

NEW RECORDS OF SEaweEDS FROM SOUTH-EASTERN COASTS OF COX'S BAZAR DISTRICT, BANGLADESH

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Keywords: New records; *Gracilaria tenuistipitata* var. *liui*; *Ulva linza*; *Caulerpa fergusonii*; New varieties; *C. chemnitzschi* (Esper) Weber-van Bosse var. *irregulare* Aziz & Alfasane var. nov.; *C. sertularioides* (S.G. Gmelin) M. Howe var. *robusta* Aziz & Alfasane var. nov.; St. Martin's Island; Cox's Bazar District; Bangladesh.

Abstract

Gracilaria tenuistipitata var. *liui* Zhang *et* Xia 1988 from sand-flat at Nuniachara, Cox's Bazar, *Ulva linza* Lin. from west coast of Naf R. at Noapara, Teknaf and Fishary Ghat in River Bakkhali, at Cox's Bazar, and *Caulerpa fergusonii* Murray from St. Martin's Island (SMI), have been newly recorded and illustrated from Bangladesh. *C. chemnitzschi* (Esper) Weber-van Bosse var. *irregulare* Aziz & Alfasane var. nov. and *C. sertularioides* (S.G. Gmelin) M. Howe var. *robusta* Aziz & Alfasane var. nov. from SMI, Cox's Bazar District, Bangladesh are new to science. Total number of marine algal taxa so far recorded from Bangladesh coasts is now 210.

Introduction

In the last quarter of 20th Century significant contributions have been made on the seaweed flora of the Indian subcontinent and adjacent regions (Islam, 1976). In Bangladesh National Professor AKM Nurul Islam was the pioneer on algal researches and published the monumental work "Contribution to the Study of the Marine algae of Bangladesh" in 1976 where 69 genera with 140 taxa of seaweeds were reported. Later the first author joined with Prof. Islam and a number of students over the years did M. S. theses on seaweeds under the supervision of the first author and Prof. Islam adding 65 seaweed taxa including sub-littoral seaweeds collected with the help of Bangladesh Navy in 2013 till 2015 (Aziz *et al.*, 2015) making the total number of taxa 205 along Bangladesh coasts mainly SMI (Aziz, 2015). Billah *et al.*, (2018) investigated relative abundance of 11 greens, 14 browns and 12 red sub-littoral seaweeds collected from January to June in 2007 (but five seaweeds reported as new records were all reported earlier by Islam 1976 and Aziz *et al.*, 2015). Recently, seaweed researches in Bangladesh extended to the analysis of chemical composition and extraction of phycocolloids from a few of them for use as food and in industries (Hassan 2018, Roy 2018). In view of the importance mentioned taxonomic studies of the concerned seaweeds and some other related species collected were found to be new records for Bangladesh which are described and illustrated in this communication.

Materials and Methods

Gracilaria tenuistipitata var. *liui* Zhang *et* Xia 1988 from a sand-flat (300 m East-west × 2000 m North-south) at Nuniachara (21° 28' 07" N 91° 56' 58" E to 21° 28' 37" N 91° 58' 02" E) south-east of Moheshkhali Channel and east of Sonadia, *Ulva linza* Lin from West coast of Naf river estuary, Noapara, Teknaf (21° 06' 48" to 21° 06' 58" N and 92° 12' 07" to 92° 12' 17" E) and

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Bakkhali R. at Fishery Ghat, about 3 km north-east of Nuniachara, Cox's Bazar, *Caulerpa fergusonii* Murray, *C. chemnitzschi* (Esper) Weber-van Bosse var. *irregulare* var. nov. and *C. sertularioides* (S.G. Gmelin) M. Howe var. *robusta* Aziz & Alfasane var. nov. from west coast of the SMI (20° 34' 26" to 20° 39' 10" N and 92° 18' 51" to 92° 18' 51" to 92° 20' 17" E) and Cox's Bazar Districts growing abundantly in winter and spring seasons were collected, pressed onto herbarium sheets or photographed alive and also preserved in formaldehyde. Habitat and ecology, geographical distribution, etc. are given at the end of each taxon.

