

## Seasonal Burrow Distribution of the Ghost Crab, *Ocypode ceratophthalmus* (Pallas, 1772), on Sandy Shores of Gujarat, India

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International Journal of Marine Science, 2017, Vol.7, No.34 doi: [10.5376/ijms.2017.07.0034](https://doi.org/10.5376/ijms.2017.07.0034)

Received: 26 Jul., 2017

Accepted: 18 Aug., 2017

Published: 08 Sep., 2017

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### Preferred citation for this article:

Trivedi J.N., and Vachhrajani K.D., 2017, Seasonal burrow distribution of the ghost crab, *Ocypode ceratophthalmus* (Pallas, 1772), on sandy shores of Gujarat, India, International Journal of Marine Science, 7(34): 344-352 (doi: [10.5376/ijms.2017.07.0034](https://doi.org/10.5376/ijms.2017.07.0034))

**Abstract** Seasonal variation in burrow distribution pattern of *Ocypode ceratophthalmus* (Pallas, 1772) was studied at four different sandy shores along the Saurashtra coast, Gujarat state, India. Burrow numbers were quantified in terms of three different ecological attributes like density, abundance and frequency of occurrence monthly for one year. Three different abiotic factors like sediment temperature, salinity and pH were measured for three seasons at each site. Burrow density, abundance and frequency of occurrence were varied significantly between different seasons and study sites. The sediment pH showed more impact on the burrow abundance as compared to other abiotic parameters. A strong positive correlation was observed between burrow opening diameter and crab carapace width, and burrow diameter and abundance also increased and decreased respectively from the lower to upper shore indicating that these attributes were highly dependent on crab body size. The highest burrow abundance was recorded in the monsoon season as compared to other seasons which is peak juvenile recruitment season of the species. The species is large in size and occurs in high abundance on sandy shores and the burrow distribution of the species is highly dependent on the seasons.

**Keywords** Ghost crab; Seasonal variation; Abiotic factors; Saurashtra coast

## Introduction

Burrowing is a common behavior exhibited by invertebrates living in soft marine sediments. The burrowing activity of these animal increases the complexity of the habitat because animal constructs different kind of biogenic structures and adopt different behavior patterns for their maintenance (Jones and Jago, 1993; Hannides et al., 2005). The distribution of the burrows and their morphological features can affect the physical and biochemical properties of the sediment (Mermillod-Blondin et al., 2004; Kristensen, 2008; Katrak et al., 2008). Burrow patterns and morphology are mostly species specific; however, species can modify their burrowing activity and burrow morphology in different sediment types and according to changes in environmental conditions (Bertness and Miller, 1984; Takeda and Kurihara, 1987; Morrisey et al., 1999; Lim and Diong, 2003; Chan et al., 2006). Burrow morphology and density of *Ocypode* crabs have, for example, been shown to vary with distance from the water line, more complex structure of burrows with low density of crabs were observed on the upper part while simple burrow structure with high density of crabs were observed on the lower part of sandy shore (Strachan et al., 1999; Chan et al., 2006).

*Ocypode ceratophthalmus* (Pallas, 1772) is a large crab species (carapace size > 8 mm) and occurs in high abundance on sandy shores and is widely distributed on sandy shores of Indo Pacific region (Ng et al., 2008) where it plays an important role in the ecology of these shores (Valero-Pacheco et al., 2007). The burrows of *O. ceratophthalmus* play a significant role in providing shelter from desiccation and predators, as well as a safe space for molting and reproduction. The adults of *O. ceratophthalmus* are nocturnal and stay inside the burrows during the day time, while the juveniles may leave their burrow and move to the water line to renew their respiratory water during day time (Morton and Morton, 1983). The burrows of this species have circular or 'hole' type openings and therefore counting the number of such burrow entrances is an effective tool to measure the population of *Ocypode* species on sandy shores (Moss and McPhee, 2006). As *Ocypode* crabs are form the highest

trophic position amongst the invertebrate predators on sandy shores and also play an important role as prey for other vertebrate predators, so changes in the population of *Ocypode* crab can be used as a ecological indicator to predict the impact of various factors on sandy shore ecosystems (Chan et al., 2006; Valero-Pacheco et al., 2007; Lucrezi et al., 2009; Tureli et al., 2009). *Ocypode ceratophthalmus* is the most common brachyuran crab species occurring on the sandy shore habitat of Gujarat state (Trivedi and Vachhrajani, 2016) still ecology of local population of the species has not been studied in detail. So, to fill the lacunae of information, the present study was carried out at accessible sandy shores located on the coastal areas of Gujarat state. In the present study, we studied the seasonal burrow distribution pattern of *O. ceratophthalma* on four different sandy shores located along the Saurashtra coast of Gujarat, India. We hypothesize that the burrow distribution of the species varies with different season and between sites and, more specifically that burrow abundance and burrow diameter will vary along the vertical gradient of the shore.

