

INVESTIGATION ON THE OCCURRENCE OF GENUS *ULVA* FROM THE SHORELINE OF ANDHRA PRADESH

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The indication on the existence of genus *Ulva* in Andhra Pradesh is sporadic and poorly reported since 1952. Hence, an attempt was made to prepare the detailed account of genus *Ulva* from the coastal districts of Andhra Pradesh. Totally 112 localities were surveyed in different seasons from March 2017 – August 2019. A total of 14 species of *Ulva* were spotted from the nine maritime districts, among them seven species (*U. clathrata*, *U. conglobata*, *U. linza*, *U. profunda*, *U. prolifera*, *U. quilonensis*, *U. rigida*, and *U. taeniata*) were treated as new distributional records to the marine macroalgae flora of Andhra Pradesh. Further, four species of *Ulva* were reported for the first time from the east coast of India. Also, the present study confirms the presence of two endemic species (names of 2 endemic species here) of India. The description, occurrence, specimen examined, and distribution of 14 species are furnished in detail in this article.

Keywords: East Cost, Endemic, India, New distributional records, Ulvaceae.

Ulva L. is a prominent genus of the family Ulvaceae under the class Chlorophyceae. It is a thallophytic group with widespread occurrence in the marine ecosystem. It shows different morphological plasticity in many taxa and cause complication in identity.

The generic name *Ulva* was confined and legitimated with nine species under cryptogams by Linnaeus (1753). Later, Link (1820) proposed a new genus for taxa with monostromatic blades and tubular thallus as *Enteromorpha* and treated distromatic blades with flattened thallus under *Ulva*. The sequences of ITS nrDNA from 29 taxa highlighted simple morphology but high degree of phenotypic plasticity in *Ulva*. The result of the molecular studies states that both the genera (*Enteromorpha* and *Ulva*) have similar molecular orientations (Hayden *et al.* 2003). Hence, genus *Enteromorpha* was transferred to *Ulva* on the priority publication by Linnaeus (1753), and the same is now followed at the global level. But, in most of the Indian literature taxa under this group are still treated under two distinct genera i.e., *Enteromorpha* and *Ulva* (Oza and Zaidi 2001, Rao and Gupta 2015). The genus is common in tropical waters but their records in the Indian

coastline are limited (Joshi and Krishnamurthy 1972).

The distribution, diversity, occurrence, taxonomy, and various aspects of the genus *Ulva* was reported by several pioneer workers from the various maritime habitats of India (Ramanathan 1939, Sarma and Suryanarayana 1967, Dixit 1968, Rao and Sreeramulu 1970, Joshi and Krishnamurthy 1972, Krishnamurthy 2000, Oza and Zaidi 2001, Jha *et al.* 2009, Pereira and Almeida 2012, Kamboji *et al.* 2019, Palanisamy and Kumar 2020). Currently, genus *Ulva* represents 31 taxa (include species, subspecies, variety and forma) in India (Rao and Gupta 2015).

The evidence on the existence and distribution of *Ulva* on the east coast of India, especially of Andhra Pradesh is inadequate and poorly documented by a few of the investigators. Sreeramulu (1952, 1953), Rao and Sreeramulu (1964, 1970), Murthy and Rao (2003), Ghosh and Keshri (2010), Rao *et al.* (2011), Sowjanya and Sekhar (2017), Bast and Rani (2019) cited the occurrence of *Ulva* (as *Enteromorpha* and *Ulva*) in Andhra Pradesh but their observation restricted merely to Visakhapatnam District.

Ulva compressa, *U. flexuosa*, *U.*

fasciata, *U. intestinalis* *U. lactuca*, and *U. uniseriata* are the species previously reported in the coastline of Andhra Pradesh (Ghosh and Keshri 2010, Sowjanya and Sekhar 2017, Bast and Rani 2019). Account on existence and distribution of the genus *Ulva* from the north (Srikakulam and Vizianagaram) and south coastline (East Godavari, West Godavari, Krishna, Guntur, Prakasam, and Nellore) of Andhra Pradesh are meager. With respect to the above facts an attempt is made to document the diversity and distribution of genus *Ulva* from the coastal districts of Andhra Pradesh.

