Data Paper

New records of benthic brown algae (Ochrophyta) from Hainan Island (1990 - 2016)

Tamara V. Titlyanova[1], Eduard A. Titlyanov[1], Li Xiubao[2], Bangmei Xia[3], Inka Bartsch[4]

[1]National Scientific Centre of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences, Palchevskogo 17, Vladivostok, 690041, Russia; [2]Key Laboratory of Tropical Marine Bio-Resources and Ecology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China; [3]Institute of Oceanology, Chinese Academy of Sciences, 7 Nanhai Road, 266071 Qingdao, PR China; [4]Alfred-Wegener-Institute for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany

Corresponding author: E Titlyanov, e-mail: etitlyanov@mail.ru

Abstract

This study reports on the intertidal and shallow subtidal brown algal flora from Hainan Island in the South China Sea, based on extensive sample collection conducted in 1990, 1992 and 2008–2016. The analysis revealed 27 new records of brown algae for Hainan Island, including 5 species which also constitute new records for China. 21 of these species are described with photographs and an annotated list of all species with information on life forms, habitat (localities and tidal zones) and their geographical distribution is provided.

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

Introduction

Hainan Island is located on the subtropical northern periphery of the Pacific Ocean in the South China Sea (18˚10′-20˚9′ N, 108˚37′-111˚1′ E). The coastline of the island is more than 1600 kilometers long, and shallow areas are characterized by extensive coral reefs, but seagrass beds and mangroves are present as well to a lower degree (Zhang *et al*. 2006). The species diversity within the coral reefs has been declining since the 1950s (Hutchings & Wu 1987; Zhang *et al*. 2006) due to overall reef destruction (e.g. Fiege *et al*. 1994; Hodgson & Yau 1997; Tadashi *et al*. 2008). Overall, algal species richness also changed.

Partial inventory of the benthic flora of Hainan has already been carried out (Titlyanov *et al*. 2011a, 2015, 2016; Titlyanova *et al*. 2014). The first sampling campaigns (early collection, EC) of marine plants along the coast of Hainan were performed by Tseng and co-workers in 1933−1935 (Tseng 1935, 1936, 1938) and the 1960′s−1970′s (Tseng & Chang 1962; Tseng *et al*. 1962; Zhu & Liu 1980; Tseng 1983). During EC, a total of 240 taxa (species, their taxonomic forms and varieties) were collected, among which

75 species were brown algae (Titlyanov *et al*. 2011a, 2015, 2016).

The second sampling of marine plants in Hainan Island was conducted in 1990 and 1992 during the German-Chinese expeditions (intermediate collection, IC). In total, 203 species were recorded; of which 32 taxa were brown algae (Titlyanov *et al*. 2016).

The third sampling was performed in 2008–2016 (later collection, LC) by the first three authors of this article. In total, 298 species were found, 52 being brown algae.

Here we report 27 new additions of brown algae (Phaeophyceae) to the flora of Hainan based on more recent collections between 1990 and 2016, which covered similar habitats, seasons and locations of the EC collection. We present an annotated list of new findings of brown algae sampled in Hainan Island in 1990, 1992 and 2008–2016, short descriptions and photographs of the species, and point out new records for China.

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Materials and Methods

Study time and area in 1990-1992

In the framework of a German-Chinese cooperation, two expeditions took place to the island of Hainan in the autumn 1990 and spring 1992. Detailed descriptions of the sampling sites (Fig 1) are given in Titlyanova *et al*. (2012) and an overview about historical collections sites are provided in Titlyanov *et a*l. (2011a). In 1990 and 1992, the intertidal/ infralittoral reef flats were characterized by drifting blocks of dead corals, stones or boulders interspersed with sandy areas. Poorly developed mangrove areas with extensive mudflats or seagrass fields were present at Qukou and Qinglan Gang. At Shalao there was an Eucheuma farm characterized by a sandy bay with an offshore reef flat composed mostly of dead corals. The offshore islet Ximao Zhou was the only place where many living corals were still found in the shallow subtidal. At Meixia in the North, there were extensive stony intertidal areas with an offshore reef flat mostly composed of dead corals. Nearby at Nanmai there was an extensive reef flat with many living corals over/ between dead corals.

Fig. 1 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.

Study time and area in 2008-2016

Sampling of benthic macroalgae was carried out in October 2008 at Luhuitou, Dadong Hai, Xiaodong Hai, in April 2009 and in December 2010 at Luhuitou, in February–April 2012 at Luhuitou, Meixia, Wenchang, Xian Hai, Yalong Wan, in April 2014 at Luhuitou, Xiaodong Hai, Ying Ge Hai, in March 2015 at Luhuitou, Xiaodong Hai, in March–April 2016 at Luhuitou, Xiaodong Hai, Hong Tang Bay and in November–December 2016 at Luhuitou, Xiaodong Hai (Figure). In 2008–2016, Luhuitou, Xiaodong Hai and Dadong Hai were characterized by damaged coral reefs (live corals covering c. 25%, 10% and 3–5%, respectively); seaweeds were collected in the intertidal and upper subtidal zones.

The locality Yalong Wan (Xipai, small rocky islet) was characterized by a sandy bottom with moving blocks of dead corals, stones, boulders and rocky bottom near the islet, seaweeds were sampled in the intertidal and upper subtidal zones.

At the locality Wenchang algae were collected from the intertidal zone of damaged coral reef. In Xian Hai seaweeds were collected from cast ashore and fishery nets which were placed on coral reef, poor in live corals. Ying Ge Hai was characterized by dead coral reef and heavily polluted seawater by coastal waste, seaweeds were collected up to 4 m depth.

Collection, conservation and floristic analysis of samples

Specimens were catalogued with consecutive numbers and were preserved as herbarium specimens. Two sets of herbaria were assembled: one set is deposited at BRM in Bremerhaven, Germany; the other set in Qingdao, at the Institute of Oceanography, Chinese Academy of Sciences. Materials identified by B. Xia and I. Bartsch in 1990-1994 and by T. Titlyanova and E. Titlyanov in 2007-2009. Anatomical studies were made using slides prepared from pre-soaked herbarium material, sectioned by hand with a razor blade.

During the period 2008-2016 macroalgae were collected in the upper, middle, lower intertidal and the upper subtidal zones (from 0.5 to 4m depth during low tide) by Titlyanova T.V., Titlyanov E.A. In the upper subtidal zone, sampling of the marine plants was carried out via snorkeling and SCUBA diving (by Li Xiubao) during low and high tides. Algae were collected from all types of substrata. The algal collection of 2008–2016 deposited at the A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences.

Fresh and dried specimens were identified by Titlyanova T.V. and Titlyanov E.A. using monographic publications, floristic studies and systematic articles cited in previous publications (Titlyanov *et al*. 2011a, b, 2014a; Titlyanova *et al*. 2012, 2014). The systematics and nomenclature followed Guiry & Guiry (AlgaeBase, http://www.algaebase.org; searched in 2017). Hierarchical classification of the phylum Rhodophyta was assessed according to Saunders & Hommersand (2004). All publications concerning studies on Hainan Island have been reviewed in Titlyanova *et al*. 2014. The previously known and newly recorded species for Hainan and China were verified using Algaebase, the Catalogue of Life China 2010: Annual Checklist and the checklist of Marine Biota of China Seas (Liu 2008). Results of these investigations represented as guidebook with descriptions and color photographs for 77 common and abundant species found during the period from 2008 to 2016.

Results of the present study are presented in two sections. In Part 1, a floristic analysis of the new findings of brown algae from Hainan Island is presented with an annoted list of 27 species. In Part 2, photographs and descriptions of 21 species (out of 27) collected in 2008-2016 are given.

Part 1: Floristic analysis

Table 1 gives a list of brown algae collected from Hainan Island during 1990-2016. Eleven taxa of brown algae found in the expeditions of 1990 and 1992 were newly recorded for Hainan Island: of them 4 taxa belong to the Family Dictyotaceae, 3 taxa belong to the Family Sargassaceae, 2 taxa belong to the Family Sphacelariaceae and by one taxon belonging to the families Scytothamnaceae and Ectocarpaceae. Epilithic algae amounted to 8 taxa or 72% of the species found for the first time, and epiphytic algae amounted to 3 taxa or 28%. The greatest number of new findings of brown algae (7 taxa or 64% of new-recorded) belonged mainly to the widespread species in tropical and subtropical areas of the Word Ocean, of them, one taxon (*Sphacelaria rigidula*) was common in temperate and Antarctic waters; 4 taxa (36%) were common only in tropical and subtropical areas of the Indo-Pacific (Table).

Seven taxa (64%) of the species found for the first time in 1990 and 1992 were again sampled in Hainan Island within 2008-2016. The greatest number of species (by 4 taxa of new-recorded to the island) was found in Yalong Wan and in Xiaodong Hai, by 3 taxa in Tian Ya Hai Tiao and Nanmai, by 2 taxa in Luhuitou, Xincun, Linchang and Shalao, by 1 taxa in Dadong, Ximao Zhou and Wenchang. *Sphacelaria rigidula* was found at 10 localities, *Feldmannia irregularis*

Table 1. List of new finds of brown algae collected from Hainan Island during 1990-2016.
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. In the first and the last columns: §, new record for Hainan Island in 1990, 1992; ¶ new record for Hainan Island in 2008-2016 and ¶¶ new record for China. Localitiy abbreviations: 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	
PHYLUM OCHROPHYTA					
CLASS PHAEOPHYCEAE					
Order SCYTOTHAMNALES					
Family Asteronemataceae					
Asteronema breviarticulatum (J. Agardh) Ouriques & Bouzon §	HS	T,S			§ Yw / ¶ Lh, Lh
Order ECTOCARPALES					
Family Acinetosporaceae					
Pylaiella littoralis (Linnaeus) Kjellman ¶	HS Ep	T,S,M,An	++	+	¶ Lh
Feldmannia irregularis (Kützing) Hamel §	HS Ep	T,S			§ Xc, Yw, Xh, Lh / ¶ Lh, Yg
Family Chordariaceae					
Chilionema ocellatum (Kützing) Kornmann ¶¶	Ep Cr	T,S,M	+	+	¶ Lh
Myrionema strangulans Greville ¶¶	Ep Cr	T,S,M,An		+	¶ Lh
Family Scytosiphonaceae					
Hydroclathrus tenuis C.K. Tseng & Lu ¶	HS	T,S		++	¶ Lh, Xh
Order RALFSIALES					
Family Neoralfsiaceae					
Neoralfsia expansa (J. Agardh) P.-E. Lim & H. Kawai ex Cormaci & G. Furnari ¶	HS Cr	T,S	+++	+	¶ Lh, Dh
Order SPHACELARIALES					
Family Sphacelariaceae					
Sphacelaria carolinensis Trono ¶	Ep	T,S,(I-P)	+	++	¶ Lh
Sphacelaria novae-hollandiae Sonder §	HS Ep	T,S			§ Ty / ¶ Lh, Mx, Wc, Yw, Xh
Sphacelaria rigidula Kützing §	HS Ep	T,S,M,An			§ Lc, Nm, Sl, Xc, Yw, Dh, Xh, Lh, Xz, Ty / ¶ Lh, Wc, Yw, Xh, Yg

Table 1. Continued.

