# SPECIES AND THALLUS STRUCTURE DIVERSITY OF CHLOROPHYTA IN SHORE PLATFORM OF DWARKA (GUJARAT COAST, INDIA)

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**KEYWORDS**: macroalgae, Chlorophyta, shore platform, species, thallus structure, diversity.

**ABSTRACT**

Present study shows the species and thallus structure diversity of Chlorophyta in shore platform of Dwarka, Gujarat Coast. Chlorophyta were surveyed based on systematic random sampling for two years: April 2013 to April 2015. Total 27 species of Chlorophyta were identified through intensive fieldwork survey based on line transect and quadrate based methods. This study identifies four orders, nine families, 13 genera and 27 species among the green macroalgae population inhabiting the rock shore platform of Dwarka. Total 27 species of Chlorophyta have been found with major nine thallus types and 19 sub types of thallus structure. Ramiform and filamentous types of thallus structure are most common in this study.

**ZUSAMMENFASSUNG**: Diversität der Arten und Thallusstruktur bei Grünalgen (Chlorophyta) an der Dwarka Küstenplattform (Gujarat-Küste, Indien).

Vorliegende Studie befasst sich mit der Arten- und Thallustrukturdiversität von Chlorophyten der Küstenplattform von Dwarka im Bereich der Meeresküste Gujarat, Indien. Die Grünalgen wurden mit Hilfe systematischer Zufallsstichproben über einen Zeitraum von zwei Jahren, von April 2013 bis April 2015 untersucht. Insgesamt wurden bei intensiver Feldarbeit durch in situ Methode mit Linientransekten sowie in Quadraten 27 Arten von Grünalgen festgestellt. Diese sind vier Ordnungen, neun Familien und 13 Gattungen von Makroalgenpopulationen der Felsküstenplattform von Dwarka zugeordnet. Unter den insgesamt 27 Arten von Grünalgen wurden bezüglich Thallusstruktur neun Haupt- und neunzehn Subtypen vorgefunden. Dabei wurde deutlich, dass die verzweigten und die fadenförmigen Thallusstruzkturen am häufigten waren.

**REZUMAT**: Diversitatea speciilor și a structurii talului la alge verzi (Chlorophyta) pe platforma marină Dwarka (coasta Gujarat, India).

Prezentul studiu se ocupă de diversitatea speciilor și a structurii talului algelor clorofite de pe platforma marină Dwarka de pe coasta Gujarat, India. Clorofitele au fost investigate luându-se probe prin sondaj pe o perioadă de doi ani și anume din aprilie 2013 până în aprilie 2015. În total au fost găsite, în cadrul activităților intensive de teren, cu ajutorul metodei transectelor lineare şi a cvadratelor, 27 de specii de alge clorofite. Ele fac parte din patru ordine, nouă familii 13 genuri de macropopulații ale platformei marine de la Dwarka. Cele 27 de specii de clorifite identificate se prezintă din punct de vedere a structurii talului cu nouă tipuri principale și 19 subtipuri. Cele mai comune structuri de tal înregistrate au fost cele ramificate şi filiforme.

## INTRODUCTION

Coastal areas all over the world are tremendously important and valuable for human society but they are largely inappropriately managed due to the high impact of human activity in the inner watersheds and marine areas (Novac and Shurova, 2008; Sabai and Sisitka, 2013; Afkhami et al., 2013; Ghasemi, 2014; Sosai, 2015; Dimpal et al., 2015; Bănăduc et al., 2016; Balasaheb et al., 2017).

Algae is one of the largest group of organisms, with significant ecological importance for a high variety of aquatic ecosystems (Round, 1981; Lee, 2008; Barinova, 2018).

Seaweeds or macroalgae comprise a diverse group of lower plants that represent various growth forms in algae (*). In general, the macroalgae organisms are divided by specialists into three groups based on their colors: green, brown, and red (MacArtain et al., 2007). They appear similar to land plants, however, they lack complex reproductive structure and functional tissues as found in seagrass and land plants (**). They constitute one of the most important living resources of the ocean and are found attached to solid substrates such as rocks, dead corals, pebbles, shells, and plants (Sahayaraj et al., 2014).