MATERIAL AND METHODS

Andhra Pradesh is geographically positioned between 12°41' - 19° 07'N latitude and 69°37' - 84°44'E longitude in the southern part of India. The boundaries of the state are restricted by Tamil Nadu to the south, Karnataka to the southwest and west, Telangana to the northwest and north, and Odisha to the northeast. The eastern part of the state is bounded by the coastline along the Bay of Bengal. Andhra Pradesh has got a coastline of around c.1000 km, running from Pulicat Lake (Nellore district) in the south to Donkuru (Srikakulam District) in the North. The study area is divided into three major zones i.e., South (Nellore, Guntur, and Prakasam), middle (Krishna, West Godavari, and East Godavari), and north (Visakhapatnam, Srikakulam, and Vizianagaram). Godavari and Krishna are the major rivers running in the state with enormous biodiversity. The extensive network of waterways are connected with the ports of Dugarajapatnam, Gangavaram, Kakinada, Krishnapatnam, Machilipatnam and Visakhapatnam. The islands such as Sriharikota, Nagarjunakonda, Bhavani, Hope Island are major sites situated in Andhra Pradesh. The offshore rocky plateaus stretched from Srikakulam district to Visakhapatnam district has enormous diversity of seaweeds while the remaining coastline is endowed with the sandy beach.

A total of 112 localities were surveyed

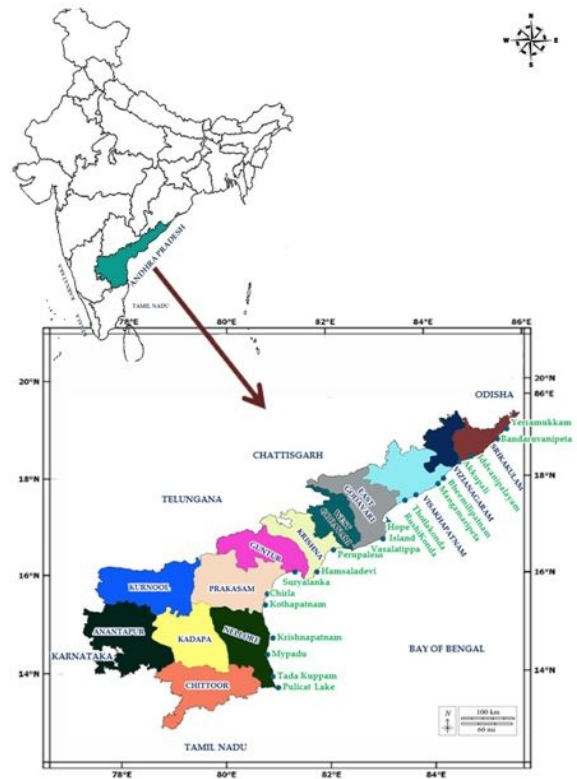


Figure 1: Map of Study area

for the collection of marine macroalgae during low tides in different seasons from March 2017 – August 2019. The collected samples were preserved (Wet method and Herbarium) by following standard methodologies at Botanical Survey of India, Southern Regional Center, Coimbatore. These specimens were identified based on morphological and microscopic observations; referring standard books and monograph such as *Catalogue of the Benthic Marine Algae of the Indian Ocean* (Silva et al. 1996), *Algae of India and neighboring 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 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); consulting the herbarium specimens deposited at MH, Coimbatore, ISIM, Kolkata, and CSIR-CSMCRI-MARS, Ramnad. The nomenclature

uncertainties were clarified with the assistance of online resources such as Macroalgal Herbarium Portal (<http://macroalgae.org/>), Algae Base (<http://www.algaebase.org/>), WoRMS (<http://www.marinespecies.org>) and Marine Biological Association of the UK (<http://www.mba.ac.uk/>) to provide valid data on the genus *Ulva* of Andhra Pradesh.