## 1 Materials and Methods

### 1.1 Study area

The present study was conducted on sandy shores at four different sites *viz.* Veraval (20°54'37" N, 70°21'04" E), Sutrapada (20°49'53" N, 70°29'17" E), Dhamlej (20°46'29" N, 70°36'19" E) and Kodinar (20°45'29" N, 70°39'39" E) on the Saurashtra coast of Gujarat state, India (Figure 1). Study sites like Sutrapada, Dhamlej and Kodinar are located 30, 40 and 50 kilometers away from Veraval study site respectively. The average width of the sandy shore at each study site was ~20 meters and all shores were steeply (> 2.5° slope) sloping. All the study sites experience three different seasons like summer (March to June), monsoon (July to October) and winter (November to February) in which summer is hot (42 °C mean air temperature) while winter is cold (25 °C mean air temperature). The tides are semi diurnal with maximum tidal range of 2 meters.

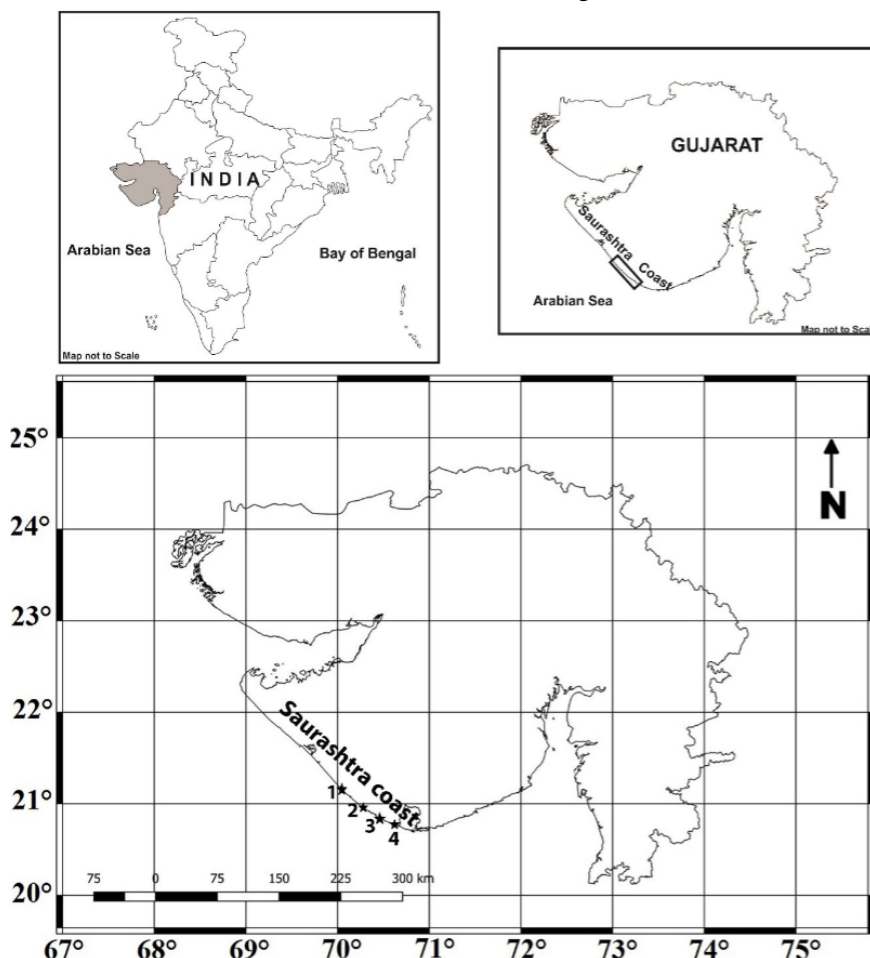


Figure 1 Map of study area showing the four sampling sites (1) Veraval (2) Sutrapada (3) Dhamlej (4) Kodinar

