to understand ecological changes in the coastal ecosystem.

During the study, the highest temperature (34.6 °C) recorded in March (summer) at site-1 whereas the lowest (28 °C) during January (winter) at site-3 (fig.3). The study also recorded that the higher density and abundance value shown at the mean temperature of 29 °C. The mean temperature was 31.55 ± 2.35, 30.10 ± 1.69 and 30.66 ± 2.37 °C at site-1, site-2 and site-3, respectively. The similar result was shown by Vaghela *et al.*, (2010) [29] at Sikka and Vadinar coast of Gujarat during winter and summer months. Present study results also satisfied with the result of Vase *et al.*, (2018) [31] at Veraval coast, who recorded maximum temperature during April (summer) and lowest during December (winter).

The present study recorded the statistically significant difference ($p<0.05$) in temperature at all three sampling sites. The values of coefficient of correlation (r) shown the weak positive correlation ($r = 0.323$, $r = 0.324$) between the limpet population density and abundance value with temperature, while the frequency ($r = 0.655$) shown strong positive correlation with temperature (table 1). This showing that increased in maximum temperature (34.6 °C) leads to a decrease of limpet density at all sampling site. As per Branch (1981) [2], a temperature plays a crucial role on the density of limpet because it's inhabited on rocky substratum, at higher temperature rocky substratum become hotter which directly impact on the shelf life of limpet. The limpets rather ineffective (or poor regulator) in lowering their body temperature relative to the substratum as their body temperature largely depends on substratum temperature due to extensive contact area of the foot (Vermeij, 1971) [32]. Limpet can tolerate as high as 34 °C temperature for 2 hours, whereas over 42 °C temperature for an indefinite period could lead to the death of limpets (Vermeij, 1971; Miller *et al.*, 2009) [14, 32]. Balamani (2016) [1] concluded that the temperature shows more effect on the distribution of organisms. Thus, the rise of surrounding environment temperature during low tide, direct effect on the distribution and density of intertidal organisms (Dave and Chudasama, 2018) [4]. They also revealed that the density of gastropod decline during the pre-monsoon months at Veraval cost. The similar trend of a negative correlation between temperature and molluscs was reported at Sikka and Vadinar coast by (Vaghela *et al.*, 2010) [29].

Salinity

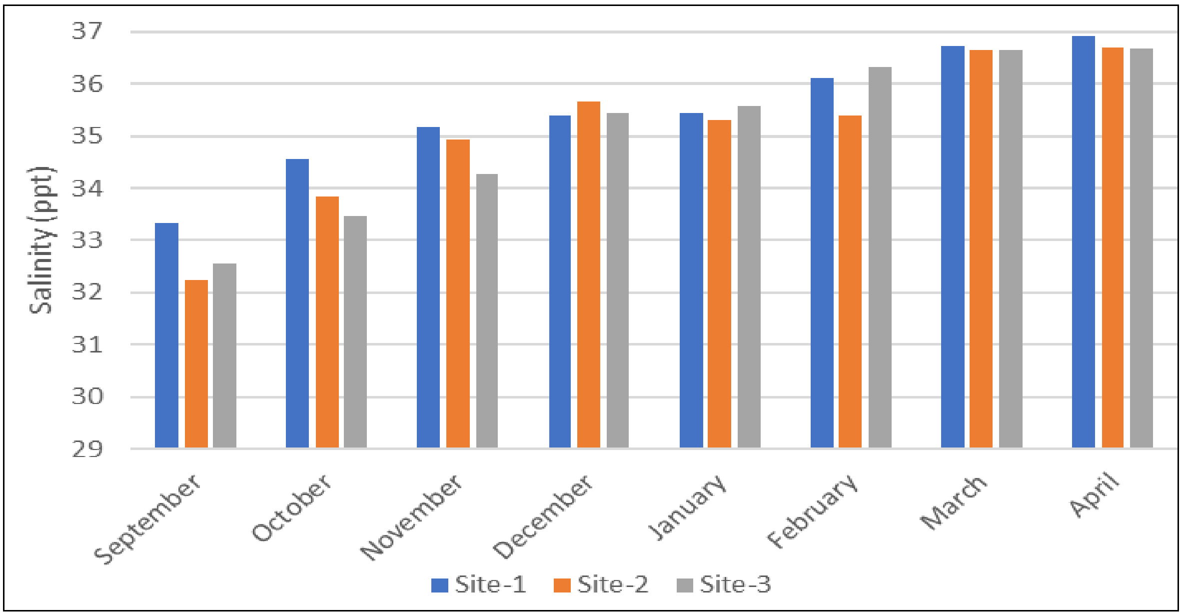

Fig 4: Monthly variation in salinity at each sampling site; x-axis: months, y-axis: salinity (ppt).

