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Macroalgae as indicator species for shore platform zones of Dwarka, Gujarat, India

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Dwarka coast of Gujarat state in India has a stable shore platform. A study was carried out to identify indicator species among the sampled macroalgae to understand their spatial preferences on the shore platform zones. For this study, the shore platform was divided into three sections in north-south direction: Northern, central, and southern sections. These sections were further divided into three microzones in west-to-east direction based on their local geomorphology and tidal inundation characteristics for more detailed study. These microhabitat zones are: Cliff Base Zone (CBZ), Intertidal Mixed Zone (IMZ) and Subtidal Zone (STZ). To identify indicator species for each microzone, the shore platform was surveyed based on systematic random sampling for two years (April 2013 to April 2015). Line intercept transects and GPS-tagged photo quadrates were carried out from land to seaward as part of the sampling procedure. Indicator species were identified on the basis of a decision-rule when a single species belonged to only one microhabitat zone in all the three sections. Total 97 species of seaweeds were recorded in the shore platform of Dwarka. Out of these, 27 belonged to chlorophyta, 21 to phaeophyta and 49 to rhodophyta. Out of all these species, rhodophyta was found as the dominant group in the shore platform. Out of 97 species, only 12 species were identified as indicator species. Out of these, only one species was from phaeophyta group and eleven from rhodophyta group. This study shows indicator species of the microhabitat zones of the shore platform, with rhodophyta sp. as the prominent macroalgae group. Indicator species can act as proxy indicators of the microhabitats created by the local geomorphology and tidal regime on the shore platform.

[Keywords: Macroalgae; Microhabitat; Indicator species; Shore platform; Dwarka]

Introduction

Macroalgae are generally found in shallow coastal waters. They grow in the shallow, intertidal and even deep sea areas up to 180 m depth and also in estuaries and back waters on the solid substrate, such as rock, dead corals, pebbles, shells, and other plant materials[1]. They belong to mainly three groups: chlorophyceae (green algae), phaeophyceae (brown algae) and substrates like shore platform, coral reef, pebbles, etc. Macroalgae are primary producers and provide habitat for near shore benthic communities. They play a significant role in the benthic food web. Macroalgae are key space occupier on rocky shores and interact with other organisms and hence play a key role in overall coastal biodiversity. They are found on shore platform in the intertidal zones as giant underwater forest.

Macroalgae grow abundantly along the Indian coastline particularly in rocky shore regions:- e.g. rich macroalgal beds occur around Visakhapatnam in the east coast; Mahabalipuram, Gulf of Mannar, Tiruchendur and Tuticorin in Tamil Nadu and Kerala in the south; Veraval and Gulf of Kachchh in the west coast; Andaman and Nicobar Islands, and Lakshadweep. They are also found in abundant around the coastal locations of Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam, and Pulicat in Tamil Nadu in the west and southern coast of India coast[2].

Macroalgae constitute one of the commercially important renewable marine living resources[3]. They are used as food, fodder, fertilizer and also as a source of raw materials for industry, production of medicines, cosmetics and other items. The floristic variation in macroalgal communities are controlled by several, environmental factors, including season, habitat, topography, duration of tidal exposure, tidal amplitude, and biotic factors (algal turf, grazing, high concentration of limpets and many others)[4]. Many scientists have worked on the seasonal variation of macroalgae in Indian waters[5,6,4,7,8,9].

The present study was aimed to identify indicator species among the sampled macroalgae to understand their spatial preferences on the shore platform zones of Dwarka, Gujarat.

Material and Methods

Study area

For macroalgae growth, geographical, geological, topographical and physical nature of the shore is very important. The rocky coast has vertical zonation worldwide[10]. It provides good platform and stable coastal environment compared to that of soft sediment coasts like beaches and spits. Shore platform represents a case environment where majority of macroalgae species grow with a firm substratum attachment.

Gujarat coast of India represents the north-western most part of peninsular India. This coastline occurs within the geographical limits of 20˚08'-24˚40'N and 68˚10'-74˚28'E. This coastline is 1,650 km long with 164,200 km^2 continental shelf[4]. It extends in the form of four major coastal ecological components: Kori creek, Gulf of Kachchh, Saurashtra coast from Okha to Porbandar, and Gulf of Khambhat. The substratum is rocky in many parts, which provides suitable environment for macroalgae growth[11]. The Saurashtra coast, which runs for an approximate length of 985 km, is characterized by rocky, sandy and muddy intertidal zones, harbouring rich and varied flora and fauna[5].