## 1.2 Sampling procedure

Monthly surveys were conducted to study the burrowing pattern during low tide timings from April 2013 to March 2014. Total 10 transects (100 meter away from each other) were laid parallel to the shore line from upper to lower part of the sandy shore. Total 5 quadrats (1 x 1 m) were laid on each transect (5 meter away from each other) every month at each site. The total numbers of burrows were counted in the quadrats and the burrow opening diameters of few randomly selected burrows in each quadrat were measured using digital vernier calipers ( $\pm 0.01$  mm; INSIZE Model No. 1137-150). Few randomly selected burrows in each quadrat were excavated after measuring their burrow opening diameter and crabs which emerged from these burrows were captured using hand picking method. Carapace width of the captured individual (as this was considered the most relevant metric, given that the crabs enter the burrow in sideways fashion) was measured to find out its relationship with burrow opening diameter of the respective excavated burrow. The quantified monthly quadrat data of burrows were integrated for different seasons like summer (March to June), monsoon (July to October) and winter (November to February) because climatic conditions of the study area do not change much in the successive months (Mishra and Kundu, 2005). The quantitative seasonal burrow data was then analyzed for three different ecological attributes like density (Total number of burrows from all the quadrates/ total number of quadrat laid), Abundance (Total number of burrows/ total number of quadrates where presence of burrow recorded) and frequency of occurrence (Total number of quadrat where burrow recorded  $\times 100$ / total number of quadrat laid).

## 1.3 Physico-chemical parameters

Abiotic variable such as sediment surface temperature, pH and salinity were also recorded at 1 hour interval during low tide on the day of survey of respective month at each site. The monthly data of abiotic variables was also analyzed for three different seasons. The probe of Digital thermometer (Eurolab ST9269B,  $\pm 0.1$  °C) was inserted in the sediment till 1 cm depth for measurement of sediment temperature. For measurement of sediment pH and salinity, a scoop of sediment was collected from 1 cm depth and 5 gm of sediment was dissolved in 25 ml of distilled water and stirred well. After the solid particles settled on the base of the flask, the pH and salinity of the supernatant was measured using digital pH meter (HANNA pHep Model  $\pm 0.1$  pH) and Hand refractometer (ERMA  $\pm 1\%$ ) respectively (Blakemore et al., 1987).

## 1.4 Statistical analysis of data

Two way ANOVA with replication was used to investigate the variation in the mean values of different ecological attributes and abiotic variables. Regression analysis was employed to investigate the relationship between various abiotic factors and mean abundance of the burrows of the *O. ceratophthalmus*. Regression analysis was also employed to investigate relationship between *O. ceratophthalmus* body size and burrow opening diameter. All the statistical analyses were carried out using Microsoft EXCEL.

## 2 Results

### 2.1 Sediment abiotic variables

Mean sediment temperature varied significantly between different seasons (ANOVA F: 131.31,  $p < 0.001$ ) but it did not vary significantly between different sites (ANOVA F: 1.98,  $p = 0.21$ ). All sites showed a similar pattern of temporal variation in sediment temperatures, reaching a maximum in summer while minimum sediment temperatures were recorded in the winter season and this variation was recorded maximum in Kodinar. Mean sediment pH varied significantly between different seasons (ANOVA F: 61.71,  $p < 0.001$ ) but it did not vary significantly between different sites (ANOVA F: 2.03,  $p = 0.20$ ). The highest sediment pH was recorded in summer at all the study sites while minimum pH was recorded in the monsoon, and this pattern was similar for all sites. Mean sediment salinity varied significantly between different seasons (ANOVA F: 107.78,  $p < 0.001$ ) as well as between different sites (ANOVA F: 9.05,  $p < 0.01$ ). The sediment salinity was recorded very high in summer at Dhamlej while minimum salinity was recorded Sutrapada and Kodinar in monsoon (Table 1).