RESULTS AND DISCUSSION

The current attempt revealed the occurrence of 14 species of *Ulva* (*U. clathrata*, *U. compressa*, *U. conglobata*, *U. fasciata*, *U. flexuosa*, *U. intestinalis*, *U. lactuca*, *U. linza*, *U. profunda*, *U. prolifera*, *U. quilonensis*, *U. rigida*, *U. taeniata*, and *U. uniseriata*) from the nine maritime districts of Andhra Pradesh in different seasons. Also, the present investigation records of seven species (*U. clathrata*, *U. conglobata*, *U. linza*, *U. profunda*, *U. prolifera*, *U. quilonensis*, *U. rigida*, and *U. taeniata*) for the first time from Andhra Pradesh and treated as new distributional record to the state algal flora (Table 1, Plate 1, 2).

The shoreline of Visakhapatnam

encompasses a greater number of species (11) in comparison to other maritime districts of Andhra Pradesh. It is followed by Srikakulam with nine species, Vizianagaram with seven species, Nellore with six species, East Godavari & Guntur with three species, and West Godavari with two species. Likewise, Krishna and Prakasam districts supported the growth of single species (*U. prolifera*). The variation in the distribution, diversity, and species composition depends on the ecological parameters of the shoreline (Palanisamy and Kumar 2020).

U. prolifera was the common species found at the various habitats from the entire coastline of Andhra Pradesh in all seasons. Likewise, *U. compressa* and *U. uniseriata* were collected on the manmade substratum associated with the shoreline of five coastal districts of the state. The species *U. clathrata*, *U. conglobata*, *U. fasciata*, *U. lactuca*, *U. quilonensis*, *U. rigida*, and *U. taeniata* were anchored firmly on the solid substratum and found at the coastline of Srikakulam, Vizianagaram, and Visakhapatnam. Whilst *U. flexuosa*, and *U. intestinalis* were free-floating and gathered from backwater sites having mangroves. Similarly, *U. linza* and *U. profunda*

Table 1: Occurrence of genus *Ulva* in the maritime districts of Andhra Pradesh (Note: SKM = Srikakulam; VNM = Vizianagaram; VKM = Visakhapatnam; EGI = East Godavari; WGI = West Godavari; KHA = Krishna; GNR = Guntur; PKM = Prakasam; NLE = Nellore; + = Present; - = absent; * = New records)

S. No.	Name of the Taxa	SKM	VNM	VKM	EGI	WGI	KHA	GNR	PKM	NLE
1.	<i>Ulvacathrata</i> (Roth) C. Agardh*	+	-	-	-	-	-	-	-	-
2.	<i>U. compressa</i> L.	+	+	+	+	-	-	-	-	+
3.	<i>U. conglobata</i> Kjellm*	+	-	+	-	-	-	-	-	-
4.	<i>U. fasciata</i> Delile	+	+	+	-	-	-	-	-	-
5.	<i>U. flexuosa</i> Wulfen	+	+	+	-	-	-	-	-	-
6.	<i>U. intestinalis</i> L.	-	+	+	-	-	-	+	-	+
7.	<i>U. lactuca</i> L.	+	+	+	-	-	-	-	-	-
8.	<i>U. linza</i> L.*	-	-	-	-	-	-	-	-	+
9.	<i>U. profunda</i> W.R.Taylor*	-	-	-	-	-	-	-	-	+
10.	<i>U. prolifera</i> O.F.Mull*	+	+	+	+	+	+	+	+	+
11.	<i>U. quilonensis</i> Sindhu&Panikkar*	-	-	+	-	+	-	-	-	-
12.	<i>U. rigida</i> C.Agardh*	+	+	+	-	-	-	-	-	-
13.	<i>U. taeniata</i> (Setch.) Setch. &N.L.Gardner*	-	-	+	-	-	-	-	-	-
14.	<i>U. uniseriata</i> Bast*	+	-	+	+	-	-	+	-	+
	Total	9	7	11	3	2	1	3	1	6