Order DICTYOTALES					
Family Dictyotaceae					
Dictyopteris pacifica (Yendo) I.K. Hwang, H.-S. Kim & W.J. Lee ¶	HS	T,S,(I-P)		+	¶ Xn
Dictyopteris repens (Okamura) Børgesen §	HS	T,S			§ Ty/•Ht
Dictyota bartayresiana J.V. Lamouroux §	HS	T,S			§ Nm, Yw, Xh/ ¶ Lh,Wc, Xh
Dictyota dichotoma var. *intricata* (C. Agardh) Greville §	HS	T,S			§ Xh
Padina arborescens Holmes ¶	HS	T,S,(I-P)		+	¶ Mx, Xn
Padina jonesii Tsuda §	HS	T,S,(I-P)			§ Sl
Spatoglossum dichotomum C.K. Tseng & Lu ¶	HS	China		+	¶ Xn
Zonaria flabellata (Okamura) Papenfuss ¶	HS Ep	T,S,(I-P)		+	¶ Wc
Order FUCALES					
Family Sargassaceae					
Sargassum agaviforme C.K. Tseng & B. Lu §	HS	China			§ Nm
Sargassum bicorne J. Agardh ¶¶	HS	T,S,(I-P)	+	++	¶ Mx
Sargassum fusiforme (Harvey) Setchell ¶	HS	T,S,(I-P)	+	+	¶ Wc
Sargassum hemiphyllum (Turner) C. Agardh §	HS	T,S,(I-P)			§ Mx / ¶ Lh, Yg, Xh, Xh
Sargassum henslowianum C. Agardh §	HS	T,S,(I-P)			§ Lc
Sargassum horneri (Turner) C. Agardh ¶	HS	T,S,(I-P)	+	+	¶ Xh, Xn, Ht, Wc
Sargassum microcystum J. Agardh ¶	HS	T,S,(I-P)		++	¶ Mx, Xh
Sargassum polyporum Montagne ¶	HS	T,S,(I-P)		+	¶ Xh
Sargassum thunbergii (Mertens ex Roth) Kuntze ¶	HS	T,S	+	+	¶ Wc

at 4 localities, *Dictyota bartayresiana* at 3 localities, the rest species were sampled only at one locality.

In 2008-2016, 16 taxa of the browns were newly recorded for Hainan Island (of those 3 species were newly recorded for China). Six species belonged to the Family Sargassaceae, 4 species to the Family Dictyotaceae, 2 species to the Family Chordariaceae, and by one species to Acinetosporaceae, Scytosiphonaceae, Neoralfsiaceae, Sphacelariaceae. Epilithic algae amounted to 80% of newly recorded taxa, epiphytic algae 20%. The greatest number of taxa new to Hainan was recorded in Luhuitou (6 species), in Xiaodong Hai and Xian Hai (by 4 species). The greatest number of new findings of algae (10 species or 62%) belonged to the marine flora of tropical and subtropical areas of the Indo-Pacific. Three of newly recorded species are the widespread species in tropical and subtropical areas of the word, three species inhabit temperate latitudes, of which two (*Pylaiella littoralis* and *Myrionema strangulans*) are distributed in the Antarctic.

Part 2: Description of brown algae collected in Hainan Island (2008-2016)

PHYLUM OCHROPHYTA

Order SCYTOTHAMNALES

Family Asteronemataceae

***Asteronema breviarticulatum* (J. Agardh) Ouriques & Bouzon [= *Ectocarpus breviarticulatus* J. Agardh]**

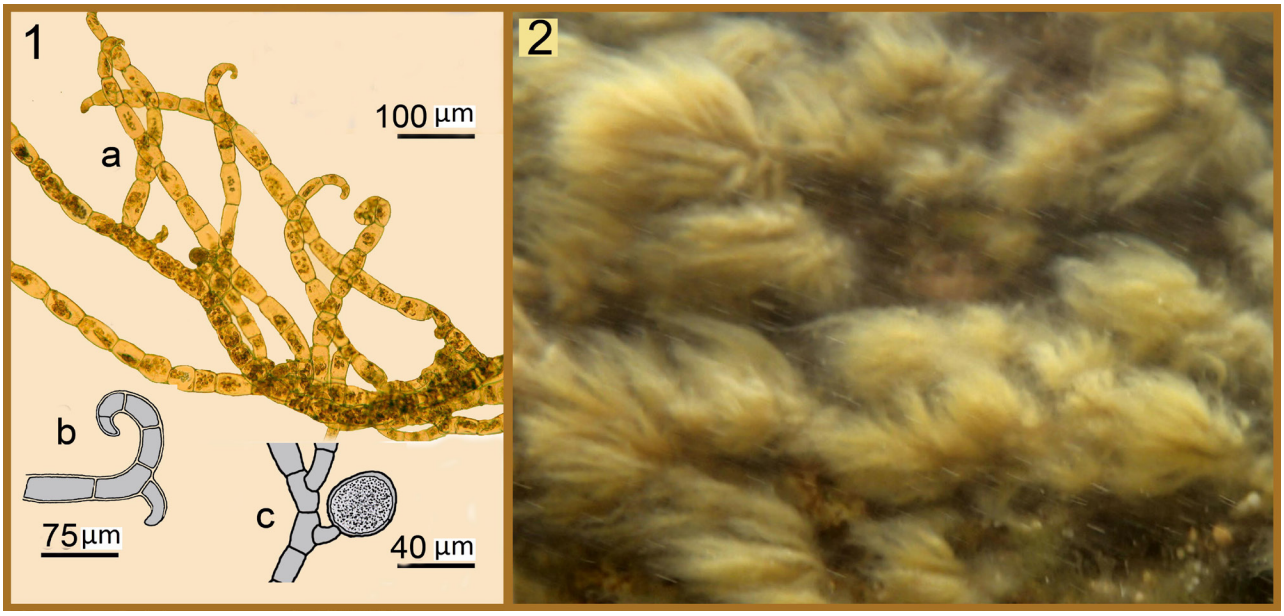

Fig. 2 ***Asteronema breviarticulatums.*** 1 (a, b, details showing hooked branchlets; c, unangium). 2. In habitat. Thallus yellow brown, forming spongy strands of intertwined filaments 2-4 cm in height. Filaments 25-30(-35) µm in diam., cells 1-2 times longer than broad. Cells contain numerous disc-like phaeoplasts. This species is characterized by the presence of numerous hooked branchlets, which hold the filaments in rope-like, spongy strands. Plurilocular sporangia develop almost at right angle to the filament, barrel-shaped, pyriform or ovoid (or near to spherical), c.40-45 µm long, 30-40(-45) µm in diam., on one-celled stalk, 15-20 µm long.

Order ECTOCARPALES

Family Acinetosporaceae

***Pylaiella littoralis* (Linnaeus) Kjellman**

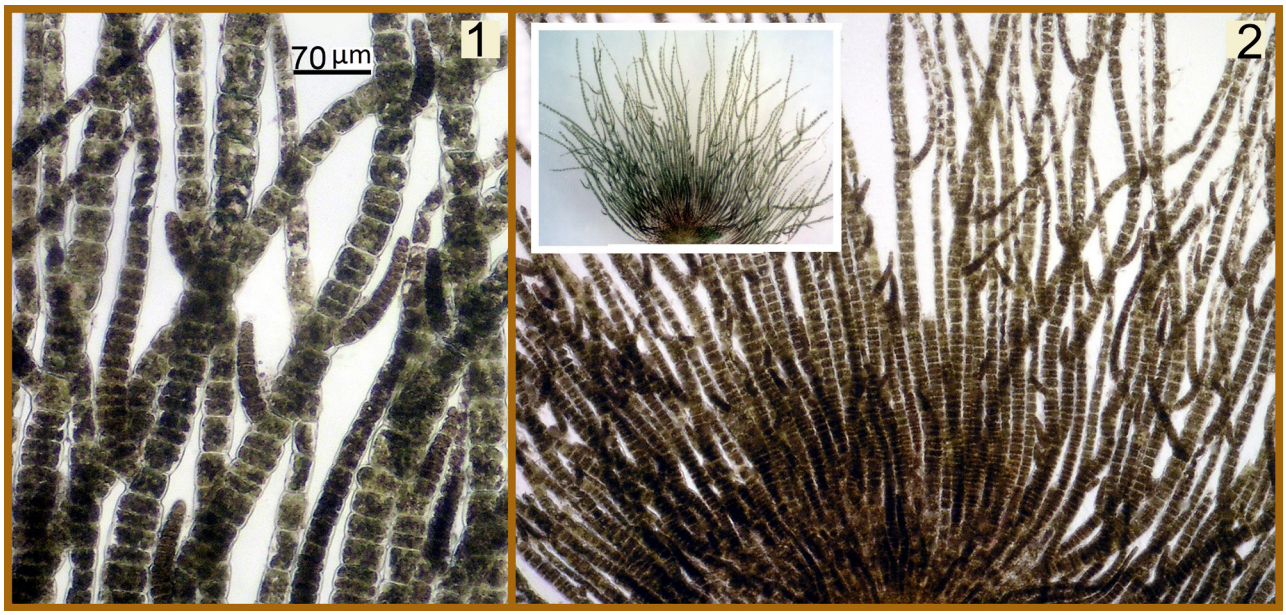

Fig. 3 ***Pylaiella littoralis.*** 1.Fragment showing branching pattern. 2. Overall morphology. Thallus composed of creeping and erect soft filaments forming tufts, 2-3 mm high, light to dark olive-brown color. Filaments at basal portion to 35 mm in diameter, in the middle portion to 30 mm in diam. tapering towards the apices to 17 mm in diameter. Branches sparse, alternate or unilateral, attenuate. Cells at the basal portion to 62 mm long, 1-3(-6) diameters long. Chloroplasts are numerous, disc-shaped (3 mm in diam.) or elongated to 14 mm long. Unilocular sporangia barrel-shaped, 40-45 mm in diam., single or in series, intercalary or at the end of lateral branches. Plurilocular sporangia multiseriate, intercalary, cylindrical, in series on branchlets. Growing epiphytic on *Turbinaria ornata* leaves.

