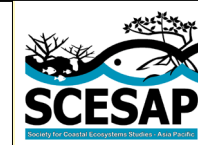


Data Paper



New records of benthic green algae (Chlorophyta) from Hainan Island (2008 - 2016)

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Abstract

This study reports on the intertidal and shallow subtidal green algal flora from Hainan Island in the South China Sea, based on a series of extensive sample collection conducted in 2008–2016. An analysis of the data revealed 22 new records of green algae for Hainan Island, including 6 species new to China. 15 of these newly-recorded species are described with photographs.

Keywords: Hainan Island, new records, seaweeds, green algae

Note

This article shares the same information as to “**Introduction**” and “**Materials and Methods**” given in Titlyanova & Titlyanov (2018) and Titlyanova *et al.* (2018). Refer to these publications for details.

Flora of green algae from Hainan (2008-2016)

A total of 22 taxa of green algae (Table 1) were newly recorded for Hainan Island, of which 7 species belonged to the Order Cladophorales, 5 species to Ulotrichales and Bryopsidales; 3 species belonged to Ulvales and one

species each to Chaetophorales and Dasycladales. Among new findings, epilithic algae amounted to 64%, epiphytic and endophytic algae 36%.

The largest number of new findings was recorded in Luhuitou (12 taxa of 22) and Wenchang locality (6 taxa). In the intertidal zone, 18 species were found in Hainan Island for the first time and in the upper subtidal zone only 10 species. 15 species (64%) were widespread species in tropical and subtropical areas, 7 species (36%) of early collections inhabiting tropics and subtropics of the Indo-Pacific, 8 being widespread species in temperate waters, and 7 in arctic and subantarctic waters. Among these new findings of green algae, invasive (not inhabiting the Indo-Pacific) species were not found in Hainan.

Table 1. List of green algae collected from Hainan Island in 2008-2016.

Abundance: rare (+); common (++); abundant (+++). Distribution: T – tropical; S – subtropical; M – temperate; An – Antarctic; T,S,M,An – from tropics to Antarctic; T,S,M – tropics to (cold) temperate zones; T,S – tropical and subtropical Indo-Pacific and Atlantic; T,S,(I-P) – tropical and subtropical Indo-Pacific. Life forms: Ep, epiphyte, HS, algae growing on hard substrate (epilithic), Cr, crust form. ¶ new record for Hainan Island; ¶¶ new record for China. Locality abbreviations (refer to Fig 1): Dadong Hai, Dh; Hong Tang Bay, Ht; Linchang, Lc; Luhuitou, Lh; Nanmai, Nm; Meixia, Mx; Shalao, Sl; Tian Ya Hai Tiao, Ty; Wenchang, Wc; Yalong Wan, Yw; Ying Ge Hai, Yg; Xian Hai, Xn; Xiaodong Hai, Xh; Xincun, Xc; Ximao Zhou, Xz.

Species, varieties and forms	Life form	Distribution	Abundance		Location in Hainan
			intertidal	upper subtidal	
DIVISION CHLOROPHYTA					
CLASS CHLOROPHYCEAE					
Order CHAETOPHORALES					
Family Chaetophoraceae					
<i>Uronema marinum</i> Womersley ¶	Ep	T,S,(I-P)	+		Lh
CLASS ULVOPHYCEAE					
Order ULOTRICHIALES					
Family Gomontiaceae					
<i>Gomontia polyrhiza</i> (Lagerheim) Bornet & Flahault ¶	En	T,S,M,Ar	+		Lh
<i>Monostroma latissimum</i> Wittrock ¶	HS	T,S	+		Mx
Family Ulotrichaceae					
<i>Ulothrix flacca</i> (Dillwyn) Thuret ¶	Ep	T,S,M,Ar,An	+		Yw, Lh
<i>Ulothrix implexa</i> (Kützing) Kützing ¶	Ep	T,S,M,Ar,An	+		Lh
<i>Ulothrix subflaccida</i> Wille ¶¶	Ep	T,S,M,Ar	+		Lh
Order ULVALES					
Family Ulvaceae					
<i>Ulva australis</i> Areschoug ¶	HS	T,S,M,Ar,An	+	+	Wc
<i>Ulva reticulata</i> Forsskål ¶	HS	T,S,(I-P)	+		Xn, Wc
<i>Ulva rigida</i> C. Agardh ¶	HS	T,S,M,Ar,An		+	Wc
Order CLADOPHORALES					
Family Boodleaceae					
<i>Cladophoropsis membranacea</i> (Hofman Bang ex C. Agardh) Børgesen ¶	Ep	T,S	+	+	Lh
Family Cladophoraceae					
<i>Chaetomorpha basiretrorsa</i> Setchell ¶	HS	T,S,(I-P)	+		Yg
<i>Chaetomorpha ligustica</i> (Kützing) Kützing ¶¶	Ep	T,S,M	+		Lh
<i>Cladophora rugulosa</i> G. Martens ¶	HS	T,S,(I-P)	+		Yg
Family Siphonocladaceae					
<i>Siphonocladus rigidus</i> M.A. Howe ¶¶	Ep	T,S	+		Wc
Family Valoniaceae					
<i>Valonia fastigiata</i> Harvey ex J. Agardh ¶	HS	T,S	+	+	Wc, Yw
<i>Valonia macrophysa</i> Kützing ¶¶	HS	T,S	+	+	Ht
Order BRYOPSIDALES					
Family Bryopsidaceae					
<i>Bryopsis plumosa</i> (Hudson) C. Agardh ¶	HS	T,S,M,Ar,An	+	+	Wc
<i>Trichosolen mucronatus</i> (Børgesen) W.R. Taylor ¶	HS	T,S,(I-P)	+		Lh
Family Caulerpaceae					
<i>Caulerpa fastigiata</i> Montagne ¶¶	HS	T,S		+	h
<i>Caulerpa mexicana</i> Sonder ex Kützing ¶	HS	T,S		+	Lh
Family Udoteaceae					
<i>Penicillus sibogae</i> A. Gepp and E.S. Gepp ¶¶	HS	T,S,(I-P)		+	Yw, Lh
Order DASYCLADALES					
Family Dasycladaceae					
<i>Bornetella nitida</i> Munier-Chalmas ex Sonder ¶	HS	T,S,(I-P)	+	+	Yw, Lh, Yg , Lh

(a)