Results and Discussion

A total of five seaweeds such as *G. tenuistipitata* var. *liui* Zhang and Xia 1988 and *Ulva linza* Lin., *Caulerpa fergusonii* Murray have been identified, described and illustrated as new records for Bangladesh. *Caulerpa chemnitzschi* (Esper) Weber-van Bosse var. *irregulare* Aziz & Alfasane var. nov. and *C. sertularioides* (S.G. Gmelin) M. Howe var. *robusta* Aziz & Alfasane var. nov. have been identified, described and illustrated as new taxa from Bangladesh.

Phylum: **Rhodophyta**; Class: **Rhodophyceae**; Order: **Gigartinales**;
Family: **Gracilariaceae**; Genus: **Gracilaria**

1. *Gracilaria tenuistipitata* var. *liui* Zhang *et* Xia 1988 (Figs 1a-k)

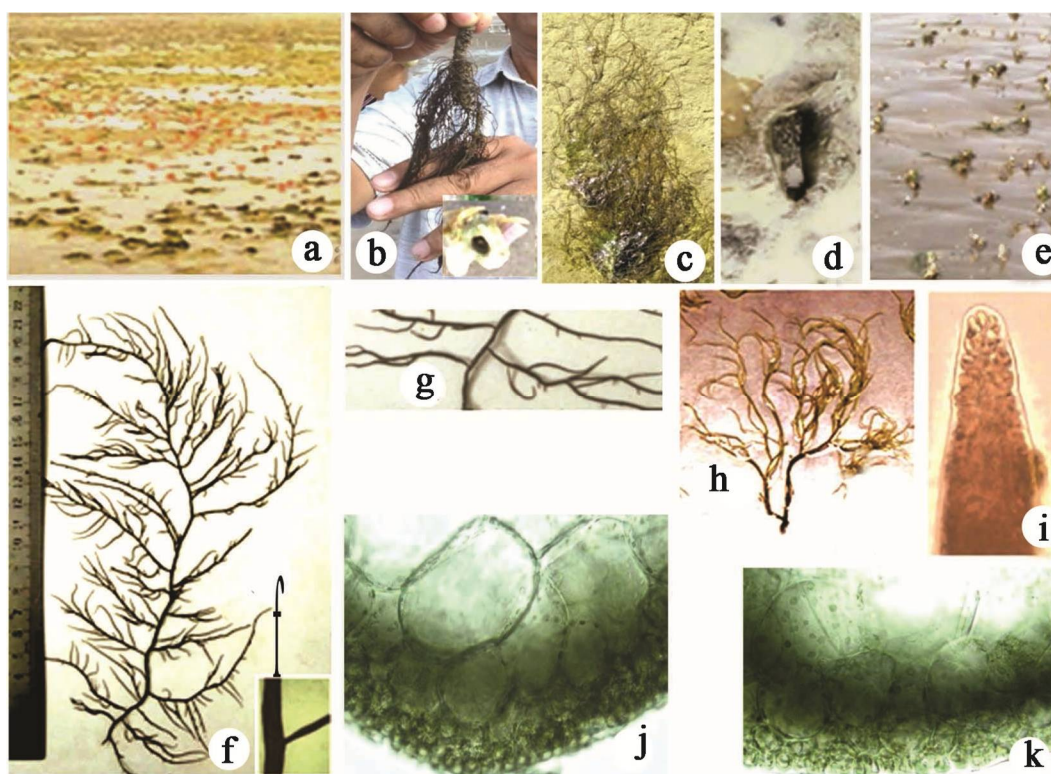
(Zhang *et* Xia 1988, Figs 1, 3-9)