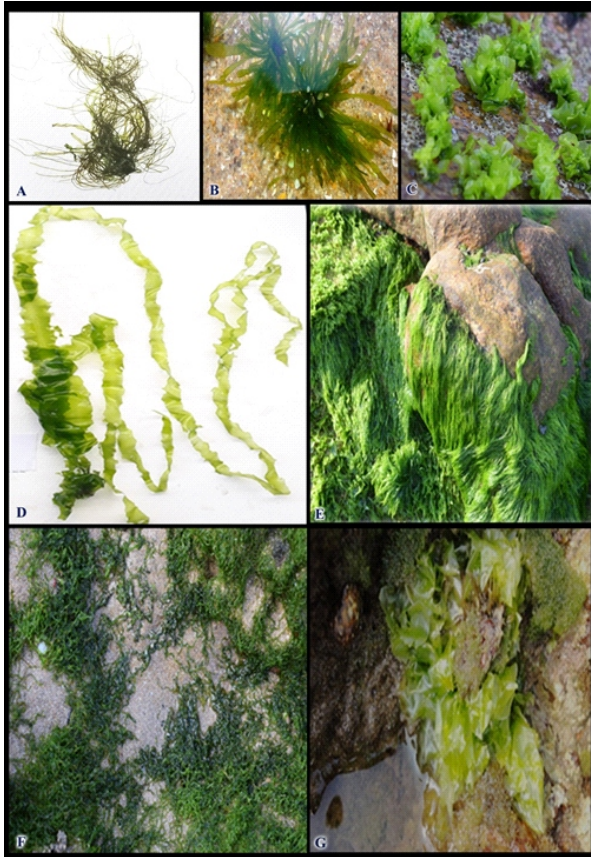


Plate -1 (A-G). Habits of different species of *Ulva* in Andhra Pradesh are as follow: **A.** *U. clathrata* (Roth) C. Agardh; **B.** *Ulva compressa* L.; **C.** *U. conglobata* Kjellm; **D.** *U. fasciata* Delile; **E.** *U. flexuosa* Wulfen; **F.** *U. intestinalis* L.; **G.** *U. lactuca* L.

were free-floating species and collected from the islands and backwater area of Nellore.

Further, *U. conglobata*, *U. profunda*, *U. quilonensis*, and *U. taeniata* were recorded for the first time from the east coast of India, however, these species are periodically reported from the west coast of India (Pereira and Almeida 2012, Rao and Gupta 2015, Palanisamy and Kumar 2020). The species *U. profunda* is being collected after the report by Dave and Parekh (1975) from the Sourashtra coast. Also, the present study confirms the occurrence of two endemic species (*U. quilonensis* *U. uniseriata*) of India from the shores of Andhra Pradesh. All the 14 species are enumerated systematically and their description, specimen examined and distribution are provided.

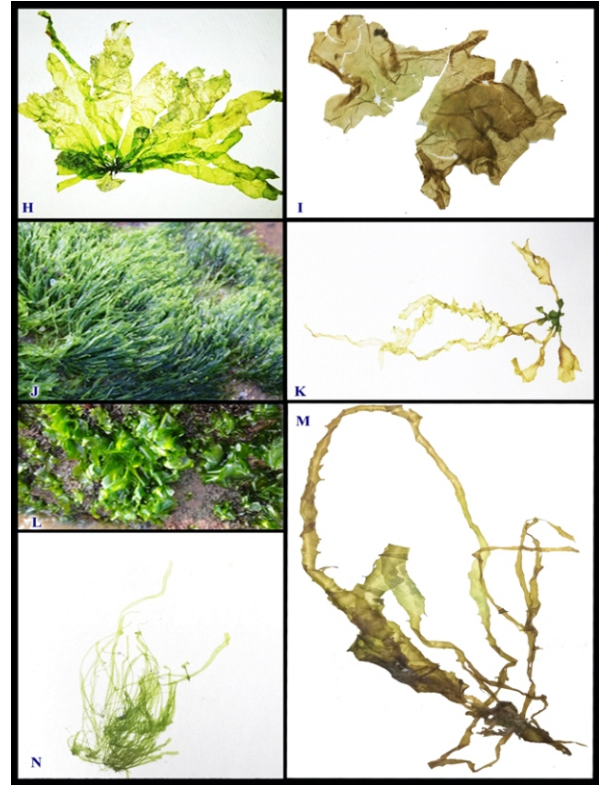


Plate-2 (H-N). Habits of different species of *Ulva* in Andhra Pradesh are as follow: **H.** *U. linza* L.; **I.** *U. profunda* W.R. Taylor; **J.** *U. prolifera* O.F. Mull; **K.** *U. quilonensis* Sindhu & Panikkar; **L.** *U. a rigida* C. Agardh; **M.** *U. taeniata* (Setchell) Setchell & N.L. Gardner; **N.** *U. uniseriata* F. Bast

