Study of seaweeds diversity of port 'Okha' in winter

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Abstract: The present study was conducted in seaweed rich moist coastal zone of Port "Okha" of Saurashtra coast, Gujarat, India in winter (December, January and February) during the year 2012 & 2013 consecutively to document the seaweed diversity of the area. A total of 72 species belonging to 26 families and 46 genera were recorded from the study area. The Chlorophyceae, Phaeophyceae and Rhodophyceae were represented by a total of 19, 22 and 31 species, respectively. Of the 26 families recorded, 7 were represented by single species, 6 by two species, 5 by three species and 6 with more than 3 species. Dictyotaceae was the dominant family with 13 species, followed by Sargassaceae and Ulvaceae with 5 species each. The maximum species richness was found to be in the month of February in comparison to December and January. This paper presents the current status of seaweed wealth of different beachfronts of 'Okha'.

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1. Introduction

Seaweeds include all the macroscopic algae occurring in the marine and brackish water habitats and are considered as one of the primary producer of marine ecosystem. They are mainly found in the intertidal and the sub-tidal region up to a depth, where 0.01 % photosynthetic light is available (Domettila *et al.*, 2013). The distribution and diversity of the seaweeds in a marine ecosystem directly depends on light exposure, depth, temperature, tides and the seashore characters (Darghalkar & Kavlekar, 2004). Seaweeds are considered as important marine living resources and are utilized by the humans in different ways. They are the only source for the production of phytochemicals namely agar-agar, carrageenan and algin, which are extensively used in various industries such as food, confectionary, textiles, pharmaceuticals, dairy and paper industry mostly as gelling, stabilising and thickening agents (Kaliaperumal et. al., 1989).

India having a coastline of more than 7,000 km. supports a rich floristic diversity of seaweeds (Oza and Zaidi 2001). These occur mainly in coastal areas with rocky substratum or rich with corals *viz.* Visakhapatnam in the eastern coast, Mahabalipuram, Gulf of Mannar, Tiruchendur, Tuticorin and Kerala in the southern coast; Veraval and Gulf of Kutch in the western coast; Andaman and Nicobar islands and Lakshadweep (Umamaheswara Rao, 1967; Silva *et al.*, 1996; Sahoo *et al.*, 2001).

"Gulf of Kutch" is one of the potential areas in India for rich growth of seaweeds. It possesses a zone of 7300 km^2 containing a system of creeks, marshy tidal flats and rocky coral reefs which provide favorable environment to a wide variety of seaweeds. A standout amongst the most fertile regions on the 'Gulf of Kutch' is Port Okha, situated in district Jamnagar. This area being at the mouth of "Gulf of Kutch" encounters strong water currents round the year as compared to other parts. A moderate temperature (21.5 to 30◦C) with salinity of 35.46 to 37.32 PSU, an exposure of 0.7–0.9 km width of intertidal zone for 3–4 hours with tidal amplitude of 4–5m creates a unique hospitable habitat for luxuriant growth of diverse seaweeds over this area (Chauhan, 1965; Misra, 1960).

The first diversity assessment of seaweeds in India was carried out by Krisnamurthy and Joshi (1970) where they had reported only 153 species belonging to 95 genera from the entire seaside of Gujarat. Subsequently, an updated checklist was prepared by Sahoo (2001) reporting about 280 species from Gujarat coast, which is 36% of total reported Indian seaweeds. Later, Jha *et al.* (2009) reported 198 species of seaweeds fitting in with 101 genera from the Gujarat coast. Regarding our study site, Murthy *et al.* (1978) made preliminary ecological investigations on the intertidal algae at Port Okha and described the zonation pattern of the seaweeds. Shah *et al.* (2001) contemplated the cyanobacterial diversity. Thakur *et al.* (2008) also reported 62 species of seaweeds from 'Okha' amid 2004 to 2005. Later on, Nakar *et al.* (2011) studied the species diversity, density and biomass of seaweeds from the same site during their survey in

2007-2008. But as the species diversity may change along with the time due to many reasons, so an updated report is always needed to know the recent status. Hence, this paper introduces the ebb and flow status of seaweed diversity of different coastal ranges of 'Okha', which is a critical venture to re-assess the sea-weeds diversity of this area.

2. Materials and Methods

2.1 Study Area

The present study was conducted in Port Okha, situated in Jamnagar district between 22˚28′N latitude and 69˚05′E longitude at the mouth of Gulf of Kutch on the north-western most part of Saurashtra coast of Gujarat (Fig. 1). The coast is characterized by tertiary rocks alternating with patches of corals and sand deposits making the area more hospitable for the growth of all types of seaweed throughout the year (Børgesen, 1934).