As photosynthetic organisms, this group plays a key role in the productivity of seas and oceans and constitutes the basis of these aquatic habitats food chain (Shalaby, 2011). They contribute substantially to the carbon budget of the coastal ecosystems (Dhargalkar et al., 2001). Macroalgae play significant ecological roles in the ecosystem (Satheesh et al., 2017). They provide habitat and nutrients to marine organisms (Dhargalkar et al., 2001). Macroalgae are used as food, fodder, fertilisers, as raw materials in industries, medicines, etc. (Dhargalkar et al., 2001). They are particularly useful organisms for studying diversity patterns and planning the conservation and sustainable use of inshore marine resources and are useful as indicators of climate change (Van der Strate et al., 2002).

Green algae contain chlorophyll a and b and store food as starch in their plastids. The green colour of the Chlorophyta is derived from amounts of chlorophyll a and b in the same proportion as the higher plants, giving them a bright green colour, as well as the accessory pigments β-carotene and xanthophylls (yellowish or brownish pigments). Most of the green algae have firm cell walls composed of cellulose along with other polysaccharides and proteins and they store carbohydrate in the form of starch. Chlorophyta are usually found in the littoral zone where there is strong sunlight. Chlorophyta ranges from the singled-celled to moderately complex structures. They appear in different forms: filamentous, membranous, cylindrical, globular or coenocytic, depending on the way their cell divides. (Guiry, 2000-2019)

The study was carried out with the following principal objectives: to study the species diversity of Chlorophyta in Dwarka, and to study the thallus structure diversity of Chlorophyta on shore platform in Dwarka.

## MATERIAL AND METHODS

### Study area

Geographical, geological, topographical and physical nature of the shore is important for the macroalgae's growth. Rocky coasts have vertical zonation (Woodward, 2003). Shore platform provides stable coastal environment as compared to soft sediment coast like beaches and spits. This represents an environment where majority of macroalgae species grow with a firm substratum attachment (Sanghvi et al., 2015). The coastline of Gujarat State covers a length of 1,600 km. It represents the north-western

most part of peninsular India. This coastline occurs within the geographical limits of 20˚00' to 24˚45'N and 68˚00' to 78˚30'E. Gujarat coast extends in the form of four major coastal ecological components from North to South: I) Kori Creek; II) Gulf of Kachchh; III) Saurashtra Coast from Okha to Porbandar, and IV) Gulf of Khambhat (Sanghvi et al., 2015). Gujarat coastline is reportedly rich with diversity of macroalgae (Chakraborty and Bhattacharya, 2012). The substratum of Gujarat Coast is rocky in many components, which provides felicitous environment for macroalgae growth. The Saurashtra Coast, which runs for an approximate length of 985 km, is characterized by rocky, sandy, and muddy intertidal zones, harboring affluent and varied flora and fauna (Gohil and Kundu, 2012).

The present research was carried out completely on the shore platform of Dwarka, located on the Saurashtra Coast, Gujarat, India (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 of the shore platform sampled is 143.8 m, and it covers a surface area of 82,293.86 $m^2$ (Sanghvi et al., 2015). In this research area three groups of macroalgae: Chlorophyta, Phaeophyta, and Rhodophyta are found. From these three groups, Chlorophyta was selected for the present study.

**Field data collection**

The research area was divided into three sections in North-South directions: I) Northern; II) Central; III) Southern sections for systematic-field sampling. Field sampling of macroalgae was done from April 2013 to April 2015. Field surveys/samplings were performed during the low tide periods. For qualitative and quantitative assessment, GPS (Spheroid and Datum: WGS 84) tagged Line Intercept Transect (LIT) were carried out. The length of the transect lines depended on the tidal exposure of the shore platform during the survey. Maximum depth of the subtidal zone sampled for macroalgae in the present study is 0.5 m. For quantitative assessment of the macroalgae in the given area, line transect was laid perpendicular to the coast in a seaweed direction with the help of a long rope of 50 m (Dhargalkar and Kavlekar, 2004). 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 quite high as compared to other parts of the Indian coast and the west coast in particular. Growth of 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 one km (Jha et al., 2009). Each of the three sections on the shore platform was represented by one transect line: thus resulting 33 transect lines wherever the algae growth, density and diversity were high. 258 quadrates were done on the thirty three transect lines. Seaweed species present within the quadrates were sampled.

**Field data analysis**

Morphological criteria and reproductive structure were analyzed for taxa identification.

