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Cover: Himalayan Gray Langur *Semnopithecus ajax* (adult female) © Rupali Thakur.



Intertidal Ophiuroidea from the Saurashtra coastline, Gujarat, India

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Abstract: Present communication reports the diversity of intertidal Ophiuroidea (Phylum: Echinodermata) from the intertidal zones of the Saurashtra coastline, Gujarat state. Saurashtra coastlines were extensively surveyed from January 2019 to March 2022 for the Ophiuroidea diversity. A total of nine species of Ophiuroidea belonging to eight genera and six families were noted from the intertidal zones of the Saurashtra coastline. Amongst these, *Macrophiothrix variabilis*, *Ophiothrix savignyi* and *Ophiomaza cacaotica* are newly observed species from the Gujarat coastline. The results of similarity indices show that each sampling site has a diverse variety of brittle star, making them spatially different from each other.

Keywords: Brittle star, echinoderms, intertidal, marine invertebrate, species diversity.

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Author details: RAHUL KUNDU is the head and professor at the Department of Biosciences, Saurashtra University whose research interest in marine biodiversity and ecology. HITISHA BAROLIYA pursuing her PhD working on diversity, distribution and ecological status of intertidal Echinodermata from the Saurashtra coast, Gujarat. BHAVNA SOLANKI pursued her master degree and did dissertation at prof. Rahul Kundu' lab.

Author contributions: HB and RK conceived the study; HB and BS did the field work, collected data and identification; BS survey literature; HB analyzed the data and preceded the manuscripts writing; RK review the manuscript. All authors contributed significantly to draft the manuscript.

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INTRODUCTION

The Ophiuroidea are known as brittle stars, basket stars (euryalids with branching arms) and snake stars (euryalids with non-branching arms). It is the largest group among extant living echinoderms, with 2,116 described species found in all oceans from the intertidal to the greatest depths (Stöhr et al. 2021). Among them, 160 species have been recorded from Indian waters (Samuel et al. 2017). Recently nine new brittle stars are reported from India (Parameswaran et al. 2021). *Macrophothrix aspidota* was the first Ophiuroid reported from Gujarat (James 1969). After that, *Ophioplocus imbricatus* was recorded from Pirotan Island (Clark & Rowe 1971). A total of 12 species were reported from Gujarat (Sastry 2004; Gohil & Kundu 2012; Poriya 2015). The literature indicates that not many studies were conducted, nor significant data were available for the species diversity of intertidal ophiuroids from the Saurashtra coastline, Gujarat.

The present study aims to better document the species diversity of ophiuroids from the Saurashtra coastline, Gujarat. An extensive sampling effort in the rocky intertidal coastal zone was undertaken at eight localities around the Saurashtra coastline. Below, we discuss each species encountered and compare species composition between selected localities.

MATERIALS AND METHODS

Total of eight locations were chosen for ophiuroids sampling (Figure 1, Table 1) during the low tide from January 2019 to March 2022. In situ photography of live specimens was carried out. Voucher specimens of some species were collected by direct hand-picking method from various habitats for further identification. Specimens were relaxed with magnesium chloride and fixed in 95% ethanol and 4% formalin. Encountered Ophiuroidea species preliminary identification was done with the monograph of Clark & Rowe (1971) and Cherbonnier & Guille (1978). Confirmed determinations up to species level was done using various research articles such as O'Hara et al. (2018) for family rank and above, Hoggett (1990) for *Macrophothrix*, Thomas (1975) for *Ophioplocus*, and Clark (1953) for Ophionereis. Voucher specimens were deposited in the Museum of the Department of Biosciences, Saurashtra University. In the present study, the Jaccard similarity index (J) was measured using R to compare the similarity and diversity of the different sampling sites.

RESULTS

Diversity of Intertidal Ophiuroidea: In the present study, nine species of ophiuroids belonging to eight genera and six families were noted from the intertidal zones of the Saurashtra coastline (Table 2). Among these, only one species was reported from Simbor, three species each from Diu, Dhamlej, Mangrol, & Shivrajpur, five from Veraval, six from Dwarka, and seven species from Okha (Table 3). Systematic position, explanation, and habitation of noted ophiuroids are as follows:

Systematics section

Family Ophiocomidae Ljungman, 1867

Genus *Ophiocomella* A.H. Clark, 1939

***Ophiocomella sexradia* (Ducan, 1887)**

Image 1A

Material: Diu (Gangeshwar coast, Jalandhar coast) - 8 specimens; Dhamlej - 3 specimens; Veraval - 6 specimens; Mangrol - 4 specimens; Dwarka - 5 specimens; Shivrajpur - 2 specimens; Okha - 6 specimens. Three specimens having Museum ID: ZEOOOO(5)19H, ZEOOOO(1)19H, ZEOOOO(8)19H, coll. Hitisha Baroliya, are deposited in the museum.