Plants thalloid dark-red, slender, bearing many delicate, short to long flagelliform lateral branches about 50 cm long, 0.25 to 1.0 mm wide (Figs 1a-c, f-h) firmly attached deep inside the semi-solid Tube-worm cases lodged in the intertidal sand-flat (Figs 1a-d), but no disc having vertical threads for attachment was visible like other species, in other words attachment organ not specifically developed (Figs 1f), axis with tapered branch lets (terete fronds) present in loose spirals (Figs 1f-g), also from circulating aquarium (Fig. 1h). The base of branches distinctly narrowed, <0.5mm wide for about 2 mm distance and then gradually widen to 0.50 to 1.00 mm (Figs 1f-g). Branch tip possesses four to five side by side ellipsoidal apical about five cells (Fig. 1i) and cross-section consists of several very large medullary cells (axial cells absent) derived from the apical cells called multiaxial growth/construction, followed by one, some part with two layers of smaller cortical cells ending with radial rectangular epidermal cells covered by cuticle (Figs 1j-k).

The repeatedly curled flagelliform tapered branches in laboratory cultured seaweeds (Fig. 1h) was exactly similar to the holotype (Haikou, Hainan Island, Guangdong Province, China, Zhang and Xia, AST 85-652, April 1, 1986) with narrowed base of branches as observed by Zhang and Xia (1988, Fig. 1). The habit of the present plant variety was close to *G. tenuistipitata* by having enormous morphological variations but constriction at the base of branches was not found (Barufi *et al.*, 2010, Fig. 1A; Song *et al.*, 2015); type specimen contains urn-shaped cystocarp (Zhang and Xia, 1988, Fig. 4) but not found in the present natural and laboratory-grown plants. Identification of *Gracilaria* species is difficult due to lack of sexual reproduction in most of the species (Lewmanomont, 1996). In the present study plants collected every month from nature during the growing period did not produce any cystocarp, propagation was vegetative. However, Aziz *et al.*, (2002) reported *G. dura* (Ag.) J. Ag., *G. spinuligera* Börg. and a related seaweed *Gracilariopsis rhodotricha* Dawson from coasts of SMI during March in mid 1990's.

Habitat and ecology: *G. tenuistipitata* var. *liui* grew abundantly attached to tube-worm cases (Figs 1a-c) on an intertidal sand-flat at Nuniachara, north of Cox's Bazar Airport, south-east of Moheshkhali Channel and north-east of Sonadia Is., having 1.5 to 2.0 m high tides. The plant

growth was severely affected by silt deposition due to dredging in the Moheshkhali Channel on the sand-flat destroying its habitat when Tube-worms moved on to the shore (Fig. 1d-e) severely decreasing the population. Physical and chemical conditions of the seawater were 25 to 33°C temperature, turbidity ranging from 20 to 27 (>40) NTU and 22 to 30‰ salinity. There are reports of occurrence of the seaweed at salinity as low as 7.00‰, temperature 34°C on sandy mud in South China (FAO/NACA-P, 1996). The base of a plant appears to be immersed into the worm case, not visible from outside. During rainy season (rain water degrades the exterior part of the plant on Tube-worm) bases of the plant persisted deep inside the case and grow by mid September having little or no rain and turbidity, salinity about 26‰ and temperature about 30° C continued up to April next year. Zhang and Xia (1988) frequently found the type variety in fish ponds and shallow intertidal areas in muddy substrate of South China from November to April each year.



Figs 1a-k. *Gracilaria tenuistipitata* var. *liui* Zhang et Xia: (a) Sand-flat at Nuniachara, Cox's Bazar with dark-brown bunches of the seaweed during lowest tide (red crabs roaming around); (b) About a dozen plants attached to over 6 cm long Tube-worm case (inset shows the shiny head of the worm inside the tube); (c) Plants on the sand-flat attached to a Tube-worm case; (d) Foot-print showing extent of silt deposited on the seaweed; (e) Tube-worms moved on to shore due to silt deposits; (f) Semi-dried plant mildly spread on herbarium sheet without pressing (0.3 ×), inset shows constricted base of a branch (2 ×); (g) A portion of the non-pressed main axis enlarged showing curly branches; (h) A portion of the cultured seaweeds showing branching pattern (0.7 ×); (i) A magnified branch tip; (j-k) T. S. (manually) of an axis.