Table 1 Seasonal variation in the mean values (Mean  $\pm$ SD) of different abiotic variables of the sediments at the four different sites

	Veraval	Sutrapada	Dhamlej	Kodinar
Sediment temperature ( °C)				
Winter	29.33 $\pm$ 0.45	28.46 $\pm$ 0.83	28.60 $\pm$ 0.72	28.00 $\pm$ 0.81
Summer	33.35 $\pm$ 1.04	33.60 $\pm$ 1.08	33.62 $\pm$ 0.65	33.66 $\pm$ 1.15
Monsoon	31.10 $\pm$ 1.13	29.70 $\pm$ 0.56	30.3 $\pm$ 0.84	29.6 $\pm$ 0.98
Sediment pH				
Winter	7.76 $\pm$ 0.15	8.05 $\pm$ 0.15	7.96 $\pm$ 0.05	8.06 $\pm$ 0.20
Summer	8.25 $\pm$ 0.17	8.32 $\pm$ 0.22	8.32 $\pm$ 0.09	8.35 $\pm$ 0.17
Monsoon	7.50 $\pm$ 0.14	7.50 $\pm$ 0.15	7.75 $\pm$ 0.21	7.55 $\pm$ 0.35
Sediment salinity (%)				
Winter	38.66 $\pm$ 0.57	37.09 $\pm$ 1.07	39.75 $\pm$ 1.08	36.66 $\pm$ 2.08
Summer	39.75 $\pm$ 1.07	39.00 $\pm$ 0.81	40.00 $\pm$ 1.82	38.75 $\pm$ 1.5
Monsoon	35.00 $\pm$ 1.41	32.5 $\pm$ 0.70	34.0 $\pm$ 1.41	32.5 $\pm$ 0.85

## 2.2 Biotic variables

There was a strong positive relationship between crab carapace width and burrow opening diameter ( $R^2=0.95$ ;  $p<0.001$ , Figure 2). Burrow abundance of *O. ceratophthalmus* was recorded very low in the lower part of the shore, which increased maximally in the mid part and then decreased slightly on the upper part of the shore at all the sites (Figure 3B). Burrow diameter showed the opposite pattern, with increasing size towards the mid and upper part of the shore at the study sites (Figure 3A).

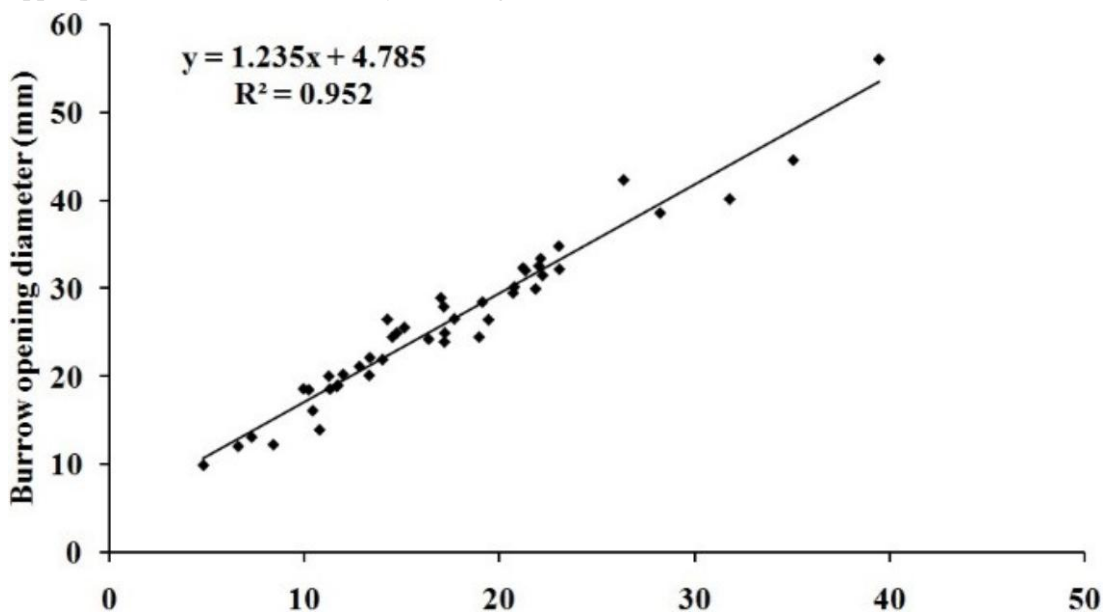


Figure 2 Regression analysis for the relationship between crab carapace width and burrow opening diameter pooled for the four sites throughout the year (n=45)