Physicochemical properties of seawater at Port Okha are as follows: temperature ranged from 21.5 to 30◦C, salinity from 35.46 to 37.32 PSU, D.O. from 5.3 to 6.7 ppm, turbidity from 0 to 200 ppm, phosphate phosphorus from 0.1 to 1.05 μg atom/l, nitrate nitrogen from 2.0 to 11.5 μg atom/l (Chauhan, 1965).

2.2 Algal Sampling

Random sampling technique has been applied in the algal collection procedure. Collections of macro-algal specimens were carried out at five different sites on the Okha coast. All the specimens were collected from the intertidal region during winter (December, January and February) in the year 2012 & 2013 consecutively. Collections were made during dawn and morning hours from their natural habitats. The collections of the samples were done using long forceps and scalpels. The fresh specimens were temporarily preserved in 4% formalin solution and brought to the Department of Botany, Kurukshetra University, India. Later some of the collected specimens were permanently preserved in formaldehyde solution and some others were dried and mounted on Herbarium sheets. The samples were identified using authenticated manuals and books on Seaweeds and given accession number. Herbarium of algal samples was deposited at the Department of Botany, Kurukshetra University, India.

3. Results

During the study period a total of 72 species of seaweeds were found, belonging to 46 genera and 26 families (Table. 1). The maximum diversity was exhibited by Rhodophyceae with 31 species, followed by Phaeophyceae with 22 species and Chlorophyceae with 19 species. Twenty-five genera of red algae fitting into 15 families were reported from the study site. Halymeniaceae and Rhodymeniaceae were the most diverse families and at generic level *Gracilaria* and *Scinaia* showed the maximum species diversity. Whereas, the least distributed red algae was *Solieria robusta*. In Pheophyceae, 12 genera were found belonging to 4 families *viz.* Dictyotaceae, Scytosiphonaceae, Cystoceiraceae and Sargassaceae. Dictyotaceae was the most abundant family followed by Sargassaceae, where as Cystoceiraceae showing the least abundance. *Sargassum* was the most abundant genus but maximum species diversity was reported in *Dictyota*. Among the members of Chlorophyceae, twenty-five genera included into 15 families were reported, out of which Caulerpaceae was the most abundant and Cladophoraceae and Udoteaceae were the least abundant families. *Caulerpa* and *Ulva* were the most abundant genus and *Caulerpa racemosa* showed the highest species richness. On contrary, *Valoniopsis pachynema* showed lowest species richness.

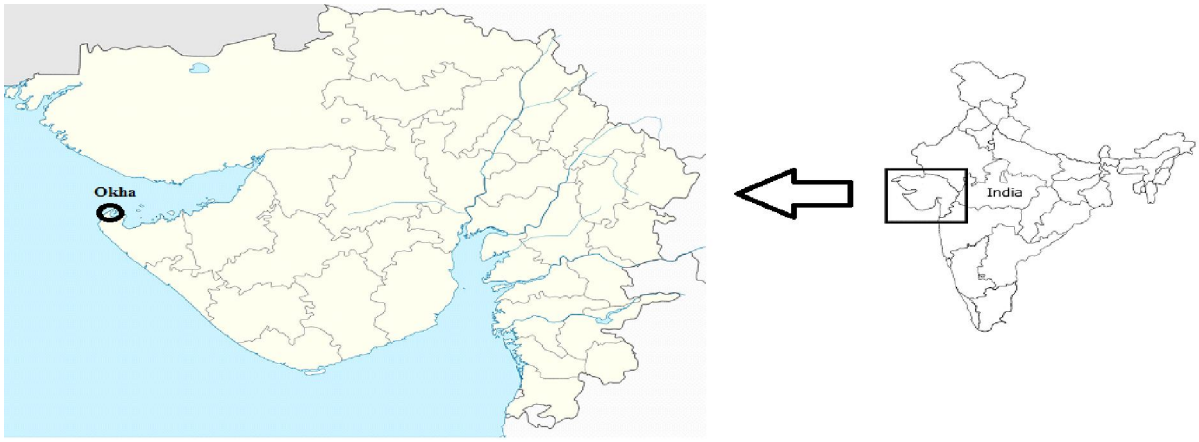

Fig. 1. Map showing the study site: Port Okha, Gulf of Kutch.