Remarks: Commonly observed six arms *O. sexradia* at the Saurashtra coast, but we observed one specimen with seven arms. Specimens have small and imbricating scales and papillae, narrow and oval shaped radial shield, three to five elongate and blunt arm spines, one tentacle scale. Three to eight oral papillae on each side of jaw and one to six pair of dental papillae with one to seven square-tipped teeth.

Habitat: Rock crevices and under algal holdfast.

Distribution: Common across the Indo-West Pacific (Clark & Rowe 1971).

Previous records from Gujarat: Dwarka and Okha (Sastry 2004).

Present study: Veraval, Diu, Mangrol, Dwarka, and Okha.

Family Hemieuryalidae Verrill, 1899

Genus *Ophioplocus* Lyman, 1861

***Ophioplocus imbricatus* (Müller & Troschel, 1842)**

Image 1B

Material: Dwarka - 3 specimens; Shivrajpur - 1 specimen; Okha - 4 specimens. Two specimens having Museum ID: ZEOAHO(1)19H, ZEOAHO(13)19B, coll. Bhavna Solanki and Hitisha Baroliya, are deposited in the Museum.

Remarks: Disk Covered by small and imbricating

Table 1. Detailed information about sampling localities evaluated in the study.

Site name	GPS coordinates	Description
Diu	20.70207 N, 70.91727 E	Island located on outer rim of Gulf of Kambhat. Sampling sites: Nagoa and Gangeshwar.
Simbor	20.76603 N, 71.15496 E	Small islet located at the mouth of Sahil river at the Bay of Simbor. Sandy-rocky coast. Sampling site: rocky outcrop of ~350m length.
Dhamlej	20.77034 N, 70.61462 E	Near the Sutrapada, around 2 km long rocky substratum. Flat emergent rocky habitat covered by <i>Zoanthus</i> .
Veraval	20.91691 N, 70.34221 E	Largest fish landing site, 3 km long with fully rocky substratum with coral, zoanthid and Cerithium assemblage.
Mangrol	21.0984 N, 70.11417 E	40 km west of Veraval. Coastal stretch 3 km long with fully flat rocky substratum.
Dwarka	22.23676 N, 68.9254 E	South-west part of Saurashtra coastline. Light house, 800 m long, sandy-rocky coastal area.
Shivrajpur	22.33049 N, 68.95123 E	'Blue Flag beach', located between Dwarka and Okha. 1 km in length.
Okha	22.47974 N, 69.08047 E	Located outer rim of the Gulf of Kutch, coastal length for this study was 3 km. Intertidal zone contains hard rocky substratum with sandy-rocky patches.