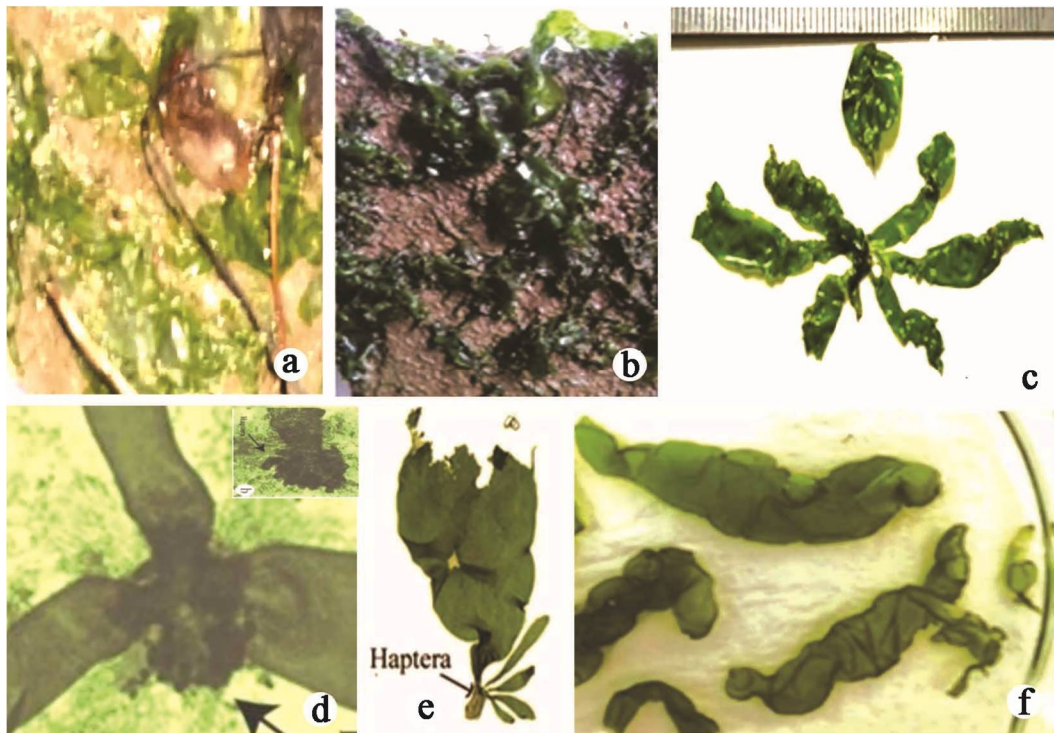
Phylum: **Chlorophyta**; Class: **Chlorophyceae**; Order: **Ulvales**;
 Family: **Ulvaceae**; Genus: *Ulva*

2. *Ulva linza* Lin.

(Figs 2a-g)

(Van Patten, 2006, p. 27; Guiry and Guiry, 2020)

Plants bright “spring” yellow-green colour, unbranched, two layered thick leaf-like and flattened tube at old age with ruffled edges, 3-5 cm long, 1 to 2 cm wide, several growing gregariously from a point and attached by haptera consisting of numerous rhizoids (Figs 2a-d). Upper part of mature plants produces spores released by decomposition (Fig. 2e); fully developed inflated fronds with ruffled edge developed in old laboratory cultures (Fig. 2f).



Figs 2a-g. *Ulva linza* Lin.: (a) Leafy plants on upper littoral clayey sandy soil, Noapara, during lowest tide; (b) Plants of different ages on a brick surface, 0.4× Bakkhali R.; (c) A bunch of 8 thalli from the brick surface spread on herbarium sheet (scale in mm); (d) Three plants aggregated and attached by haptera (arrow); inset showing numerous rhizoids at the base); (e) Herbarium of a mature plant with decomposed upper part producing spores, four young plants developed at the base, 1.5×; (f) Fully developed fronds inflated with ruffled edge from old laboratory cultures spread on a Petri dish with medium, 1×.