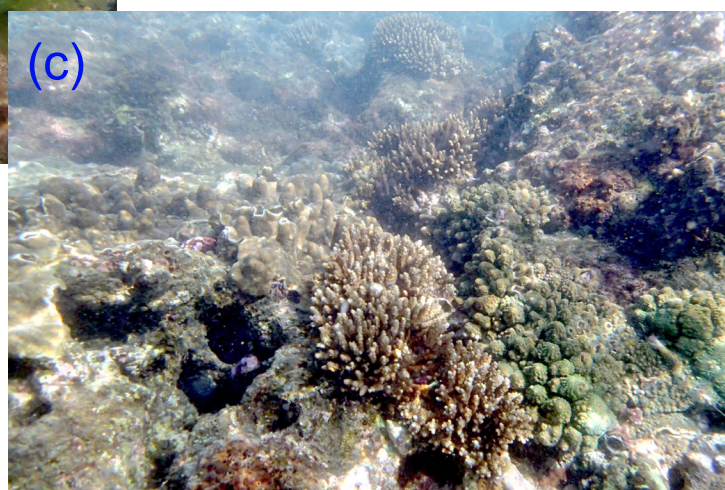
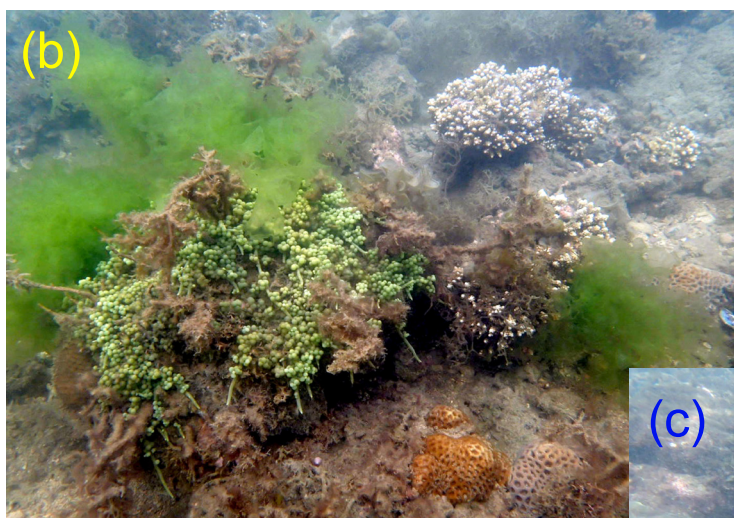


Fig. 1 (a) Collection sites on Hainan Island, China. (Filled circles), collection sites of C.K. Tseng and coworkers in the 1930s–1980s (old spellings of site names); (Stars), collection sites of two German-Chinese expeditions during October–December 1990 and March–April 1992; (Plus), collection sites of T. Titlyanova, E. Titlyanov and Li Xiu Bao in 2008–2016. (b) Luhuitou, upper subtidal, 2 m depth, April 2012. (c) Xiaodong Hai, upper subtidal, 1.5 m depth, December 2016.

Description of green algae collected in Hainan Island 2008-2016

DIVISION CHLOROPHYTA

Order CHAETOPHORALES

Family Uronemataceae

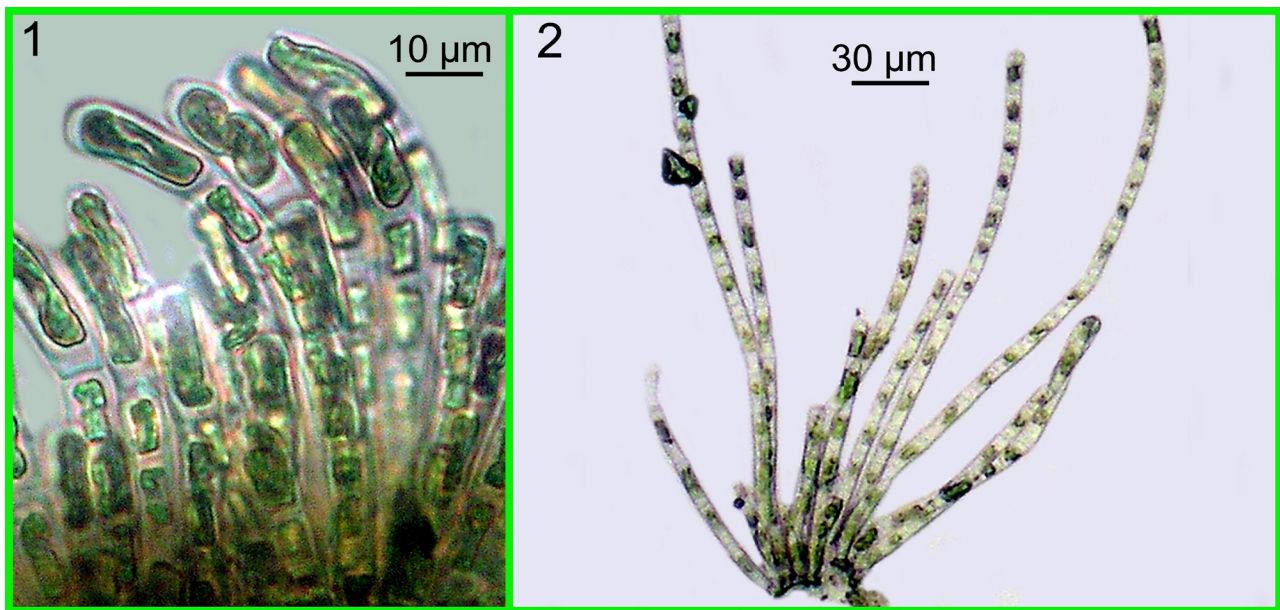
Uronema marinum Womersley

Fig. 2 *Uronema marinum*. 1. Magnified, near Wenchang, March 2012. 2. Overall morphology. Luhuitou, April 2012.

Characteristics: Thallus composed of erect, straight or slightly curved, uniseriate and unbranched filament, to 400 µm high, originating from conical base, forming tomentose spots of light to dark green color. Filaments are cylindrical increasing in diameter from base upwards, slightly constricted (or not constricted) at cross walls, apical cell with rounded top. Cells 5.0 µm in diam. at base, 7.5 µm at apical cells, 15–25 µm long (2–4 diameters long). Chloroplast single, commonly with one large pyrenoid (rarely two). Cell walls about 1 µm thick. Growing epiphytic on *Anadyomene wrightii*, *Ceramium marshallense*.

Order ULOTRICHALES

Family Monostromataceae

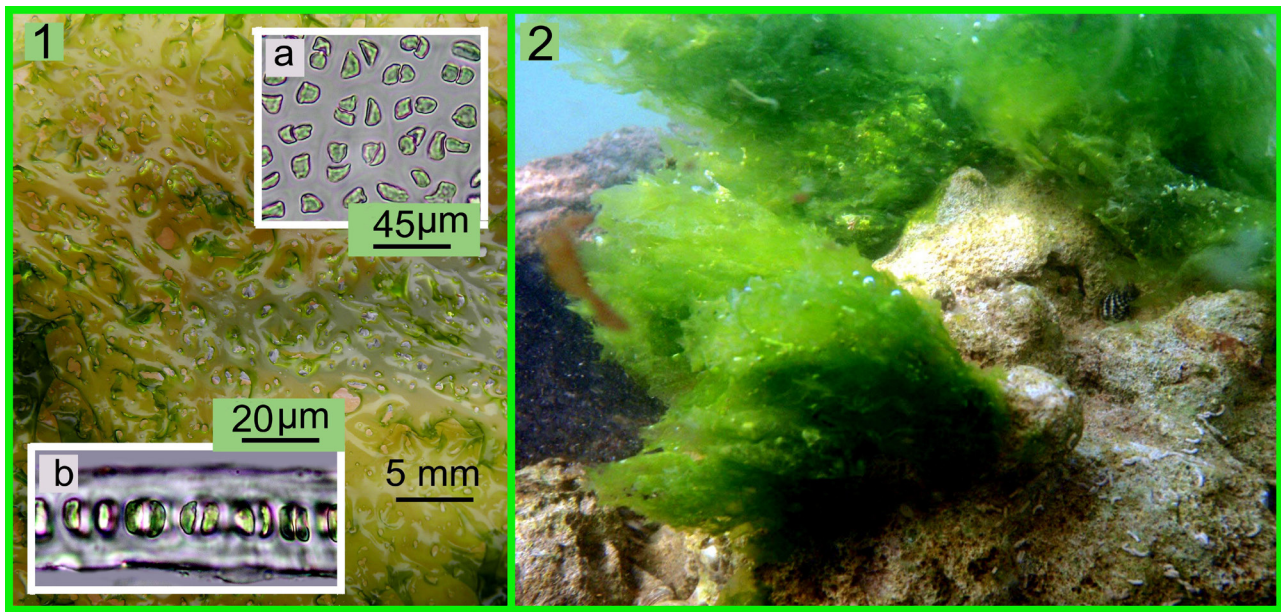
Monostroma latissimum Wittrock

Fig. 3 *Monostroma latissimum*. 1. Part of the thallus showing perforations with raised proliferating margins. Insets: a – surface view of cells; b – transverse section of blade. 2. In habitat at low tide, Meixia locality. April 2012.