***Feldmannia irregularis* (Kützing) Hamel**

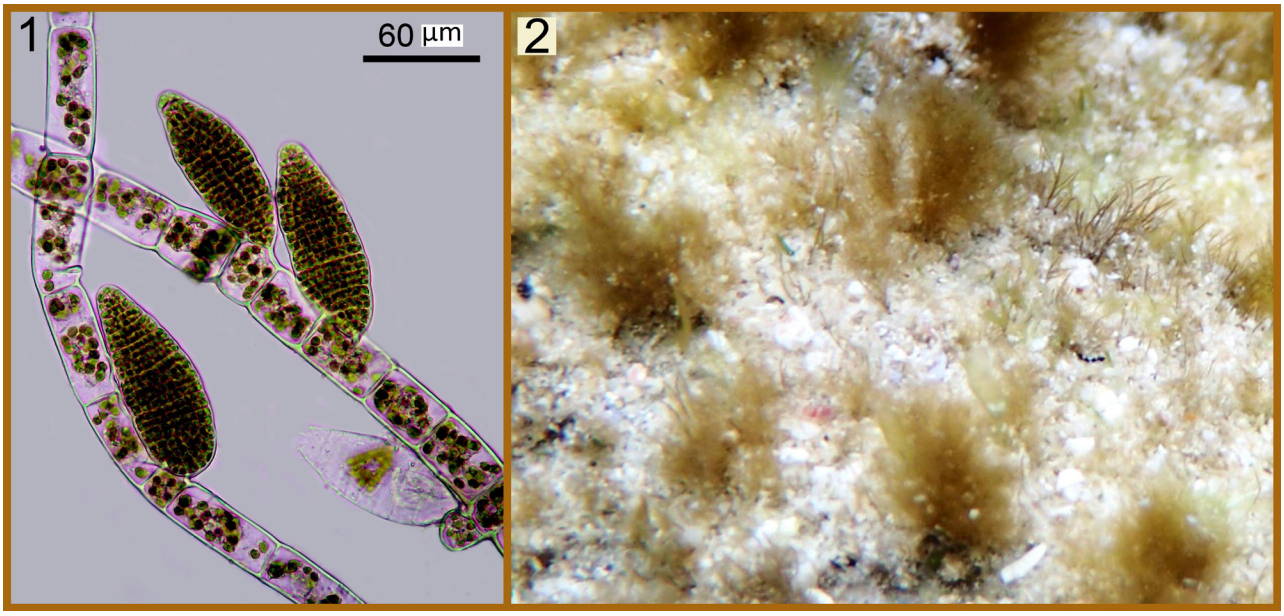

Fig. 4 ***Feldmannia irregularis.*** 1. Detail showing plurilocular sporangia. 2. In habitat. Thallus yellow-brown, filamentous, forming soft loose tufts to 2 cm high, attached by prostrate entangled rhizoidal filaments. Erect axes numerous, irregularly branched. Filaments 23-30(-40) µm in diam., slightly constricted at cell walls, slightly tapering towards apices, ending into colorless hairs. Cells with numerous discoid phaeoplasts, 19-21(30) µm in diam., 0.5-1 diameters long in meristematic zone, 1-3 diameters long at lower and 2-4 diameters long at the upper portions. Plurilocular sporangia develop below the meristematic zone, sessile or shortly pedicellate, cone-shaped, c.25-35 µm in diam., 60-70(-120) µm long. Growing epiphytic on *Colpomenia sinuosa, Padina australis*.

Family Chordariaceae

***Chilionema ocellatum* (Kützing) Kornmann**

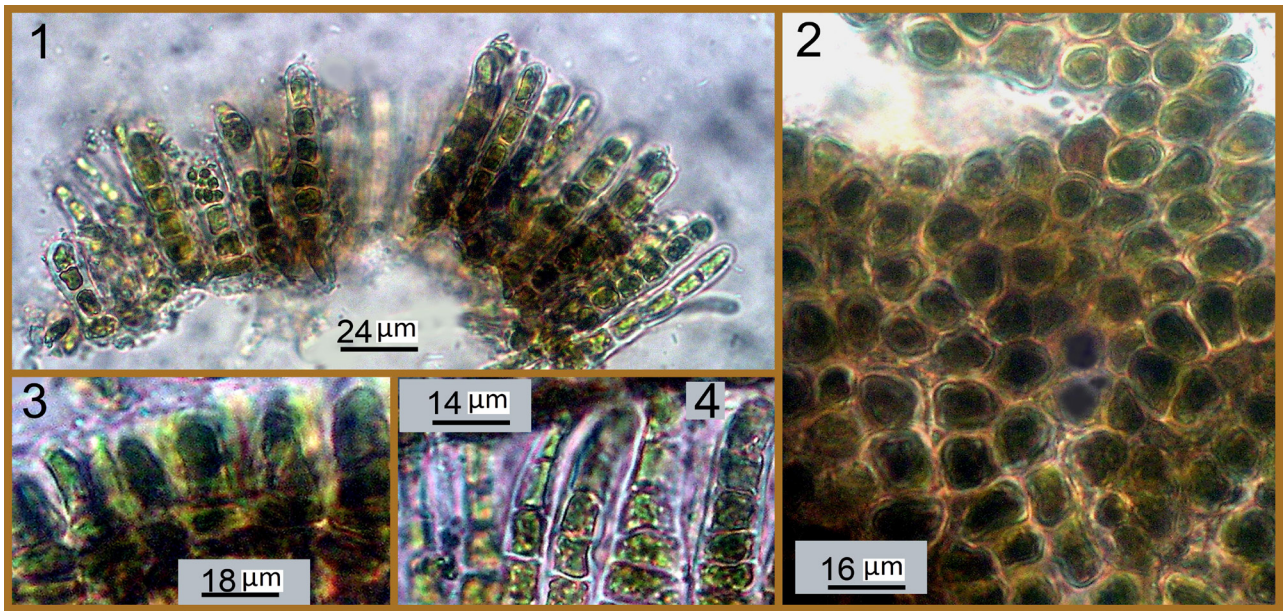

Fig. 5 ***Chilionema ocellatum.*** 1, 4. Erect filaments. 2. Surface view. 3. Detail showing two basal cell layers. Thalli forming small, dark olive-brown spots composed of basal creeping filaments consisting of mono-, distromatic layers and erect filaments 50-60 µm high. In cross section, basal layers consists of closely adjacent cells (15-16 µm in diam., 5-10 µm high) tightly adhering to the host surface. Erect assimilatory filaments (5-8 cells high) develop from every cell of the basal layer. Cells of the erect filaments 10-15 µm in diam., 7.5-15 µm high. Growing epiphytic on *Sargassum sanyaense* phylloids.

***Myrionema strangulans* Greville**

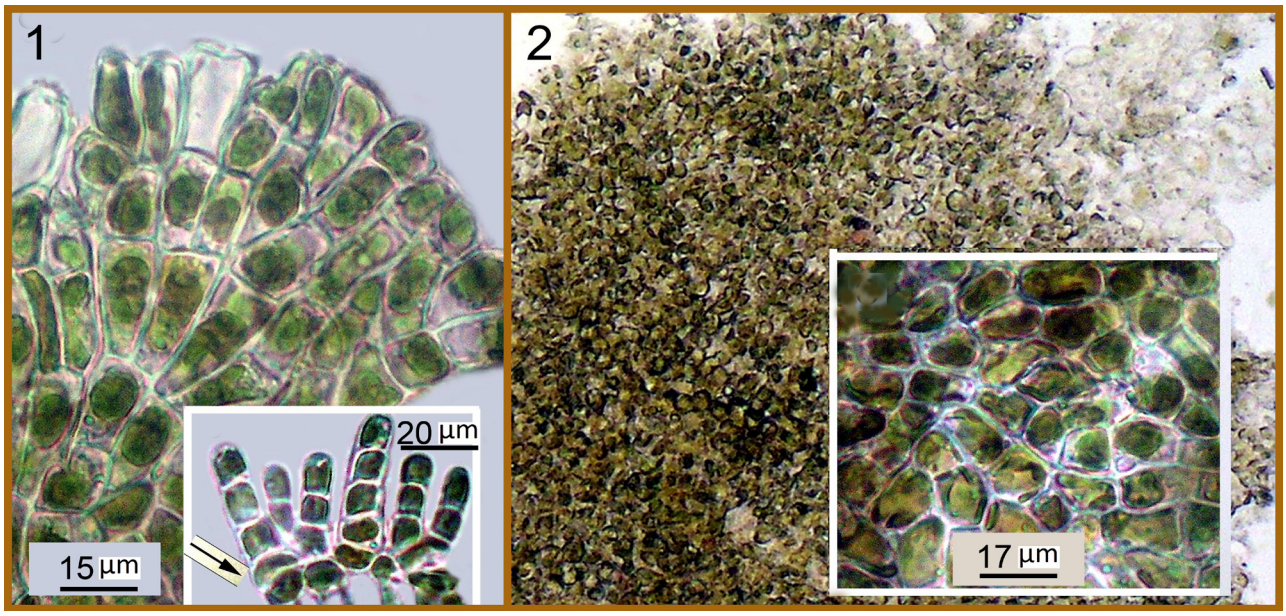

Fig. 6 ***Myrionema strangulans.*** 1, Detail showing basal radiating filaments. Inset: Erect filaments; basal cells (arrow). 2. Greenish-brown spot from surface view. Inset: Basal cells of monostromatic disc in the central part. Thalli forming small, dark greenish-brown velvety spots (0.2-)0.6×1.0 mm composed of basal creeping filaments forming monostromatic disc and erect filaments 30-50(-100) µm high. Surface cells roundish angular, 3-6 µm across. The basal layer consists of subdichotomous, radiating, closely adjacent filaments (7.5-10 µm in diam.) tightly adhering to the host surface. Marginal cells of the basal layer are 10 µm in diam., 20-22 µm long. Erect assimilatory filaments composed of (3-)5-7 cells arising from every cell of the basal layer (except margins). Growing epiphytic on *Padina australis, P. minor,* and *Sargassum sanyaense* phylloids.

Family Scytosiphonaceae

***Hydroclathrus tenuis* C.K. Tseng & Lu**

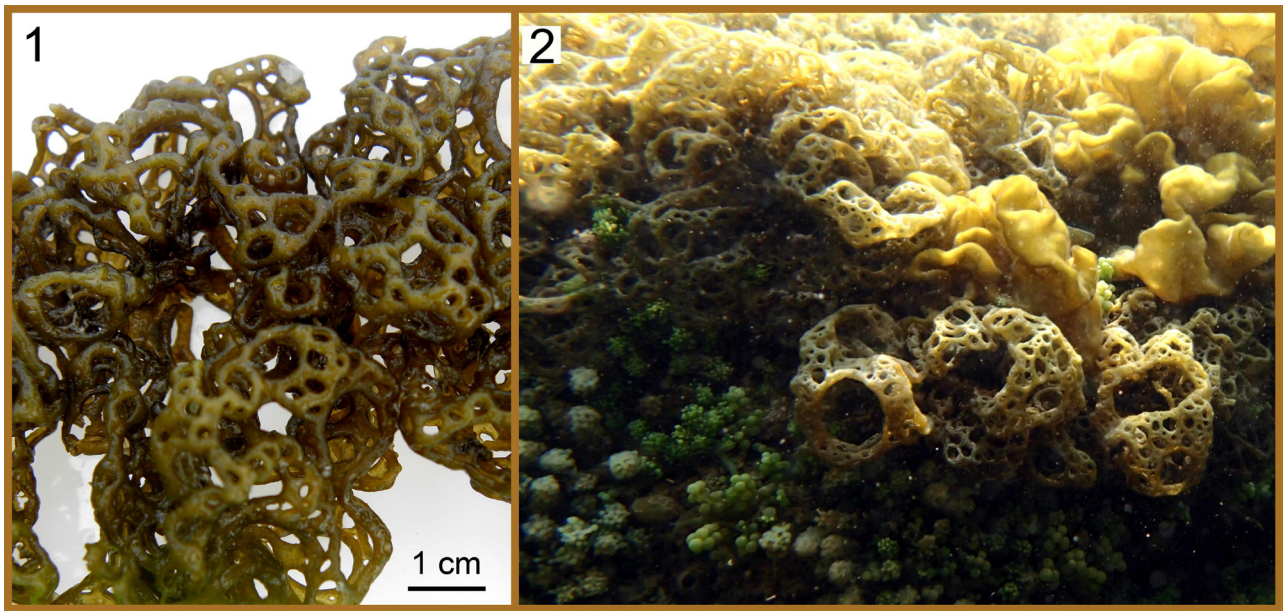

Fig. 7 ***Hydroclathrus tenuis.*** 1.Overall morphology. Inset: 2. In habitat. Thallus net-like, fine, soft, fleshy, irregularly-lobed, near to spherical, sessile, irregularly vesicular when young and reticulate when old, light brown, yellowish-brown to orange-brown color. The perforations 10-15 mm in diam., with inrolled margins. Net-like membrane (75)-250-300 µm thick. The cortex consists of pigmented, small cuboidal cells, 7-10 µm across. Medulla composed of several large, colorless parenchymatous cells, 62.5-80×25-50 µm. Attachment by broad holdfasts at many points to hard substrata.