Islam (1976) reported *Ulva lactuca* from SMI without illustrations, while Aziz *et al.* (2008) described and illustrated *Ulva lactuca* L. var. *rigida* (C. Ag.) Le Jolis from Inani beach, Cox’s Bazar, including which the total number of taxa is now three. Van Patten (2006) recorded the species dimension as more than 40 cm by 5 cm from Long Island Sound, USA. *Ulva* having many

species are difficult to identify because of their simple morphologies and high plasticity, and thus ecological properties like salinity preference and phenology have been reported for a limited number of species (Ogawa *et al.* 2013).

U. linza is called “Mini Sea Lettuce” by Americans, in English “Slender Sea Lettuce”, Japanese “Usaba Aonori” (Guiry and Guiry, 2020), and used as Garnish on “Seaweed salad” in fancy restaurants (Van Patten 2006).

Habitat and ecology: The seaweed was first found on clayey sandy soil west coast of Naf R. estuary, upper intertidal zone (Fig. 2a) beside salt producing ponds from January to June, Noapara, Teknaf, salinity 24-31 ‰, pH 7.5-7.8, turbidity 20-31 NTU (>40). Later it was found growing abundantly on bricks along intertidal zone at Fishary Ghat, Bakkhali River, Cox’s Bazar (Figs 2b, c, e), from September to April and rotten during June-August, salinity ranging from 17-30‰, pH <8.00.

Geographic distribution: Kang *et al.* (2016) described *U. linza*, a brackish areas green seaweed dissociate from substrata facilitating the initiation of blooms, and the subsequent movement of fronds from estuaries to the inshore, then to offshore environment. Ogawa *et al.* (2013) found it among four marine species by analyzing the internal transcribed spacer regions of 125 marine specimens and 1169 specimens from seven brackish sites, and phenologically some species appeared only for a few months, and others were found at all times of the year.

Phylum: **Chlorophyta**; Class: **Ulvophyceae**; Order: **Bryopsidales**;

Family: **Caulerpaceae**; Genus: **Caulerpa**

3. *Caulerpa fergusonii* G. Murray (Figs 3a-e)

(Bold systems: Taxonomy browser, v3.boldsystems.org; https://en.wikipedia.org/wiki/Caulerpa_fergusonii; https://www.algaebase.org/search/species/detail/?species_id=3753; as *C. cactoides* in Islam 1976, Pl. 12, figs 94-95; Pl. 14, fig. 103)

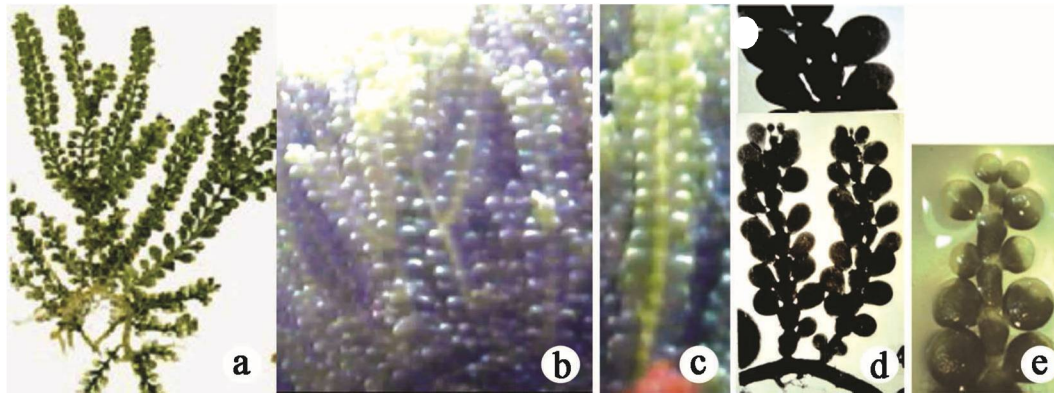
Plants thalloid coenocytic, colourless stolon producing rhizoids from below and erect olive green branches or frond/pinnae from above, 4.0 to 9.0 cm tall, 1.0 to 1.5 cm wide; fronds may produce single to several lateral branches from an axis spreading about 18 cm tall in February collections, pinna consisting of an axis of series of pyriform or ob-pyriform (balloon-like) 10 to up to 30 segments each producing a pair of relatively larger pyriform or balloons called pinnae up to the tip, no internodal cells found (Figs 3a-d); pinnules 5 to 6 mm long and 3 to 4 mm wide; during reproductive phase pinnae of the upper part become spherical when the whole olive-green cell content of lower half of fronds moves on to the upper half filling lower half of each pinna and axial segments (Fig. 3e).

