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Spatiotemporal variations in the population dynamics of a few prominent brittle star species (Echinodermata: Ophiuroidea) from the intertidal flat of the Veraval coast, Gujarat, India

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The present communication reports the spatiotemporal variation in the population dynamics of three prominent Ophiuroidea species: *Amphipholis squamata*, *Ophiactis savignyi* and *Ophiocomella sexradia* at the rocky intertidal zone at Veraval (21°35' N, 69°36' E) Gujarat, off the Arabian Sea. The two sampling areas with different substratum and community structures were investigated from April 2019 to March 2020. Brittle stars were found inhabited in the coralline bed, zoanthid bed, algal holdfast, rock pool crevices and underneath rocks in the studied coastal areas. *A. squamata* was the most abundant species followed by *O. savignyi* and *O. sexradia* at the Veraval coast. The current study described a few remarkable revelations between the patches of coralline algae and Ophiuroidea abundance. Brittle star population revealed major spatial variations between both sampling sites. Cluster analysis and nMDS support population abundance in a seasonal pattern distribution.

[**Keywords**: Intertidal, Ophiuroidea, Population status, Veraval]

Introduction

Echinodermata species are abundantly seen in the benthic community of intertidal and subtidal areas worldwide, with various substrata such as rock, sand, mud and corals[1]. Echinodermata may alter the community composition and structure[2-4] which provide space for the settlement of other animals and increase biodiversity, which regulates the populace of benthic groups such as molluscs, polychaetes, corals and algae[5-7]. Echinodermata such as Ophiuroidea significantly contribute to various benthic communities as species diversity, abundance and biomass of the fauna of world oceans[8,9]. Ophiuroidea diversity generally decreases with depth in several areas which are dominated by other mega-fauna. Their profusion significantly impacts soft bottom community ecology through their exploitation and processing of redistribution of organic matter of the sea floor[9-14]. Most of the Indian echinoderm research concerns only taxonomy with much less information on the ecology and other aspects. Many studies on the echinoderms that are intertidal, inhabiting primarily coral reefs, sandy beaches, muddy flats, and rocky coasts, have as ecological habitats of concern[15]. Comprehensive information on abundance, diversity and distribution patterns of echinoderms in the south-eastern Arabian Sea was also examined[16]. The ecology of the *A. depressus* was investigated from the Cochin area of the south Indian coastline off the Arabian Sea[17]. A few Ophiuroidea species were reviewed in a sparse and general manner, not in a species-specific manner from the Gujarat coast[18-20].

The present study was undertaken to understand the ecological status of the intertidal Ophiuroidea (Echinodermata) from the rocky coast of Veraval, Gujarat, off the Arabian Sea. The literature survey yielded a few reports on the species-specific study and the effect of anthropogenic pressure on the intertidal fauna of this coastline, but Echinodermata was sparsely studied in those reports. Comprehensive studies and the current scenario of intertidal Ophiuroidea ecology of Veraval are not done earlier and are not clear in terms of spatio-temporal.

Materials and Methods

Sampling site

Veraval (21°35' N, 69°36' E) is situated at the south Saurashtra coastline off the Arabian Sea (Fig. 1). The studied coastal stretch was around 3 km with rocky substratum with occasional sandy patches.

Fig. 1 — Map of the study area

For the present study, the site was divided into two micro sampling sites (micro sampling site-1 and micro sampling site-2) based on their structural habitat, substratum and community structure. The micro sampling site-1 is around 1 km long bare rocky substratum with many rock pools and puddles dominating the coral community. The micro sampling site-2 is around a 1.2 km long stretch having a flat rocky substratum with crevices and small pools with major biota Zoanthid and *Amphiroa* algal sp.

Sampling method

For the present study, the random quadrate method was used[21]. A 50×50 cm (0.25 m²) quadrats were laid on each site which replicate to 1 m² for the data analysis following an oblique direction covering the maximum area for both sampling sites during low tide. Data collection was done every month from April 2019 to March 2020.

