



## ORIGINAL RESEARCH ARTICLE

# Account of the marine macroalgae from the northern coastal district of Andhra Pradesh, India

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## Abstract

The reports on the occurrence of the marine macroalgae from Andhra Pradesh are sporadic and merely reported from the middle part (Visakhapatnam district) of the state and the rest of the southern and northern parts of the coastal areas were not yet be covered. Hence, the present attempt was subjected to instigate the details on the occurrence of marine macroalgae from the northern coastal districts (Vizianagaram and Srikakulam) of Andhra Pradesh during March 2017 - August 2019. A sum of 57 taxa of marine macroalgae belongs to 27 genera of 20 families under 15 orders collected from the 22 localities. Among them, class Rhodophyceae (46%) is the predominant group in species composition followed by Chlorophyceae (35%) and Phaeophyceae (19%). Also, the present study highlights the correlation of ecological parameters of the coastline with the distribution and diversity of seaweeds in Andhra Pradesh. Further, it reveals the occurrence of 16 taxa reported for the first time from the coastline of Andhra Pradesh.

**Keywords:** Andhra Pradesh, Additions, Diversity, Northern districts, Physio-chemical parameters.

## Introduction

Marine macroalgae (seaweeds) are the key components and regulatory elements of the aquatic ecosystem with significant ecological and economic roles. They are exclusively found in marine habitats including estuaries, lagoons, brackish water, salt marshes, and mangroves ranging from tropical to temperate counties. They have nonvascular plant bodies differentiated into holdfast, stipe, and fronds with various forms of unicellular to multicellular macroscopic filamentous or thallus (Lightowler and Davies 2002). They constitute about 11, 000 species, of which includes 7, 200 taxa of Rhodophyceae, 2, 000 taxa of Phaeophyceae, and

1,800 taxa of Chlorophyceae (<http://www.seaweed.ie/>). The occurrence, distribution, and diversity of seaweeds differ greatly according to their ecological and hydrological factors. The coastline of India is endowed with 865 taxa of seaweeds reported from the various maritime states. Rhodophyceae is the predominant class encompasses 138 genera of 33 families with 442 (51%) taxa, Chlorophyceae with 212 taxa (25%) belonging to 46 genera of 19 families and Phaeophyceae covers 50 genera of 13 families with 211 taxa (24%) (Rao and Gupta 2015). The marine macroalgal diversity is always enormous on the west coast of India than the east coast of India due to continuous stretches of rocky plateaus, hydrological parameters, and other environmental factors. Tamil Nadu coast shows the maximum number of seaweeds (426 taxa), followed by Andaman & Nicobar Islands (244 species); Maharashtra (240 species); Gujarat (198 species); Kerala (147 taxa); Goa (145 taxa); Lakshadweep islands (114 species); Karnataka (108 species); Diu Island (70 species); Odisha (21 species) and West Bengal (14 species).

Though the Indian coastline is endowed with an enormous diversity of seaweeds, most of the states are having the lacuna on the knowledge of seaweeds. Perusal of the literature survey indicate the occurrence of seaweeds on the east coast especially of Andhra Pradesh is limited and poorly studied. Sreeramulu (1952, 1953), Rao and Sreeramulu (1964, 1970), Anonymous (1984), Murthy and Rao (2003), Lakshmi and Rao (2009), Ghosh and Keshri (2010), Rao *et al.*,

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(2011), Kaliaperumal and Chennubhotla (2015) Sowjanya and Sekhar (2017), Kumar and Palanisamy (2021) were inspected the distribution, diversity, occurrence, and other prospects of seaweeds from Andhra Pradesh in different decades. They merely surveyed Visakhapatnam, the midst coastline of Andhra Pradesh. Information on seaweeds from the northern (Srikakulam and Vizianagaram) and southern coastline (East Godavari, West Godavari, Krishna, Guntur, Prakasam, and Nellore) of Andhra Pradesh are sporadic and poorly known. Hence, this present study is subjected to furnish the data on the occurrence of the marine macroalgae from the northern coastal districts Srikakulam and Vizianagaram of Andhra Pradesh in different seasons.