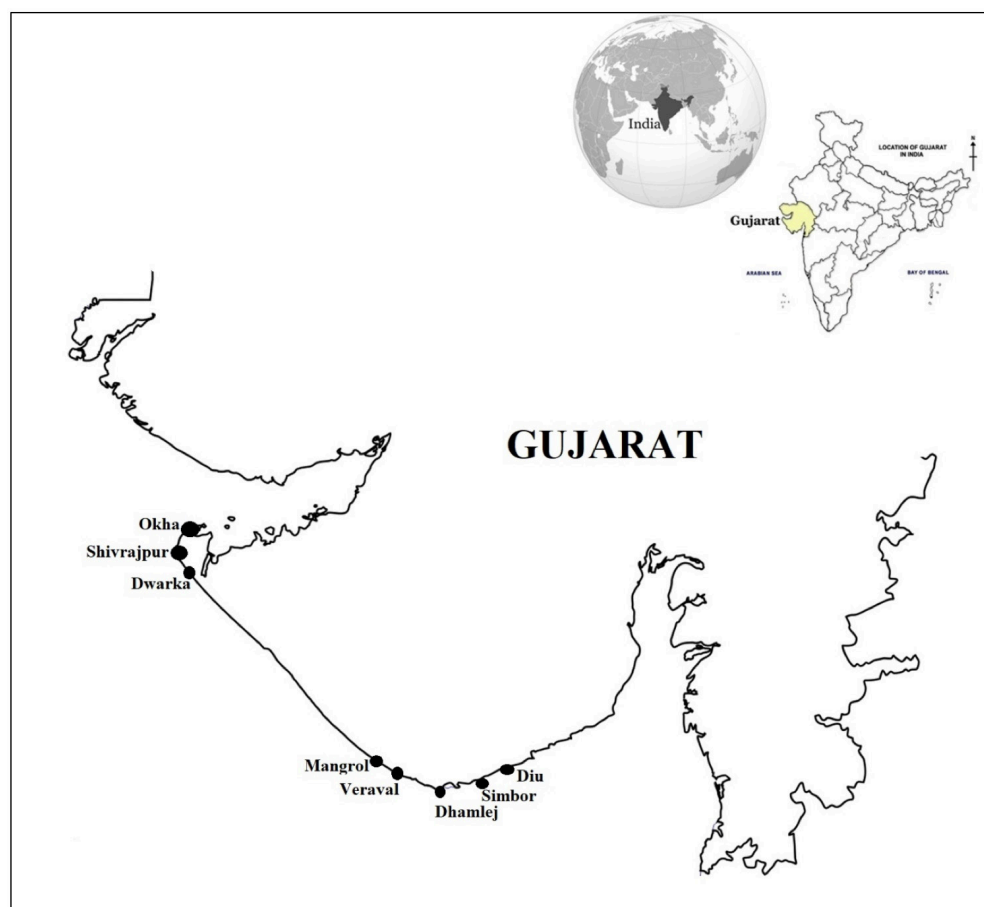


Figure 1. The sampling stations of Saurashtra coast.

scales. Dorsal arm plate fragmented into number, three short and blunt arm spines, two tentacle scales. Four square shaped oral papillae on each side while as dental papillae absent, five square tipped teeth present in each jaw.

Habitat: Underneath of rock in shallow pool.

Distribution: West India, Pakistan, Sri Lanka, Bay of

Bengal, East Indies, northern Australia, Philippine, China, southern Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe 1971); eastern Africa to Hawaii (Tortonese 1980); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Okha, Beyt Island, Hanuman Dandi, and Sikka (Sastry 2004).

Present study: Dwarka, Okha, and Shivrajpur

lighthouse area.

Family Ophionereididae Ljungman, 1867

Genus *Ophionereis* Lütken, 1859

***Ophionereis dubia dubia* (Müller & Troschel, 1842)**

Image 1J

Material examined: Veraval - 1 specimen; Okha - 3 specimens. One specimen having Museum ID: ZEOAOO(13)19H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Rare to moderately occurred at intertidal area of the Saurashtra coast. Radial shield trapezium shaped. Three arm spine, one ellipse shaped tentacle scale. Dorsal arm plate fan triangular shaped, ventral arm plate octagonal, concave by sides, four oral papillae, quadrate shaped one tooth on infradental plate.

Habitat: Under the rock crevices.

Distribution: Persian Gulf, west coast of India, Pakistan, Maldives, Sri Lanka, Bay of Bengal, East Indies, northern Australia, Philippine, China, and southern Japan (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Sikka and Pirotan Island (Sastry 2004).

Present study: Veraval and Okha.

Family Amphiuridae Ljungman, 1866

Genus *Amphipholis* Ljungman, 1866

***Amphipholis squamata* (Delle Chiaje, 1828)**

Image 1C

Material: Diu (Gangeshwar, Jalandhar, and Nagoa) - 17 specimens; Dhamlej - 6 specimens; Veraval - 28 specimens; Mangrol - 8 specimens; Dwarka - 7 specimens; Shivrajpur - 4 specimens; Okha - 8 specimens. Five specimens having Museum ID: ZEOAAA (5)19H, ZEOAAA(8)19H, ZEOAAA(4)20H, ZEOAAA(13)19H, ZEOAAA(6)21H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Most common species of Saurashtra coast. Central primary plate is clearly visible, imbricating scales on disc. Radial shields separated proximally by a scale line, two tentacle scales, dorsal arm plate broader than long, three conical, erect, arm spines with serrated tip. Two oral papillae on each side, one distal long and opercular. A pair of infradental papillae with square tipped teeth.