Table 1: Checklist of Seaweeds Diversity of Port Okha, Gujarat.

S	Species	Class	Order	Family	Site 1	Site 2	Site 3	Site 4	Site 5
	Boodlea composita (Harvey) Brand	Chlorophyceae	Cladophorales	Siphonocladaceae	+	+	-	-	+
	Caulerpa racemosa (Forssk˚al) J. Agardh	Chlorophyceae	Bryopsidales	Caulerpaceae	+++	++	+++	++	++
	Caulerpa scalpelliformis (R. Brown ex Turner) C. Agardh	Chlorophyceae	Bryopsidales	Caulerpaceae	+	+	+	-	+
	Caulerpa sertularioides (S. Gmelin) Howe	Chlorophyceae	Bryopsidales	Caulerpaceae	++	++	+	++	+
	Caulerpa taxifolia (Vahl) C. Agardh	Chlorophyceae	Bryopsidales	Caulerpaceae	++	+	+	-	++
	Caulerpa veravalensis Thivy & Chauhan	Chlorophyceae	Bryopsidales	Caulerpaceae	++	+	+	+	-
	Chaetomorpha spirallis Okamura	Chlorophyceae	Cladophorales	Cladophoraceae	+	-	-	+	+
	Codium decorticatum (Woodward) Howe	Chlorophyceae	Bryopsidales	Codiaceae	++	+	+	+	+
	Codium dwarkense (Boergs.)	Chlorophyceae	Bryopsidales	Codiaceae	++	+	+	-	+
	Codium tomentosum (Huds.)	Chlorophyceae	Bryopsidales	Codiaceae	++	+	++	+	+
	Enteromorpha compressa (Linn) Nees	Chlorophyceae	Ulvales	Ulvaceae	+	-	+	+	-
	Halimeda macroloba Decaisne	Chlorophyceae	Bryopsidales	Halimedaceae	++	+	+	-	+
	Halimeda tuna (Ellis & Solander) Lamouroux	Chlorophyceae	Bryopsidales	Halimedaceae	+	-	-	+	+
	Udotea indica A. Gepp & E. Gepp	Chlorophyceae	Bryopsidales	Udoteaceae	+	+	-	+	-
	Ulva beytensis Thivy & Sharma	Chlorophyceae	Ulvales	Ulvaceae	+	++	++	+	+
	Ulva fasciata Delile	Chlorophyceae	Ulvales	Ulvaceae	++	+	++	+	+
	Ulva lactuca Linnaeus	Chlorophyceae	Ulvales	Ulvaceae	+++	+	++	++	+
	Ulva rigida C. Agardh	Chlorophyceae	Ulvales	Ulvaceae	+	++	+	+	++
	Valoniopsis pachynema (G. Martens) Børgesen	Chlorophyceae	Cladophorales	Siphonocladaceae	+	-	-	+	-
	Colpomenia sinuosa (Merens ex Rotyh) Derbes & Solier	Phaeophyceae	Chordariales	Scytosiphonaceae	++	+	++	++	++
	Cystoseira indica (Thivy & Doshi) Mairh	Phaeophyceae	Fucales	Cystoceiraceae	++	++	+	+	++
	Dictyopteris acrostichoides J. Agardh	Phaeophyceae	Dictyotales	Dictyotaceae	+	++	+	-	+
	Dictyopteris australis (Sonder) Askenasy	Phaeophyceae	Dictyotales	Dictyotaceae	++	++	+++	+	++
	Dictyota bartayresiana Lamouroux	Phaeophyceae	Dictyotales	Dictyotaceae	++	+	+	++	++
	Dictyota cervicornis (Kützing)	Phaeophyceae	Dictyotales	Dictyotaceae	+	++	+	+	+
	Dictyota ciliolata Sonder ex Kützing	Phaeophyceae	Dictyotales	Dictyotaceae	+	++	+	++	+
	Dictyota dichotoma (Hudson) Lamouroux	Phaeophyceae	Dictyotales	Dictyotaceae	++	+++	+	++	++
	Dictyota divaricata J. Agardh	Phaeophyceae	Dictyotales	Dictyotaceae	+	+	++	+	++
	Dictyota fasciola (Roth) J.V. Lamouroux	Phaeophyceae	Dictyotales	Dictyotaceae	+	+	-	+	+
	Iyengaria stellata (Børgesen) Børgesen	Phaeophyceae	Chordariales	Scytosiphonaceae	+	++	++	++	+
	Lobophora variegata (J. V. Lamouroux) Womersley ex E.C. Oliveira	Phaeophyceae	Dictyotales	Dictyotaceae	+	-	+	-	-
	Padina tetrastromatica Hauck	Phaeophyceae	Dictyotales	Dictyotaceae	++	+++	+	++	+