Order RALFSIALES

Family Neoralfsiaceae

***Neoralfsia expansa* (J. Agardh) P.-E. Lim & H. Kawai ex Cormaci & G. Furnari**

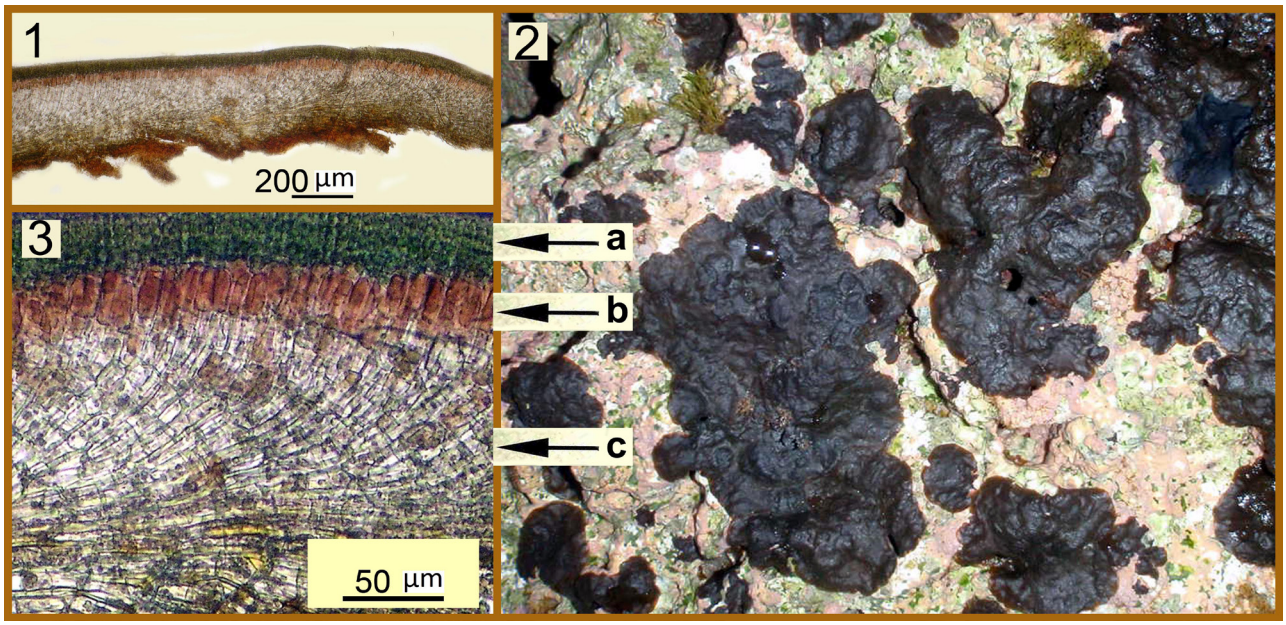

Fig. 8 ***Neoralfsia expansa.*** 1, 3. Transverse section of the thallus.: a, layer of assimilatory filaments; b, cortical layer; c, radiating filaments. 2. In habitat. Thalli form coriaceous crusts with roundish margins, smooth and becoming rugose with age, with more or less visible concentric striations, dark-brown to almost black color, lightly adhering to the substratum. In cross section, 350-400(-600) µm thick, thallus consists of basal layer of radial filaments curved to the substratum and upper layer of parallel densely packed filaments curved in opposite direction. Cortical layer of 5 rows of pigmented cells, 5-7.5 µm in diam., 7.5-10(-12.5) µm long; subcortical cells 12.5-15 µm in diam. and medullary cells 12.5-20×(22.5-)40-50 µm. Attachment by multicellular rhizoids from lower side of the crusts.

Order SPHACELARIALES

Family Sphacelariaceae

***Sphacelaria novae-hollandiae* Sonder**

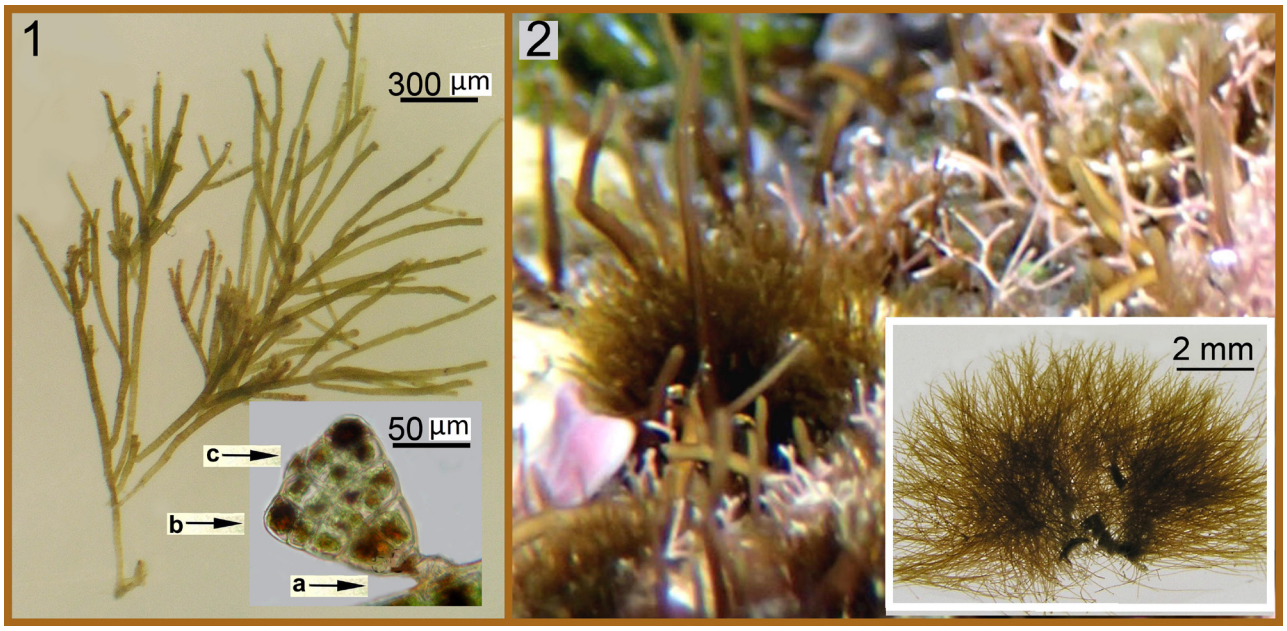

Fig. 9 ***Sphacelaria novae-hollandiae.*** 1, Branch isolated from tuft. Inset: Propagula. 2. In habitat. Inset: Overall morphology. Thallus filamentous, dark brown, forming dense tufts (2.3)-6.5-7 mm in height arising from a stoloniferous base. Sparingly branching with numerous short and long branchlets at narrow angles. Filaments erect, terete, 40-50 µm in diameter near base and 75-87(-90) µm in diam. near tips, of almost equal diameter through, slightly tapering toward apices, terminating in well-developed apical cells (40-50 µm in diam.). Segments 25-35(-42) µm long with 3-5 longitudinal walls. Hairs 10-12.5 µm in diam. Propagules stalked ,1-3-celled (a, arrow), (100)-150-200 µm long (from lenticular cell to the bottom), 80-120 µm across (at the upper portion from left to right corner), with a small lenticular cell on the top (c, arrow).. Corner cells divided by two walls at right angle or by a single straight wall cutting off the terminal cells (b, arrow).. Growing on dead coral blocks, artificial substrata, and epiphytic on larger algae.

***Sphacelaria rigidula* Kützing [=** *Sphacelaria furcigera* **Kützing]**

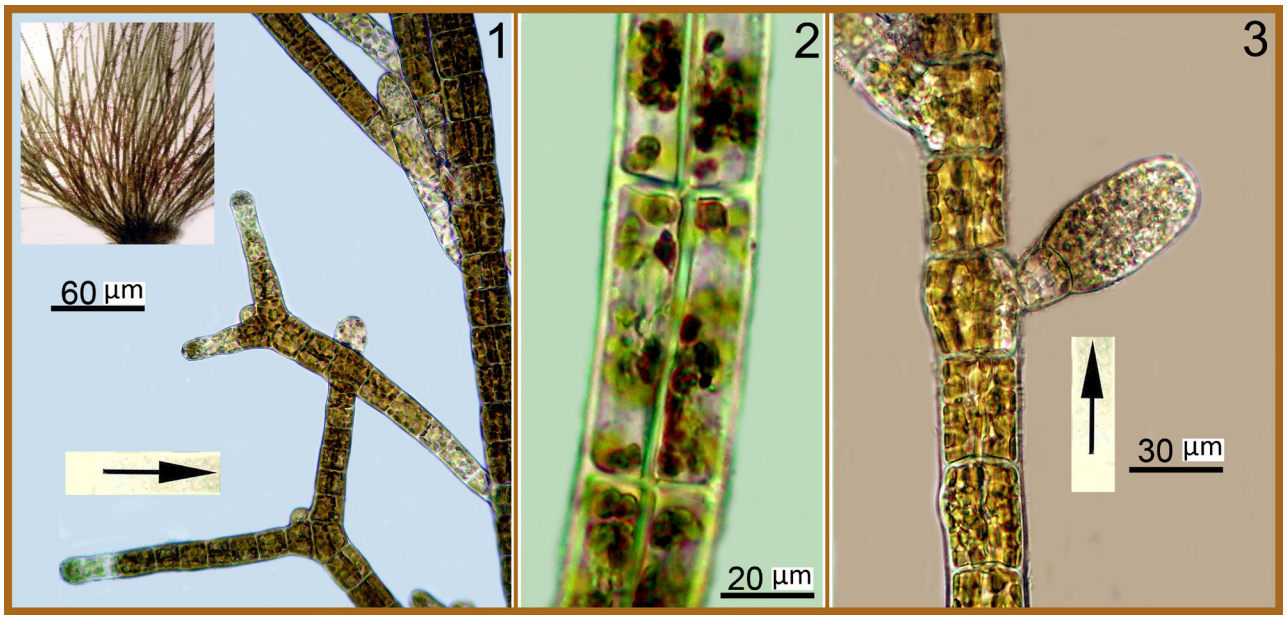

Fig. 10 ***Sphacelaria rigidula.*** 1, Propagules (arrow). Inset: Overall morphology. 2. Fragment showing segments consisting of cells with discoid plastids. 3. Detail showing monosporangia (arrow). Thallus filamentous, forming dense tufts up to 1 cm high, yellow brown to greenish-olive brown. Branching irregular, sparse to frequent, at narrow angles. Erect filaments terete, (15)-25-45 µm in diam. of almost equal diameter throughout or slightly tapering toward apices to 25 µm, with segments 2-3 diameters long, becoming shorter to apices (17.5 µm); arising from discoid monostromatic (or stoloniferous) hapteron. Segments with 1-3(-4) longitudinal cell walls. Hairs lateral and subterminal, 20 µm in diam., to 700 µm long, deciduous. Propagules stalked, bifurcate, bearing two cylindrical arms, to 25 µm in diam. slightly tapering to apices, up to 150-400(-520) µm long; stalk -800 µm long and 25(-46) µm in diam.. Monosporangia 25×40-45 µm, on one-celled stalk. Plurilocular sporangia ovoid, 24-30(-50)×45-65 µm, on one-celled stalk. Growing on dead coral blocks, mollusks and epiphytic on larger algae.