A cladogram was prepared for identifying algae species in order to generate classification statistics of Chlorophyte i.e. number of genera and species pertaining to different classes as shown in figure 2.

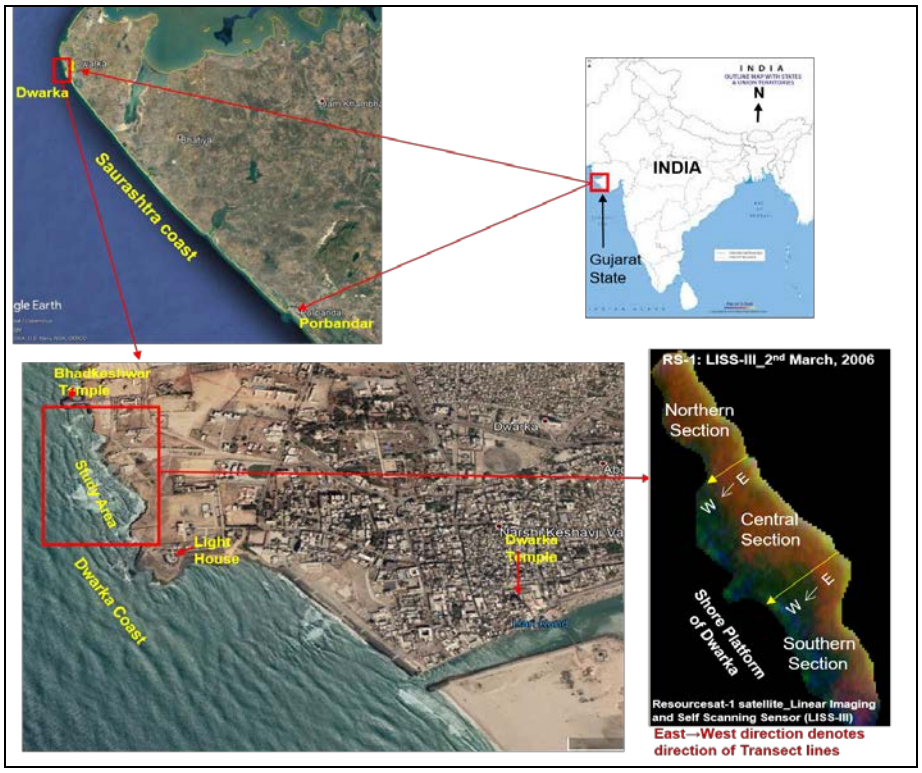


Figure 1: Location map of study area: Shore platform, Dwarka, Gujarat Coast, India; (Source: India outline map- mapsofindia.com and others: google.com/intl/en_in/earth/).