The seasonal variation in salinity caused due to precipitation and evaporation, which is most likely to influence the faunal distribution in the intertidal zone (Kumar and Khan, 2013) [13]. Limpets movement determined as salinity varies according to the shore (Balamani, 1996) [1]. The minimum salinity (32.23 ppt) recorded during September (monsoon) month at site-2 and maximum (36.93 ppt) during April month (summer) at site-1(fig.4). The recorded average mean salinity values were 35.46 ± 1.17, 35.09 ± 1.47 and 35.12 ± 1.54 ppt at site-1, site-2 and site-3, respectively.

Salinity show significance difference ($p < 0.05$) at all three sampling sites and it perceived a slight positive correlation ($r = 0.323$, $r = 0.324$ and $r = 0.649$) with limpet population density, abundance and frequency (fig.1). Garg *et al.*, (2009) [7] also recorded a positive correlation between salinity and gastropods. This shows that an increase in salinity within the observed range favors the abundance of studied species. The higher density of molluscs observed during post-monsoon and winter month and lower density during monsoon month, which indicate that the density was greater at higher salinity value. During monsoon months, molluscs group migrated from the upper littoral zone to the lower littoral zone to avoid low salinity (Vaghela *et al.*, 2010) [29]. Temkar *et al.* (2014) [27] reported seawater salinity varied between 34.75 ppt to 35.67 ppt along the Veraval coast, a similar study was done by Vase *et al.* (2018) [31] who observed salinity varied from 32.20 ppt to 36.86 ppt. According to Joshi *et al.* (2018) [10], minimum salinity 31.15 ppt during the month of August and the highest 38.08 ppt during May was recorded at Poshitra and Narara coast of Gulf of Kutchh. The present study was satisfied with the results of earlier researchers as comparable salinity value recorded at all the sampling sites. In response to salinity changes in the environment, *C. radiata* (Born) splashes seawater by raise or lower the shell which would enable the animal to feed even during low tide (Sukumaran and Krishnaswamy, 1961) [26].

pH

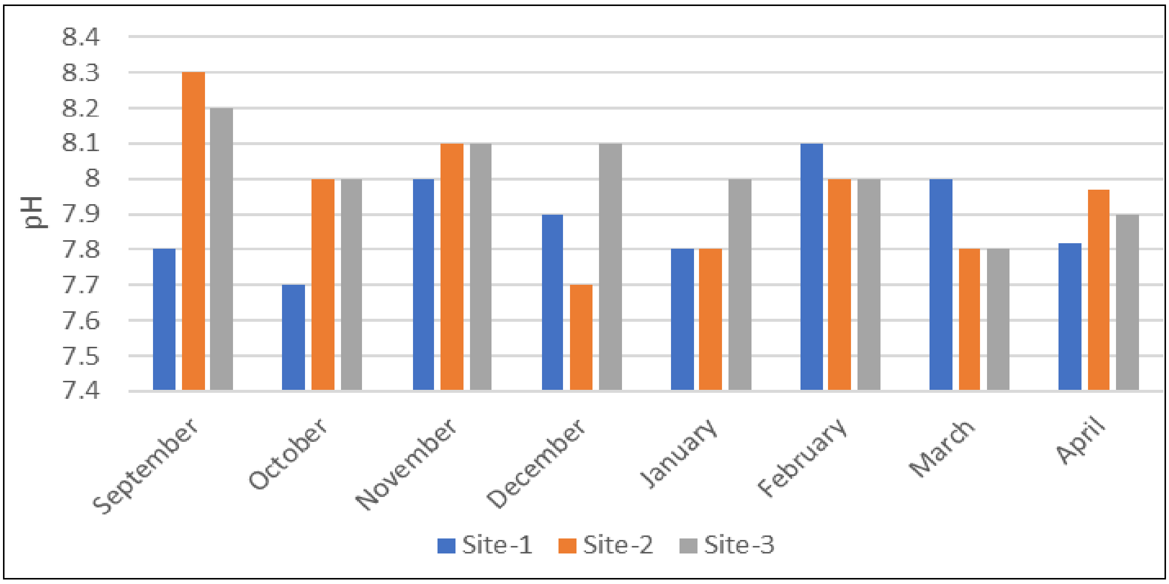

Fig 5: Monthly variation in pH at each sampling site; x-axis: months, y-axis: pH.