Characteristics: Thallus membranous, flaccid, soft, thin, ruffled surface and perforated with many holes of various size, light green, 10–20 cm across. Margins smooth or undulating. Cell from surface view rectangular to polygonal with rounded corners, disordered, often in groups of 2–3(–4), 15–17 µm across. In transverse section, blade of one cell thick, 30(–35) µ at the basal portion and 20–25 µ above; cells vertically oval 12.5–17.5(–20) µ high. Chloroplast single, central with one pyrenoid. Attachment by small holdfast

Order ULVALES

Family Ulvaceae

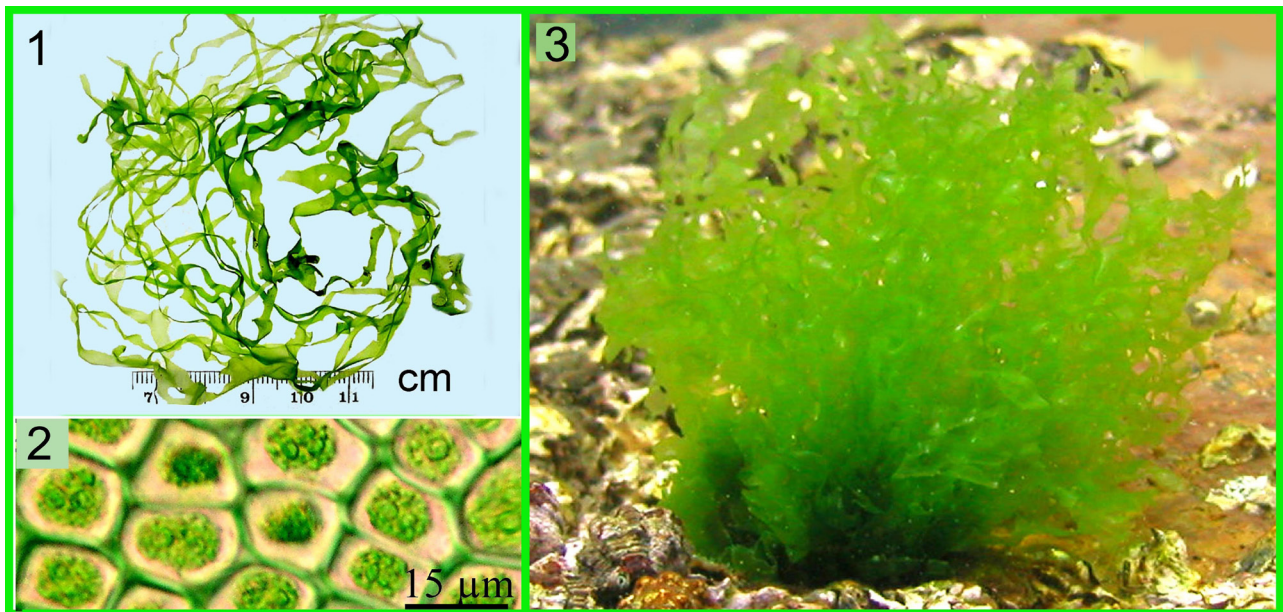
Ulva reticulata Forsskål

Fig. 4 *Ulva reticulata*. 1, Overall morphology. 2, Surface view of cells. 3, In habitat.

Characteristics: Thallus rough, ribbon-like, firm in texture, reticulate, netlike (membrane with numerous large and small holes), deeply and irregularly lobed, light to dark green, to 80 cm across. Margins of the thallus and edges around the holes are with microscopic serrations. Cells from surface view rounded polygonal, $20\text{--}22 \times 12.5\text{--}15\text{ }\mu\text{m}$. In transverse section, the membrane composed of two cells layers, $45\text{--}50\text{--}(76)\text{ }\mu\text{m}$ thick; cells are oval to roundish, commonly higher than wide, or of more equal sizes, $20\text{--}25\text{ }\mu\text{m}$ high, $10\text{--}20\text{--}(22)\text{ }\mu\text{m}$ broad. Growing on hard substrate from upper intertidal to subtidal, common as epiphytes on *Sargassum* spp., seagrasses and other algae. Plants also form masses entangled into larger algae, in moderately wave-exposed shores. Abundant in polluted areas. Plants are often unattached and washed ashore.

Order CLADOPHORALES

Family Boodleaceae

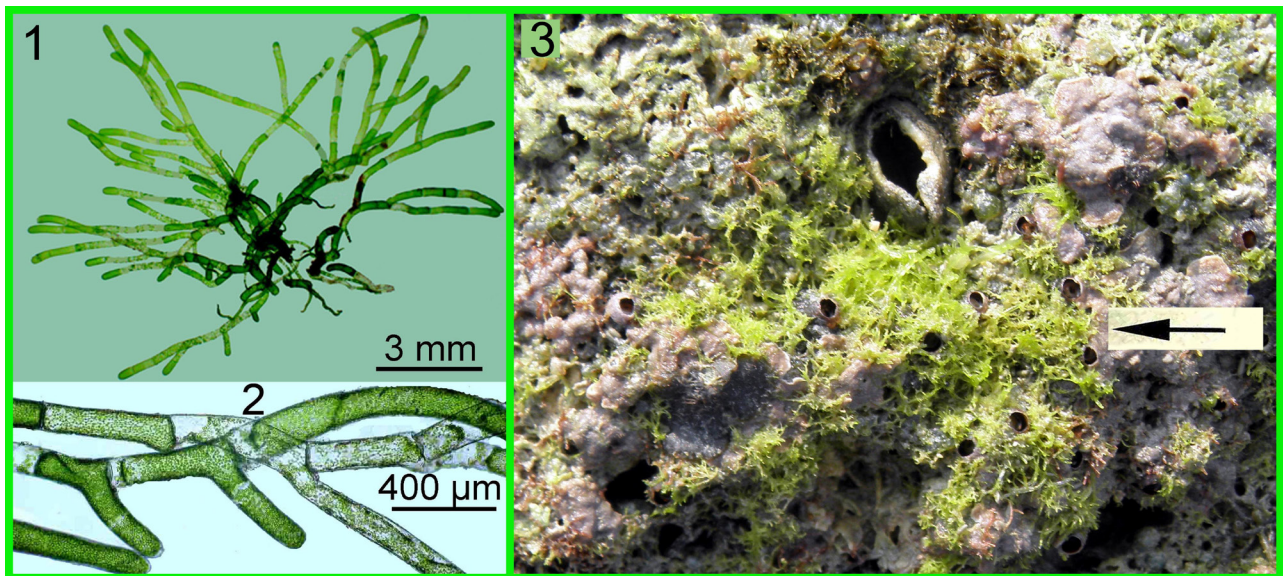
Cladophoropsis membranacea (Hofman Bang ex C. Agardh) Børgesen

Fig. 5 *Cladophoropsis membranacea*. 1, Overall morphology. 2, Branching pattern. 3, In habitat, the low intertidal zone (arrow). Hainan Island, Luhuitou, April 2012.

