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GUIDE TO THE DOMINANT MACROALGAE OF THE STROMATOLITE FRINGING REEF COMPLEX, HIGHBORNE CAY, BAHAMAS

BY

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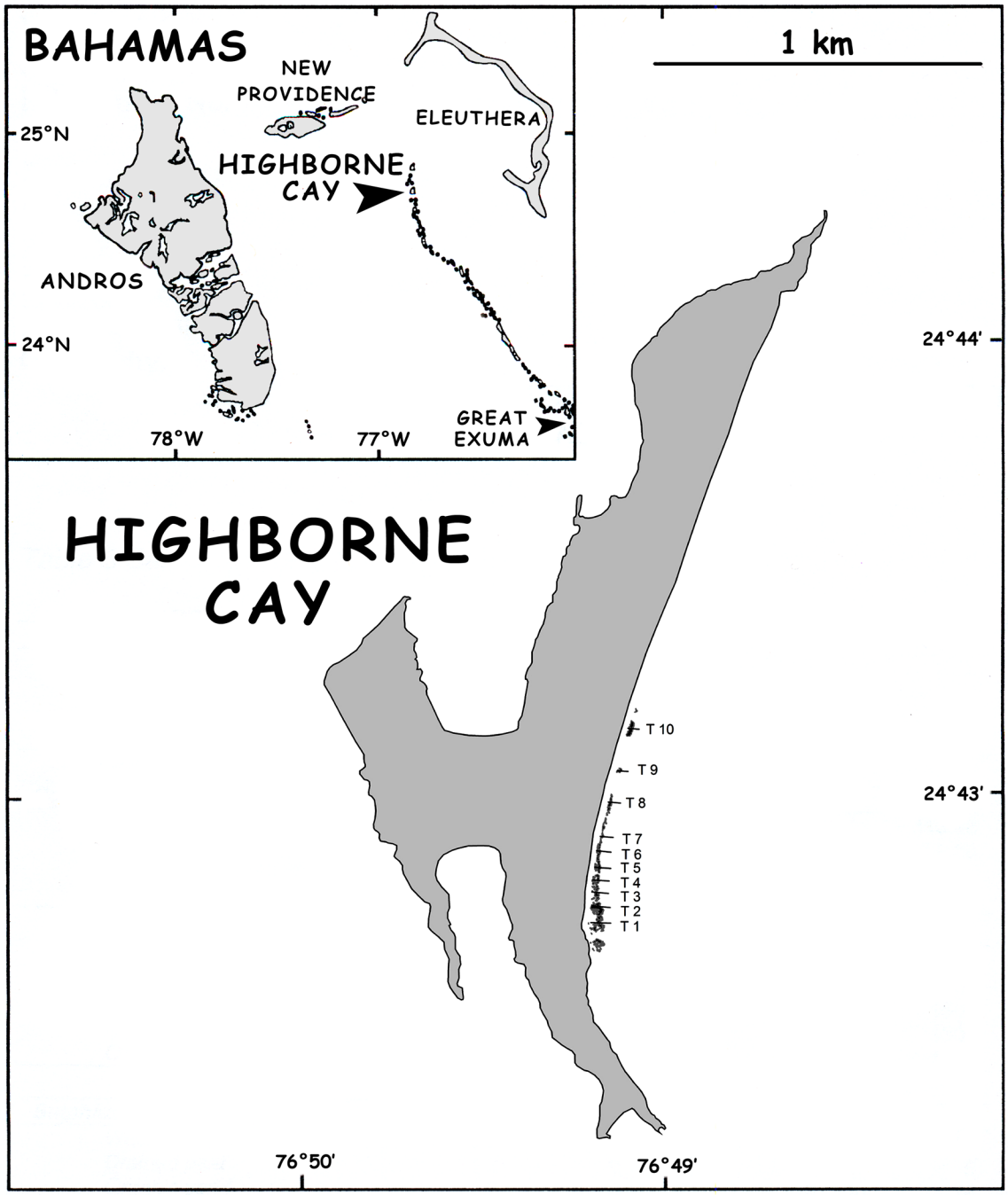

Figure 1. Location of Highborne Cay, Bahamas showing the fringing reef and stromatolite areas prominent along the eastern shore. T's mark the 10 established research transects across the Highborne Cay stromatolite fringing reef complex.

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ABSTRACT

This is the first description of macroalgae documented from a stromatolite reef complex. Because of the sediment stress conditions that promote the development of stromatolites in this open marine environment, macroalgae are generally limited in species diversity and are sparse except for the crustose coralline alga *Neogoniolithon strictum*, which forms the elevated reef crest behind which the sediments and stromatolites accumulate. At the 10 sites sampled, a total of 22 species were encountered, 10 Rhodophyta, 9 Chlorophyta, 2 Phaeophyta and 1 Cyanobacteria.