### Materials and Methods

Andhra Pradesh is geographically positioned between 12°41' - 19° 07'N latitude and 69°37' - 84°44'E longitude at the southern part of India. The boundaries of the state are restricted by Tamil Nadu to the south, Karnataka to the southwest and west, Bay of Bengal to the east, Telangana to the northwest and north, and Odisha to the northeast. Among the other coastal states, Andhra Pradesh has got a coastline of around 973 km, running from Pulicat Lake (Nellore district) in the south to Donkuru (Srikakulam District) in the North. Vizianagaram and Srikakulam are the northern coastal districts of Andhra Pradesh with coastal length of 222 km (Vizianagaram - c. 28 km & Srikakulam - c. 194 km). The boundaries of the northern districts limited by Odisha in the northwest, Visakhapatnam in the south, Bay of Bengal in the East. The length of the Nagavali, Vegavathi, Gomukhi, Suvarnamukhi, Champavathi and Gostani are the major rivers flowing in Vizianagaram District. Similarly, the rivers Nagavali, Vamsadhara, Mahendratana, Champavati, Bahuda, Kumbhikota Gedda, Suvarnamukhi, Vegavati, Gomukhi are stretched in Srikakulam District. The habit of the coast is sandy along with eroded coarse boulders, calcareous rocks, mosaic Rocks, granites and rocky beds support the luxuriant growth of seaweeds (Figures 1–5).

A sum of 22 localities was fixed for the collection of marine macroalgae during low tides in different seasons from March 2017-August 2019. The collected samples were preserved using standard methods of Wet (Liquid preservation) and Dry (Herbarium) adopted by Srinivasan (1969). To avoid the misperception of species, the external and internal morphology of specimens were examined using optical microscopes (Nikon Eclipse 50i; Carl Zeiss. Axio Lab. A1) coupled with a computer attached digital sight DS-Fil camera. Also referred the standard books and monographs such as *Catalogue of the Benthic Marine Algae of the Indian Ocean* (Silva et al., 1996), *Algae of India and neighbouring countries: Chlorophyta* (Krishnamurthy 2000), *A Revised Checklist of Indian Marine Algae* (Oza and Zaidi 2001), *Seaweeds of India: The diversity and distribution of seaweeds in Gujarat*



Figure 1: Map of study area Northern coastal districts of Andhra Pradesh, India

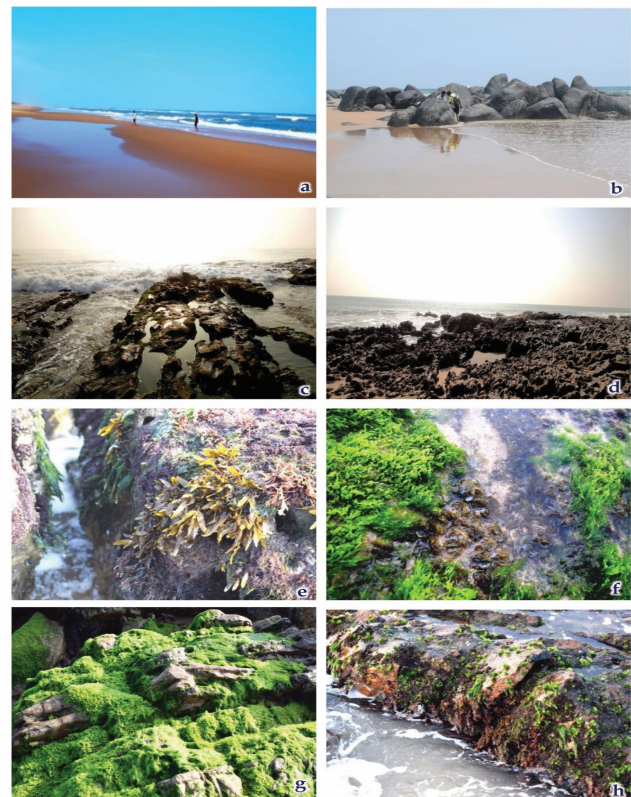
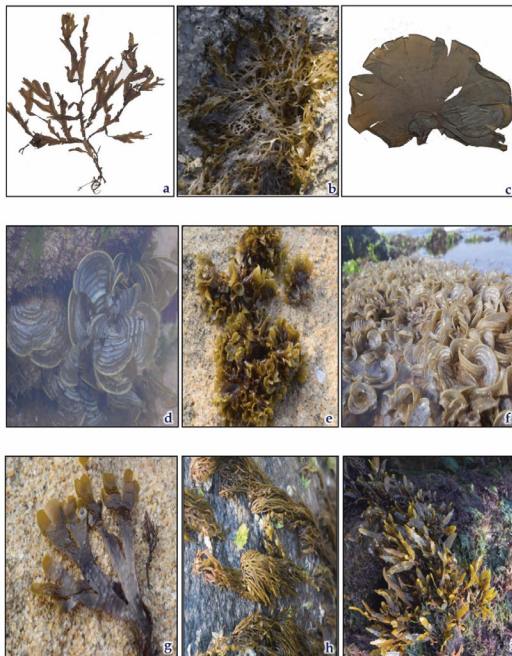