	Rosenvingea intricata (J.Agardh) Børgesen	Phaeophyceae	Chordariales	Scytosiphonaceae	-	+	-	-	+
	Sargassum cinctum J. Agardh	Phaeophyceae	Fucales	Sargassaceae	++	+	++	++	+
	Sargassum cinereum J. Agardh	Phaeophyceae	Fucales	Sargassaceae	++	++	+	++	+
	Sargassum johnstonii Setchell & Gardner	Phaeophyceae	Fucales	Sargassaceae	+++	+++	++	++	+
	Sargassum tenerrimum J. Agardh	Phaeophyceae	Fucales	Sargassaceae	++	+++	+++	+++	++
	Spatoglossum asperum J. Agardh	Phaeophyceae	Dictyotales	Dictyotaceae	++	+++	++	++	++
	Spatoglossum variabile Figari & De Notaris	Phaeophyceae	Dictyotales	Dictyotaceae	++	++	++	++	+
	Stoechospermum marginatum (C. Agardh) J. Agardh	Phaeophyceae	Dictyotales	Dictyotaceae	+++	++	++	+	++
	Turbinaria conoides J. Agardh	Phaeophyceae	Fucales	Sargassaceae	++	+	++	+	+
	Agardhiella subulata (C. Agardh) Kraft & Wynne	Rhodophyceae	Gigartinales	Solieriaceae	-	-	+	+	-
	Amphiroa anceps (Lamarck) Decaisne	Rhodophyceae	Corallinales	Corallinaceae	+	++	+	-	++
	Botryocladia botryoides J. Agardh	Rhodophyceae	Rhodymeniales	Rhodymeniaceae	-	-	+	+	+
	Ceramium rubrum Auctorum	Rhodophyceae	Ceramiales	Ceramiaceae	+	-	-	-	+
	Champia indica Børgesen	Rhodophyceae	Rhodymeniales	Champiaceae	+	-	+	+	-
	Chondria dasyphylla (Woodward) J. Agardh	Rhodophyceae	Ceramiales	Rhodomelaceae	+	++	++	++	++
	Coelarthrum muelleri (Sonder) Børgesen	Rhodophyceae	Rhodymeniales	Rhodymeniaceae	+	+	-	+	+
	Corallina officinalis Linnaeus	Rhodophyceae	Corallinales	Corallinaceae	+	++	++	+	-
	Corynomorpha prismatica (J. Agardh)	Rhodophyceae	Cryptonemiales	Corynomorphaceae	-	+	+	+	-
	Cryptonemia undulate Sonder	Rhodophyceae	Cryptonemiales	Halymeniaceae	-	+	+	+	-
	Gelidiella acerosa (Forsskål) Feldmann & Hamel	Rhodophyceae	Gelidiales	Gellidiallaceae	+	+	-	+	-
	Gelidiopsis variabilis (J. Agardh) Schmitz	Rhodophyceae	Rhodymeniales	Rhodymeniaceae	+	-	-	+	-
	Gelidium pusillum (Stackhouse) Le Jolis	Rhodophyceae	Gelidiales	Gelidiaceae	+	++	+	+	+
	Gracilaria corticata (J. Agardh) J. Agardh	Rhodophyceae	Gracilariales	Gracilariaceae	++	+	++	++	+
	Gracilaria salicornia (C.Agardh) Dawson	Rhodophyceae	Gracilariales	Gracilariaceae	+	+	++	+	+
	Gracilaria verrucosa (Hudson) Papenfuss	Rhodophyceae	Gracilariales	Gracilariaceae	+	++	++	++	+
	Grateloupia indica Børgesen	Rhodophyceae	Cryptonemiales	Halymeniaceae	++	++	+	++	+
	Griffithsia rhizophora Frunow ex Weber – van Bosse	Rhodophyceae	Ceramiales	Ceramiaceae	-	+	-	+	+
	Haloplegma duperreyi Mont.	Rhodophyceae	Ceramiales	Ceramiaceae	-	-	+	+	+
	Halymenia porphyraeformis P.G. Parkinson	Rhodophyceae	Cryptonemiales	Halymeniaceae	-	+	-	+	+
	Halymenia venusta Børgesen	Rhodophyceae	Cryptonemiales	Halymeniaceae	++	++	+++	++	++
	Hypnea musciformis (Wulfen) Lamouroux	Rhodophyceae	Gigartinales	Hypneaceae	+	-	++	+	-
	Laurencia pedicularioides Cribb	Rhodophyceae	Ceramiales	Rhodomelaceae	+	-	-	+	-