Characteristics: Thallus filamentous, glossy, forming tufts or dense cushion-like clumps, or mats, bright green color, 2–5 cm high. Branching sparse, mainly irregular, alternate below and unilateral above. Filaments coarse, 170–270(–300) µm in diam., lateral filaments 100–140 µm in diam. No cell wall at the base of lateral branches (in open connection with mother cell). Chloroplasts are ellipsoidal, with one well visible large pyrenoid. Attachment by small, colorless, branched rhizoids ending into pads; secondary attachments (or tenaculae) develop from apices as extension of lateral decumbent filaments.

Family Cladophoraceae

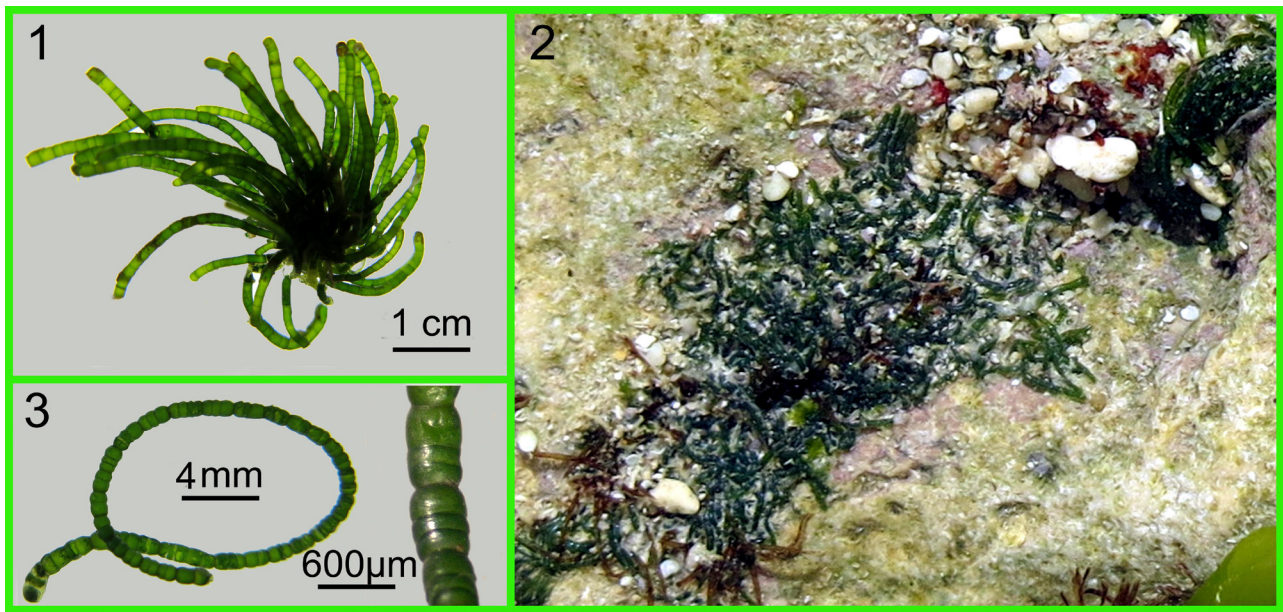
Chaetomorpha basiretrors Setchell

Fig. 6 *Chaetomorpha basiretrors*. 1, Overall morphology. 2. In habitat, Ying Ge Hai, April 2014. 3. Detail showing filament and cells.

Characteristics: Thallus filamentous, rigid, caespitose, gregarious, with curved downward filaments, 2–3(–4.5) cm long, shining, dark-green and iridescent in water. Filaments 500–800(–1000) μm in diam. gradually decreasing to the base to 200–300 μm in diam. Cells cylindrical, slightly swollen, barrel-shaped, 0.3–4 diameters long, constricted at joints. Cell wall 25–45 μm thick, striated, grayish or light brownish especially in the basal cell. The basal cell to 1.6 mm long ending into long branched rhizoids in open connection with the mother (basal) cell. In most cases, secondary finger-like rhizoids develop laterally on the basal cell. Growing in the middle intertidal zone on hard substrate, forming dense clusters occupying areas to 15 cm in diam.

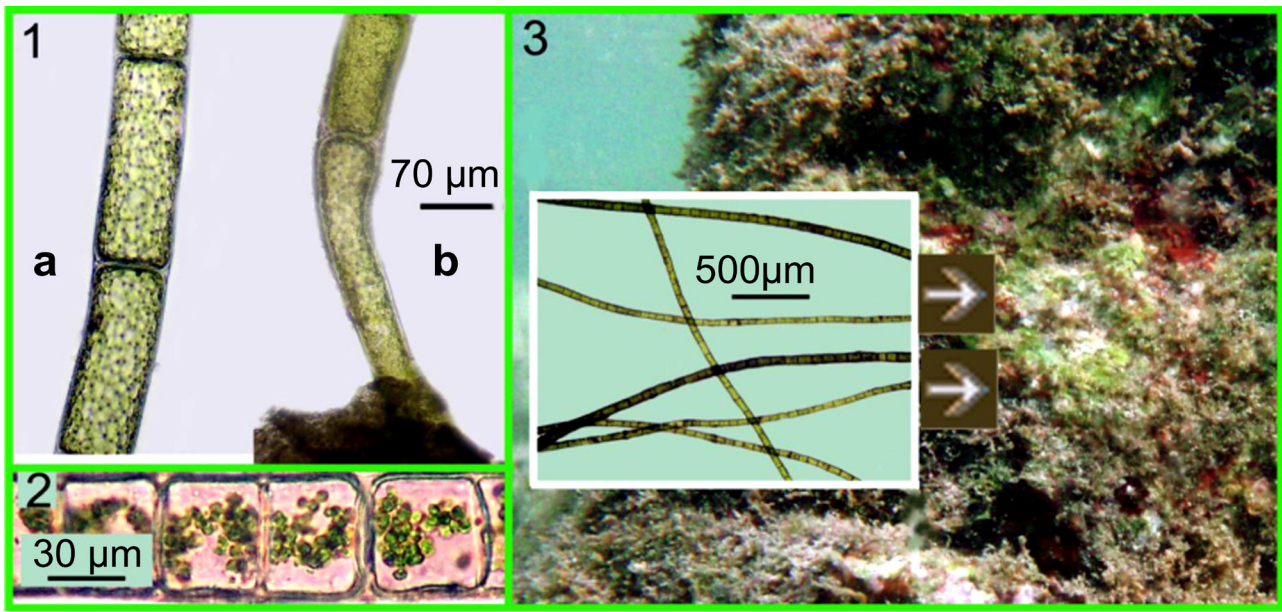
***Chaetomorpha ligustica* (Kützting) Kützting**

Fig. 7 *Chaetomorpha ligustica*. 1, Basal portion of filament. Detail showing cells. 2, In habitat, the lower intertidal zone at Xiaodong Hai, among turf algae (arrows). October 2008.