Order DICTYOTALES

Family Dictyotaceae

Dictyopteris pacifica **(Yendo) I.K. Hwang, H.-S. Kim & W.J. Lee [= *Spatoglossum pacificum* Yendo]**

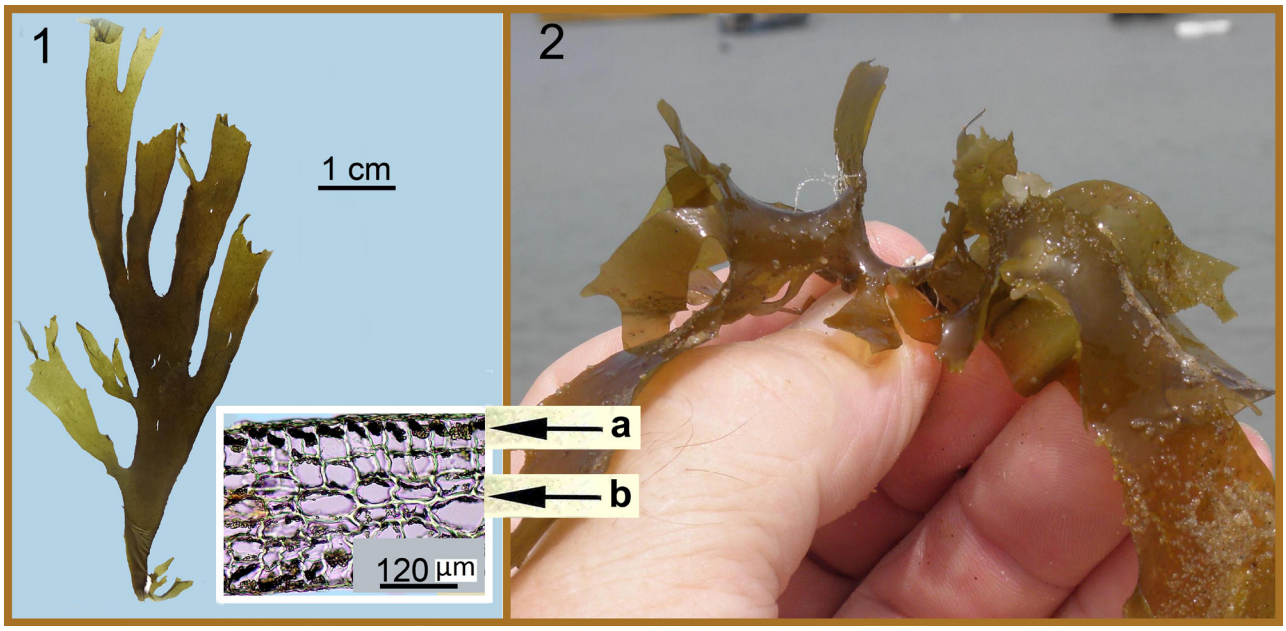

Fig. 11 ***Dictyopteris pacifica.*** 1, 2. Overall morphology. Inset: Transverse section of the thallus; (arrow a, cortical cells; b, medullary cells). Thallus flat, smooth, not zonate and without percurrent midrib and veins, with cuneate base, 10–20 cm high, yellowish-brown, olive-brown to dark brown color. Branching irregular, repeatedly dichotomous. Thallus divided into several blades (that gives palmate view), with round axils. Margins of the blades entire or with sparse short spines. In transverse section, blade 180–250(–270) µm thick, composed of cortex composed of a single cell layer and medulla of several cell layers; cortical cells 20–25 µm long, 15–20 µm wide; medullary cells 40–70 µm across. Attachment by inconspicuous holdfast.

Dictyopteris repens **(Okamura) Børgesen**

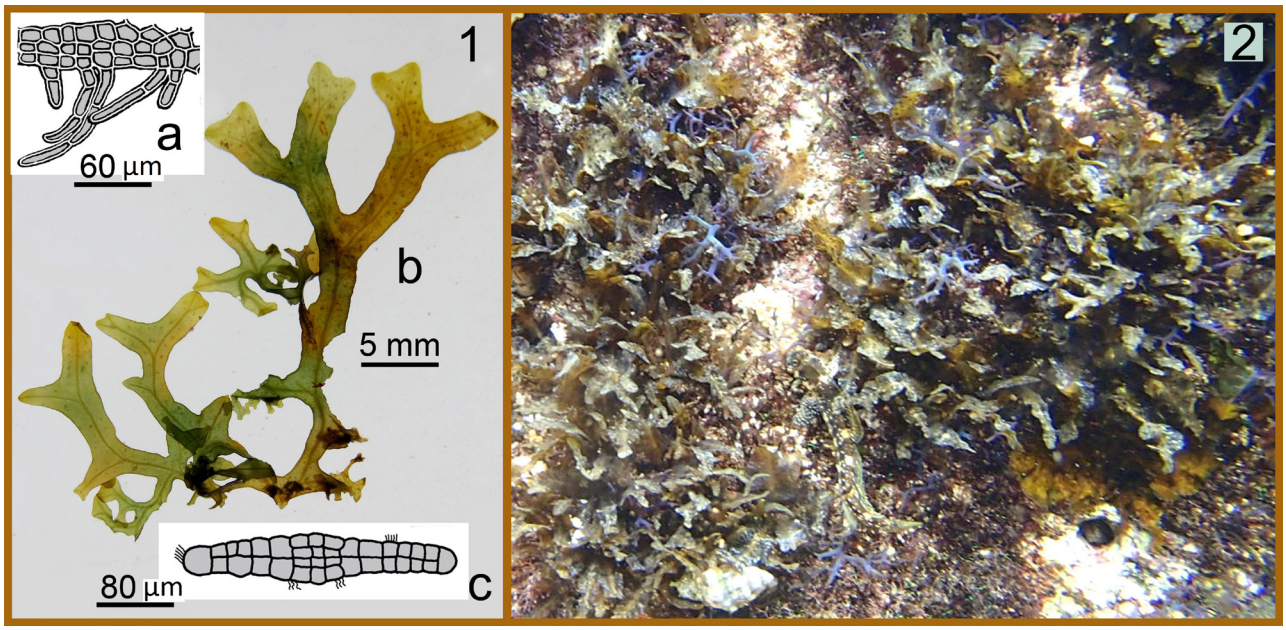

Fig. 12 ***Dictyopteris repens.*** 1. Overall morphology. Insets: a, detail showing marginal rhizoids; c, transverse section of the blade. 2. In habitat, in association with young plants of *Sargassum*. Thallus prostrate, or erect, membranaceous, yellow green to light brown color, about 1-3 cm long. Branching irregularly dichotomous. Blades strap-shaped, 2-3 mm wide and 60-70 µm thick, with distinct midrib. In cross section, the midrib has three to four cell layers; blade margin has one cell layer and other parts composed of two cell layers. Rhizoids form tufts on lower surface of the midrib and on the margins. Growing on hard substrata and epiphytic on larger algae.

***Dictyota bartayresiana* J.V. Lamouroux [= *Dictyota patens* J. Agardh]**

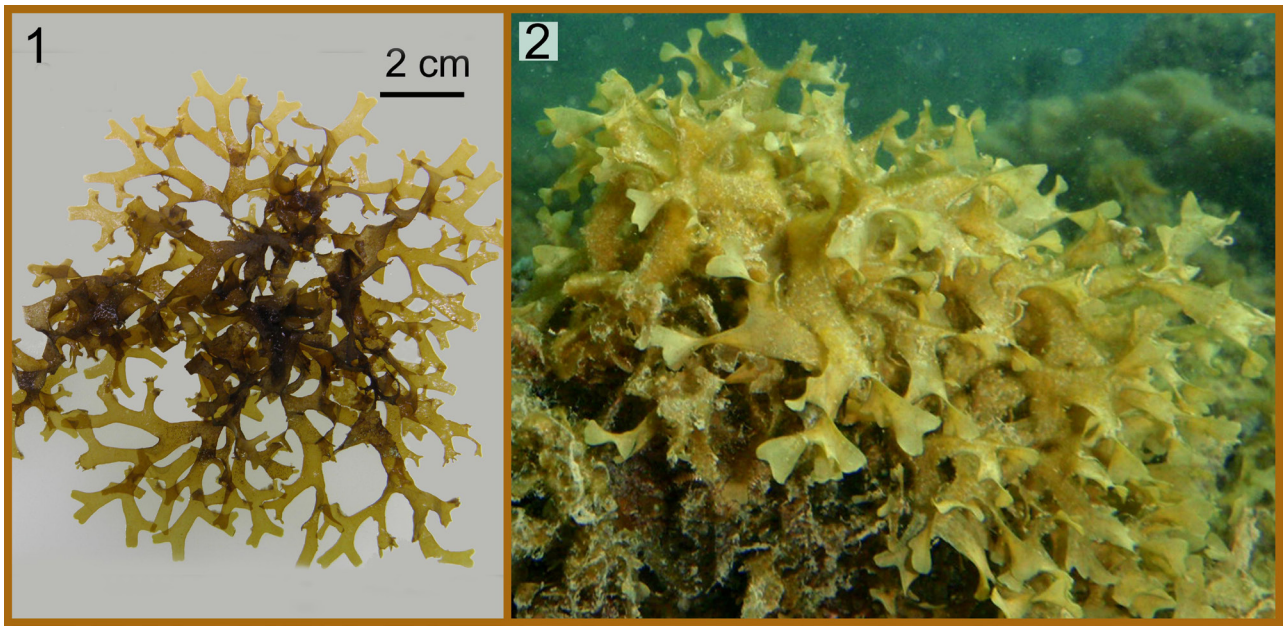

Fig. 13 ***Dictyota bartayresiana.*** 1. Overall morphology. 2. In habitat. Thallus greenish-brown or light brown, crispy and relatively fragile in texture, forming compact or loose clumps up to 8 cm high. Branching dichotomous at an angle of 45-90˚. Blades 85-95 μm thick in cross section, (1)-2-6 mm broad ending into acute or sometimes rounded apices, often twisted in the upper parts of thalli. Margins smooth, spiny or proliferous. Sporangia scattered, 100-120 μm in diam. Rhizoids marginal and on lower side at the basal part of the thallus. Growing on hard substrata.