The density (Figure 4A) abundance (Figure 4B) and frequency of occurrence (Figure 4C) of *O. ceratophthalmus* burrows varied between different seasons and sites. Maximum density (Figure 4A) abundance (Figure 4B) and frequency of occurrence (Figure 4C) of burrows were recorded at Kodinar followed by Sutrapada, Dhamlej and Veraval in the monsoon season. The result of Two – way ANOVA showed significant variation for the mean values of the seasonal and site specific burrow density, abundance and frequency of occurrence of the species (Table 2). Regression analysis between sediment temperature and burrow abundance of the *O. ceratophthalmus* did not show significant correlation at all the study sites. Sediment salinity also did not show significant correlation with the abundance of the species for different study sites except Kodinar. Sediment pH showed

significant correlation with the abundance of the species at Sutrapada and Kodinar but significant correlation was not observed at Veraval and Dhamlej (Table 3).

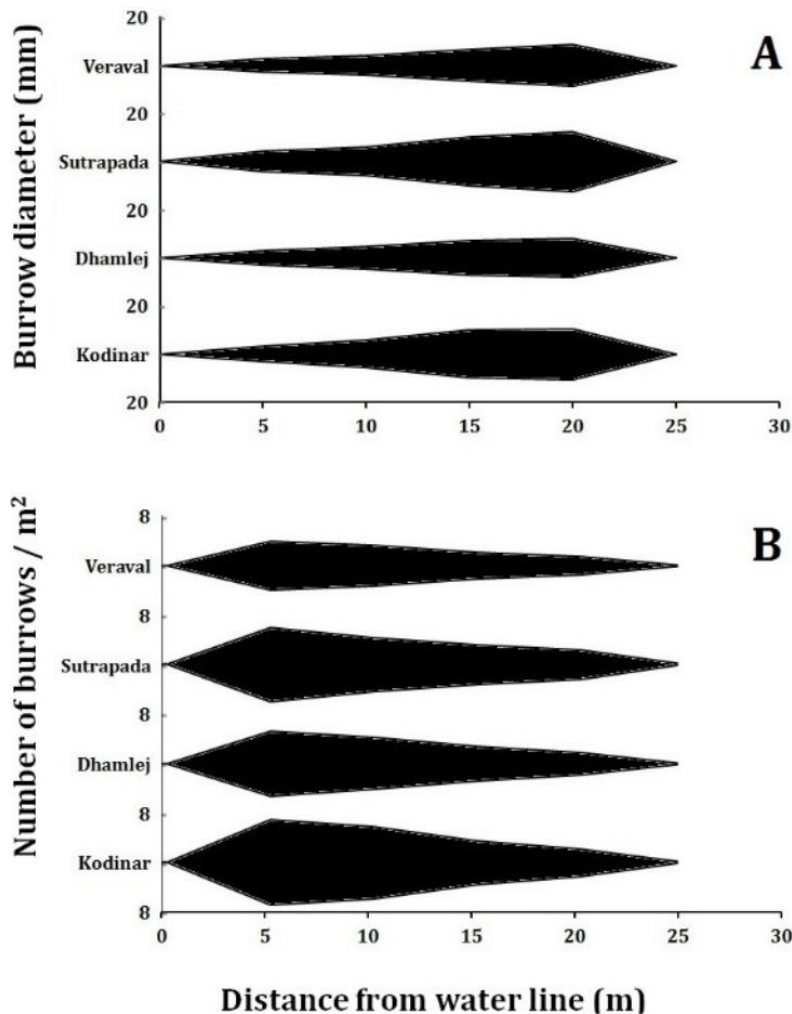


Figure 3 Kite diagram showing (A) Variation in burrow diameter and (B) Variation in burrow abundance of *O. ceratophthalmus* in relation to distance from the low water line at the four different study sites (0 represents water line)

Table 2 Results of Two – way ANOVA with replication to investigate variation in mean seasonal density, abundance and frequency of occurrence values of *O. ceratophthalmus* burrows sampled at three different sites (df values are presented in the table)

Source of Variation	Density (no. of burrows/ m <sup>2</sup> )	Abundance (no. of burrows/ m <sup>2</sup> )	Frequency of occurrence (% occupation / m <sup>2</sup> )
Site	6.38 *	6.78*	7.87**
Season	27.63***	42.88***	20.86***