Data analysis

Ecological attributes such as population density and abundance were calculated to check the spatiotemporal pattern of the studied Ophiuroidea species. One-way ANOVA analysis was performed to check the significant variation, if any, in the temporal scale of ecological attributes between two micro sampling sites. The temporal pattern of the studied species was analysed for every month using group average linking on Bray-Curtis similarity. nMDS was performed using the Bray Curtis matrix to produce ordinations based on the abundance of the species in each month. All the multivariate analysis was performed using primer v.6.

Results and Discussion

In the present work, three species *A. squamata*, *O. savignyi* and *O. sexradia* were studied to evaluate their population ecological status from the Veraval coast. Both the micro-sampling sites have unique substratum characteristics like crevices, puddles, pools and algal cover[22] which affect the distribution and population of these species in the intertidal zones. Population data of studied species for one year indicate that the pattern of temporal variations of three species at both micro sampling sites was more or less similar except during the winter season.

Species density

A. squamata was the most commonly observed species in the middle littoral zone. Its density was highest in January 2020 at micro sampling site-2. For the micro sampling site-1, it showed a similar trend up to October 2019, then started increasing in November – December 2019 and again declined to follow a steady trend. At micro sampling site-1, all three species showed similar density trends during monsoon and post-monsoon and from November 2019 onward, all species showed an increasing density trend (Figs. 2 & 3). This might be due to heavy rainfall and storm surge, high wave actions and water turbidity which affect the distribution and population of Ophiuroidea in monsoon and post-monsoon seasons. The highest density of *O. savignyi* and *O. sexradia* was observed in December 2019 at micro sampling site-2. In the winter season, the population of the *A. squamata* was denser and clumped beneath the holdfast of the *Amphiroa* sp. algae. *A. squamata* up to 1 cm in size was not easily recognized with the complex structure of branches of this alga. The population status of *O. savignyi* showed marked variations in different habitats. It was densely distributed with the clumped formation and evenly distributed in rock pool crevices. It was mostly observed on the periphery of the rock pools associated with sedentary and mobile worms. This may be due to the lower temperature in the winter season and higher food availability, which was more due to high algal growth[24-25]. In *O. savignyi*, the habitat variations and their reproductive state influenced their population densities[23]. Among all three species, *A. squamata* had the highest density, followed by *O. savignyi* while, *O. sexradia* showed lower density at both the micro sampling sites compared to the other two species.

Species abundance

The highest abundance of *A. squamata* was observed in January 2020 at micro sampling site-2,

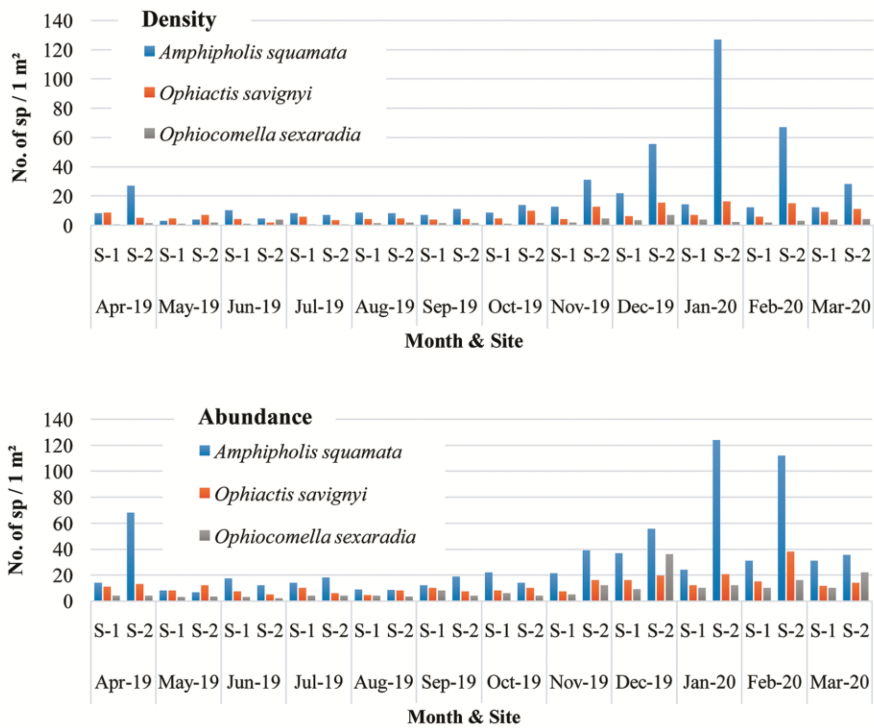


Fig. 2 — Monthly variations in the ecological attributes (Density & Abundance) of all three species at Veraval