The present study was carried out on the shore platform at Dwarka, located on the Saurashtra coast (22˚14'22"-22˚14'38"N and 68˚57'15"- 68˚57'25" E) (Fig. 1). Total length of the study area is 572.28 m, maximum width sampled is 143.8 m and covers a surface area of 82,293.86 m^2 [12]. Previous surveys of marine algal resources along the Gujarat coast, performed at the intertidal zone, have revealed great diversity of marine algae in this region[13] .

Field data collection

For the present study, the study area was divided into three sections (in North-South direction): northern, central, and southern sections. Field sampling of macroalgae was done from April 2013 to April 2015. Field survey and sampling were performed during the low tides.

For sampling procedure, line intercept transect and GPS (Spheroid and Datum: WGS 84) tagged photo quadrates were carried out from land to seaward direction. Line intercept transect was laid perpendicular to the coast from land to sea with the

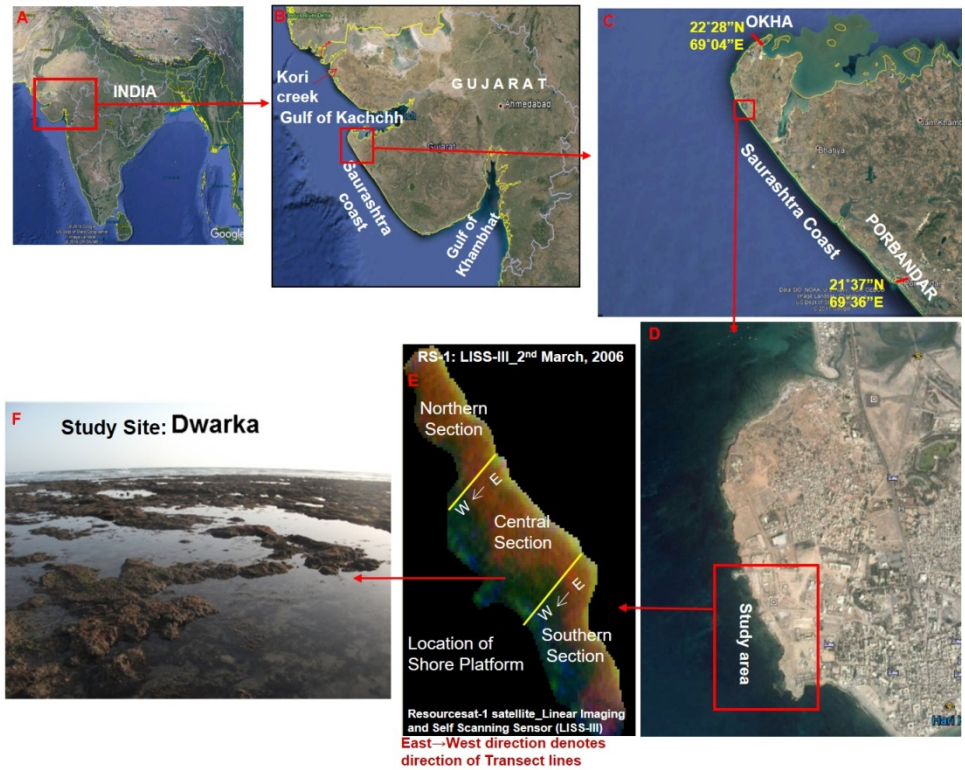

Fig. 1 — Study area: Shore platform, Dwarka (E→W lines denote direction of transect lines)

help of a long rope (50 m)[14,15]. A sampling point along the rope is marked depending on the gradient and exposure of intertidal and subtidal areas. In Saurashtra coast, the tidal amplitude is very high as compared to other parts of the west coast and the entire east coast of India. Growth of seaweeds or macroalgae in intertidal and shallow subtidal regions can be easily observed in this area as the spring tides expose the intertidal area up to a maximum length of 1 km.[4] Each of the three sections of the Dwarka shore platform was represented by one transect line; thus resulting in 36 transect lines sampling months. Quadrates of 1 m^2 were positioned on the transect lines where the algae growth, density and diversity were high. Two hundred sixty quadrates were performed on 36 transect lines in Dwarka. GPS tagged photos of quadrates were taken for further analysis. Macroalgae present within the quadrates were sampled.