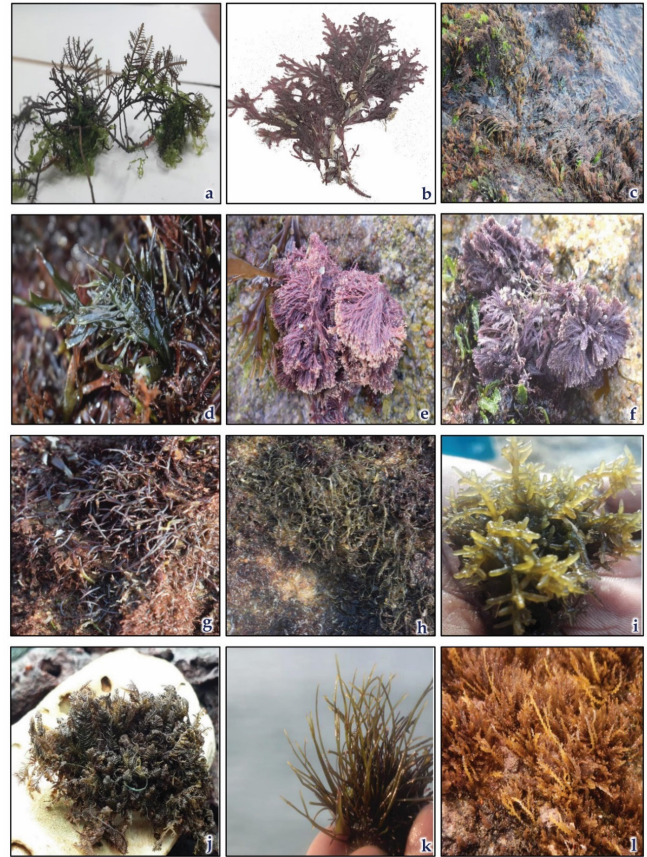
Figure 2 (a-h): Habit and habitats of marine macroalgae from Northern coastal districts. a. Baruva; b. Yeramukkam; c. Bandaruvanipeta; d. Mukkam; e - f. Mixed marine macroalgal diversity at Yeramukkam and Bandaruvanipeta; g. Monospecific diversity of *Ulva flexuosa* on granite rocks at Lakshimpuram; h. Juvenile stage of red and green algae at Chintapalli.



**Figure 3 (a-l):** Chlorophyceae. a. *Ulva linza*; b. *U. rigida*; c. *U. prolifera*; d. *Chaetomorpha antennina*; e. *C. linum*; f. *C. spiralis*; g. *Acrosiphonia orientalis*; h. *Bryopsis plumosa*; i. *Acrocladus herpesticus*; j. *Valoniopsis pachynema*; k. *Caulerpa racemosa*; l. *C. scalpelliformis*.



**Figure 4 (a-i):** Phaeophyceae. a. *Dictyopteris australis*; b. *Dictyota dichotoma*; c. *Padina boergesenii*; d. *P. boryana*; e. *P. tetrastromatica*; f. *P. pavonica*; g. *Stoechospermum polypodioides*; h. *Chnoospora minima* i. *Sargassum cinereum*.