SYSTEMATIC TREATMENT

1. *Ulva clathrata* (Roth) C. Agardh, Disp. algar. 2:23. 1811. (Plate 1:A)

Basionym: *Conferva clathrata* Roth.

Light yellowish green, 3–9 cm long with discoidal holdfast. Stipe tubular, small, fronds cylindrical, tufted, profusely branched throughout main axis, tubular at base and narrowly compressed, margins entire, apex obtuse or acute. Cells elongated, large, irregularly arranged, uninucleate, chloroplast plate-like and pyrenoids one to two.

Seasonal availability: Monsoon & Rare.

Distribution: Andaman & Nicobar Islands, Goa, Gujarat, Karnataka, Kerala, Lakshadweep Islands, Maharashtra and Tamil Nadu.

Specimen Examined: Andhra Pradesh: Srikakulam District - Iddvanipalayam, 06.09.2018, *Palanisamy & Aron Santhosh Kumar* 137523 (MH).

2. *Ulva compressa* L. Sp. Pl. 2: 1163. 1753. (Plate 1: B)

Light to dark green in colour, 2–7 cm long, tubular to hollow, sparingly to profusely branched. Fronds many, tubular, slightly flattened at base and gradually expanded and compressed towards apex. Cells squarish-elongate or irregular, cell wall with thin sheath, uninucleate and chloroplast concave with single pyrenoid.

Seasonal availability: Throughout the year & Common.

Distribution in India: Andaman & Nicobar Islands, Andhra Pradesh, Goa, Gujarat, Karnataka, Lakshadweep Islands, Maharashtra, Odisha and Tamil Nadu.

Specimen Examined: Andhra Pradesh: Srikakulam District - Yerramukkam, 06.09.2018, *Palanisamy & Aron Santhosh Kumar* 137528 (MH).

3. *Ulva conglobata* Kjellman, Bih. Kongl. Svenska Vetensk.-Akad. Handl. 23(11): 10. 1897. (Plate 1: C)

Light-bright green, 1.5–3 cm long, leafy, undivided, forming tufted globular mass, mostly gregarious and lithophilic. Holdfast minute, rhizoidal, firmly attached. Stipe small, foliaceous, simple, fronds leafy, undivided, firmly contorted; blades 1–3 cm wide, surface smooth, cartilaginous below and gradually membranous above, margins entire to frequently undulate, apex acute to obtuse. Cells polygonal in shape-squarish, distromatic, uninucleate, chloroplast cup like.

Seasonal availability: Monsoon & Rare.

Distribution in India: Goa, Gujarat, Karnataka & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Mangamaripeta, 10.09.2018, *Palanisamy & Aron Santhosh Kumar* 137528 (MH).

4. *Ulva fasciata* Delile, Fl. Egypt. Expl. Pl. 2 : 297, Pl. 58. Fig. 5. 1813. (Plate 1: D)

Dark-light green, 5–40 cm long, leafy, ribbon shaped, gregarious, tufted, lithophilic, holdfast small, rhizoidal, tufted, stipe small, foliaceous, simple or branched. Fronds leafy, deeply divided into several linear blades, uniformly flattened, surface smooth, membranous, irregularly lobed, gradually tapering towards apex; margins entire to frequently undulate, apex acute to obtuse. Cells in surface view polygonal - squarish, distromatic, compactly arranged, uninucleate with plate like chloroplast.

Occurrence: Throughout the year & Common.