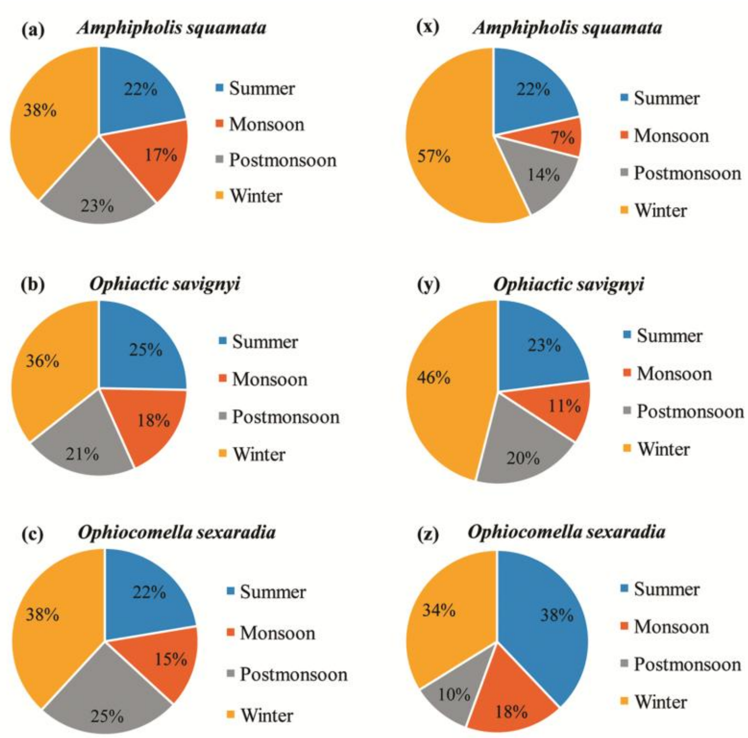


Fig. 3 — Seasonal variations in the Abundance of studied species at both the sites (a, b, c represent sampling site-1 and x, y, z represent sampling site-2)

whereas for *O. savignyi* in February 2020 and *O. sexradia* in December 2019. It indicates that winter was the most favourable season for all species and supported the studied species larger scale of abundance. The population abundance of all studied species decreased from summer to monsoon season at both micro sampling sites (Fig. 3). The population of brittle stars fluctuated significantly in the summer season due to the reproduction or dispersal rate because of the stressful environment[26], including temperature and salinity[27]. The possibility of a stressful environment is known to cause fission in such populations[28]. Further, it was supported and noted that some Echinodermata populations showed seasonal patterns of asexual reproduction by fission[29], which depended on substratum structure and seasonal environment. We observed fission in *O. savignyi* and *O. sexradia* during winter and early summer. The pattern of the population of studied species showed unevenness throughout the year for both sampling sites, but values of micro sampling site-2 were higher compared to micro sampling site-1, with some exceptions in June and September 2019. The abundance was higher at micro sampling site-2 due to the flat substratum with many crevices like habitats and rich growth of coralline algae *Amphiroa* sp., which supports the highest abundance of *A. squamata* from April to October (Fig. 2). *A. squamata* was abundantly found in shallow, sub-tidal algal holdfasts[31] and intertidal algal turfs fringing tide-pools[30-32]. *O. savignyi* and *O. sexradia* seem to follow a more or less similar pattern throughout the year, with higher abundance in the winters (Fig. 3) and early months of the summer season, which may be the reason for more food resources available during these months[24-25]. *O. savignyi* was generally seen with sponges and rock pool crevices as compared to other habitats. Brittle star population dynamics are increased and sustained by asexual, sexual, and fission. *O. savignyi* spawning then aids in lowering the cost of energy, providing strength for fission to survive and breed again which providing strength to generate more juveniles[26]. The distribution and abundance of *O. savignyi* in tropical and subtropical regions may be explained by this reproductive adaptation[26]. *O. sexradia* had the lowest abundance throughout the year as compared to other species. It was found mainly in the rock pools and under the holdfast of *Ulva* sp. due to their colour pattern, which may protect them from predation. The seasonal population growth pattern of brittle stars was somewhat uneven at micro sampling site-2 (Fig. 2). Population growth of all studied species was higher in the winter season at both the micro sampling sites (Fig. 3). The abundance of studied species was high in the winter season followed by post monsoon at micro sampling site-1, while at micro sampling site-2, population abundance was high in winter season followed by summer season (Fig. 3). One-way ANOVA for the monthly ecological attributes of studied species showed significant variations at both micro sampling sites (Table 1). It may be because these species were abundantly present in the middle littoral zone, which may offer different types of microhabitats and compositions of community structures which seasonally alter and may have an impact on the population in the sampling sites.