**Figure 5 (a-l):** Rhodophyceae. a. *Gelidiella acerosa*; b. *Gelidium micropterum*; c. *Gracilaria corticata*; d. *Grateloupia lithophila*; e. *Jania rubens*; f. *Jania spectabile*; g. *Chondracanthus acicularis*; h. *Hypnea cervicornis*; i. *Champia compressa*; j. *Bostrychia tenella*; k. *Ceratodictyon repens*; l. *Acanthophora spicifera*.

coast (Jha *et al.*, 2009), *A Checklist of Indian Marine Algae: Algae of India Vol. 3* (Rao and Gupta 2015) and *Pictorial Guide to Seaweeds of Gulf of Kachchh, Gujarat* (Kamboj *et al.*, 2019);

Further, consulted the herbarium specimens housed at Central National Herbarium (CAL), Industrial Section in the Indian Museum (BSIS) Kolkata; Madras Herbarium (MH), Coimbatore; National Facility for Marine Algae Herbarium (NFMAH), Mandapam, Ramanathapuram. The systematic treatment and nomenclature uncertainties were clarified with the aid of online resources such as Macroalgal Herbarium Portal (<http://macroalgae.org/>), Algae Base (<http://www.algaebase.org/>) and Marine Biological Association of the UK (<http://www.mba.ac.uk/>).

**Results and Discussion**

The current attempt reveals the occurrence of 57 taxa of marine macroalgae belong to 27 genera of 20 families under 15 orders collected from the 22 localities of Srikakulam (18 localities) and Vizianagaram (4 localities) during March 2017 to August 2019. Rhodophyceae is the predominant class represents 26 taxa (46%); Chlorophyceae shows

moderate diversity with 20 taxa (35%) and Phaeophyceae shows minimum diversity with 11 taxa (19%) reported from the study area. The class Chlorophyceae represents with 6 genera belonging to 5 families under 4 orders. Whilst, Rhodophyceae denotes with 15 genera of 12 families fall under 8 orders. Phaeophyceae comprise 6 genera with 3 families under 3 orders (Table 1). The order Ulvales (*Ulva*) and Dictyotales (*Dictyopteris*, *Dictyota*, *Padina*, *Stoechospermum*) signified with 8 taxa in each class. The order Cladophorales includes 6 taxa belong to the family Cladophoraceae with 2 genera (*Chaetomorpha* and *Acrocladus*). Order Gracilariales has encountered 5 taxa under 2 genera (*Gracilaria* & *Hydropuntia*). Bryopsidaceae (2 taxa) and Caulerpaceae (3 taxa) are characterised with 5 taxa. The rest of the orders Ulotrichales, Ectocarpales, Bangiales contain single taxon. Fucales (2 taxa of Sargassaceae), Gelidiales (3 taxa belong to Gelidiaceae & Gelidiellaceae), Cryptomaniales (2 taxa of Halymeniaceae), Corallinales (3 taxa of Corallinaceae), Rhodymeniales (4 taxa of 2 families) and Ceramiales (2 taxa of Ceramiaceae & Rhodomelaceae) are the orders of moderate values. (Tables 1 and 2).