Habitat: Rock crevices, underneath of rock and under the algal holdfast.

Distribution: Cosmopolitan distribution in cold to tropical and temperate ocean from intertidal to 1,300 m depth (Gage et al. 1983).

Table 2. Systematic position of species recorded in present study from Saurashtra coast.

Class	Order	Family	Species
Ophiuroidea	Ophiacanthida	Ophiocomidae	<i>Ophiocomella sexradia</i>
	Amphilepidida	Hemieuryalidae	<i>Ophioplocus imbricatus</i>
		Ophionereididae	<i>Ophionereis dubia dubia</i>
		Amphiuridae	<i>Amphipholis squamata</i>
			<i>Amphiura ambigua</i>
		Ophiactidae	<i>Ophiactis savignyi</i>
		Ophitrichidae	<i>Macrophiothrix virabilis</i>
	<i>Ophiomaza caeotica</i>		
	<i>Ophiiothrix savignyi</i>		

Previous reports from Gujarat: Diu, Veraval, Holiday camp, Narara beyt, Dwarka, and Okha (Sastry 2004).

Present study: Diu (Jalandhar, Nagoa, & Gangeshwar), Dhamlej, Veraval, Mangrol, Dwarka, Shivrajpur, and Okha.

Genus *Amphiura* Forbes, 1843

***Amphiura ambigua* (Koehler, 1905)**

Image 1D

Material: Dwarka - 1 specimen; Okha - 2 specimens. One specimen having Museum ID: ZEOAAA(1)19H coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Rarely observed at Saurashtra coast. Five imbricating greyish black blotches clearly observed on the central part of the disc. Radial shield barrel shaped, flat, and longer, two radial shields distally separated by a single scale line and only united at proximal part. Five conical shaped arm spines.

Habitat: Underneath of rock.

Distribution: Indo west pacific (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Dwarka, Beyt Island, Balapur bay, and Hanuman Dandi (Sastry 2004).

Present study: Dwarka and Okha.

Family Ophiactidae Matsumoto, 1915

Genus *Ophiactis* Lütken, 1859

***Ophiactis savignyi* (Müller & Troschel, 1842)**

Image 1E,F

Material: Diu (Gangeshwar coast, Jalandhar, and Nagoa coast) - 13 specimens; Dhamlej - 5 specimens; Veraval - 23 specimens; Mangrol - 6 specimens;