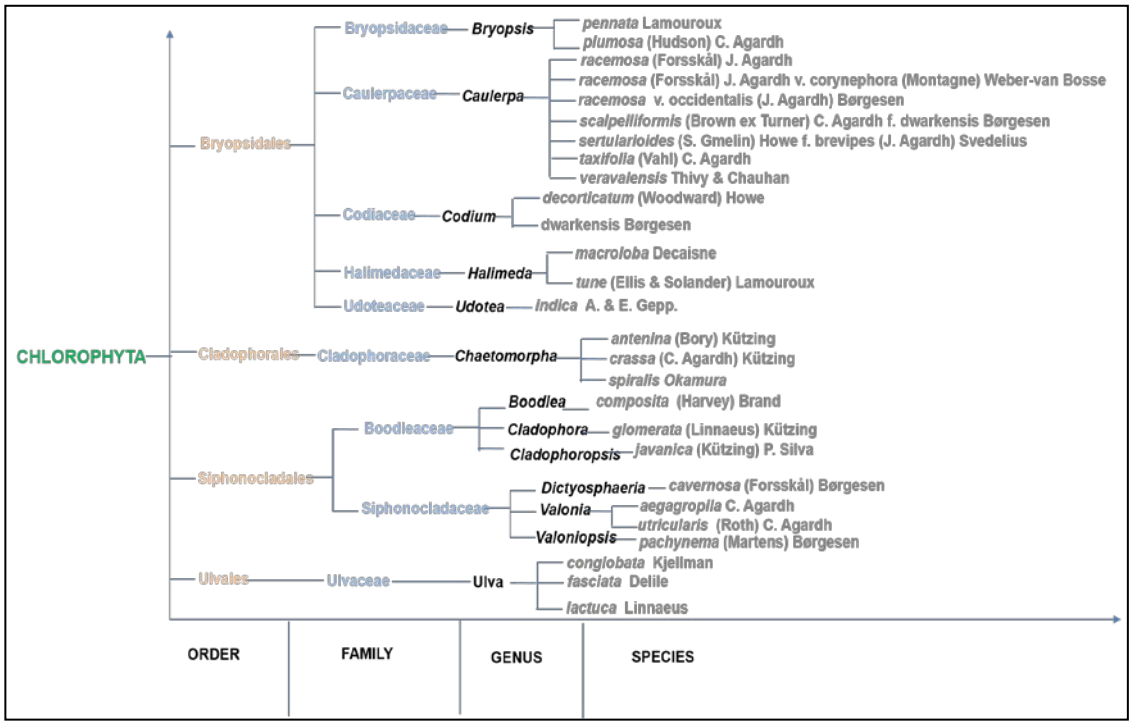


Figure 2: Cladogram of Chlorophyta species found from shore platform, Dwarka.

## RESULTS AND DISCUSSION

Macroalgae on the shore platform were surveyed based on systematic random sampling for two years (April 2013 to April 2015). A total of 27 species of Chlorophyta (Tab. 1) were identified from this site through intensive fieldwork based on Line Intercept Transect (LIT) and Quadrate based sampling methods.

From this study, the species and thallus structure diversity of Chlorophyta in shore platform, Dwarka, Gujarat Coast was reported (Tab. 1). Chlorophyta encompasses four orders, nine families, 13 genera and 27 species among the macroalgae population inhabiting the shore platform of Dwarka as shown in the cladogram (Fig. 2). Each species was studied with respect to their occurrence observed through quadrate survey within the study sites. Out of four orders, Bryopsidales order includes five families: Bryopsidaceae, Caulerpaceae, Codiaceae, Halimedaceae, and Udoteaceae. Bryopsidaceae is found to have two species: *Bryopsis pennata* Lamouroux and *Bryopsis plumose* (Hudson) C. Agardh having ramiform and feathery thallus (Fig. 3A). Caulerpaceae is found to have seven species which belongs to *Caulerpa* genus. Out of seven species, six species *Caulerpa racemosa* (Forsskål) J. Agardh, *C. racemosa* (Forsskål) J. Agardh v. *corynephora* (Montagne) Weber-van Bosse, *C. racemosa* v. *occidentalis* (J. Agardh) Børgesen, *C. sertularioides* (S. Gmelin) Howe f. brevipes (J. Agardh) Svedelius, *C. taxifolia* (Vahl) C. Agardh and *C. veravalensis* Thivy and Chauhan having ramiform and creeping thallus (Fig. 3B) and one species *C. scalpelliformis* (Brown ex Turner) C. Agardh f. dwarkensis Børgesen have rhizomatous with flat assimilator thallus (Fig. 3C). Codiaceae is recorded to have two species *Codium decorticatum* (Woodward) Howe and *C. dwarkensis* Børgesen have ramiform and spongy thallus (Fig. 3D). Halimedaceae is found with two species *Halimeda macroloba* Decaisne and *H. tuna* (Ellis and Solander) Lamouroux have articulated and calcified form thallus (Fig. 3E). Udoteaceae is recorded one species *Udotea indica* A. and E. Gepp. Has fan like blades thallus (Fig. 3F). Cladophorales order includes one family: Cladophoraceae where three species *Chaetomorpha antennina* (Bory) Kützing has filamentous and brush-like tufts in flocks thallus structure (Fig. 4A), *Chaetomorpha crassa* (C. Agardh) Kützing has filamentous and entangled mass thallus structure (Fig. 4B) and *Chaetopmpha spiralis* Okamura has filamentous and coiled thallus structure. Siphonocladales order includes two families: Boodleaceae and Siphonocladaceae. Booodleaceae have three species, *Boodlea composita* (Harvey) Brand has spongy, branched cushion (Fig. 4C), *Cladophora glomerata* (Linnaeus) Kützing has erect or prostrate filaments and sparsely branched (Fig. 4D) and *Cladophoropsis javanica* (Kützing) P. Silva has spongy, filamentous and prostrate thallus structure (Fig. 4E). Siphonocladaceae includes four species *Dictyosphaeria cavernosa* (Forsskål) Børgesen has Hollow, spherical, irregularly lobed or globose type of thallus (Fig. 4F), *Valonia aegagropila* C. Agardh has compact vascular mass thallus structure (Fig. 5A), *V. utricularis* (Roth) C. Agardh has loose vesicle like patches thallus (Fig. 5B) and *Valoniopsis pachynema* (Martens) Børgesen has cushions or spongy patches type of thallus structure (Fig. 5C). Ulvales order includes one family: Ulvaceae which has three species *Ulva conglobata* Kjellman has leafy and undivided thallus, *U. fasciata* Delile has leafy and ribbon-like thallus (Fig. 5D) and *U. lactuca* Linnaeus has leafy and membranous thallus structure (Fig. 5E).