Padina arborescens **Holmes**

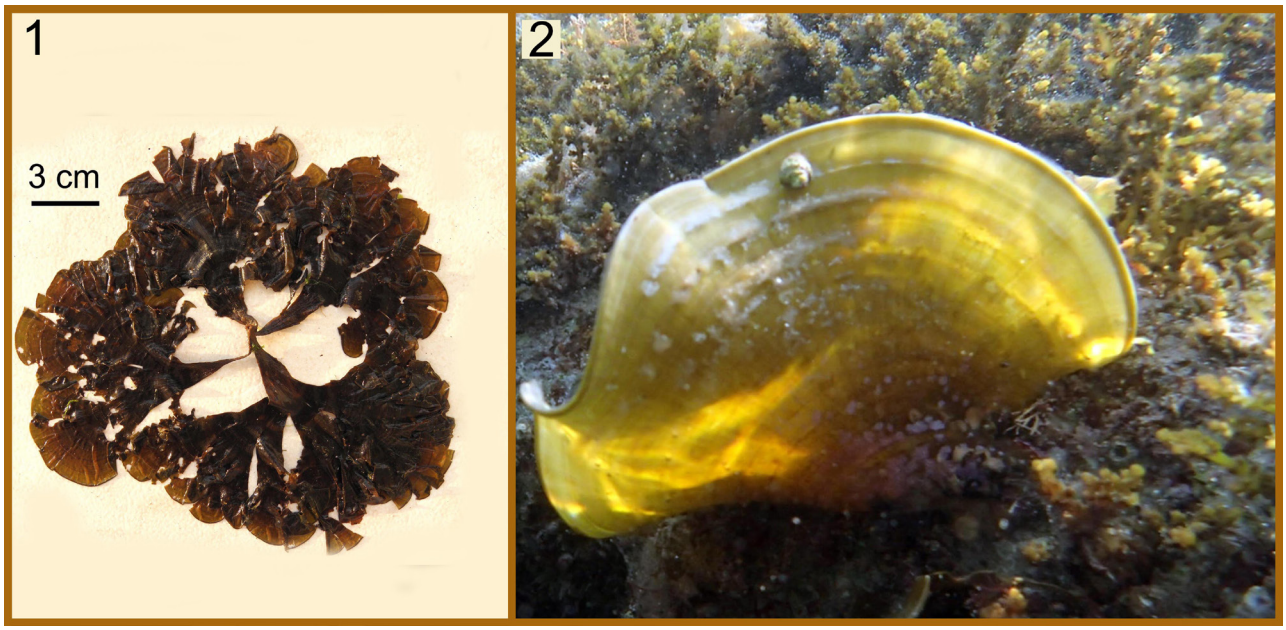

Fig. 14 ***Padina arborescens.*** 1.Old plant (dried specimen). 2. Young plant in habitat. Thallus coriaceous, flabelliform, with entire or shallowly split at margins when young, old thalli deeply split into several lobes, golden brown, olive-brown to dark brown color when dried, 8–20 cm high, 10-30 cm in diam. Outer margins inrolled. The base of thalli stypose, covered with brown hairs. In transverse section, blade to 380 μm thick, composed of 10–13 cell layers at the basal portion, of 5–6 cell layers (120–250 μm thick) in the middle portion and 2–3 cell layers (60–100 μm thick) in the upper portion of the blade. Surface hairs arranged in concentric lines. Attachment by stypose holdfast. .

Zonaria flabellata **(Okamura) Papenfuss [= *Homoeostrichus flabellatus* Okamura]**

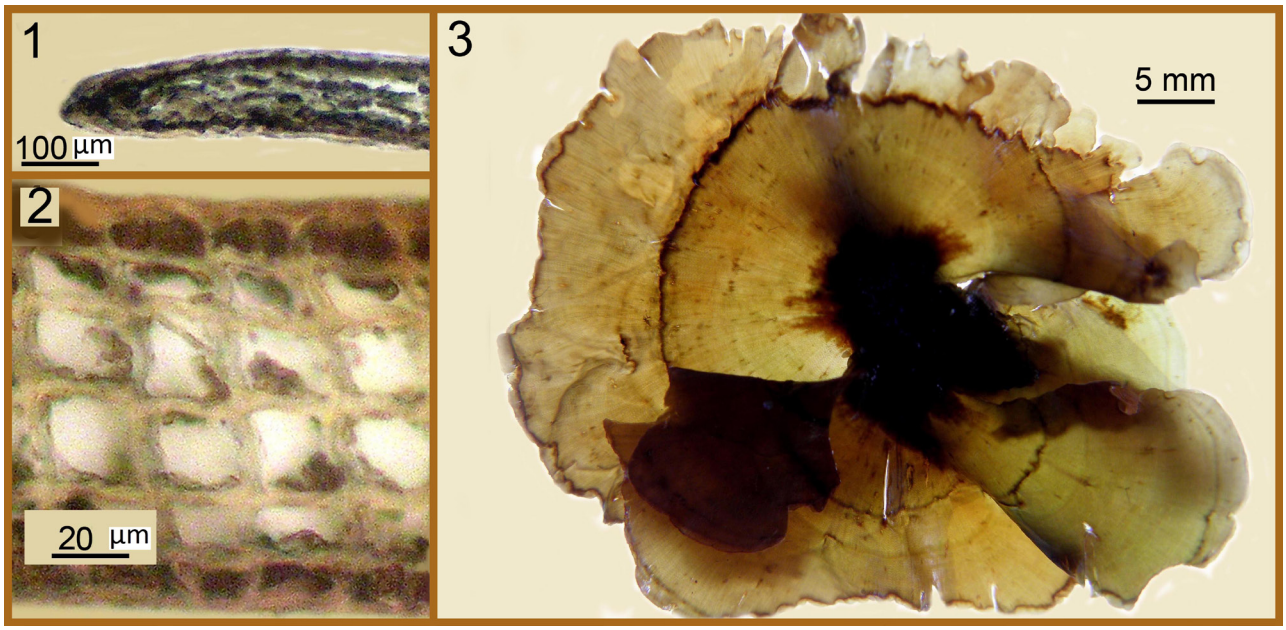

Fig. 15 ***Zonaria flabellata.*** 1, 2. Transverse section (at the margin, in the middle portion). 3. Overall morphology. Thallus blade-like, flabellate, fan-shaped, 7–10 cm across, light yellowish brown to dark brown color at the lower portion of the thallus. Surface cells arranged in longitudinal rows. In cross section, of the middle portion, thallus 100 µm thick, medulla composed of four layers of colorless rectangular cells bound on both sides by a single cortical layer of pigmented cells. Medullary cells 10–20 µm thick, 25 µm long, cortical cells 10×10–25 µm; in the upper portion of the thallus, medullary cells 20 µm thick, 45 µm wide, cortical cells 12.5 µm thick, 22.5 µm wide. Cast ashore, found epiphytic on *Carpopeltis maillardii.*

Order FUCALES

Family Sargassaceae

***Sargassum bicorne* J. Agardh**

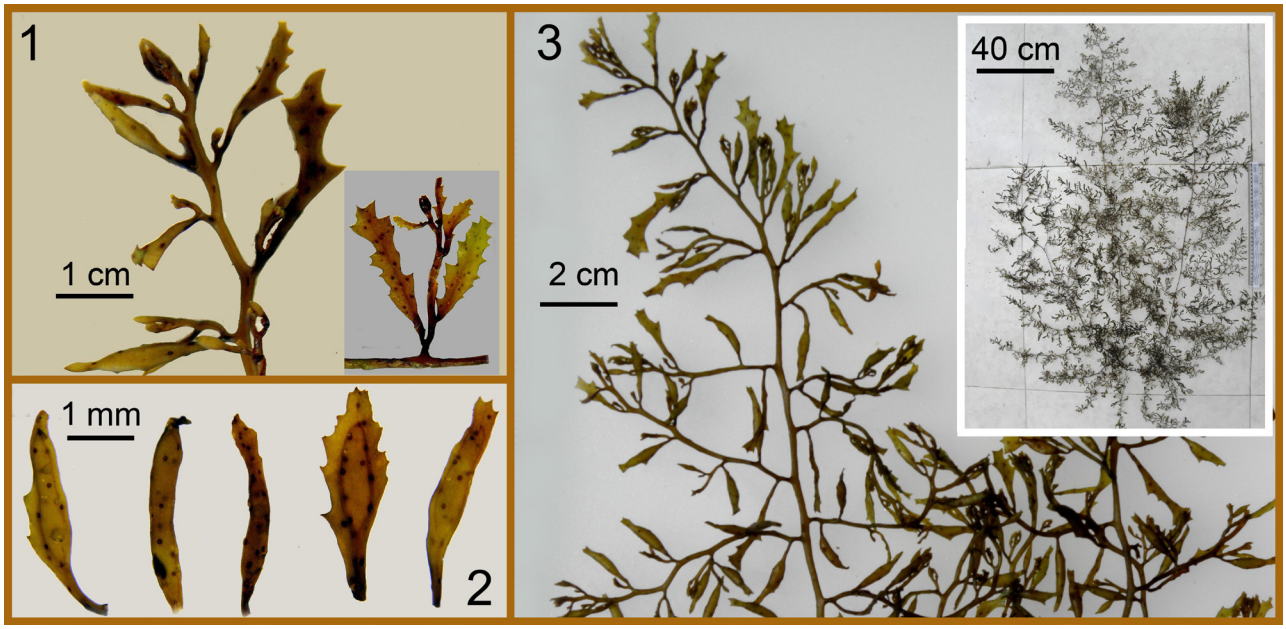

Fig. 16 ***Sargassum bicorne.*** 1, Upper part of branch. 2. Vesicles. 3. Fragment showing branching pattern. Inset: Habit. Thallus leathery, bushy, yellowish-olive to brown, to 1 m high. Main axis 5 mm long, 2.5 mm in diameter, giving rise to 5 cylindrical or slightly compressed primary branches, 40–80 cm long. Branching alternate. Branches of the second order (16–25 cm long) bear branches of the third order (5–8.6 cm long). Phylloids oblong, lanceolate, 2–2.2 cm long, 6 mm wide with asymmetric base, serrate margins and midrib, vanishing below the double-edged apex. Vesicles numerous, ellipsoidal, apiculate, small, 1–4 mm long, stalked, often elate at margins and with leaf formation on the top. Receptacles borne in axils of phylloids, solitary, cylindrical, 3–4 mm long. Attachment by cone-like holdfast.

Sargassum fusiforme **(Harvey) Setchell**

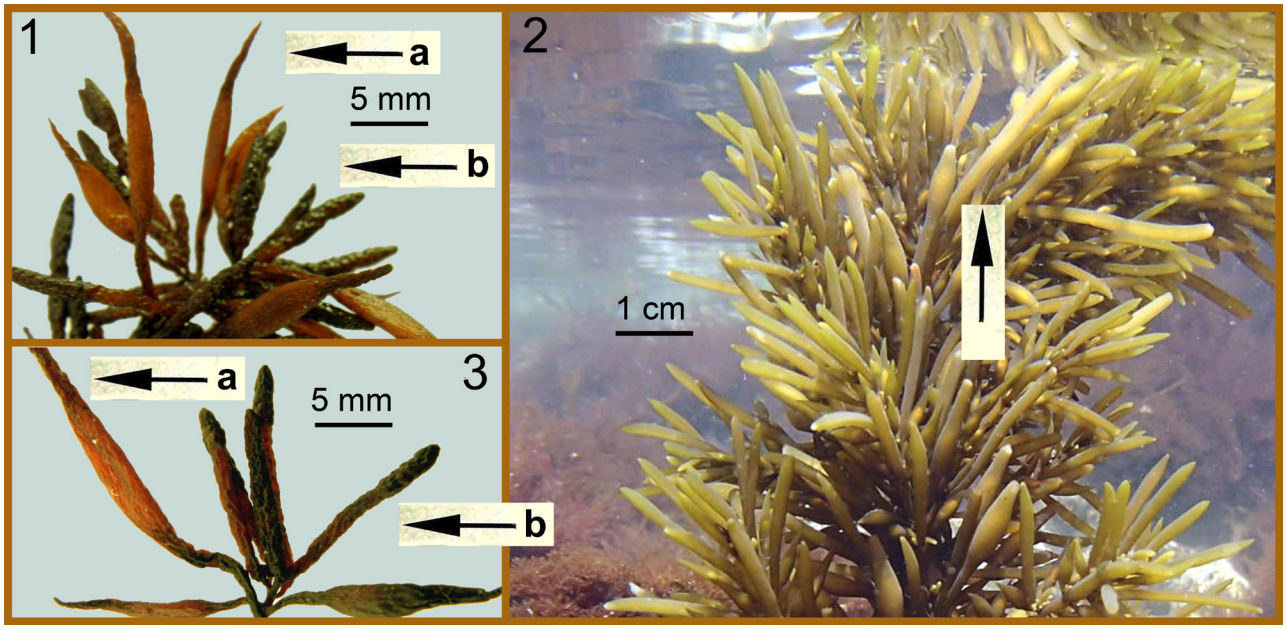

Fig. 17 ***Sargassum fusiforme.*** 1, 3. Details showing vesicles (arrow a) and receptacles (arrow b). 2. In habitat, vesicles (arrow). Thallus thick-fleshy, 0.2–1 m high, yellowish, olive-brown color. Main axis cylindrical, to 1 cm long, 3–4 mm in diameter. Primary axes cylindrical bearing short cylindrical phylloids of various sizes and vesicles in whorls (from all sides). Phylloids shortly stalked, thickened, long (up to 3.4 cm), without midrib, with entire margins or toothed (at the basal part of the thallus), of various shape, commonly filiform, linear-spathulate, clavate, ovate. Vesicles stalked, fusiform with mucronate apices, 1.3–2.2 cm long, 2.0–2.5 mm in diam. Receptacles stalked, cylindrical, simple or branched with obtuse apices, crowded in axils of the phylloids or terminal. Attachment by well-developed fibrous holdfast and stolons.