Field data analysis

Collected macroalgae samples were taken to laboratory for identification. Morphological criteria were analysed for taxa identification. For understanding their microhabitat preference, quadrate data was analysed. Indicator species were identified on the basis of a decision-rule when a single species belonged to only one microhabitat zone in all the three sections. Some species are found to grow only in particular zones and are called indicator species of that particular zone.

Results and Discussion

The shore platform of Dwarka was further divided into three microzones in east-to-west direction based on their local geomorphology and tidal inundation characteristics. The microhabitat zones are: Cliff Base Zone (CBZ), Intertidal Mixed Zone (IMZ), and Subtidal Zone (STZ). These zones are based on the general geomorphological and topographical characteristics of the shore platform, level of tidal inundation and dominance of seaweeds as observed during the field surveys. Macroalgae distributions were tagged with shore platform's zonal morphology as part of this study. CBZ has many rock shore pools as compared to other zones. It is followed by a mixed intertidal area, where there is a transition from phaeophyta to chlorophyta. Mixed zone also rock pools but in less frequency. The subtidal zone is always submerged in water, but in spring tide this zone gets exposed.

Macroalgae growing on the platform were surveyed based on systematic random sampling for two years (April 2013 to April 2015). Out of total 97 taxa, 27 belong to chlorophyta, 21 to phaeophyta[12], and 49 to rhodophyta (Table 1) were identified from this site through intensive fieldwork based on line intercept transect and quadrate based sampling methods.

Table 1 — List of macroalgae present and their temporal variation on shore platform, Dwarka (A: Absence, P: Presence)

Sr. No.	Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun
	CHLOROPHYTA								
1	*Boodlea composita (Harvey) Brand*	*P*	*P*	*P*	A	*P*	*P*	*P*	*P*
2	*Bryopsis pennata* Lamouroux	A	A	A	A	A	P	A	A
3	*Bryopsis plumosa* (Hudson) C. Agardh	P	P	P	A	A	A	P	A
4	*Caulerpa racemosa* (Forsskål) J. Agardh	A	P	A	P	P	P	P	P
5	*Caulerpa racemosa* (Forsskål) J. Agardh v. corynephora (Montagne) Weber-van Bosse	A	P	P	P	P	P	P	A
6	*Caulerpa racemosa* v. occidentalis (J. Agardh) Børgesen	P	A	P	A	A	A	P	A
7	*Caulerpa scalpelliformis* (Brown ex Turner) C. Agardh f. dwarkensis Børgesen	A	A	P	P	P	A	P	P
8	*Caulerpa sertularioides* (S. Gmelin) Howe f. brevipes (J. Agardh) Svedelius	P	P	P	P	A	P	P	P
9	*Caulerpa taxifolia* (Vahl) C. Agardh	A	P	P	P	A	P	P	P
10	*Caulerpa veravalensis* Thivy & Chauhan	A	A	P	P	P	A	P	A
11	*Chaetomorpha antennina* (Bory) Kützing	A	A	P	P	A	A	A	A
12	*Chaetomorpha crassa* (C. Agardh) Kützing	A	P	P	P	P	A	A	A
13	*Chaetomorpha spiralis* Okamura	A	A	P	A	A	A	A	A
14	*Cladophora glomerata* (Linnaeus) Kützing	A	A	P	P	A	A	A	A
15	*Cladophoropsis javanica* (Kützing) P. Silva	A	A	A	A	A	A	P	A
16	*Codium decorticatum* (Woodward) Howe	A	A	A	A	A	P	A	A

(*Contd*.)

Table 1 — List of macroalgae present and their temporal variation on shore platform, Dwarka (A: Absence, P: Presence) (*Contd*.)