Note: \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001

### 3 Discussion

In the present study, the number of burrows decreased towards the upper part of the sandy shore away from the water line. Burrows with large diameter burrows were recorded near upper part of the sandy shore while burrows with small diameter were recorded near the water line. Shuchman and Warbung (1978) and Strachan et al. (1999) also recorded similar findings where they noted that high numbers of burrows with small diameter were occupied by juveniles living closer to the water line, while less number of burrows with large diameter were occupied by adults located on the upper part of the shore away from water line. On the basis of these observations, they proposed that this phenomenon is most probably occurring due to the physiological competence between individuals of the species. Chakrabarty (1981) and Chan et al. (2006) and also observed a similar pattern of

distribution of juvenile and adult burrows of *O. ceratophthalmus* and stated that juveniles live near the water line because they have smaller gill areas and cannot tolerate prolonged air or sunlight exposure without renewing their respiratory water. As a result, the juveniles have to leave their burrow frequently to go to renew their respiratory water from the sea, while the adults have bigger gill surface areas which help them to tolerate longer periods of emersion.

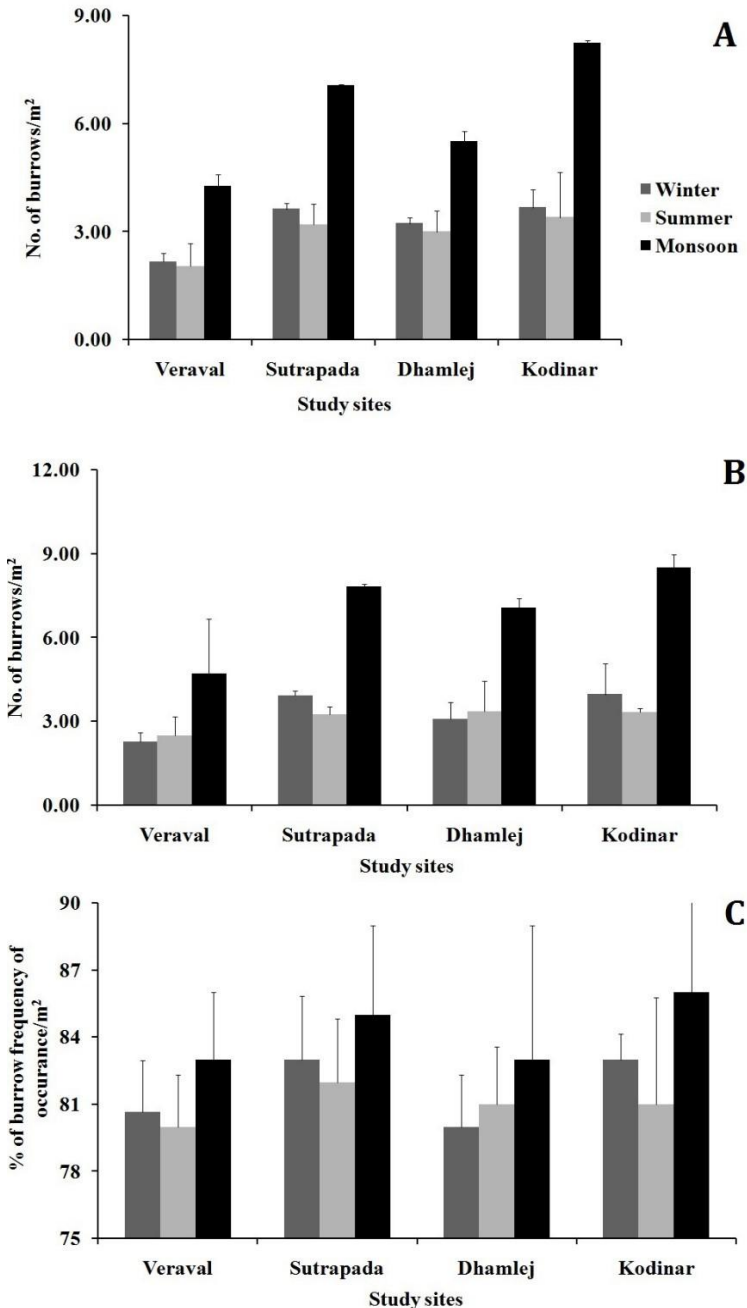


Figure 4 Mean seasonal (Mean  $\pm$  SD) variation in ecological attributes of *O. ceratophthalmus* at the four different study sites. (A) Density of burrows (B) Burrow abundance and (C) Frequency of occurrence of burrows