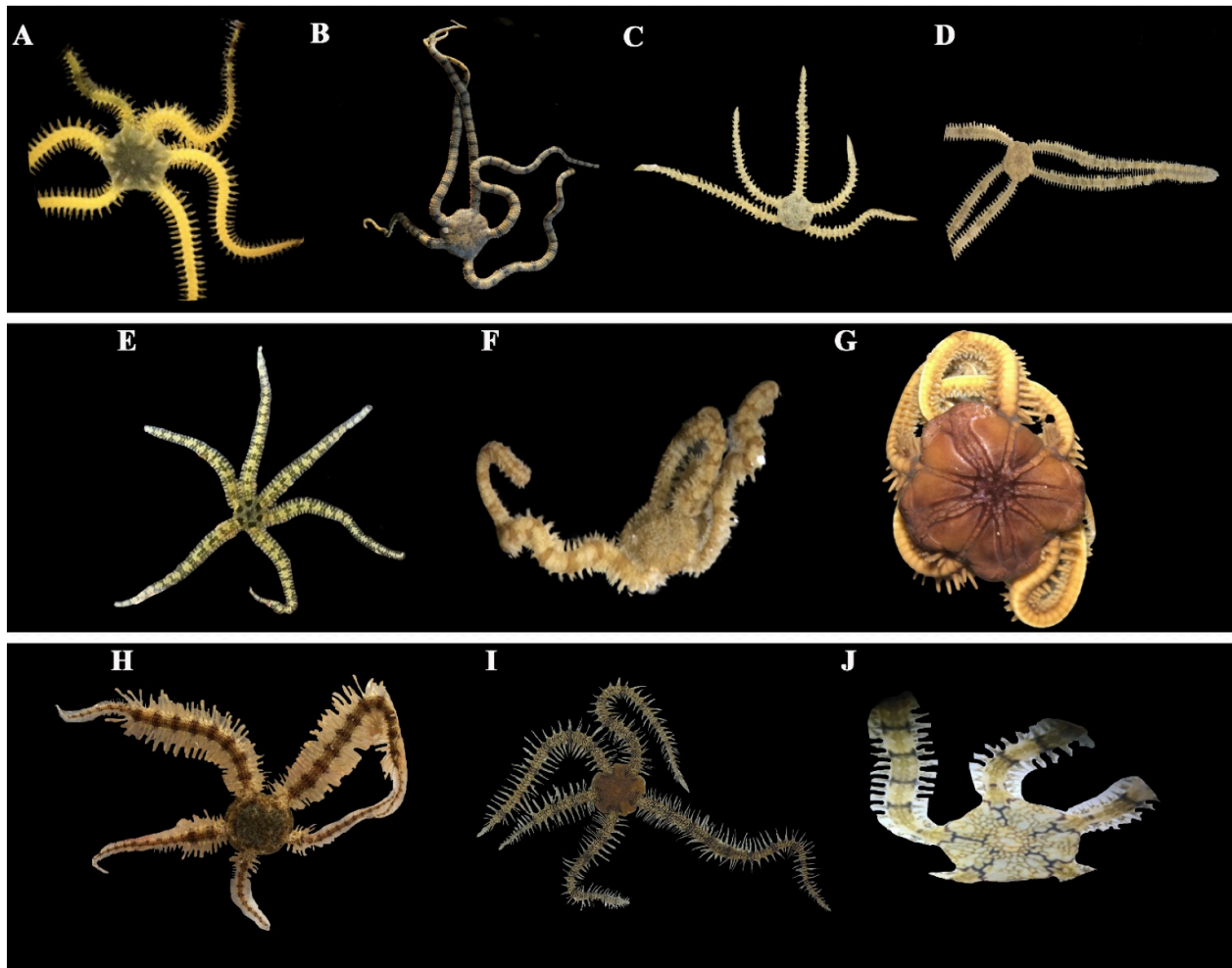


Image 1. Species reported in Saurashtra coastline: A—*Ophiocomella sexradia* | B—*Ophioplocus imbricatus* | C—*Amphipholis squamata* | D—*Amphiura ambigua* | E—*Ophiactis savignyi* | F—*Ophiactis savignyi* (color morph) | G—*Ophiomaza cacaotica* | H—*Macrophiothrix viriabilis* | I—*Ophiothrix savignyi* | J—*Ophionereis dubia dubia*. © Hitisha Baroliya

Table 3. Checklist of the recorded ophiuroids species at sampling sites. (Signs denote: '+' presence, '-' Absence). SM—Simbor | DH—Dhamlej | VRL—Veraval | MGL—Mangrol | DWK—Dwarka | SRP—Shivrajpur | OK—Okha

	Species	Rocky intertidal zone							
		DIU	SM	DH	VRL	MGL	DWK	SRP	OK
1	<i>Ophioplocus imbricatus</i>	-	-	-	-	-	+	+	+
2	<i>Ophionereis dubia dubia</i>	-	-	-	+	-	-	-	+
3	<i>Macrophiothrix viriabilis</i>	-	-	-	+	-	-	-	+
4	<i>Amphipholis squamata</i>	+	-	+	+	+	+	+	+
5	<i>Amphiura ambigua</i>	-	-	-	-	-	+	-	+
6	<i>Ophiactis savignyi</i>	+	-	+	+	+	+	+	+
7	<i>Ophiomaza cacaotica</i>	-	+	-	-	-	-	-	-
8	<i>Ophiocomella sexradia</i>	+	-	+	+	+	+	-	+
9	<i>Ophiothrix savignyi</i>	-	-	-	-	+	-	-	-

Dwarka - 8 specimens; Shivrajpur - 6 specimens; Okha - 10 specimens. Four specimens having Museum ID: ZEOAOO(8)19H, ZEOAOO(4)19H, ZEOAOO(5)19H, ZEOAOO(1)19H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Most occurred species at Saurashtra coastline. Radial shields large, oval, contiguous distally. Six arm spines, with denticles along margin and at tip. Two oral papillae each side, one pair of infradental papillae with square shape former teeth. During study, color morph of *O. savignyi* was observed from Dwarka. Which has reddish brown patches over pale yellow, five arms, five arm spine and base of arm spine broad, spines present on interradius, having only one oral papillae. As mentioned in fauna de Madagascar (Cherbonnier & Guille, 1978).