Sr. No.	Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun
	CHLOROPHYTA								
17	*Codium dwarkense* Børgesen	A	A	A	A	A	A	P	A
18	*Dictyosphaeria cavernosa* (Forsskål) Børgesen	A	A	A	A	P	P	P	A
19	*Halimeda macroloba* Decaisne	A	A	A	P	P	P	P	P
20	*Halimeda tuna* (Ellis & Solander) Lamouroux	P	P	P	P	A	A	P	P
21	*Udotea indica* A. & E. Gepp.	A	P	P	P	P	P	P	P
22	*Ulva conglobata* Kjellman	A	P	P	P	P	A	A	A
23	*Ulva fasciata* Delile	A	P	P	P	P	P	P	A
24	*Ulva lactuca* Linnaeus	P	P	P	P	P	P	P	A
25	*Valonia aegagropila* C.Agardh	P	P	A	A	A	A	A	P
26	*Valoniopsis pachynema (*Martens) Børgesen	P	P	P	P	P	A	P	P
Sr. No.	Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun
27	*Valonia utricularis* (Roth) C. Agardh	A	A	A	A	P	A	A	A
	PHAEOPHYTA								
28	*Colpomenia sinuosa* (*Mertens* ex Roth) Derbes & Solier	A	A	P	P	P	P	P	A
29	*Cystoseira indica* (Thivy & Doshi) Mairh	P	P	P	P	P	P	P	A
30	*Dictyopteris australis* (Sonder) Askenasy	A	A	A	A	A	A	P	A
31	*Dictyopteris acrostichoides* (J. Agardh) Bornet	A	P	A	A	A	A	A	A
32	*Dictyota ciliolata* Kützing	A	P	A	P	A	A	P	A
33	*Dictyota dichotoma* (Hudson) Lamouroux	A	A	A	P	P	P	A	A
34	*Hydroclathrus clathratus* (C. Agardh) Howe	A	A	A	P	P	P	P	A
35	*Iyengaria stellata* (Børgesen) Børgesen	A	A	A	P	P	P	P	A
36	*Lobophora variegata* (Lamouroux) Womersley ex *Oliveria*	P	P	P	P	P	A	P	A
37	*Padina boergesenii* Allender & Kraft	P	A	P	A	A	P	P	A
38	*Padina boryana* Thivy	A	P	P	A	A	A	P	A
39	*Padina tetrastromatica* Hauck	P	P	P	P	P	P	P	A
40	*Rosenvingea orientalis* J. Agardh	P	A	P	A	A	A	P	A
41	*Sargassum cinctum* J. Agardh	P	A	P	P	P	A	P	P
42	*Sargassum cinereum* J. Agardh	P	P	P	P	P	A	P	A
43	*Sargassum johnstonii* Setchell & Gardner	A	P	P	P	A	A	P	A
44	*Sargassum linearifolium* (Turner) C. Agardh	A	A	P	P	A	A	A	A
45	*Sargassum plagiophyllum* (Martens) J. Agardh	A	A	P	P	P	A	P	A
46	*Sargassum swartzii* C. Agardh	A	P	P	A	A	A	A	A
47	*Sargassum tenerrimum* J.G. Agardh	A	P	P	P	A	A	P	A
48	*Stoechospermum marginatum* (C. Agardh) Kützing	P	A	P	P	P	A	A	A
	RHODOPHYTA								
49	*Acanthophora spicifera* (Vahl) Børgesen	A	P	A	A	A	P	P	A
50	*Amphiroa anceps (Lamarck)* Decaisne	P	A	P	P	P	P	P	A
51	*Amphiroa fragilissima* (Linnaeus) Lamouroux	A	P	A	A	A	P	P	A
52	*Centroceras clavulatum* (C. Agardh) Montagne	P	P	P	P	P	P	P	P
53	*Champia compressa* Harvey	A	A	A	P	P	A	P	A
54	*Champia indica* Børgesen	A	A	A	A	A	P	A	A
55	*Champia somalensis* Hauck	A	A	A	P	A	A	P	A
56	*Cheilosporum spectabile* Harvey ex Grunow	A	A	A	A	A	A	P	A
58	*Chondria armata* (Kützing) Okamura	A	A	A	A	A	A	P	A
59	*Chondria dasyphylla* (Woodward) C. Agardh	A	A	A	P	A	A	A	A
60	*Corallina berteroi* Montagne ex Kützing	P	P	P	P	P	P	P	A
61	*Digenea simplex* (Wulfen) C. Agardh	A	A	A	P	A	A	A	A
62	*Gelidiella acerosa* (Forsskål) J. Feldmann	P	P	P	P	P	P	P	P
63	*Gelidium micropterum* Kützing	A	P	P	P	A	P	P	A
64	*Gelidium pusillum* (Stackhouse) Le Jolis	A	P	P	A	A	A	P	A
65	*Gracilaria crassa* Harvey ex J. Agardh	A	A	A	A	A	A	P	A
66	*Gracilaria corticata* (J. Agardh) J. Agardh var. cylindrica Umamaheswara Rao	A	P	A	A	A	A	A	A

(*Contd*.)