Spatio-temporal pattern

Bray-Curtis cluster analysis and nMDS plot revealed species abundance in a temporal and spatial pattern. It produced three clusters (stress value of 0.02) at a similarity of 80 % (Figs. 4, 5). Months were placed at a particular distance based on variation in the abundance of three species each month. At sampling site-1, three resemblances were formed which shared 12 % dissimilarity of abundance: first of December, January, February and March; second of April, July and September; and third of June, October and November. The cluster of December, January, February and March ordination is closer to each other, which support seasonal pattern and winter as the most favourable season. While at sampling site-2, two clusters at 60 % similarity were seen. Four clusters had 20 % or less dissimilarity: the first was January and February; the second was November and March; the third was May and August; and the fourth was July, September and October. At sampling site-1, April and July shared an equal abundance of species and ordinated most closely to each other. While at sampling site-2, they were far away because of *A. squamata* higher abundance and lie near January and February. The factor regulating these ordinations

Table 1 — Result of one-way ANOVA denotes temporal variation of ecological attributes and diversity indices of studied species between two microsites of Veraval coast. The *f*-critical value is 3.2849 (ecological attributes). * - denotes significance at $P < 5$ %

	Sampling site-1	Sampling site-2
Density	26.5767*	6.4309*
Abundance	16.9564*	6.2824*