Habitat: Rock crevices, under the algal holdfast and within crevices of zoanthid bed.

Distribution: Indo-west pacific, Arabian sea to East Indies (Clark & Rowe 1971).

Previous report from Gujarat: Veraval, Dwarka, Okha Pirotan Island, and Mandvi (Sastry 2004).

Present study: Diu (Jalandhar, Nagoa, & Gangeshwar), Dhamlej, Veraval, Mangrol, Dwarka, Shivrajpur, and Okha.

Family Ophiotrichidae Ljungman, 1867

Genus *Macrophiothrix* H.L. Clark, 1938

***Macrophiothrix variabilis* (Duncan, 1887)**

Image 1H

Material: Veraval - 1 specimen; Okha - 5 specimen. Two specimens having Museum ID: ZEOAOM(5)19H, ZEOAOM(13)20B, coll. Hitisha Baroliya and Bhavna Solanki, are deposited in the Museum.

Remarks: Brown-purple colour. Small papillae on disc. Scalene triangular-shaped radial shield, spines present on radial shield. Eight arm spines near to disc, but distal parts have less in number, middle 2 spines large & other short, broad base of spines & denticulate structure. Hexagonal-shaped dorsal arm plate, white dots in middle, ventral arm plate, hexagonal shaped but convex by side. Cluster of dental papillae with six-seven no. of teeth in a row present on each jaw.

Distribution: Northern Australia from Shark Bay, W.A. to Mackay, Philippines, Singapore and Mergui Archipelago (Hoggett, 1990).

Present study: This is the first record from Gujarat (Veraval and Okha).

Ophiomaza Lyman, 1871

***Ophiomaza cacaotica* (Lyman, 1871)**

Image 1G

Material examined: Simbor - 3 specimens. Museum ID: ZEOAOO(8)21H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: specimen has brown color disc and mustard yellow arms. Disc smooth, very large triangular radial shield present. Five arms with four to six conical shaped arm spines. Some of the arm plates are fragmented dorsally, trapezoid shaped. Ventral side octagonal shaped arm plate. Arms covered by thick skin. Two genital slit present. Triangular shaped oral shield. Cluster of numerous tooth papillae present on each jaw.

Habitat: Associated with crinoid.

Distribution: Persian Gulf, Sri Lanka, Bay of Bengal, East Indies, northern Australia, Philippine, China, southern Japan, and South Pacific Islands (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Present study: This is the first record from Gujarat (Simbor).

Ophiothrix Müller & Troschel, 1840

***Ophiothrix savignyi* (Müller & Troschel, 1842)**

Image 1I

Material examined: Mangrol - 1 specimens. Museum ID: ZEOAOO(1)22N, coll. Niyati Gajera, are deposited in the museum.

Remarks: This species differed from *O. foveolata* earlier reported by Sastry (2004). *O. foveolata* has conspicuous spines on the dorsal disc with few or no thorny stumps while

This species has stumps/thorns, trifold. Bare radial shield having few thorns. Five arms with five/six denticulate arm spines. Tiny thorns/stumps present on the proximal dorsal arm plate. Distal margin of the ventral arm plates is concave. Cluster of numerous dental papillae present on each jaw. Specimen has brown color disc and arms having pattern.

Habitat: underneath of rock.

Distribution: South Eastern Arabia, Persian Gulf, West India and Pakistan (Clark & Rowe, 1971).

Present study: This is the first record from Gujarat (Mangrol).

DISCUSSION

The existing diversity of the intertidal Ophiuroidea from the Saurashtra coastline is described. Mainly rocky stations of the Saurashtra coastline were surveyed for