The occurrence of *Ulva linza*, *U. prolifera*, *Chaetomorpha linum*, *Acrocladus herpesticus*, *Bryopsis plumosa*, *Dictyopteris australis*, *Padina boergesenii*, *P. boryana*, *P. pavonica*, *Gelidium micropterum*, *Gracilaria corticata* var. *cylindrica*, *Hypnea cervicornis*, *H. esperi*, *J. spectabile*, *Chondracanthus acicularis* and *Ceratodictyon intricatum* are reported for the first time from the coastline of entire and treated them as the new additions to the marine macroalgal flora of Andhra Pradesh, India. *Ulva compressa*, *U. fasciata*, *U. flexuosa*, *U. lactuca*, *U. prolifera*, *Acrosiphonia orientalis*, *Chaetomorpha antennina*, *Acrocladus herpesticus*, *Caulerpa taxifolia*, *Padina tetrastromatica*, *Stoechospermum polypodioides*, *Gracilaria corticata*, *Gracilaria corticata* var. *cylindrica*, *Grateloupia filicina*, *Amphiroa fragilissima*, *Jania rubens*, and *Chondracanthus acicularis* are the common species find in all the three different seasons. *Bryopsis plumosa*, *Caulerpa racemosa*, *Dictyopteris australis*, *Padina pavonica*, *Sargassum cinereum*, *Phycocalidia suborbiculata*, *Gelidium pusillum*, *Gracilaria foliifera*, *Hydropuntia edulis*, *Grateloupia lithophila*, *Ceratodictyon variabile* and *Acanthophora spicifera* are the mutual species found both in pre-monsoon and post monsoon seasons. *Ulva intestinalis*, *Chaetomorpha aerea*, *C. brachygona*, *C. liniodes*, *Bryopsis pennata*, *Gelidium micropterum*, *Gelidiella acerosa*, *Hypnea cervicornis*, *Hypnea esperi*, *Hypnea musciformis*, *Champia compressa*, *Ceratodictyon intricatum* and *Ceratodictyon repens* are the seasonal species found during post monsoon seasons (Table 2).

The Northern coastal districts of Andhra Pradesh gained the maximum atmospheric temperature of 37.6°C in pre-monsoon (February to May); it was quite moderated (28–29.5°C) in monsoon (June to September) and minimum

**Table 1:** Numerical data on marine macroalgae from northern coastal regions of Andhra Pradesh

Class	Order	Family	Genus	Taxa
Chlorophyceae	04	05	06	20
Pheoophyceae	03	03	06	11
Rhodophyceae	08	12	15	26
Total	15	20	27	57

(26.5–27.5°C) in post monsoon (October to January). Likewise, water temperature ranges from 29–32°C in pre-monsoon; 26.5–28°C in monsoon and 25–27°C in post monsoon. The seawater reaches extreme level of salinity (31.5–32.5 ppt) during pre-monsoon; it was average (30–31.5 ppt) in post monsoon and less (29.5–30.5 ppt) in monsoon. The salinity level of the shoreline varies from 28.0 to 29.5 ppt near to the backwater and estuarine areas due to fresh water entry. The pH level of sea water along the coastline of Andhra Pradesh is around 7.4 to 8.2; but the level of pH in post monsoon is quite greater (7.8–8.2) and it decreasing in monsoon (7.4–7.6). Dissolved oxygen content in the sea waters varied from 7.0 to 7.8 ml/l accordance with the spells of pre-monsoon (7.0–7.3 ml/l), monsoon (7.3–7.6 ml/l) and post monsoon (7.4–7.8 ml/l).

The ecological parameters of the coastline have the great influence towards the distribution and diversity of seaweeds in Andhra Pradesh (Table 3). This study indicates that, spells of post monsoon with the average level of water temperature (26.5–27.5 °C), atmospheric temperature (25–27 °C), salinity (30–31.5 ppt), pH (7.5–7.8), and D.O (7.4–7.8 ml/l) favour the optimized periods in the direction of the enormous diversity of seaweeds (47 taxa). The period of pre-monsoon expressed the moderate diversity of seaweeds (35 taxa) due to the increase of water temperature (29–32°C), atmospheric temperature (28.5–37.6°C), salinity (31.5–32.5 ppt), pH (7.8–8.2). In monsoon, the number of seaweeds was not as much of post monsoon and spotted the occurrence of 26 species account to the reduction in the water temperature (26.5–28°C), atmospheric temperature (28–29.5°C), salinity (29.5–30.5 ppt), pH (7.4–7.6). Further, the present study reveals maximum diversity of seaweeds than the investigation carried out by various researchers such as Sreeramulu (1952, 1953), Rao and Sreeramulu (1964, 1970), Anonymous (1984), Murthy and Rao (2003), Lakshmi and Rao (2009), Ghosh and Keshri (2010), Rao *et al.* (2011), Kaliaperumal and Chennubhotla (2015) Sowjanya and Sekhar (2017), from Visakhapatnam. The findings of the research from the study area are relatively similar to the coastline of Visakhapatnam based on the physiochemical parameters premeditated by Rao & *et al.* (2011). It is highly sensitive and susceptible to both natural and anthropogenic threats that lead to the deterioration and extinction of seaweeds. Hence, it is essential to extend the attention on conservation of