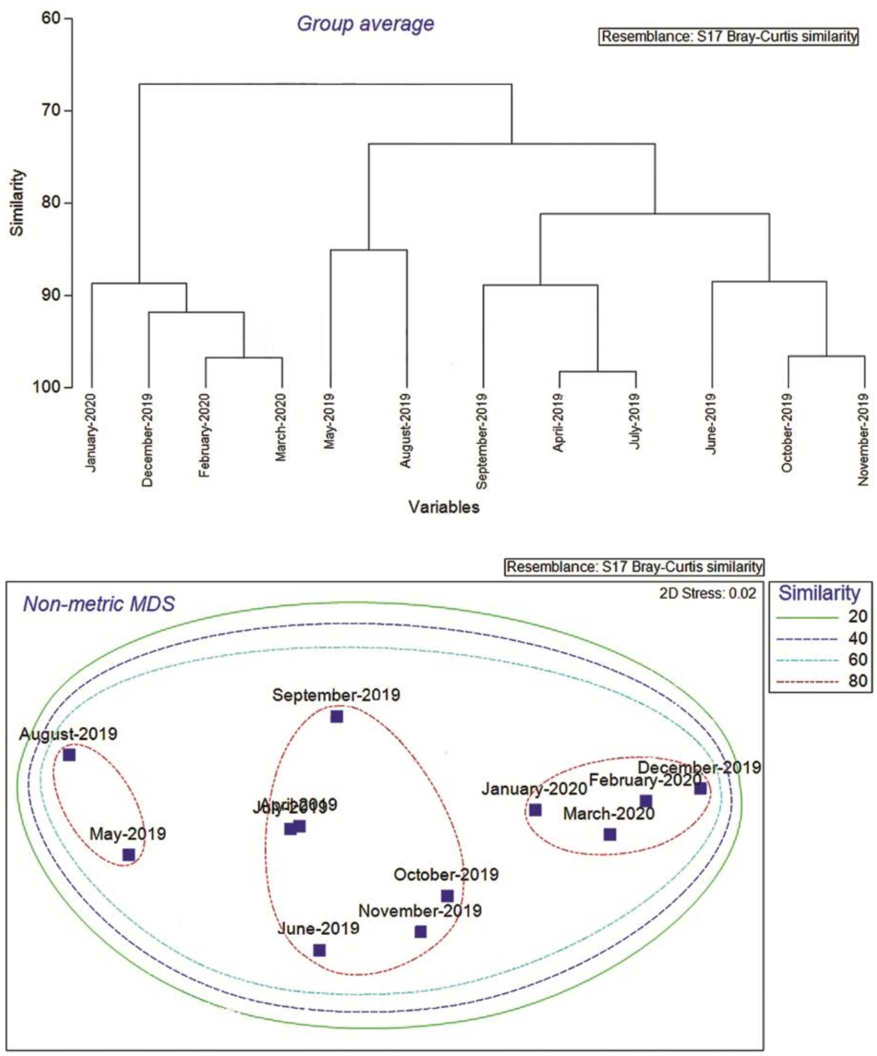
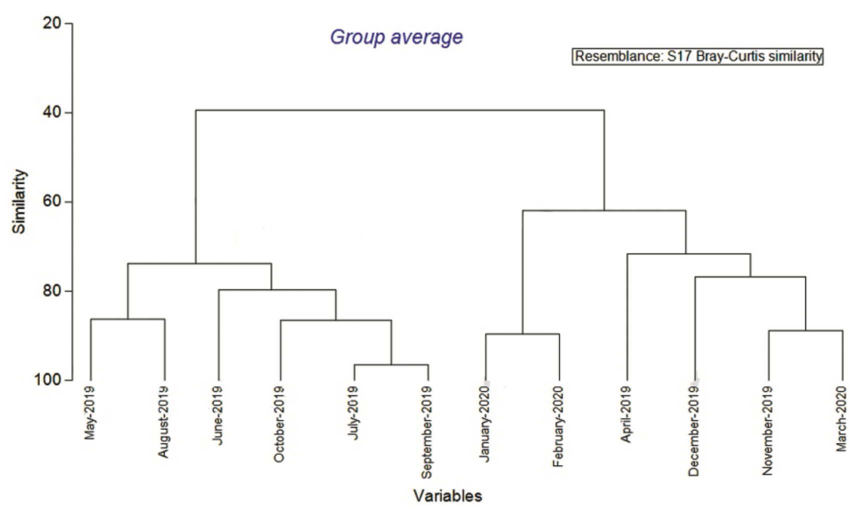


Fig. 4 — nMDS plot showing grouping of months based on species abundance with Bray-Curtis cluster analysis for the sampling site-1



(*Contd*.)

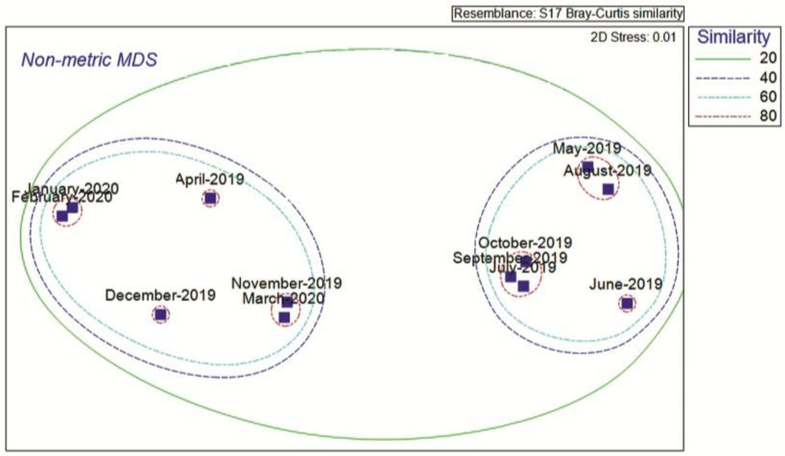


Fig. 5 — nMDS plot showing grouping of months based on species abundance with Bray-Curtis cluster analysis for the sampling site-2

based on abundance may be some structural dissimilarity between two sampling sites and various environmental factors.