A total of 27 species of Chlorophyta have been found with nine major thallus types and 19 sub types of thallus structure. Ramiform and filamentous types of thallus structure are most common on shore platform of Dwarka.

Many of the phycologists and researchers have studied on the diversity and distribution (Yedukondala Rao et al., 2005; Palanisamy, 2012; Sahayaraj et al., 2014), economic importance (Dhargalkar, 2014; Yadav et al., 2015; Jayaprakash et al., 2017; Swamalatha, 2018), frequency and biomass (Satheesh and Wesley, 2012), growth cycle (Kotiya et al., 2011), etc., of macroalgae of India but so far no one has studied thallus structure diversity of Chlorophyta in such species level on shore platform from Indian Coast.

Waghmode (2017) has studied diversity and distribution of macroalgae from the west coast of Maharashtra. He has recorded 73 species of macroalgae. Out of 73 species, 21 belongs to Chlorophyta, 17 to Phaeophyta, and 33 to Rhodophyta. He has reported red algae found more as compared to Chlorophyta and Phaeophyta. Pawar (2017) has worked on distribution pattern and species diversity of macroalgae at URAN (Navi Mumbai), West Coast of India. He has found a total of 19 species of macroalgae which is representing 16 genera, 15 families, and 13 orders. Out of these, seven species belongs to Chlorophyte and Rhodophyta each, two each to Phaeophyta and one to Charophyta. At all study sites, maximum species diversity was recorded during pre-monsoon and post-monsoon periods. Macroalgae from Uran Coast are under stress due to this region industrial pollution and port operations. Sahayaraj et al. (2014) have worked on distribution and diversity assessment of the marine macroalgae at four southern districts of Tamil Nadu, India. They have reported 57 taxa belonging to 37 genera representing 18 taxa of Chlorophyta, 14 taxa of Phaeophyta, and 25 taxa of Rhodophyta. Species wise, a higher number of algae have been recorded from Idinthakarai (84.21%). They have recorded a maximum of (59%) species from Idinthakarai and a minimum of (1%) species from Keelvaipaar.

Roy et al. (2015) have worked on diversity and distribution of macroalgae in selected reefs and island of Gulf of Kachchh. They have found 70 species of macroalgae. Out of these, 24 species belongs to Chlorophyta, 15 species of Phaeophyta, and 31 species of Rhodophyta. The numbers of macroalgae found in Chaad, Dedeka-Mundeka, Goose, and Narara were 44, 49, 33, and 31 respectively. Nirmal Kumar et al. (2017) have worked on distribution and biochemical constituents of different macroalgae collected from Okha Coast, Gujarat, India. They have observed that macroalgae were not found continuously during the study period but some species were observed only for short periods whereas other species occurred for two to three months. They have recorded a total of 70 species of macroalgae with the highest number of Rhodophyta (51.42%) species, then Phaeophyta (25.71%) and lastly Chlorophyta (22.85%). From the recorded groups of macroalgae, carbohydrate and chlorophyll contents were higher in Chlorophyta while protein was maximum in Phaeophyta, respectively Rhodophyta. On the other hand, phenol, flavonoids and carotenoids were recorded at higher rates in Phaeophyta. Jha et al. (2009) have studied the diversity and distribution of the macroalgae of Gujarat Coast. They have given the species level characteristic of the Gujarat Coast. They have recorded a total of 198 species belonging to 101 genera of macroalgae. Among these, 24 species are new reported from Gujarat and three from the Indian Coast. The Rhodophyta contained the maximum number of species 109 belonging to a total of 62 genera, followed by the Chlorophyta with 54 species belonging to a total of 16 genera, and Phaeophyta with 35 species belonging to a total of 16 genera. They have also reported thallus form and type, substratum, occurrence season and abundance of 198 species of macroalgae.