Table 1 — List of macroalgae present and their temporal variation on shore platform, Dwarka (A: Absence, P: Presence) (*Contd*.)

Sr. No.	Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun
	RHODOPHYTA								
67	*Gracilaria corticata* (J. Agarth) J. Agardh	P	A	A	P	P	P	P	A
68	*Gracilaria foliifera* (Forsskål) Børgesen	A	A	A	A	P	A	A	A
69	*Gracilaria textorii* (Suringar) De Toni	A	A	A	P	A	A	A	A
70	*Gracilaria debilis* (Forsskål) Børgesen	A	A	P	A	A	A	A	A
Sr. No.	Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun
71	*Grateloupia filicina* (Lamouroux) C. Agardh	A	A	P	A	P	A	A	A
72	*Grateloupia indica* Børgesen	A	P	P	P	P	A	A	A
73	*Halymenia porphyraeformis* Parkinson	A	A	A	P	A	A	A	A
74	*Halymenia venusta* Børgesen	A	A	A	P	A	A	P	A
75	*Hypnea esperi* Bory de Saint-Vincent	A	A	A	A	A	P	P	A
76	*Hypnea musciformis* (Wulfen) Lamouroux	A	A	P	P	P	P	P	A
77	*Hypnea pannosa* J. Agardh	A	P	A	A	A	A	P	A
78	*Hypnea spinella* (C. Agardh) Kützing	A	A	P	A	P	P	P	A
79	*Hypnea valentiae* (Turner) Montagne	A	A	P	P	P	P	P	A
80	*Jania rubens* (Linnaeus) Lamouroux	A	A	P	A	A	P	P	A
81	*Kappaphycus alvarezii* (Doty) Doty ex P. Silva	A	A	A	P	P	A	P	A
82	*Laurencia cruciata* Harvey	A	A	P	A	A	A	A	A
83	*Laurencia glandulifera* (Kützing) Kützing	A	A	P	A	A	A	A	A
84	*Laurencia obtusa (Hudson) Lamouroux*	A	A	P	A	P	P	P	A
85	*Laurencia papillosa* (C. Agardh) Greville	P	P	P	P	A	A	P	A
86	*Laurencia perforata* (Bory) Montagne	A	A	P	A	A	A	A	A
87	*Laurencia platyclada* Børgesen	A	A	P	A	P	A	P	A
88	*Laurencia sp.*	A	A	A	P	A	A	A	A
89	*Liagora ceranoides* Lamouroux	A	A	A	P	P	A	A	A
90	*Peyssonnelia obscura Weber-van Bosse var. bombayensis Børgesen*	A	P	A	A	P	A	A	A
91	*Porphyra kanyakumariensis* V. Krishnamurthy and Baluswami	A	A	A	A	P	A	A	A
92	*Sarconema filiforme* (Sonder) Kylin	A	P	A	P	A	A	A	A
93	*Scinaia fascularis* (Børgesen) Huisman	A	P	A	A	A	A	A	A
94	*Sarconema scinaioides* Børgesen	A	A	A	P	A	P	A	A
95	*Scinaia carnosa* (Kützing) J. Agardh	A	A	A	P	A	A	A	A
96	*Solieria robusta* (Greville) Kylin	A	A	P	A	A	A	A	A
97	*Tricleocarpa fragilis* (Linnaeus) Huisman & Townsend	A	A	A	A	P	A	P	A