Characteristics: Thallus filamentous, dark-green, 5–10 cm long. Filaments rather coarse, tangled, intertwined (40–)65–80(–100) µm in diam. Cells cylindrical, 1–3(–4) diameters long. Cell walls 2–3(–5) µm thick, not constricted at joints. Basal cell 50 µm in diam., to 200 µm long, ending into fine, slightly lobed attachment. Growing on hard substrates in the lower intertidal zone among turf algae, sometimes on soft grounds, or epiphytic on other algae at sheltered sites and near to estuaries.

***Cladophora rugulosa* G. Martens**

Fig. 8 *Cladophora rugulosa*. 1, Upper part of branches. 2. Overall morphology. Hainan Island, Ying Ge Hai, April 2014.

Characteristics: Thallus filamentous, caespitose, bushy, densely tufted, (1.4–)3–6 cm high, dark green. Filaments stiff, coarse. Branching is irregular, pseudichotomous, at very narrow angle between axis and branchlets. Cells of the main axes cylindrical, club-shaped, to 250 µm in diam., elongate, gradually tapering downward (6–8 diameters long) in the lower part and 6–12 diameters long in the upper one. Terminal branchlets fasciculate. Maximum number of branches at joints 3–4. Apical cells to 6 diameters long, cylindrical, slightly swollen and tapering toward blunt tips. Attachment by fine branched rhizoids, descending from the lower cells (without cross wall), and forming entangled stipe.

Family Siphonocladaceae

Siphonocladus rigidus M.A. Howe

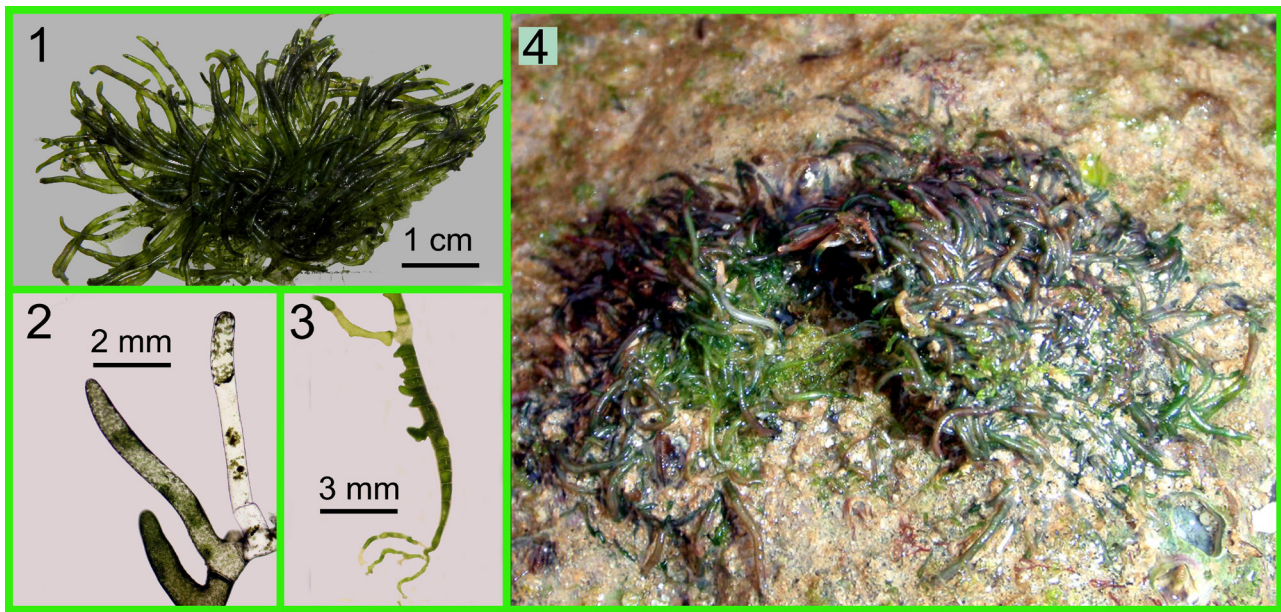


Fig. 9 *Siphonocladus rigidus*. 1, Overall morphology. 2, Detail showing lateral branches in open connection with bearing (non-septate) cells 3, Basal portion of isolated filament showing protruding laterals and descending rhizoids. 4, In habitat, on sand covered hard substratum. The vicinity of Wenchang City, March 2012.

Characteristics: Thallus filamentous, rigid, (1–)2.2–4 cm long, forms coarse tufts tightly adhering to the substratum, dark green to pale translucent olive-green color, branching irregular, unilateral. Main axes indistinct, 400 μm in diam. at the basal portion, 550–700(–1100) μm in diam. in the middle and 550 μm in diam. at apices. Branches are unilateral; branchlets are almost the same size with the branches (350–900 μm). Apices blunt, curved downward. Cell walls striated, to 20 μm thick. Spores common, spherical, dark green, develop within branch sheath. Rhizoids are branched, finger-like, about 25 μm in diam.

Family Valoniaceae

Valonia fastigiata Harvey ex J. Agardh

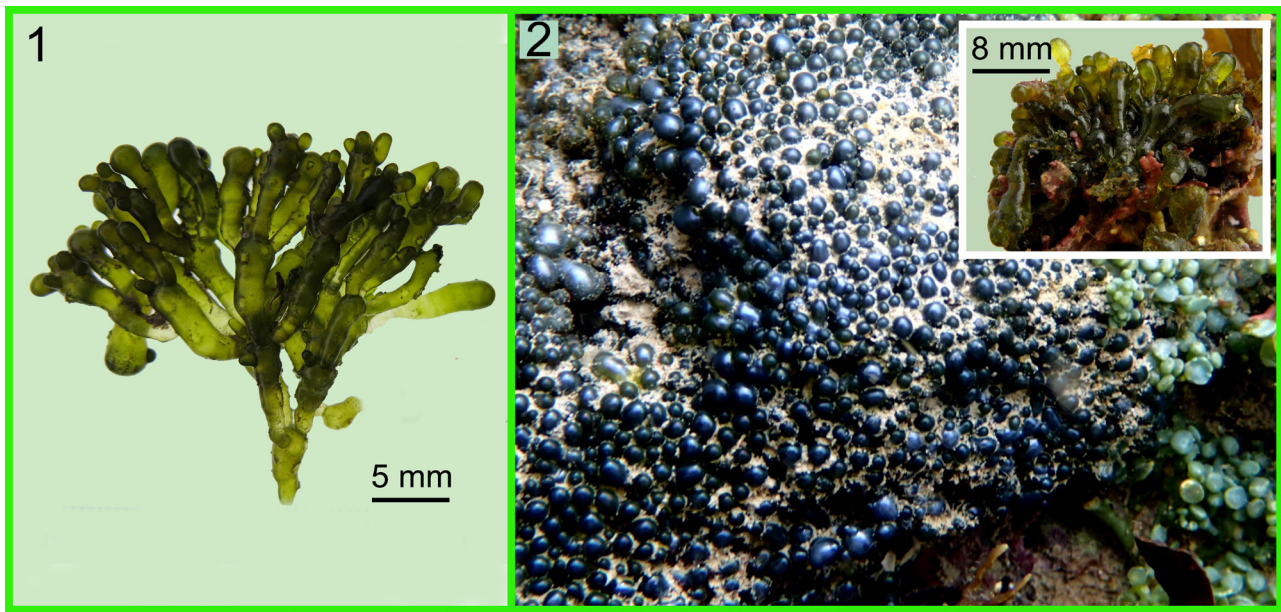


Fig. 10 *Valonia fastigiata*. 1, Isolated filament showing branching pattern. 2. In habitat, Hainan Island, Yalong Wan, March 2012.