The results showed that density, abundance and frequency of occurrence of *O. ceratophthalmus* also varied between different seasons; being higher in the monsoon season as compared summer or winter. Similar results were obtained by Strachan et al. (1999) who, studied the ecology of *Ocypode cursor* and suggested that July and August is the juvenile recruitment period of *Ocypode* species. The mean values of different ecological attributes varied significantly between different sites and seasons but more significant values were recorded for different

seasons as compared to values recorded for different sites, which shows that seasons have immense impact on the distribution pattern of the species. Similar pattern was observed for many invertebrate fauna occurring in the tropical waters (Mishra and Kundu, 2005; Trivedi and Vachhrajani, 2014; 2015). The regression study between different sediment abiotic parameters and abundance of the species revealed that out of all the abiotic parameters sediment pH showed some impact on the abundance of the species. According to Shuchman and Warbung (1978) such changes in the abiotic variables of the sediment can influence the distribution of *Ocypode* species inhabiting sandy shore habitat.

Table 3 Results of the regression analysis between mean seasonal abundance of *O. ceratophthalmus* and mean sediment temperature, salinity and pH

Sediment Temperature ( °C)	Equation	R <sup>2</sup>
Veraval	y =0.0498X+1.34	0.007
Sutrapada	y =-0.3221X+14.49	0.19
Dhamlej	y =-0.0794X+6.57	0.011
Kodinar	y =0.1434X+3.98	0.03
Sediment Salinity (%)		
Veraval	y =0.0453X+2.68	0.116
Sutrapada	y =0.1797X+3.60	0.065
Dhamlej	y = -0.4411X+21.0	0.482
Kodinar	y =-0.5807X+25.99	0.5624**
Sediment pH		
Veraval	y = 1.8861X+17.85	0.394
Sutrapada	y=-4.504X+40.79	0.764***
Dhamlej	y =4.1207X+37.38	0.361
Kodinar	y =-4.4688X+40.79	0.566**

Note: \*\* p < 0.01; \*\*\* p < 0.001

Species in the genus *Ocypode* show changes in the area they occupy in a dynamic way with changes in the conditions of available space, temperature, pH, salinity etc at each geographic region (Shuchman and Warbung, 1978). Neves and Bemvenuti (2006) have suggested that this response to environmental variables can also include human impact and proposed the quantification of number of burrows of *Ocypode* species is a rapid tool to assess anthropogenic impacts on sandy beaches and can be used effectively in environmental monitoring programs. In the present study, the ecological attributes of *O. ceratophthalmus* varied between different sites. Maximum density and abundance of the species were recorded at Kodinar followed by Sutrapada, Dhamlej and Veraval. The population of the species could be affected by the level of the anthropogenic pressure on the sandy shore because the sandy beach of the Veraval and Dhamlej are affected by high and moderate anthropogenic activities respectively while the amount of anthropogenic pressure on sandy shore of Sutrapada and Kodinar is comparatively less (Vaghela, 2010). In the present study, it was observed that burrow construction and distribution of *O. ceratophthalmus* is highly affected by seasonal variation and abiotic variables of the sediment. The variation in the distribution of the burrows of the *O. ceratophthalmus* at different sites may be affected by different variables like the geo morphology of the shore, level of anthropogenic pressure on the shore etc. The strong correlation between burrow opening diameter and crab carapace width suggested that the burrow constriction is highly dependent on the body size of an individual. The pattern observed for distribution of burrows on the different parts of the sandy shore suggested that construction of burrow varies with the life stage of an individual of the species.

#### Author's contributions

Jigneshkumar N. Trivedi and Kauresh D. Vachhrajani carried out the field work for data collection and also performed data analysis. Jigneshkumar N. Trivedi and Kauresh D. Vachhrajani prepared, read and finalized the manuscript.

## Acknowledgments

The authors are thankful to the Earth System Science Organization (ESSO), Ministry of Earth Science, New Delhi, India for financial assistance under the research project entitled “Studies on Brachyuran Crabs of Saurashtra Coast” (Grant No. MoES/16/06/2013-RDEAS dated 11.11.2014). The authors are also thankful to Mr. Vishal Pankhania and Mr. Kalpesh Gohel for technical assistance.

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