**Table 2:** Seasonal distribution of marine macroalgae from northern coastal district of Andhra Pradesh

<i>Genus</i>	<i>Binomials of the taxa</i>	<i>Pre-monsoon</i>	<i>Monsoon</i>	<i>Post Monsoon</i>
CHLOROPHYCEAE				
ORDER: ULVALES				
FAMILY: ULVACEAE				
	<i>Ulva compressa</i> L.	+	+	+
	<i>Ulva fasciata</i> Delile	+	+	+
	<i>Ulva flexuosa</i> Wulfen	+	+	+
Ulva	<i>Ulva lactuca</i> L.	+	+	+
	<i>Ulva intestinalis</i> L.	-	-	+
	<i>Ulva linza</i> L. *	-	-	+
	<i>Ulva prolifera</i> O.F. Muell. *	+	+	+
	<i>Ulva rigida</i> C. Agardh	+	+	-
ORDER: ULOTRICHALES				
FAMILY: ULOTRICHACEAE				
Acrosiphonia	<i>Acrosiphonia orientalis</i> (J. Agardh) P.C. Silva	+	+	+
ORDER: CLADOPHORALES				
FAMILY: CLADOPHORACEAE				
Chaetomorpha	<i>Chaetomorpha aerea</i> (Dillwyn) Kuetz.	-	-	+
	<i>Chaetomorpha antennina</i> (Bory) Kuetz.	+	+	+
	<i>Chaetomorpha brachygona</i> Harv.	-	-	+
	<i>Chaetomorpha linoidea</i> Kuetz.	-	-	+
	<i>Chaetomorpha linum</i> (O.F. Muell.) Kuetz. *	-	+	-
Acrocladus	<i>Acrocladus herpesticus</i> (Montagne) Boedeker *	+	+	+
ORDER: BRYOPSIDALES				
FAMILY: BRYOPSIDACEAE				
Bryopsis	<i>Bryopsis pennata</i> J.V.Lamour.	-	-	+
	<i>Bryopsis plumosa</i> (Huds.) C. Agardh*	+	-	+
ORDER: BRYOPSIDALES				
FAMILY: CAULERPACEAE				
Caulerpa	<i>Caulerpa racemosa</i> (Forssk.) J. Agardh	+	-	+
	<i>Caulerpa scalpelliformis</i> (R. Br. ex Turner) C. Agardh	-	-	+
	<i>Caulerpa taxifolia</i> (M.Vahl) C. Agardh	+	+	+
PHAEOPHYCEAE				
ORDER: DICTYOTALES				
FAMILY: DICTYOTACEAE				
Dictyopteris	<i>Dictyopteris australis</i> (Sonder) Askenasy*	+	-	+
Dictyota	<i>Dictyota dichotoma</i> (Huds.) J.V.Lamour.	+	+	-
Padina	<i>Padina boergesenii</i> Allender & Kraft*	-	+	+
	<i>Padina boryana</i> Thivy*	-	-	+
	<i>Padina gymnospora</i> (Kuetz.) Sonder*	-	-	+
	<i>Padina pavonica</i> (L.) Thivy*	+	-	+
	<i>Padina tetrastratica</i> Hauck	+	+	+
Stoechospermum	<i>Stoechospermum polypodioides</i> (J.V.Lamour.) J. Agardh	+	+	+
ORDER: ECTOCARPALES				
FAMILY: SCYTOSIPHONACEAE				
Chnoospora	<i>Chnoospora minima</i> (Hering) Papenfuss	-	+	+
ORDER: FUCALES				
FAMILY: SARGASSACEAE				
Sargassum	<i>Sargassum cinereum</i> J. Agardh	+	-	+