Conclusion

The present study indicated that *A. squamata* was the most abundant species in this group, followed by *O. savignyi* and *O. sexradia* at the Veraval coast. The overall population attributes showed a similar trend in temporal variations of studied species except in the winter season. The population attributes, however, showed spatial variation between both sampling sites. Seasonal variability of environmental factors may be responsible for this trend. However, a few other factors, such as sedimentation and associated biota might have affected the distribution of Ophiuroidea in the selected coastal area. The brittle star was found inhabiting the coralline bed, zoanthid bed, algal holdfast, rock pool crevices, and underneath loose rocks in the selected study area. Cluster analysis and the nMDS plot supported the observed seasonal population abundance of the species studied. The study showed a few remarkable revelations regarding the correlation between the patches of coralline algae and the abundance of Ophiuroidea. The complex structure of coralline algae was possibly the source of patchiness and abundance of brittle stars. During the study, the cluster size of the patches of coralline algae remained the same, but the abundance of brittle stars showed seasonal fluctuations in the abundance values. Encrusting coralline algae with the sandy-rocky substratum had the highest population of *A. squamata* compared to another substratum. The highest abundance of *A. squamata* was possibly due to the association of encrusting coralline algae from post-monsoon to early months of the summer season.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

This manuscript is part of Ph.D dissertion of first author (HB) and has been investigated and written by HB. Whole work is supervised and reviewed by RK.

References

1 Rios-Jara E, Galvan-Villa C M & Solis-Marin F A, Echinoderms from Isla Isabel National Park, Nayarit, Mexico, *Rev Mex Biodivers*, 79 (2008) 131–141.
2 Jones C G, Lawton J H & Shachak M, Organisms as ecosystem engineers, *Oikos*, 69 (1994) 373–386. doi:10.1007/978-1-4612-4018-1_14
3 Hastings A, Byers J E, Crooks J A, Cuddington K, Jones C G, *et al.*, Ecosystem engineering in space and time, *Ecol Lett*, 10 (2006) 153–164. doi:10.1111/j.1461-0248.2006.00997.x
4 Wild C, Hoegh-Guldberg O, Naumann M S, Colombo-Pallotta M F, Ateweberhan M, *et al.*, Climate change impedes scleractinian corals as primary reef ecosystem engineers, *Mar Freshwater Res*, 62 (2011) 205–215. doi:10.1071/MF10254
5 Birkeland C, The influence of echinoderms on coral-reef communities, *Echinoderm Stud*, 3 (1989) 1–79.

6 Ambrose W G Jr, Effects of predation and disturbance by ophiuroids on soft-bottom community structure in Oslofjord - Results of a mesocosm study, *Mar Ecol Prog Ser*, 97 (1993) 225–236. doi:10.3354/meps097225

7 Glynn P W & Enochs I C, Invertebrates and their roles in coral reef ecosystems, In: *Coral Reefs: An Ecosystem in Transition*, edited by Dubinsky Z & Stambler N, (Springer Press, Dordrecht), 2011, pp. 273–325. doi:10.1007/978-94-007-0114-4_18

8 Hyman L H, *The invertebrates: Echinodermata*, (McGraw-Hill, New York), 1955, pp. 763.

9 Tyler P A, Deep-sea ophiuroids, *Oceanogr Mar Biol*, 18 (1980) 125–153.

10 Grassle J F, Sanders H L, Hessler R R, Rowe G T & Mclellan T, Pattern and zonation: a study of the bathyal megafauna using the research submersible Alvin, *Deep-Sea Res*, 22 (1975) 457–481.

11 Smith C R & Hamilton S C, Epibenthic megafauna of a bathyal basin of southern California: patterns of abundance, biomass, and dispersion, *Deep-Sea Res*, 30 (1983) 907–928.

12 Carey A G, Stein D L & Rona P L, Benthos of the Gorda Ridge axial valley (NE Pacific Ocean): Taxonomic composition and trends in distribution, *Prog Oceanogr*, 24 (1990) 47–57.

13 Carey A G, Taghon G L, Stein D L & Rona P A, Distributional ecology of benthic megaepifauna and fishes in Gorda Ridge Axial Valley, In: *Gorda Ridge: A Seafloor Spreading Center in the United States Exclusive Economic Zone, New York*, edited by Mc Murray G R, (Springer) 1990, pp. 16.