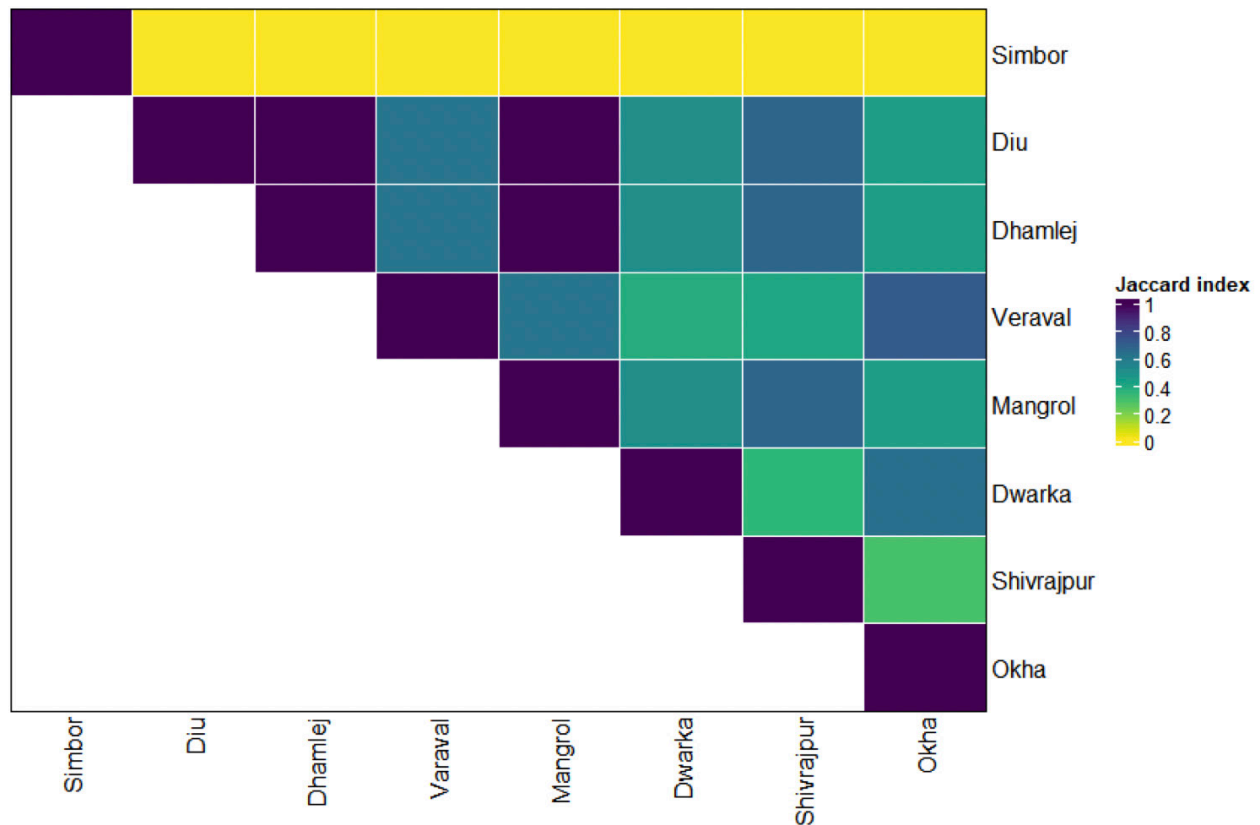


Image 2. The similarity between each sampling sites for ophiuroids species composition.

the diversity estimation. Earlier 12 ophiuroids were reported from the Gujarat coast (Sastry 2004). A recent evaluation of ophiuroids diversity fascinated with nine species, *Microphiothrix variabilis*, *Ophiothrix savignyi*, and *Ophiomaza cacaotica* are three new records for the Gujarat coast. This study revealed several unreported species from the intertidal areas of various station. *Ophiocomella sexradia*, *Ophionereis dubia dubia*, & *Microphiothrix viriabilis* first time reported from Veraval, *Ophiothrix savignyi* from Mangrol, *Ophiactis savignyi* & *O. sexradia* from Diu, *Amphiura ambigua*, *M. viriabilis*, & *O. dubia dubia* from Okha, and *Ophioplocus imbricatus* from Dwarka. Rest of the sites are first time evaluated in the present study with no previous records (Table 3). The similarity index result value varied from 0 to 1 (Image 2). Sampling site wise similarity index shows that all the seven sites were similar upto some extent in terms of species composition. Highest similarity was observed between Diu & Dhamlej, Diu & Mangrol, and Mangrol & Dhamlej because of the ophiuroid shared by this station are similar and their substratum and habitat structure are similar. While, Simbor has lowest similarity. Except two cosmopolitan species *A. squamata* and *O. savignyi*, all the species of Ophiuroidea were found to

be very much confined to selected station. The results of similarity indices show that each sampling sites has diverse variety of the Brittle Star, which makes them spatially altered from each other. Some of the species were associated with other marine creatures.

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