	<i>Sargassum polycystum</i> C.Agardh	-	-	+
RHODOPHYCEAE				
ORDER: BANGIALES				
FAMILY: BANGIACEAE				
Phycocalidia	<i>Phycocalidia suborbiculata</i> (Kjellman) Santiañez & M.J.Wynne	+	-	+
ORDER: GELIDIALES				
FAMILY: GELIDIACEAE				
Gelidium	<i>Gelidium micropterum</i> Kuetz. *	-	-	+
	<i>Gelidium pusillum</i> (Stackh.) Le Jolis	+	-	-
ORDER: GELIDIALES				
FAMILY: GELIDIACEAE				
Gelidiella	<i>Gelidiella acerosa</i> (Forssk.) Feldmann & Hamel	-	-	+
ORDER: GRACILARIALES				
FAMILY: GRACILARIACEAE				
Gracilaria	<i>Gracilaria corticata</i> (J. Agardh) J. Agardh	+	+	+
	<i>Gracilaria corticata</i> var. <i>cylindrica</i> M.U. Rao*	+	+	+
	<i>Gracilaria foliifera</i> (Forssk.) Boergesen	+	-	-
	<i>Gracilaria textorii</i> (Suringar) Hariot	+	+	+
Hydropuntia	<i>Hydropuntia edulis</i> (S.G.Gmelin) Gurgel & Fredericq	+	-	+
ORDER: CRYPTOMANIALES				
FAMILY: HALYMENIACEAE				
Grateloupia	<i>Grateloupia filicina</i> (J.V. Lamour.) C.Agardh	+	+	+
	<i>Grateloupia lithophila</i> Boergesen	+	-	+
ORDER: CORALLINALES				
FAMILY: CORALLINACEAE				
Amphiroa	<i>Amphiroa fragilissima</i> (L.) J.V. Lamour.	+	+	+
Jania	<i>Jania spectabilis</i> (Harv.) J.H.Kim, Guiry & H.-G.Choi*	-	+	-
	<i>Jania rubens</i> (L.) J.V. Lamour.	+	+	+
ORDER: GIGARTINALES				
FAMILY: GIGARTINACEAE				
Chondracanthus	<i>Chondracanthus acicularis</i> (Roth) Fredericq	+	+	+
FAMILY: CYSTOCLONIACEAE				
Hypnea	<i>Hypnea cervicornis</i> J.Agardh*	-	-	+
	<i>Hypnea esperi</i> Bory*	-	-	+
	<i>Hypnea musciformis</i> (Wulfen) J.V. Lamour.	-	-	+
	<i>Hypnea valentiae</i> (Turner) Mont.	+	+	-
ORDER: RHODYMENIALES				
FAMILY: CHAMPIACEAE				
Champia	<i>Champia compressa</i> Harv.	-	-	+
FAMILY: LOMENTARIACEAE				
Ceratodictyon	<i>Ceratodictyon intricatum</i> (C.Agardh) R.E.Norris *	-	-	+
	<i>Ceratodictyon repens</i> (Kuetz.) R.E.Norris	-	-	+
	<i>Ceratodictyon variabile</i> (J.Agardh) R.E.Norris	+	-	-
ORDER: CERAMIALES				
FAMILY: CERAMIACEAE				
Centroceras	<i>Centroceras clavulatum</i> (C. Agardh) Mont.	+	+	-
FAMILY: RHODOMELACEAE				
Acanthophora	<i>Acanthophora spicifera</i> (M.Vahl) Boergesen	+	-	+
Bostrychia	<i>Bostrychia tenella</i> (J.V. Lamour.) J. Agardh	+	+	-
Total		35	26	47

Note: (\*) - Distributional additions to the state

**Table 3:** Physico-chemical parameters of seawater from study area

Parameters	Pre-monsoon (February to May)	Monsoon (June to September)	Post monsoon (October to January)
Atmospheric Temperature (°C)	28.5–37.6	28–29.5	26.5–27.5
Water Temperature (°C)	29–32	26.5–28	25–27
Salinity (ppt)	31.5–32.5	29.5–30.5	30–31.5
pH	7.8–8.2	7.4–7.6	7.5–7.8
D.O (ml/L)	7.0–7.3	7.3–7.6	7.4–7.8

these unique habitats to protect these natural treasures from habitat destructions. The particulars furnished in present study would be the doorway to scientific community to understand the basic facts of the marine macroalgae from the northern parts of Andhra Pradesh.

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