Figure 3: A) Ramiform and feathery thallus; B) Ramiform and creeping thallus; C) Rhizomatous with flat assimilator thallus; D) Ramiform and spongy thallus; E) Articulated and calcified form thallus; F) Fan like blades thallus.

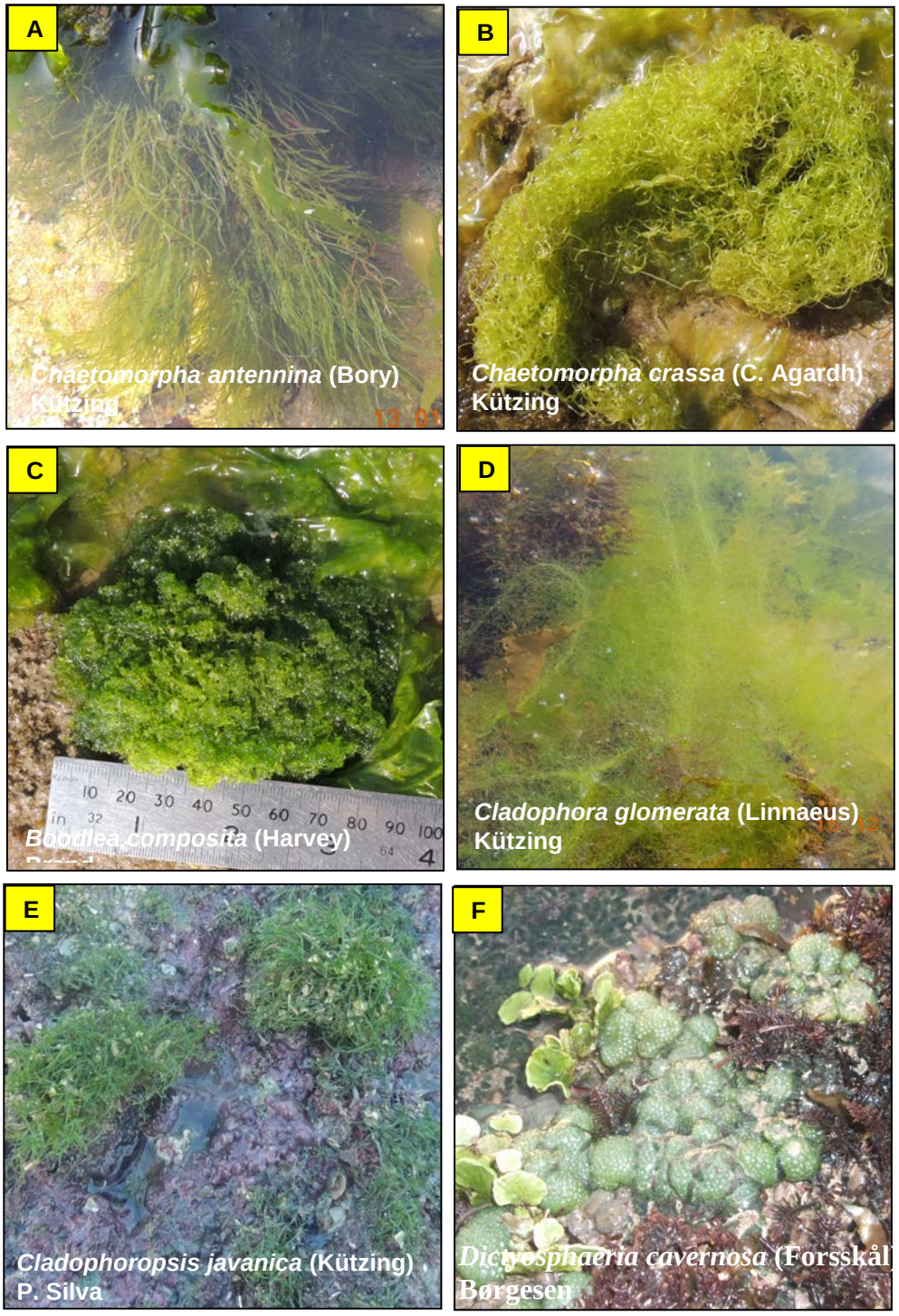


Figure 4: A) filamentous and brush-like tufts in flocks thallus;
B) Filamentous and entangled mass thallus; C) Spongy, branched cushion thallus;
D) Erect or prostrate filaments and sparsely branched; E) Spongy, filamentous and prostrate thallus; F) Hollow, spherical, irregularly lobed or globose type of thallus.