The fluctuations in pH value due to different factors like removal of CO_2 by photosynthesis, increased metabolic activities of autotrophs, bicarbonate degradation, dilution of seawater by the freshwater influx, low primary productivity and decomposition of organic matter etc. (Pandit and Fulekar, 2017; Joshi *et al.*, 2018) [16,10]. Henriques *et al.* (2017) [9] revealed that lower pH value can lead to environmental stress to various limpet species. The present study recorded maximum pH value (8.3) during September (monsoon) at site-3 and minimum value (7.7) during December (winter) at site-1 (fig.5). The mean pH values were recorded 7.88 ± 0.12, 8.00 ± 0.12, 7.94 ± 0.28 at site-1, site-2 and site-3, respectively.

Correlation result shows a weak positive correlation ($r = 0.308$, $r = 0.309$) between pH and limpet population density and abundance, whereas strong positive correlation ($r = 0.642$) with frequency (fig.1). There was a significant different in pH ($p < 0.05$) at all sampling site. The results indicate a very strong positive correlation ($r = 0.995$ and $r = 0.097$) with temperature and salinity (fig.1). Garg *et al.*, (2009) [7] also recorded very weak and negative correlation between molluscs and pH. Joshi *et al.* (2018) [10] recorded the maximum value of pH (8.38) during September and lowest (7.58) during April at Poshitra and Narara coast, analogous result noted during present investigation. The Okha coast shows slight alkaline pH values due to high anthropogenic activities (Pandit and Fulekar, 2017) [16]. The minimum pH 7.87 recorded during April month, with a range of 7.87 to 8.28 at Veraval coast (Temkar *et al.*, 2014) [27]. Dhananjayan *et al.*, (2018) [5] recorded an average value of pH 7.8 with a range of 7.5 to 8.1 at Vadinar coast. The significant pH value was recorded at all sampling sites during the study. The present study was satisfied with the results of earlier researchers as comparable pH value recorded at all the sampling sites.