Islam (1976, Pl. 12, figs 94-95; Pl. 14, fig. 103) published the coenocytic seaweed with similar body structure to the above description without internodal cells but identified as *C. cactoides* (Turner) C. Ag. Literature review revealed that *C. cactoides* is characterized by short inter-nodal segments occurring all along the frond’s axis alternating with nodal segment each producing paired pinnae (Guiry, 2013). These features are lacking in the illustrations by Islam (1976, p. 18, fig. 94-95, 103). Therefore, the present material (Figs 3a-b) and the illustrations by Islam (1976, Figs 94-95) in Fig. 3d are the same and identified as *C. fergusonii* Murray (Guiry, 2013) in this report. Dominic *et al.*, (2007) remarked that there are two known extra-Australian records of *C. cactoides*, from Bangladesh (Islam 1976) and Sumba Island in Indonesia (Coppejans and van Reine, 1992), which is a wrong identification for Bangladesh part.

Habitat: Rocky littoral or upper littoral zones of west coast of SMI. Islam (1976) recorded it as *C. cactoides* also from rocky littoral zone of the Island. The alga was also recorded in the sub-

littoral zone of extreme South of Cheradia forming submerged meadow at a depth of over 2.0 m (Fig. 3b).

Geographic distribution: Point Lonsdale, Rock pool, Victoria, Australia environment (Guiry, 2013). The seaweed is found around finch of Asia (India, Srilanka, Indonesia, Philippines, etc.) and the Pacific islands as well as New Zealand.



Figs 3a-e. *Caulerpa fergusonii* Murray (a) Herbarium of a plant with repeatedly branched fronds, 0.3 \times ; (b) Videography of submerged vegetation, south of Cheradia, SMI using underwater communication system. (c) A frond from the video enlarged showing axial segments each producing a pair of pinnules anteriorly; (d) A plant with two fronds and an enlarged portion on the top (after Islam 1976, Fig. 94) 1 \times ; (e) Upper half of a frond in reproductive stage where all segments possess gamete producing cytoplasm occupying about 50% space >1 \times .

4. *Caulerpa chemnitzschi* (Esper) Weber and Bosse var. *irregulare* Aziz & Alfasane var. nov. (Figs 4a-b)

Plants bottle-green and bushy; rhizomatous part and branches or fronds are relatively tough or hard, fronds 5.0 to 7.0 cm tall, about 1.7 cm wide at the apex and gradually narrowed (0.5 cm) basally; pinnae of the frond apex are saucer-shaped large up to 8 mm wide, attached by about 3 mm long stalk; pinnae gradually narrowed basally to about 2.5 mm while length of stalks were slightly shorter, 1.0 mm broad at the base that gradually acentrically broaden to over 3 mm wide funnel-shaped structure attaching to undersurface supporting pinnae; pinnae are arranged in irregular raceme on the solid axis; rhizoids developed from lower side attaching with calcareous materials, such as dead fronds of *Halimeda discoidea*. Aziz *et al.* (2015, Fig. 3) describe the specimen as *Caulerpa chemnitzschi* (Esper) Weber and Bosse (Syn *C. racemosa* (Forssk.) C. Ag. var. *peltata* (lamx.) Eubank) based on collection made on 08.03.2013 from SMI. The material was exactly similar to the present one collected on 06 March 2016 from west of Bangladesh Coast Guard Office, SMI. The size or width of pinnae gradually narrowed and arrangement of pinnae was irregular raceme compared to other varieties and has been considered as a new variety