Characteristics: Thallus forming dense hemispherical or flattened cushions, 2–3 cm high, 3–20 cm across, shiny, translucent, bright-green, deep dark-green to bluish-green (in the water), composed of tightly packed branched filaments of macroscopic cells. Cells cylindrical to clavate, straight, 2–3(–4) mm diam., 0.5–1.7 cm long. Branching di-, polychotomous from the apices of bearing cells. Branches almost of the same length. Attachment by minute rhizoidal cells. Growing on hard substrate in sheltered sites and exposed to moderate wave action. Sometimes torn off cushions form congestions in the intertidal pools.

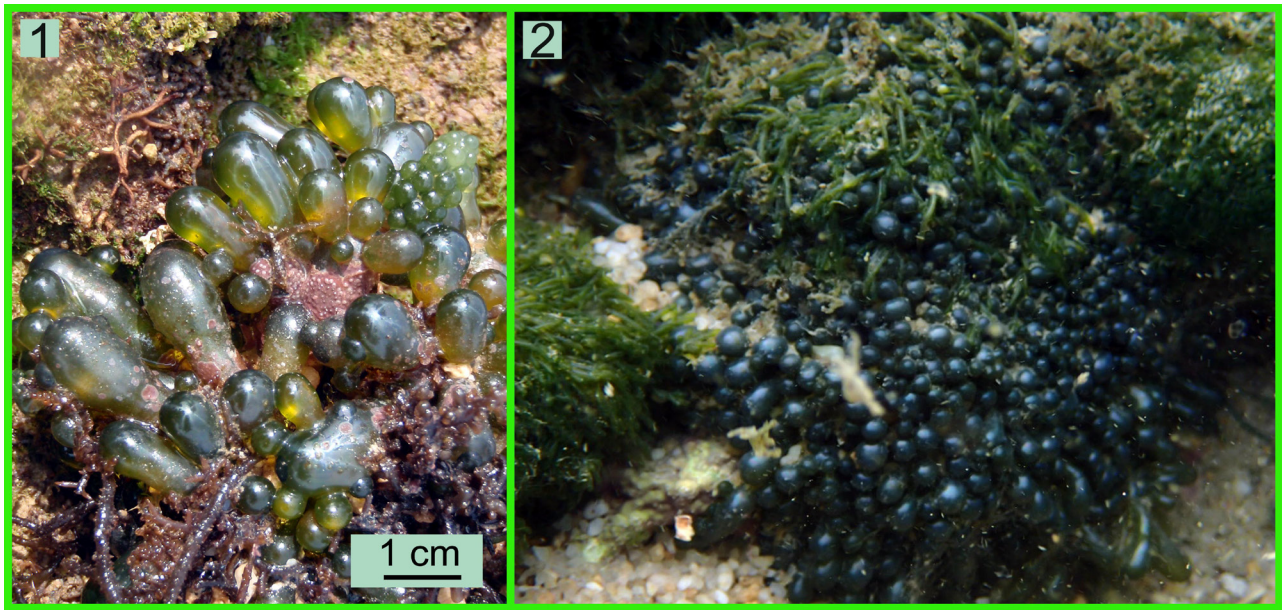
Family Valoniaceae***Valonia macrophysa* Kützting**

Fig. 11 *Valonia macrophysa*. 1, Overall morphology. 2, Occuring in association with *Valoniopsis pachynema*, Hong Tang, April 2016.

Characteristics: Thallus aggregate, prostrate, 1-3 cm high, translucent, dark olive-green to deep dark-green, composed of branched filaments of macroscopic cells. Cells firm, not densely packed, saccate (spherical, oblong, elongated, club-shaped) unicellular vesicles, 5-15 mm in diam., 1-4 cm long. Branching irregular. Attachment by minute branched rhizoids issuing from basal cells. Growing tightly adhering to hard substrata, commonly in shaded sites

Order BRYOPSIDALES

Family Bryopsidaceae

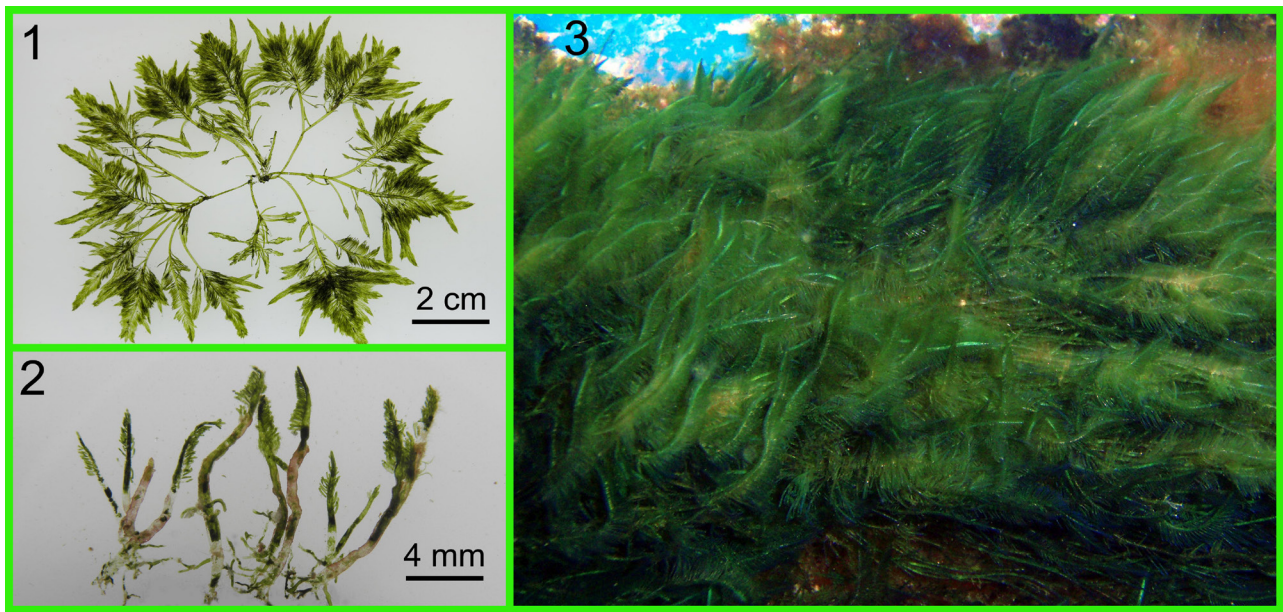
Bryopsis plumosa (Hudson) C. Agardh

Fig. 12 *Bryopsis plumosa*. 1, Overall morphology. 2, Young plants. 3. In habitat, the vicinity of Wenchang City, March 2012.