Dissolved Oxygen

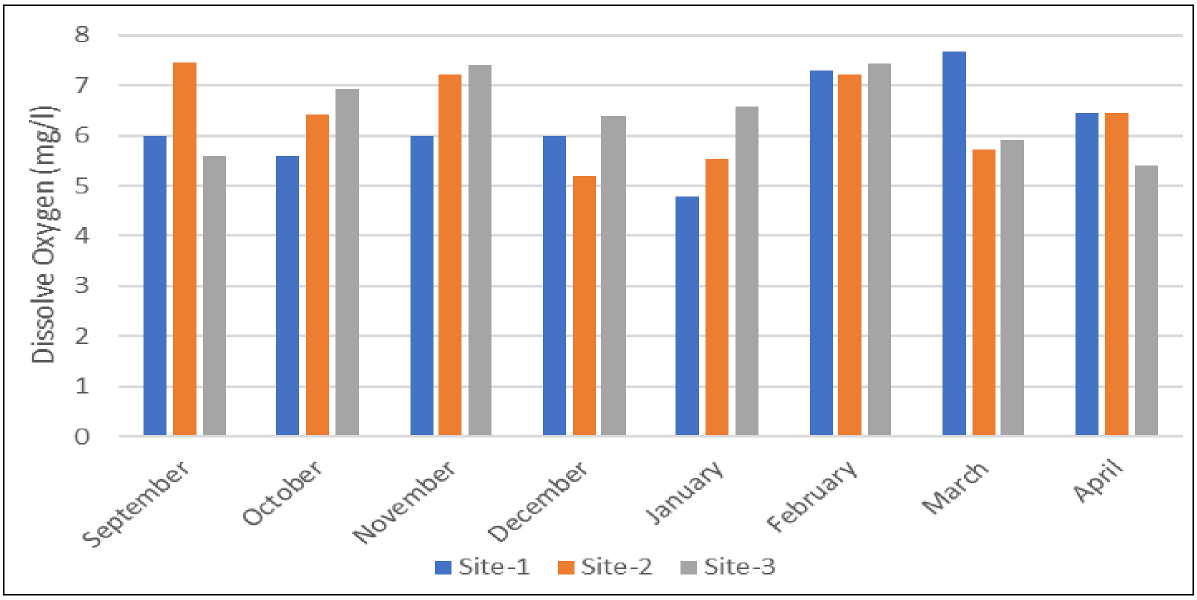

Fig 6: Monthly variation in dissolve oxygen (DO) at each sampling site; x-axis: months, y-axis: dissolve oxygen (mg/l).

Dissolved oxygen (DO) is an important characteristic to support a well-balanced aquatic life. Prime sources of DO in seawater are the photosynthetic activity of marine flora and diffusion of oxygen from atmosphere (Parmar and Mankodi, 2017) [17]. In the present study, the measured DO value fluctuated from 4.8 to 7.47 mg/l. The significant fluctuation in temperature and salinity also impact on the dissolution of oxygen (Kumar and Khan, 2013) [13]. The minimum mean DO (6.22 ± 0.12 mg/l) recorded during summer because of lower agitation and turbulence of the coastal water at all sites (Pandit and Fulekar, 2017) [16].

Throughout the study period, recorded mean DO values were 6.26 ± 0.91, 6.45 ± 0.77, 6.40 ± 0.852 mg/l at sit-1, site-2 and site-3 site, respectively. The present study also satisfied with results of Vase *et al.*, (2018) [31] recorded dissolved oxygen in an optimum range between 4.10 to 6.80 mg/l at Veraval coast. The maximum DO value (7.45 mg/l) recorded during the month of August with fluctuation rate of 5.48 to 7.45 mg/l at Poshitra and Narara coast (Joshi *et al.*, 2018) [10]. Dhananjayan *et al.*, (2018) [5] recorded significant fluctuation of DO value within a range of 5.00 to 6.80 mg/l off Vadinar and Sikka coast. In case of DO value, the present study agreed with earlier researched study. There was a significant fluctuation observed in DO ($p < 0.05$) at all sampling sites, which elucidated weak positive correlation ($r = 0.307$, $r = 0.309$) with limpet population density and abundance, whereas, it exhibits strong positive correlation with ($r = 0.627$) frequency (fig.1). Saddozai *et al.* (2013) [22] obtained a negative correlation between population density and DO. The fluctuation in dissolved oxygen did not impact on molluscs populations as some molluscs can survive in very low oxygen conditions (Garg *et al.*, 2009) [7].

Balamani (1996) [1] recorded that the upper limit distribution of *C. radiata* (Born) is generally governed by physical factors *viz.*, temperature, desiccation, salinity and wave action, whereas lower the limit is probably governed by competition on the intertidal zone. A similar trend in the distribution of *C. karachiensis* (Winckworth, 1930) was recorded during study. The lethal temperature for *C. radiata* (Born) was found to be 42 °C and salinity below 20 ppt and above 37 ppt found to be critical (Rao and Ganapati, 1972) [21]. Contrast to *C. karachiensis* (Winckworth, 1930), *Siphonaria* sp., has less ability to tolerant fluctuating salinity and temperature level observed, an analogous study recorded at Veraval coast by Faladu *et al.*, 2014 [6] and Vakani *et al.*, 2014) [30]. Kuk-Dazul and Diaz-Castaneda (2016) [12] revealed that oxygen depletion in seawater impacts the abundance and distribution of benthic fauna on the coast. The result obtained in present work strongly affirmed with earlier studies.

Conclusion

The present work found that most of the limpet species shows a level of tolerance for different physico-chemical parameters. The correlation analysis shown that there is a slight positive correlation between limpet density and abundance with abiotic factors (temperature, salinity, pH and dissolved oxygen). But the correlation between frequency and abiotic factors were strongly positive, which indicate a cumulative influence on the distribution pattern of limpets at studied sites. The present study confirmed that the environmental parameters are marginally important to understand the distribution and abundance of four limpet species on the intertidal region of the studied site.

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