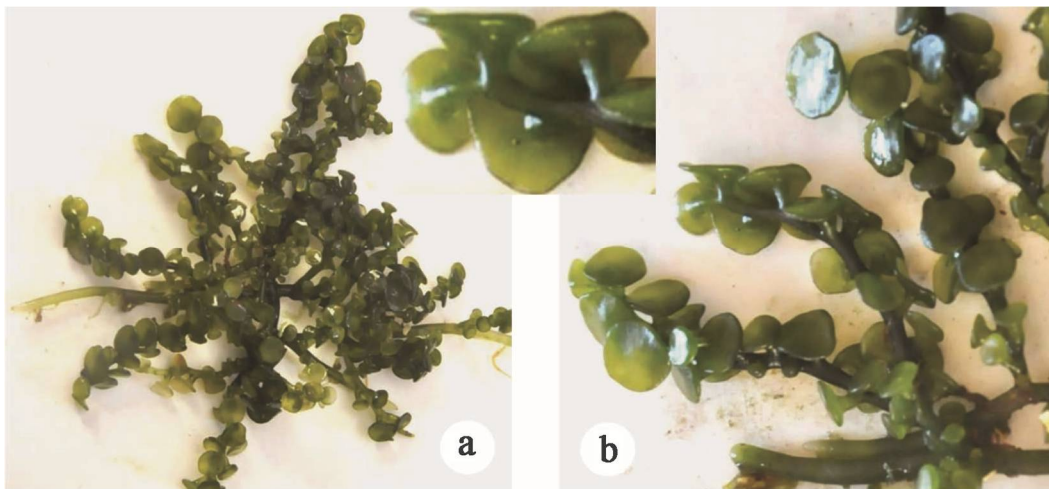
Etymology: Branches with distal pinnae up to 8 mm wide, saucer-shaped top, <1.0 mm thick margin, stalk short solid 3mm long, 1.0 mm wide at the base gradually broad acentrically to about 3 mm wide attached to pinna; pinnae also arranged in irregular raceme on the solid frond.

Specimens examined: St. Martin's Island (SMI), Aziz & Alfasane, 1382(PLHL), 08.03.2013; 1472(PLHL), 06.03.2016.

Holotype: Bangladesh, Aziz & Alfasane, 1382(PLHL), 08.03.2013; Herbarium of Phycology Limnology and Hydrobiology Laboratory, Department of Botany, University of Dhaka

Distribution in Bangladesh: St. Martin's Island (SMI), abundant on rocky sub-littoral zone at two locations: south of Cheradia, roughest rocky coast at depths of 1.5 to 7.0 m on 08 March 2013, Fig. 4a, facing the Bay of Bengal, and west of Bangladesh Coast Guard Office, moderately rough area at 3.0 m depth on 08.03.2013 and 06.03.2016, Fig. 4b.

Geographical distribution: Tropical rocky substratum.



Figs 4a-b. *Caulerpa chemnitzschii* (Esper) Weber and Bosse var. *irregulare* Aziz & Alfasane var. **nov.**: a) A whole plant 0.8 \times , collected in 2013; (b) A portion of another plant enlarged 2 \times , terminal part further enlarged 4 \times showing details of asymmetric stalked saucer-like pinnae, collected in 2016.

5. *Caulerpa sertularioides* (S.G. Gmelin) M. Howe var. **robusta** Aziz & Alfasane var. **nov.**

(Figs 5a-b)

The plant is dark-green, fronds stout, short feather-like and upright, 2.0-3.0 cm high, about 2.0 cm wide consisting of nearly straight 3 to 11 mm long, 1 to 1.5 mm wide needle-like pinnae with narrow base oppositely arranged, closely associated without spaces in between attached by narrow stalk, shorten abruptly near the tip giving broadly conical to moderately pointed appearance; fronds appear robust with short stalk; stolons cylindrical creeping 2 to 2.5 mm diameter and creeping up to about 2 metres, more or less straight; branched rhizoids from below penetrate the sandy substrate.