Characteristics: Thallus fine feather-like, in tufts, soft, 3–6(–15) cm high, translucent light or dark green with bluish iridescent under water. Branching repeatedly pinnate, in one plane. The main axes and branches 0.5–1.5 mm in diam. naked in the basal portion (c. 1/3 from the base) and above covered with primary (alternate) and secondary oppositely arranged branches bearing ultimate branchlets (pinnules) shortening to apices, which give the plant a pyramidal shape. Pinnules are arranged in two opposite rows, constricted at the base, 65–100(–250) μm in diam. and slightly taper to apices. Attachment by tightly interwoven rhizoids.

Family Caulerpaceae

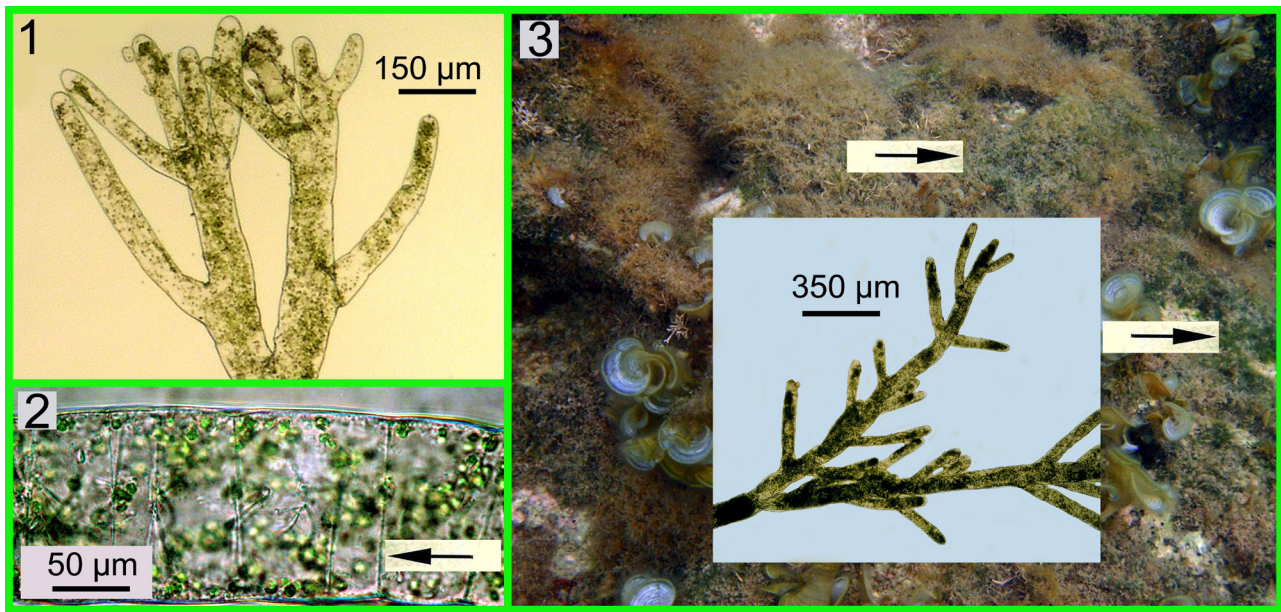
Caulerpa fastigiata Montagne

Fig. 13 *Caulerpa fastigiata*. 1, Upper part of branch. 2, Detail showing inner trabeculae of a creeping stolon (arrow). 3, In habitat, among turf algae (arrows). Inset: Erect branch. Hainan Island, Luhuitou, April 2012.

Characteristics: Thalli filamentous from light green to dark green color forming mat-like inconspicuous congestions, consisting of creeping stolons and erect slender branches matted and interspersed with sand and shell particles. Creeping stolons 90–130(–150–200) µm in diam., to several centimeters long, bearing dichotomously branched rhizoids. Rhizoids are hyaline, hair-like, 60 µm in diam. at the base and 20 µm in diam. at their ends. Erect filaments fastigiata, 1.5–3 cm high, branching opposite, alternate, dichotomous or irregular. Main axes and branches are of almost equal diameters (to 120 µm).

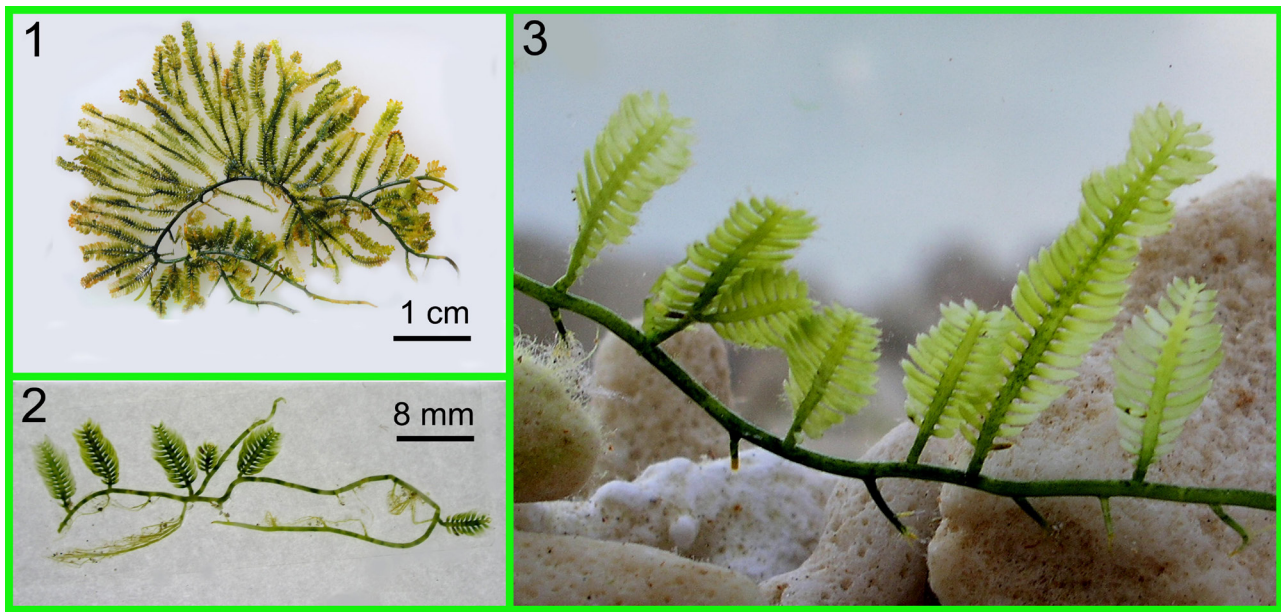
***Caulerpa mexicana* Sonder ex Kützinger**

Fig. 14 *Caulerpa mexicana*. 1, 2. Overall morphology. 3, Plant in aquarium. Luhuitou village. March 2015.