Out of all the species, species of rhodophyta are found as the dominant group in shore platform, Dwarka. Out of 97 species, only 12 species were identified as indicator species. Out of these, 1 species belongs to phaeophyta group and 11 to rhodophyta group (Table 2). *Chondracanthus acicularis* (Roth) Fredericq, *Halymenia venusta* Børgesen, *Jania rubens* (Linnaeus) Lamouroux and *Laurencia cruciate* Harvey belong to rhodophyta group and they are indicator species of the cliff base zone. Rhodophyta group of species *Champia somalensis* Hauk, *Gelidium micropterum* Kützing, *Hypnea pannosa* J. Agardh, *Kappaphycus alvarezii* (Doty) Doty ex p. Silva, *Laurencia glandulifera* (Kützing) Kützing, *Laurencia sp.* and *Liagora ceranoides* Lamouroux are indicator species of the Intertidal Mixed zone. *Dictyota dichotoma* (Hudson) Lamouroux belongs to phaeophyta group and is an indicator species of the subtidal zone.

Rhodophyta group is found as dominant as indicator species of shore platform, Dwarka. The chlorophyta group was found in almost all the zones and phaeophyta was also found in all zones except one species *Dictyota dichotoma* (Hudson) Lamouroux. Out of 49 species of rhodophyta group, 11 species were found as indicator species in shore platform, Dwarka.

Many researchers have worked on the seasonal variation of seaweeds, growth, chemical components, etc. Dhargalkar *et al.*[16] have worked on the marine macroalgal diversity along the Maharashtra coast; particularly on the distribution and abundance of marine macroalgae at six sites with the data available from 1935. They observed typical cyclic changes in distribution, abundance and the reproductive features in these algal forms. The northern part of Maharashtra is subjected to increasing industrial pollution and habitat destruction. There are some pockets wherein

Table 2 — List of indicator species of microhabitat zones in shore platform, Dwarka

Sr. No.	Zonal indicator species	Cliff base	Mix zone	Subtidal zone
1	*Dictyota dichotoma* (Hudson) Lamouroux	A	A	P
2	*Chondracanthus acicularis* (Roth) Fredericq	P	A	A
3	*Champia somalensis* Hauk	A	P	A
4	*Gelidium micropterum* Kützing	A	P	A
5	*Hypnea pannosa* J. Agardh	A	P	A
6	*Halymenia venusta* Børgesen	P	A	A
7	*Jania rubens* (Linnaeus) Lamouroux	P	A	A
8	*Kappaphycus alvarezii* (Doty) Doty ex P. Silva	A	P	A
9	*Liagora ceranoides* Lamouroux	A	P	A
10	*Laurencia cruciata* Harvey	P	A	A
11	*Laurencia glandulifera* (Kützing) Kützing	A	P	A
12	*Laurencia sp.*	A	P	A

high macroalgal diversity occurs. Srinivasa Rao and Umamaheswara Rao[17] have worked on seasonal growth pattern in *Sargassum polycystum* C. Agardh (Phaeophyta, Fucales) at Visakhapatnam, east coast of India. They have studied field data collected on mean thallus length, mean number of primary shoots, frequency of different size classes and reproductive conditions as well as on some environmental factors, for two years. They found maximum number of primary shoots and higher frequency of larger size classes during the winter season. They also found significant negative correlation with temperature, indicating it as a causal factor. Gohil and Kundu[5] have studied diversity of the intertidal macrofuana at west coast of Gujarat. They have found 27 species of intertidal algae. Out of these, 11 chlorophyceae, 9 phaeophyceae and 7 rhodophyceae have been recorded. They identified chlorophyceae as the dominant algae group on this coast while this paper lists 97 species of macroalgae at shore platform of Dwarka. Out of 97 species, 27 belongs to chlorophyta, 21 to phaeophyta and 49 to rhodophyta. Jha *et al.,*[4] have worked on the diversity and distribution of seaweeds of Gujarat coast. They have given the species level characteristics of the Gujarat coast. They have reported 70 species of seaweeds (15 of Chlorophyta, 12 of Phaeophyta and 43 of Rhodophyta) for Dwarka. This research work recorded 97 species of macroalge. In this paper 12 species is recorded as indicator species. Out of these species, Jha *et al.*,[4] have reported 7 species but did not comment on the microhabitat of these species.

Conclusion

This study shows the indicator species of the microhabitat zones of the shore platform of Dwarka. Rhodophyta is found as the prominent macroalgae group in this location. Indicator species can act as proxy indicators of the microhabitat created by the tidal regime on the shore platform. These findings will help to study the different algae based on microhabitat zones and habitat their preference.

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