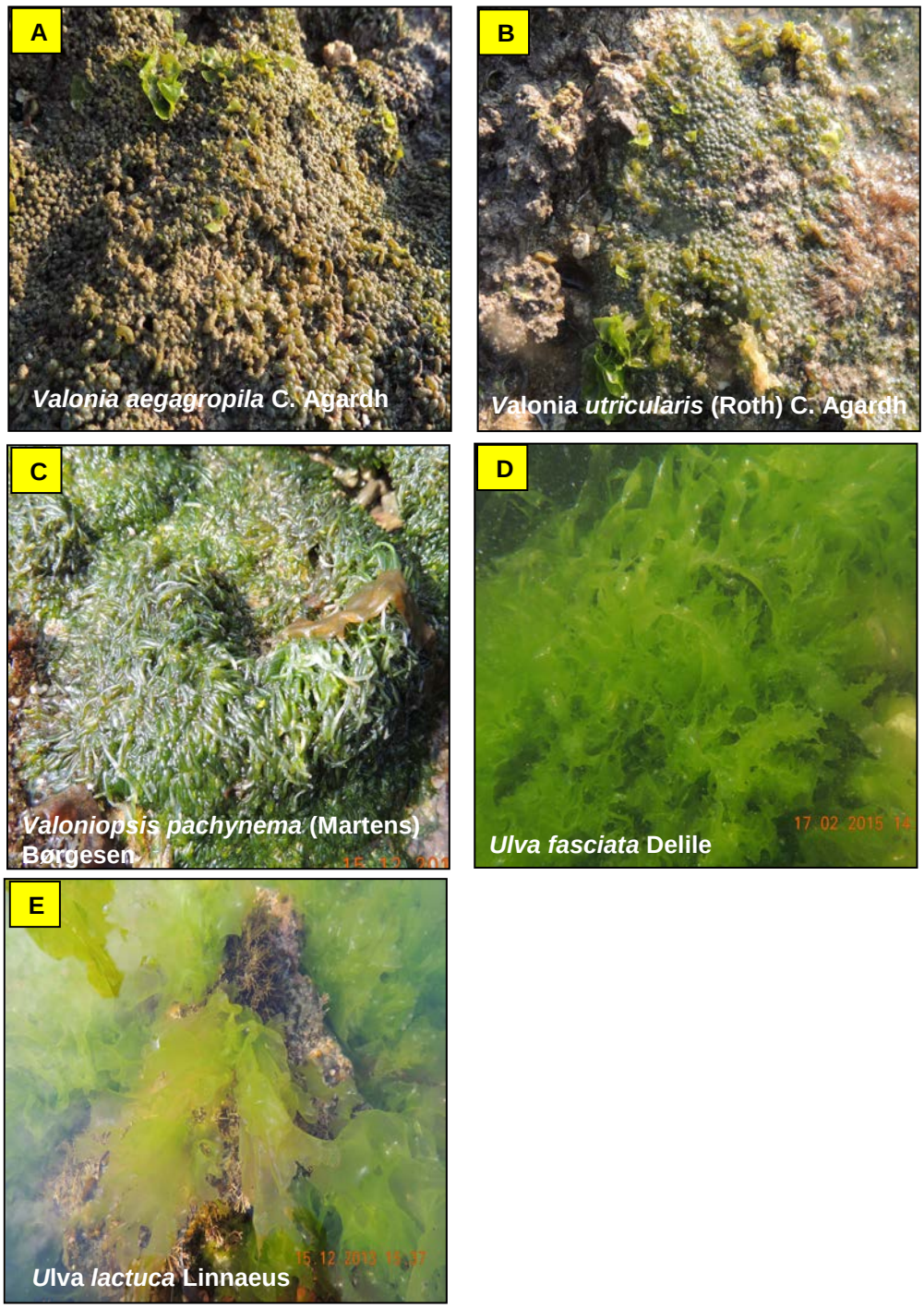


Figure 5: A) compact vascular mass thallus; B) Loose vesicle like patches thallus; C) Cushions or spongy patches type of thallus; D) Leafy and ribbon-like thallus; E) Leafy and membranous thallus structure;
F) Hollow, spherical, irregularly lobed or globose type of thallus.