Distribution in India: Andaman & Nicobar Islands, Goa, Gujarat, Karnataka, Kerala, Lakshadweep, Maharashtra, Puducherry & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Vizianagaram District – Chintapalli, 20.03.2019, *Palanisamy & Aron Santhosh Kumar* 138026 (MH).

5. *Ulva flexuosa* Wulfen, Crypt. Aquat. 3: 1. 1803. (Plate 1: E)

Yellowish green, up to 25 cm long, tubular, hollow, lithophilic, holdfast small, discoid. Stipe small, flat at maturity, 5–20 cm long tubular at base and gradually becoming flexuous towards apex, margins entire, apex obtuse to round. Cells polygonal, uninucleate, chloroplast completely filling almost entire cell, pyrenoids spherical and 4–5.

Seasonal availability: Throughout the year & Common.

Distribution in India: Goa, Gujarat, Karnataka, Kerala & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Vizianagaram District – Chintapalli, 20.03.2019, *Palanisamy & Aron Santhosh Kumar* 138027 (MH).

Note: Ghosh and Keshri (2010) reported the *Enteromorpha lingulata* J. Agardh from Visakhapatnam and currently, it has been treated as *U. flexuosa* (Guiry and Guiry 2021).

6. *Ulva intestinalis* L., Sp. Pl. 2: 1163. 1753. (Plate 1: F)

Light-yellowish green, up to 18 cm long, tubular, contorted, mature filaments intestine like, holdfast minute, discoidal. Fronds proliferated, thin, cylindrical below and becoming inflated and irregularly constricted above, lumen inflated with air bubbles, margins entire to undulate. Cells in surface view rounded to polygonal, thin, uninucleate, chloroplast cup shaped with 2–4 pyrenoids.

Seasonal availability: Throughout the year & Common.

Distribution in India: Goa, Gujarat, Karnataka, Kerala & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Vizianagaram District – Konada, Pusapatirega, 22.08.2019, *Palanisamy & Aron Santhosh Kumar* 140412 (MH).

7. *Ulva lactuca* L., Sp. Pl. 2: 1163. 1753. (Plate 1: G)

Light-dark green, up to 10 cm long, 6 cm broad, lettuce type, tufted, translucent, membranous, rosette like, discoidal holdfast, minute. Stipe small, simple, fronds foliaceous, thin with several lobes, margins undulated, wavy, apex obtuse. Cells rectangular, uninucleate, chloroplast cup shaped with one or two pyrenoids.

Seasonal availability: Throughout the year & Common.

Distribution in India: Andaman & Nicobar, Goa, Gujarat, Karnataka, Kerala, Maharashtra & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Thotlakonda 21.03.2019, *Palanisamy & Aron Santhosh Kumar* 140327 (MH).

8. *Ulva linza* L., Sp. Pl. 2: 1163. 1753. (Plate 2: H)

Light-olive green, foliaceous, flattened, constricted at base, slightly tubular, 5–16 cm long. Holdfast small, discoidal, stipe tubular, flattened upwards. Fronds simple, linear to lanceolate, margins entire or undulate, apex obtuse. Cells rectangular, thin walled,

uninucleate, chloroplast concentrated with pyrenoid single.

Seasonal availability: Post-monsoon & Moderate.

Distribution in India: Karnataka, Kerala & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Nellore District – Pulicat Lake 15.09.2018, *Palanisamy & Aron Santhosh Kumar* 137948 (MH).

9. *Ulva profunda* W.R. Taylor, Marine alg. Florida 57, 1928. (Plate 2: I)

Light-olive green, up to 25 cm long, 18 cm broad, flattened, translucent, membranous with discoidal holdfast, minute sometimes free floating in nature. Stipe small, fronds foliaceous, thin, with lobes highly perforated, margins undulated, wavy, apex obtuse. Cells rectangular, uninucleate, chloroplast cup shaped with two pyrenoids.

Seasonal availability: Monsoon & Rare.

Distribution in India: Tamil Nadu.

Specimen Examined: Andhra Pradesh: Nellore District – Pulicat Lake 29.09.2019, *Palanisamy & Aron Santhosh Kumar* 142516 (MH).