Characteristics: Thallus consist of creeping stolons (0.6–1.25 mm in diam.) bearing numerous descending delicate rhizoids and erect branches at distance 4–8(–13) mm from each other. Branches green, dark green, simple or occasionally branched, ending abruptly in a short apex, shortly stalked, feather-like, oblong or broadly lanceolate, dwarf, 1–3 cm high, 4–8(–10) mm broad, with flat midrib, 1–3 mm broad and with pinnules on both sides of the midrib. The pinnules are flat, oval to oblong, opposite, densely placed, sometimes overlapping each other, upcurved, slightly constricted at base, 0.5 mm broad, to 2.6 mm long, with apiculate tips.

Family Udoteaceae

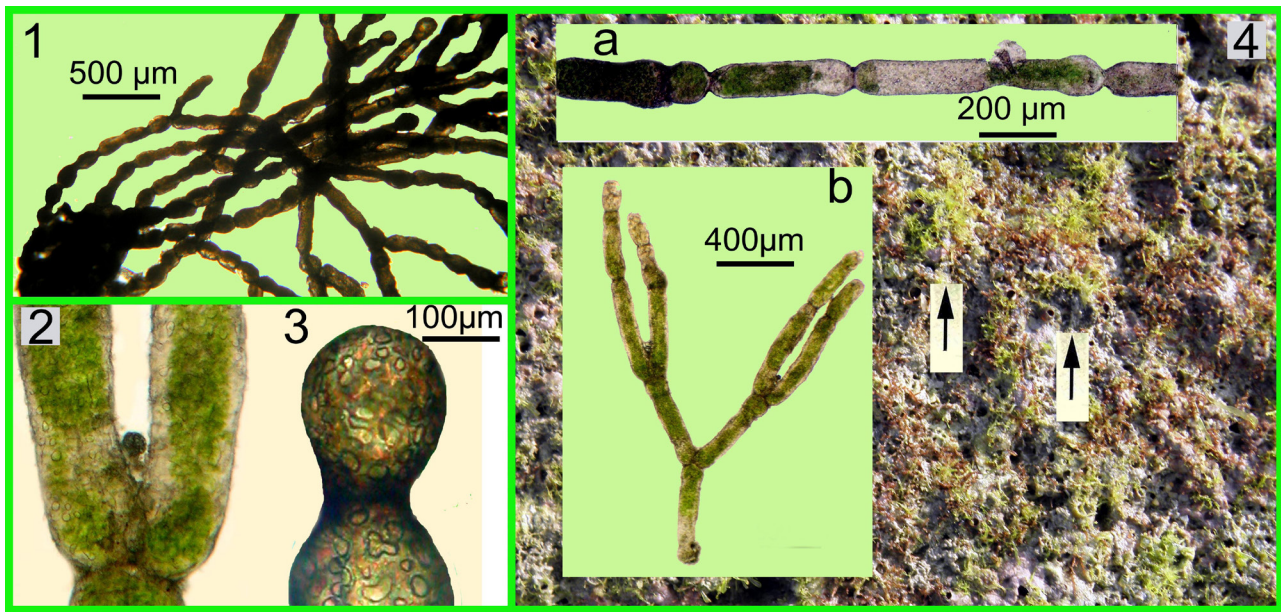
Penicillus siboga A. Gepp and E.S. Gepp

Fig. 15 *Penicillus siboga*. 1, Overall morphology. 2, Detail showing evenly constricted siphons at the dichotomy. 3, Fragment showing cell structure. 4, In habitat (arrow), Hainan Island, Yalong Wan, March 2012. Insets: a – filament with constrictions; b – fragment showing branching pattern.

Characteristics: Thallus filamentous, solitary, inconspicuous, very small, 1.8–2 mm high (rarely higher), greenish or sometimes whitish color. Filaments stiff, lightly calcified. Branching dichotomous. Siphons 100–140 µm in diam., with constrictions in between dichotomies, evenly constricted at the dichotomies. Apices blunt. Holdfast inconspicuous, small, disc-like. Growing on hard substrate covered with sand and mud in the middle, lower intertidal to upper subtidal zones.

Order DASYCLADALES

Family Dasycladaceae

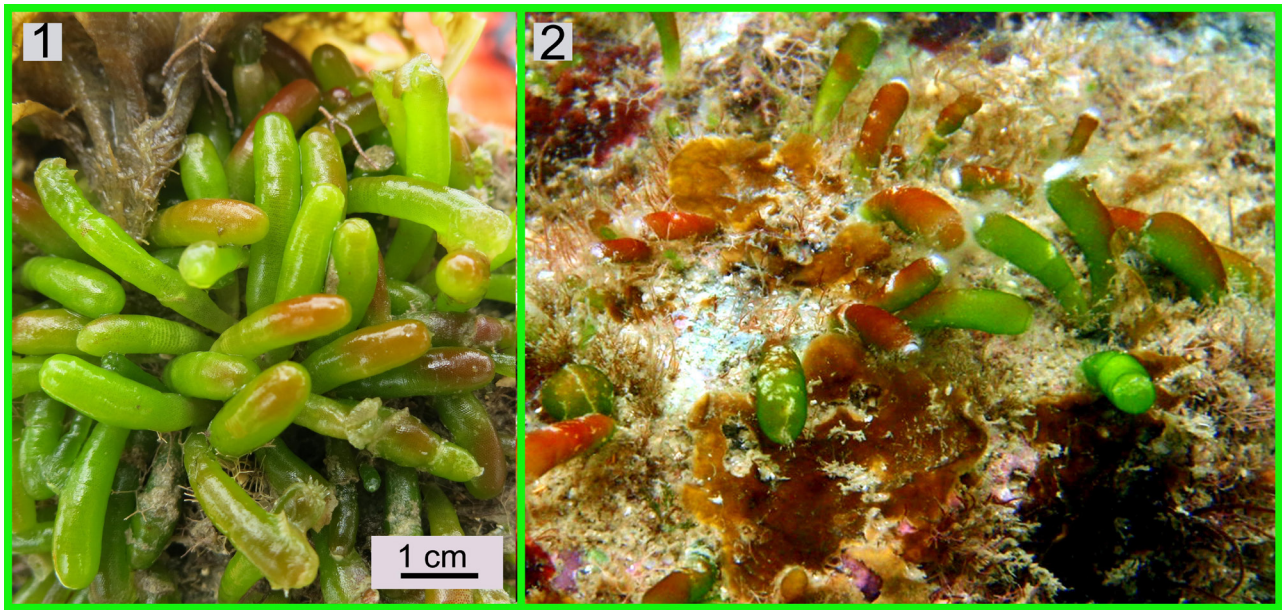
Bornetella nitida Munier-Chalmas ex Sonder

Fig. 16 *Bornetella nitida*. 1, 2, In habitat, at the low intertidal zone. Hainan Island, Luhuitou, April 2012.

Characteristics: Thallus solitary, or in groups, subcylindrical, clavate, slightly curved, bright green, brownish-red or brownish-red-green, shining, lightly calcified, (0.7)–1.9–3(–5) cm high, 3.5–4 mm in diam. above, narrowing to the base to 2–2.5 mm. Inner structure: central axis (400–650 μm in diam.) bearing 24–30 primary branches with 4–6(–7) short capitate secondary branches joined together and forming a monostromatic cortex of hexagonal (in surface view) cells, 180–210 μm across. Aplanosporangia (1–2) borne laterally on primary branches; shortly stalked, spherical (130)–180–220 μm in diam., containing 8–24(–26) oval aplanospores. Attachment by small rhizoid-like holdfast to rocks, dead coral blocks.

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