Sargassum hemiphyllum **(Turner) C. Agardh**

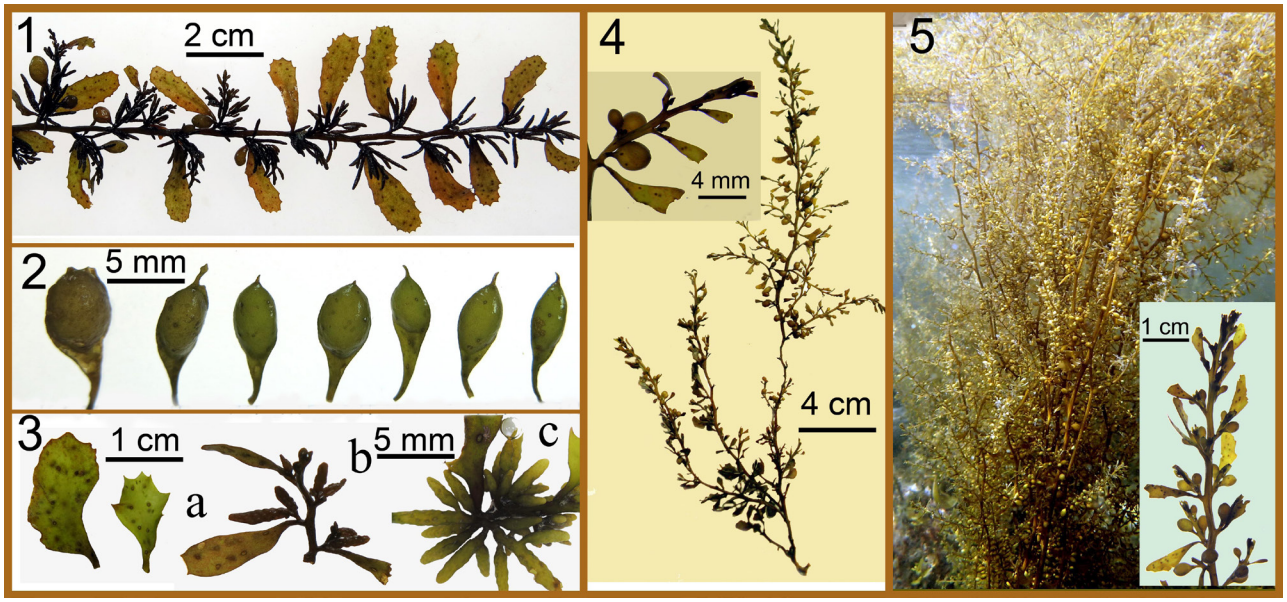

Fig. 18 ***Sargassum hemiphyllum.*** 1, Branch with phylloids, vesicles and receptacles. 2. Vesicles. 3: a, phylloids; b, branchlet with phylloids and receptacles; c, cluster of receptacles. 4. Habit. Inset: Branchlet with phylloids and vesicles. 5. In habitat. Inset: Branch with branchlets. Thallus yellow brown, about 30-50 cm high. A short cylindrical stem originating from small discoid holdfast or from stolone-like subdichotomously branching rhizoids. Primary branches filiform, slightly compressed, becoming terete above. Phylloids flat, short, cuneiform with truncated apices, without midrib. At the basal part, lowest blades are nearly symmetrical, in the upper part of plants, blades generally with asymmetrical base (one margin of the blade outwardly curved or convex and coarsely dentate, the other inwardly curved or concave) and with entire margins. Vesicles spherical-obovate, pyriform in the lower parts of frond, 1-4 mm in diam. and to 5 mm long, smooth or sometimes with spines and prominent cryptostomata, and elliptical to fusiform with acute tips in the upper parts; stalk cylindrical or flattened. Receptacles in clusters, develop at the base of stalk of blades or vesicles, simple or branched, terete, distally compressed, with teeth or spines in mature receptacles.

Sargassum horneri **(Turner) C. Agardh**

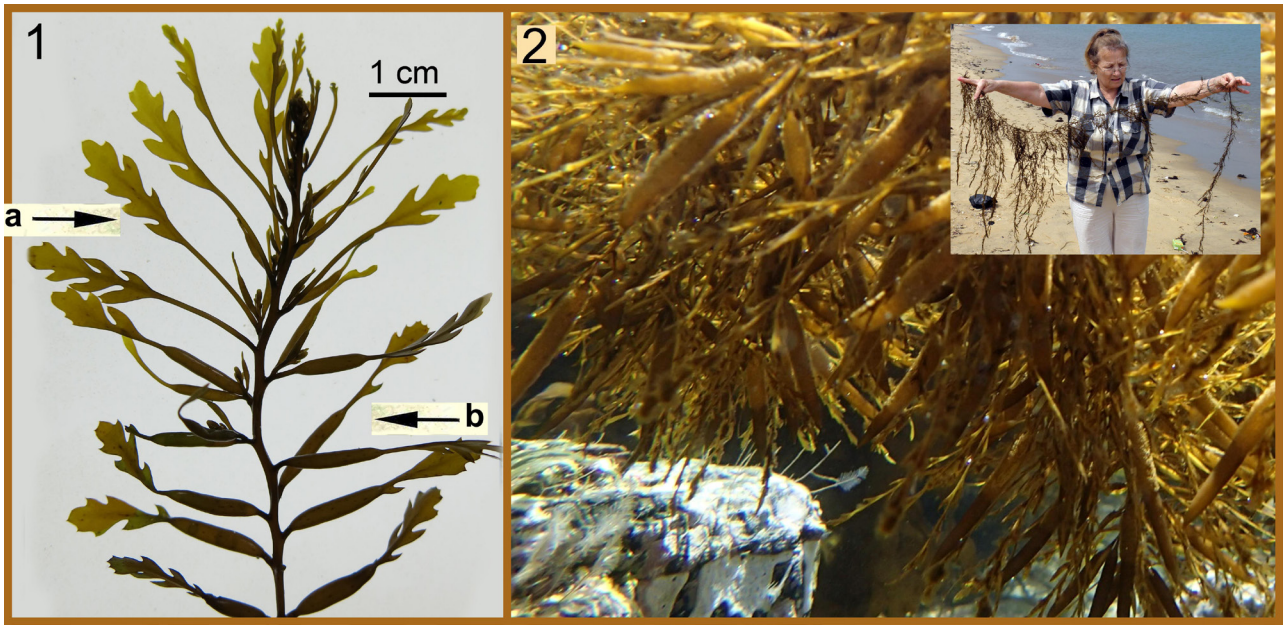

Fig. 19 ***Sargassum horneri.*** 1, Detail showing ellipsoid vesicles with pinnatifid outgrowth (arrow b). 2. In habitat. Thallus densely branched, leathery, bushy, 2-5 m high, yellowish-brown. Stalk twisted, ribbed, and cylindrical. Main axis to 3 mm in diam., cylindrical with furrows, bearing primary long branches. Phylloids alternately pinnately deeply parted (arrow a), with prominent midrib; with sharp teeth on the top of segments, develop in the lower and middle portions of thallus. Vesicles stalked, cylindrical, long ellipsoidal (3-5 diameters long), crowned with pinnatifid leaflet-like outgrowth, develop in the upper portion of the thallus, on separate branchlets in alternate manner. Plants dioecious. Receptacles stout, simple, cylindrical gradually attenuating to acute apices: male receptacles more slender than female one. Holdfast rough, discoid, lobed. Growing subtidally on hard substrata.

Sargassum microcystum **J. Agardh**

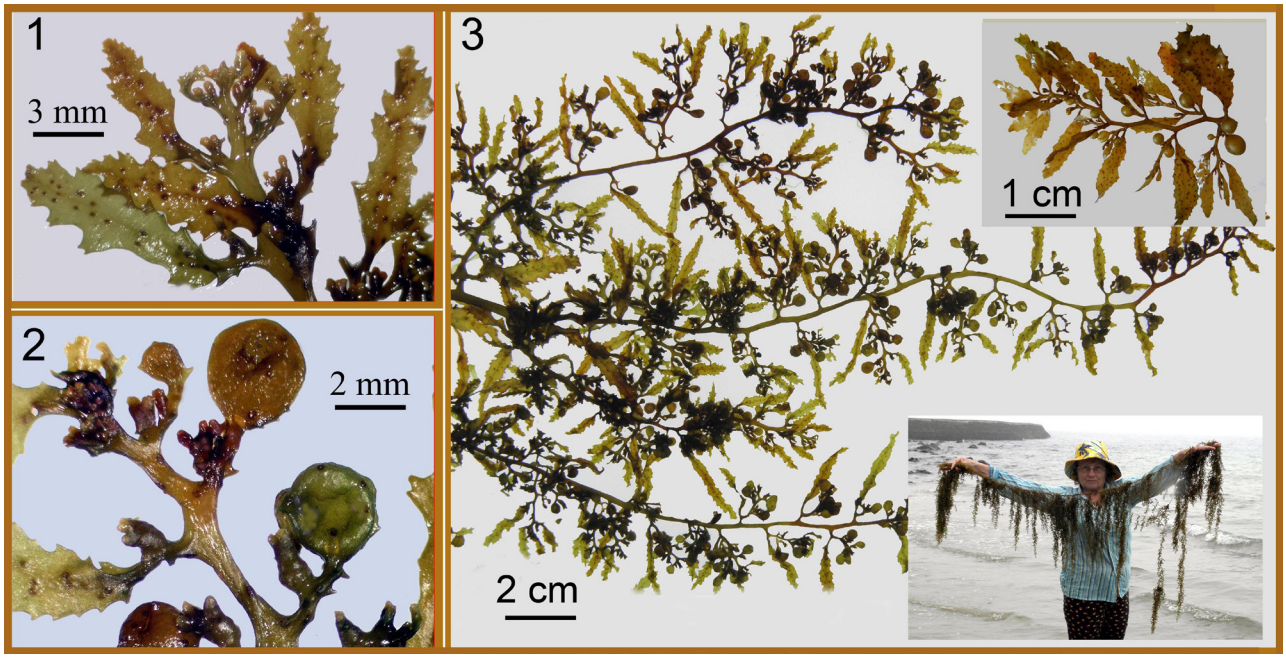

Fig. 20 ***Sargassum microcystum.*** 1, Upper part of branch with phylloids and young vesicles. 2. Vesicles. 3. Detail showing branching pattern. Inset: Branchlet with phylloids and vesicles. Thallus tough, coriaceous, to 2 m high. Main axis cylindrical, filiform, entire, bearing several primary branches from all sides. Secondary branches branchlets and phylloids alternately branched. The upper phylloids narrowly lanceolate (2-2.5×12-17 mm). Midrib distinct, prominent on both sides of phylloids, percurrent or vanishing below apices. Vesicles numerous, single or in groups, spherical, oval to elliptical, small, 1-2.5 mm across, sometimes with narrow dentate wing on one side and with well visible stalk (often with spines) develop on branchlets in axils of the phylloids. Cryptostomata prominent, scattered on both sides of the midrib and vesicles. Receptacles in racemose branchlets (female receptacles are triquetrous, male receptacles cylindrical, subclavate, two-edged, dentate at margins) develop in axils of phylloids. Attachment by discoid holdfast.