10. *Ulva prolifera* O.F. Muell., Fl. Dan. 5(13): 7, pl. 763 (1). 1778. (Plate 2: J)

Dark-yellowish green, up to 45 cm long, proliferated, intricately masses, regularly tubular at base and compressed above, holdfast small, stipe slender, small. Fronds tubular, highly proliferated from main axis forming several secondary proliferations, margins entire, apex obtuse. Cells oblong, uninucleate, chloroplast complete with many pyrenoids.

Seasonal availability: Throughout the year & Common.

Distribution in India: Andaman & Nicobar, Goa, Gujarat, Karnataka, Kerala, Maharashtra & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Thotlakonda 23.03.2017, *Palanisamy & Aron Santhosh Kumar* 137214 (MH).

11. *Ulva quilonensis* Sindhu & Panikkar, Feddes Repert. 106: 123, figs. 25-27. 1995. (Plate 2: K)

Light to dark green, 18–25 cm long, attached on substratum by discoidal holdfast with a conspicuous stipe. Fronds with several laminae, linear, ribbon-like with wavy and ruffled margin, base narrow. Cells elongated, distromatic, thick walled, uninucleate, and chloroplast complete with 1–2 pyrenoids.

Seasonal availability: Pre-monsoon & Rare.

Distribution in India: Kerala.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Thimmapuram, 23.03.2017, *Palanisamy & Aron Santhosh Kumar* 137195 (MH).

12. *Ulva rigida* C. Agardh, Spec. Alg. 1(2): 410. 1823. (Plate 2: L)

Light-yellowish green, up to 8 cm long, leafy, leathery, rigid, small rosette, lithophilic, holdfast minute, discoid, stipe small. Fronds foliaceous, ovate, slightly lobed, tufted, up to 5 cm wide, margins entire, undulated. Cells elongated, thick walled, compactly arranged, uninucleate, chloroplast cup shaped with one pyrenoid.

Seasonal availability: Throughout the Year & Common.

Distribution in India: Andaman & Nicobar, Goa, Gujarat, Karnataka, Kerala, Maharashtra & Tamil Nadu.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Bheemunipatnam, 23.03.2017, *Palanisamy & Aron Santhosh Kumar* 137168 (MH).

13. *Ulva taeniata* (Setchell) Setchell & N.L. Gardner, Alg. Pac. North America 2: 286. pl. 28. Plate 2: M)

Light to dark green, up to 24 cm long, leafy, membranous, ribbon like, lithophilic, holdfast minute, discoid, stipe small. Fronds foliaceous, slightly lobed, tufted, up to 5 cm wide, margins entire, undulated. Cells elongated, thick walled, compactly arranged, uninucleate, chloroplast cup shaped with one pyrenoid.

Seasonal availability: Monsoon & Common.

Distribution in India: Goa & Maharashtra.

Specimen Examined: Andhra Pradesh: Visakhapatnam District – Thotlakonda, 21.03.2019, *Palanisamy & Aron Santhosh Kumar* 140317 (MH)

14. *Ulva uniseriata* Bast & Rani, Indian J Mar Sci. 48(11): 168, 1691. 2019. (Plate 2: N)

Light green to olive green in colour, saxicolous, 3–15 cm long, uniseriate, filamentous, unbranched, compressed, tufts with minute rhizoidal holdfast. Fronds unbranched, flattened, slightly tubular, uniseriate with identical broad, margin wavy, apex acute or obtuse. Cells quadrilateral to elongated, ends rounded; parietal chloroplast with multiple pyrenoids.

Seasonal availability: Monsoon & Common.

Distribution in India: Andhra Pradesh.

Specimen Examined: Andhra Pradesh: East Godavari District – Kakinada Backwater area, 25.08.2019, *Palanisamy & Aron Santhosh Kumar* 142502 (MH).

Note: Bast and Rani (2019) discovered novel species *U. uniseriata* from the coastline of Pulicat Lake, Nellore district. This same species was collected from the shoreline of Srikalulam, Visakhapatnam, East Godavari, Guntur and Nellore.

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