14 Gage J D & Tyler P A, *Deep-Sea Biology: A Natural History of Organisms at the Deep-sea Floor*, (Cambridge University Press, New York), 1991, pp. 504.

15 James D B, Research on Indian echinoderms - A review, *Mar Biol Assoc India*, 25 (1-2) (1983) 91–108.

16 Parameswaran U V, Abdul Jaleel K U, Gopal A, Sanjeevan V N & Anil Kumar V, On an unusual shallow occurrence of the deep-sea brittle star *Ophiomyces delata* in the Duncan Passage, Andaman Islands (Northern Indian Ocean), *Mar Biodivers*, 36 (1) (2016) 151-156.

17 James D B, Studies on Indian Echinodermata-4 On the brittle-stars *Amphioplus gravelyi* sp. nov., and *Amphioplus depressus* (Ljungman) from the Indian Coasts, *Mar Biol Assoc India*, 12 (1971) 139–145.

18 Gohil B & Kundu R, Diversity of the intertidal macrofauna at west coast of Gujarat, India, *Life Sciences Leaflets*, 12 (2012) 135–145.

19 Bhadja P, Poriya P & Kundu R, Community structure and distribution pattern of intertidal invertebrate macrofauna at some anthropogenically influenced coasts of Kathiawar peninsula, India, *Adv Ecol*, (2014) p. 547395. http://dx.doi.org/10.1155/2014/547395

20 Poriya P, *Ecological status of the intertidal macrofaunal assemblage in a rocky intertidal coast, Gujarat*, Ph.D. thesis, Saurashtra University, Gujarat, 2015.

21 Stephenson T A & Stephenson A, The universal features of zonation between tide-marks on rocky coasts, *J Ecol*, 37 (1949) 289–305.

22 Poriya P & Kundu R, Interaction between two prominent benthic communities in intertidal ecosystem of Kathiawar peninsula, *Int J Ecol Envi Sci*, 42 (4) (2016) 287–293.

23 Mladenov P V & Emson R H, Density, size structure and reproductive characteristics of fissiparous brittle stars in algae and sponges: evidence for interpopulational variation in levels of sexual and asexual reproduction, *Mar Ecol Prog Ser*, 42 (1988) 181–194.

24 Vaghela A, Bhadja P, Ramoliya J, Patel N & Kundu R, Seasonal variations in the water quality, diversity and population ecology of intertidal macrofauna at an industrially influenced coast, *Water Sci Technol*, 61 (6) (2010) 1505–1514.

25 Bhadja P & Kundu R, Status of the seawater quality at few industrially important coasts of Gujarat (India) off Arabian Sea, *Indian J Geo-Mar Sci*, 41 (1) (2012) 954–961.

26 Chao S M & Tsai S S, Reproduction and population dynamics of the fissiparous brittle star *Ophiactis savignyi* (Echinodermata: Ophiuroidea), *Mar Biol*, 124 (1995) 77–83.

27 Mladenov P V, Emson R H, Wilkie I C & Colpit L V, Asexual reproduction in the West Indian brittle star *Ophiocomella ophiactoides* (H L Clark**)** (Echinodermata: ophiuroidea), *J Exp Mar Biol Ecol*, 12 (1983) l–23.

28 Emson R H & Wilkie I C, Fission and autotomy in echinoderms, *Oceanogr Mar Biol Ann Rev*, 18 (1980) 155–250.

29 Mladenov P V & Burke R D, Echinodermata: Asexual Propagation, In: *Reproductive biology of invertebrates, Vol VI, Part B, Asexual Propagation and Reproductive Strategies*, edited by Adiyodi K G & Adiyodi R G, (Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Bombay, Calcutta), 1994, pp. 339–383.

30 Rumrill S S, *Contrasting Reproductive Patterns among Ophiuroidea*, MSc Thesis, University of California, Santa Cruz, 1982.

31 Emson R H & Foote J, Environmental tolerances and other adaptive features of two intertidal rock pool echinoderms, In: *Echinoderms: Present and Past*, edited By Jangoux M, (A. A. Balkema, Rotterdam), 1980, pp. 163–169.

32 Boffi E, Ecological aspect of ophiuroids from the phytal of S.W. Atlantic Ocean warm waters, *Mar Biol*, 15 (1972) 316–328.