	Porphyra indica V. Krishnamurthy & M. Baluswami	Rhodophyceae	Bangiales	Bangiaceae	+	+	+	-	-
	Porphyra okhaensis H. Joshi, Oza & Tewari	Rhodophyceae	Bangiales	Bangiaceae	+	-	+	+	+
	Rhodymenia sonderi Silva	Rhodophyceae	Rhodymeniales	Rhodymeniaceae	-	-	+	+	+
	Scinaia fascicularis (Bthetaorg.) Desikach et. Singh	Rhodophyceae	Nemaliales	Galaxauraceae	+	-	+	-	+
	Scinaia hatei J. Agardh	Rhodophyceae	Nemaliales	Galaxauraceae	++	-	+	-	-
	Scinaia moniliformis J. Agardh	Rhodophyceae	Nemaliales	Galaxauraceae	+	-	-	+	+
	Sebdenia polydactyla (Børgesen) M. Balakrishnan	Rhodophyceae	Gigartinales	Sebdeniaceae	-	+	+	-	+
	Solieria robusta (Greville) Kylin	Rhodophyceae	Gigartinales	Solieriaceae	+	-	-	-	+

+++ abundant; ++ good; + fair; – absent.

4. Discussion

Species composition of seaweeds largely depends upon season, population structure and several other ecological factors (Krishnamurthy, 1967). Several workers have reported a drastic change in the water level and quality in 'Gulf of Kutch'. A continuous increase in the inflow of nutrients has been reported from different areas of the 'Gulf'. Due to a decrease in the area of continental shelf, an increase in the water level has also been documented (Sanagoudra and Bhat 2013). All these events are resulting into a change in the marine ecosystem continuously in different areas of the 'Gulf of Kutch 'along with the time. Our study area, being situated at the mouth of the 'Gulf of Kutch', also faces these kinds of changes. Added to these, many industrial and other developmental activities have accelerated in and around 'Okha' in recent years which generate a huge anthropogenic pressure. Due to the continuous change in local environmental conditions several microclimatic pockets have been generated affecting the structure and characteristic features of algal community prevailing there. According to earlier surveys done at Port Okha, algal season occurs from November to May, whereas a very few species are available during other months (Joshi and Murthy, 2004). During June to September (monsoon season of Gujarat) the wave action is very high and so the exposure is very less which hampers the survey work. So, we have selected the three months of winter (December, January and February) for this work, which satisfies the preliminary condition for the survey. In our study the species diversity and abundance of sea weeds were found to be maximum in the month of February in comparison to the months of December and January, similar trend was also noted by previous workers in their study (Thakur *et al.*, 2008) .

According to our observations made, seaweeds showed remarkable difference in their habitat preference within the intertidal zone. The continental shelf at Okha port consists of tertiary rocks and corals along the shore and sandy bottoms towards the Gulf. As we move from the shore towards the gulf, there is a change in the habit of seaweeds. At the rocky substratum along the shore, the species with holdfast like, *Ulva sp., Sargassum sp., Halymenia sp.* etc were seen attached to the corals and rocks. Whereas in deeper water, the species with heterotrichous habit like *Caulerpa* sp., *Champia sp.,* were most common. *Halimeda sp.* and *Udotea sp.* although have holdfast like structure but still found in the deep water. In the present study, Rhodophyceae was found in a maximum number representing 31 species belonging to 25 genera and 15 families. Similar type of observation was also reported by Nakar *et al.* (2011), but they reported only 15 species. Nakar *et al.* (2011) also found that the species abundance next to Rhodophyceae was that of Chlorophyceae followed by Phaeophyceae. But according to our observation Phaeophyceae was more abundant than Chlorophyceae. In overall, the most abundant seaweed species found from the study site was a brown algae namely, *Sargassum tenerrimum*. Similar type of report has also been published by Thakur *et al.* (2008).

In conclusion, the Okha Port harbors a complex variety of seaweeds, many of which have been reported from other parts of the Indian coast also (Sahoo *et al.*, 2003; Satheesh *et al.*, 2012; Domettila *et al.*, 2013).

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