Sargassum polyporum **Montagne**

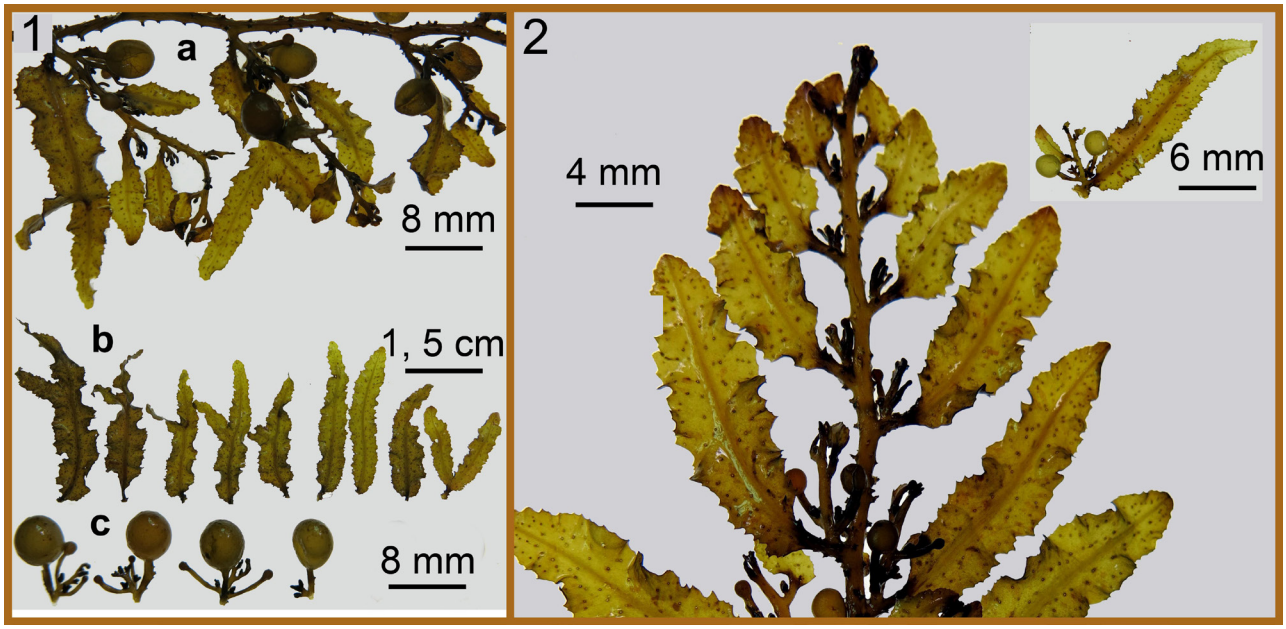

Fig. 21 ***Sargassum polyporum.*** 1, Details showing branchlets, phylloids, vesicles and immature receptacles. 2. Upper part of branch. Inset: phylloid with vesicles and receptacles. Thallus coarse, bushy, 23 cm high, brown. Main axis cylindrical, to 3 cm high, c.2-4 mm in diam. with sharp spines. Primary terete branches covered with spines and bearing densely spirally or alternately arranged secondary spinous branches. Phylloids narrowly spatulate to linear at lower part and alternately pinnately branched above, flat or twisted, densely arranged, with entire or wavy margins, symmetric or asymmetric cuneate base and obtuse apices. Midrib percurrent or vanishing below the apex. Cryptostomata irregularly scattered or disposed on both sides of the midrib. Vesicles spherical, to obovoid, to 6.5 mm long, smooth at apices, on terete or compressed stalk shorter than vesicles or nearly same length, rarely with spines or dentate wings. Receptacles terete, warty, forked, racemosely arranged. Attachment by conical-discoid holdfast.

***Sargassum thunbergii* (Mertens ex Roth) Kuntze**

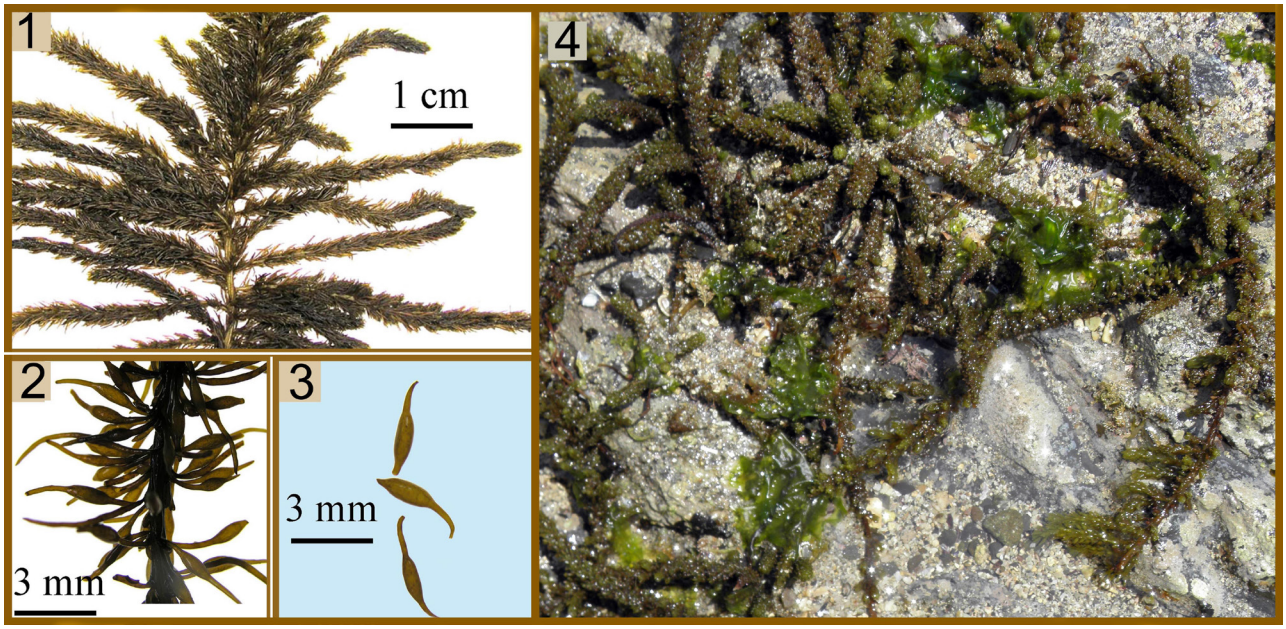

Fig. 22 ***Sargassum thunbergii.*** 1, Part of plant with branches. 2. Detail showing vesicles and phylloids. 3. Vesicles. 4. In habitat Thallus wiry, bushy, 30-100 cm high, dark brown to almost black. Main axis terete with phylloid scars, short (3-7 mm high), bearing above primary branches which are long in the lower half and short in the upper portion of thallus and covered with closely crowded (clustered) phylloids from all sides. Phylloids filiform, lanceolate, 4-10 mm long, 1-3 mm broad, with entire or coarse toothed margins. Vesicles stalked, small, elongate ellipsoidal or fusiform (to 5 mm long), extending into acute point. Plants dioecious with single or aggregate, long ellipsoidal or terete, slightly swollen receptacles, 5-15 mm long, develop in axils of the phylloids. Attachment by small, flattened discoid holdfast with lobed margins. Growing on middle, low intertidal rocks and dead corals in open and sheltered calm shores.

Discussion

Our previous publications (Titlyanov *et al.* 2011a, 2015, 2016; Titlyanova *et al*. 2014) and results of this study showed that the marine flora of Hainan Island has undergone significant changes in species composition between the 1930′s−1980′s and 1990′s, and also, between the 1990′s and 2000′s. Comparison of algal species diversity and composition in collections of the 1930′s−1980′s and the 1990′s showed that the maximum similarity boundary values between the floras of the browns in Hainan Island amounted to 41%. At the same time, the maximum similarity boundary values between the floras of the browns in collections of the 1990′s and 2008−2010 was higher and amounted to 55% (Titlyanova *et al*. 2014). The higher similarity value between the IC and LC floras compared to the value for EC and IC was due mainly to a smaller difference in the number of lost species in LC compared with IC. The greatest number of new findings of brown algae in both collections (IC and LC) was in families such as Sargassaceae and Dictyotaceae with foliose forms inhabiting hard substrata.

Among the new findings in IC and LC, the relative amount of epiphytic algae was small (36% and 20%, respectively). At the same time, the relative amount of epiphytic algae among new findings of red algae amounted to more than 60% and 40% in IC and LC, respectively (Titlyanov *et al*., 2015, 2016; Titlyanova *et al*. 2014). Enrichment of the marine flora by epiphytic algae (with filamentous, thin-filamentous and finely branched form) suggests that the reason of decadal changes is eutrophication of coastal environments (Kinzie III 2008; Oliveira & Qi 2003; Titlyanov *et al*. 2011a, 2015, 2016). Thus on the basis presented in this article and previously obtained data, we cannot exclude that significant changes in species composition of marine flora caused by eutrophication (especially in Sanya), under the influence of urbanization and development mariculture farms (Titlyanov *et al*. 2011b; Li *et al*. 2016).

Among brown algae collected in 2008−2016, representatives inhabiting only tropics and subtropics constitute the vast majority (80%), half of which being found only in the Indo-Pacific. Cosmopolitan species constitute 4%. A similar geographic distribution of new findings has been found for the green and red algae in 2008−2010 (Titlyanov *et al.* 2011a, 2015). Invasive species were not found among the new findings that suggests sustainability of the marine flora of Hainan Island to the introduction of alien species (not from the Indo-Pacific). The greatest number of new findings of the browns was in Yalong Wan and Xiaodong Hai in 1990−1992, in Luhuitou and Xiaodong Hai in 2008−2016 (Table 1). In all probability, a large number of new findings reflects high species diversity of algae in these localities, as has been shown in our previous study (Titlyanova *et al*. 2014).

Acknowledgements

E. Titlyanov and T. Titlyanova are grateful to Prof. Christian Wiencke and Dr. Inka Bartsch for invitation to work at the Alfred-Wegener-Institute for Polar and Marine Research and are also grateful to collaborators of the Botanical Department for technical help, use of facilities and hospitality. Special thanks to Prof. Huang Hui for invitation to work at the Marine Biological Station (South China Sea Institute of Oceanology, Chinese Academy of Sciences). This study was partially supported by the Russian Foundation for Basic Research (grant numbers 08-04-00735-a, 12-04-01424-a), by three research grants from the Alfred-Wegener Institute of Polar and Marine Research to T. Titlyanova and E. Titlyanov and the grant “China–Russia special funds 2009” from the Chinese Academy of Sciences.

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Published: 31 December 2018