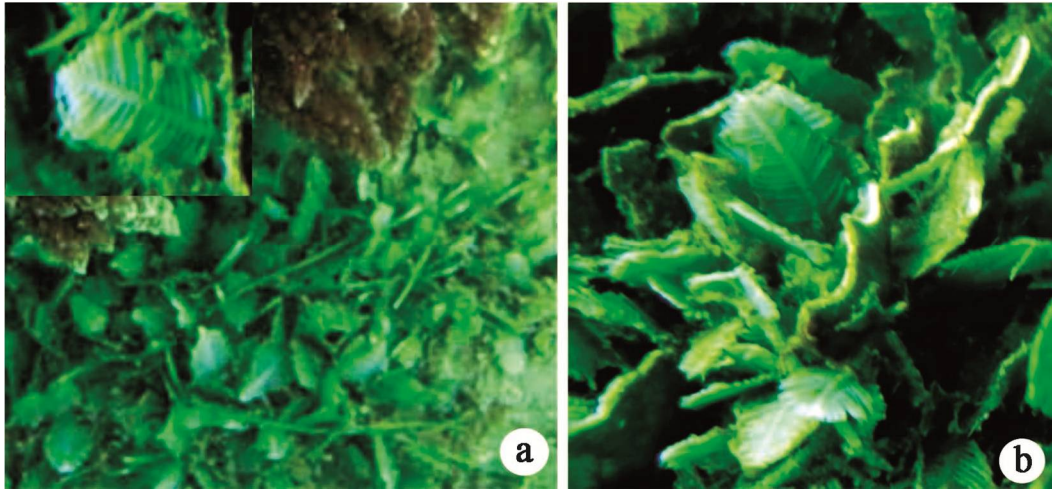
Etymology: Plants dark-green, short stalked stout feather-like fronds attached to straight and stout creeping stolon; pinnae wide needle-like stout, not curved but slightly upwardly directed giving broadly conical to moderately pointed apex.

Holotype: Bangladesh, Aziz & Alfasane, 1383(PLHL) 08.03.2013; Herbarium of Phycology Limnology and Hydrobiology Laboratory, Department of Botany, University of Dhaka

Habitat: It grows on sandy floor at a depth of 2 to 3 meters, sub-littoral along with *Asparagopsis taxiformis* and *Halimeda discoidea* bushes, west coast of SMI in March 2017.

Geographic distribution: North Carolina to Florida, also found throughout the Caribbean around Bermuda, Bahamas, Greater and Lesser Antilles and in the Gulf of Mexico and in the

southern Atlantic Ocean to Brazil; the Pacific Ocean along the in Australia, Western Australia, Papua New Guinea, Philippines and Palau.



Figs 5a-b. *Caulerpa sertularioides* (S.G. Gmelin) M. Howe var. *robusta* Aziz & Alfasane var. nov.: (a) Submerged creeping plants beside *Asparogopsis taxiformis* bush, inset showing enlarged fronds attached to stolon, 1.2 \times ; (b) fronds growing upright with *Halimeda discoidea* bush (1.0 \times).

Islam (1976) described and illustrated 11 species/taxa of *Caulerpa* from SMI and Aziz and Rahman (2011) later added *C. certuluroides* fa *corymbosa* to the list. Including the present three species, total *Caulerpa* species is 15.

Total seaweed taxa occurred along Bangladesh coast now stand at 210, the absolute majority of which were from the SMI.

Acknowledgements

In the herbaria of seaweeds collected over several decades National Prof. AKM Nurul Islam identified a red seaweed as *Hypneamus ciformis* and also published *Caulerpa cactoides* Islam (1976). During visit of seaweed specialist Dr. Lawrence Liao, Hiroshima University, Japan in February 2018 the first author presented a seminar of seaweed flora of Bangladesh. Dr. Liao identified the two organisms as *G. tenuistipitata* var. *liui* and *Caulerpa fergusonii*, respectively for which the author is grateful to him. Authors are grateful to Bangladesh Navy authority specially Commander M Zahid Hossain (TAS) PSC Co BNS SAIKAT for providing Scuba Divers with underwater photographic and Communication Systems.

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