Table 1: Species and thallus diversity of macroalgae in shore platform, Dwarka, Gujarat, India.

| Group | Order | Family | Genus | Species | Thallus form and type |
|---|---|---|---|---|---|
| Chlorophyta | Bryopsidales | Bryopsidaceae | *Bryopsis* | *pennata* Lamouroux | Ramiform and feathery |
| | | | | *plumosa* (Hudson) C. Agardh | Ramiform and feathery |
| | | Caulerpaceae | *Caulerpa* | *racemosa* (Forsskål) J. Agardh | Ramiform and creeping |
| | | | | *racemosa* (Forsskål) J. Agardh v. corynephora (Montagne) Weber-van Bosse | Ramiform and creeping |
| | | | | *racemosa* v. *occidentalis* (J. Agardh) Børgesen | Ramiform and creeping |
| | | | | *scalpelliformis* (Brown ex Turner) C. Agardh f. dwarkensis Børgesen | Rhizomatous with flat assimilator |
| | | | | *sertularioides* (S. Gmelin) Howe f. brevipes (J. Agardh) Svedelius | Ramiform and creeping |
| | | | | *taxifolia* (Vahl) C. Agardh | Ramiform and creeping |
| | | | | *veravalensis* Thivy and Chauhan | Ramiform and creeping |
| | | Codiaceae | *Codium* | *decorticatum* (Woodward) Howe | Ramiform and spongy |
| | | | | *dwarkensis* Børgesen | Ramiform and spongy |
| | | Halimedaceae | *Halimeda* | *macroloba* Decaisne | Articulated and calcified fronds |
| | | | | *tuna* (Ellis and Solander) Lamouroux | Articulated and calcified fronds |
| | | Udoteaceae | *Udotea* | *indica* A. and E. Gepp. | Fan like blades |
| | Cladophorales | Cladophoraceae | *Chaetomorpha* | *antennina* (Bory) Kützing | Filamentous and brush-like tufts in flocks |
| | | | | *crassa* (C. Agardh) Kützing | Filamentous and entangled mass |
| | | | | *spiralis* Okamura | Filamentous and coiled |

Table 1 (continued): Species and thallus diversity of macroalgae in shore platform, Dwarka, Gujarat, India.

| Group | Order | Family | Genus | Species | Thallus form and type |
|---|---|---|---|---|---|
| Chlorophyta | Siphono-cladales | Boodle-aceae | *Boodlea* | *composita* (Harvey) Brand | Spongy, branched cushion |
| | | | *Cladophora* | *glomerata* (Linnaeus) Kützing | Erect or prostrate filaments and sparsely branched |
| | | | *Cladophoropsis* | *javanica* (Kützing) P. Silva | Spongy, filamentous and prostrate |
| | | Siphonocl adaceae | *Dictyosphaeria* | *cavernosa* (Forsskål) Børgesen | Hollow, spherical, irregularly lobed or globose |
| | | | *Valonia* | *aegagropila* C. Agardh | Compact vasicular masses |
| | | | | *utricularis* (Roth) C. Agardh | Loose vesicle like patches |
| | | | *Valoniopsis* | *pachynema* (Martens) Børgesen | Cushions or spongy patches |
| | Ulvales | Ulvaceae | *Ulva* | *conglobata* Kjellman | Leafy and undivided |
| | | | | *fasciata* Delile | Leafy and ribbon-like |
| | | | | *lactuca* Linnaeus | Leafy and membranous |

**CONCLUSIONS**

This study reports species and thallus structure of macroalgae sampled in shore platform, Dwarka, India.

This research offer data about which type of macroalgae grow on hard substratum like the studied shore platform.

Nine major types of thallus and 19 sub types of thallus structure are identified. Ramiform and filamentous types of thallus structure are most common on shore platform of Dwarka. Ramiform type of thallus belongs to the Bryopsidales order and filamentous type belongs to the Cladophorales and Siphonocladales orders.

This study is to help in future studies to identify the macroalgae.

Species and thallus diversity of macroalgae can help to identify the substratum, resource inventory and monitoring of macroalgae.

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