INTRODUCTION

Stromatolites, which are laminated microbial deposits, have a unique geologic history that dates back to more than three billion years and extends right up to the present day. Dravis (1983) was the first to report modern marine stromatolites on the northeastern margins of Exuma Sound. Following this initial discovery, marine stromatolites were reported at numerous locations throughout the Exuma Cays, on the western margin of Exuma Sound (Dill et al., 1986; Dill, 1991; Reid and Brown, 1991; Reid et al., 1995). These stromatolites all occur in tidal channels with the exception of those off Stocking Island, Darbay Island and Highborne Cay (Fig. 1) where they form part of a fringing reef that has a reef crest formed by the sediment-tolerant crustose coralline algal

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Neogoniolithon strictum (Steneck et al., 1997). The facies pattern of these fringing reefs is well illustrated in a series of cores collected off Stocking Island to study their growth history (Macintyre et al., 1996).

For modern stromatolites to exist, the environmental conditions have to be under severe stress to eliminate most other benthic organisms that can out-compete and destroy these microbially laminated sedimentary structures. In the marine environment this stress is usually hyper-saline conditions or, as found off Highborne Cay, stress associated with the constant movement and inundation of sediments (Andres and Reid, 2005). As macroalgae are one of the competitors with stromatolite growth, little attention has been paid to the limited numbers of macroalgae species that can survive these severe conditions of sediment stress. This is the first description of the macroalgae that are found in a stromatolite-reef complex. A complete description of this complex ecosystem is found in Reid et al., 1999 with ample photographs of the area and thorough documentation of the internal and external structures of the microbial buildup and surface mats characteristic to this unique habitat.

SETTING

Off the east-facing beach of Highborne Cay (76°49'W; 24°43'N), an island in the northern Exuma Cays, a fringing mixed microbial-coralline-algal reef extends along this windward coast for about 2.5 km (Fig. 1). The shelf, with average water depths of 10–20 m, extends seaward for 1–2 km before dropping off into the Exuma Sound with depths of up to 20 km.

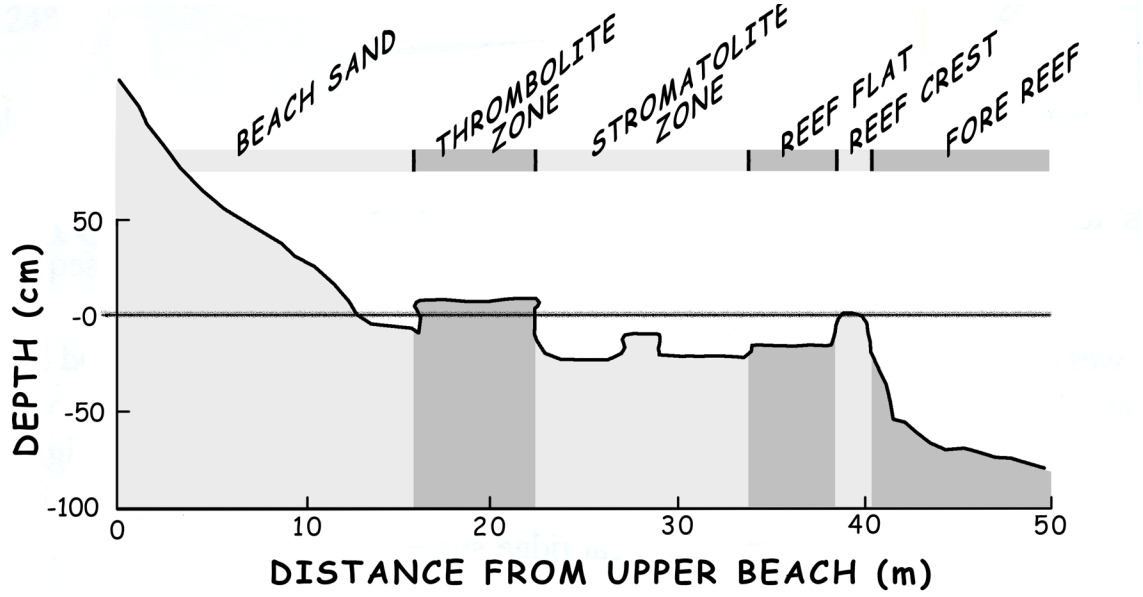


Figure 2. Schematic profile of the near shore reef at Highborne Cay, Bahamas. The above zones serve as a location reference in reporting the distribution of macroalgal species. (modified from Reid et al. 1999, Fig. 3)

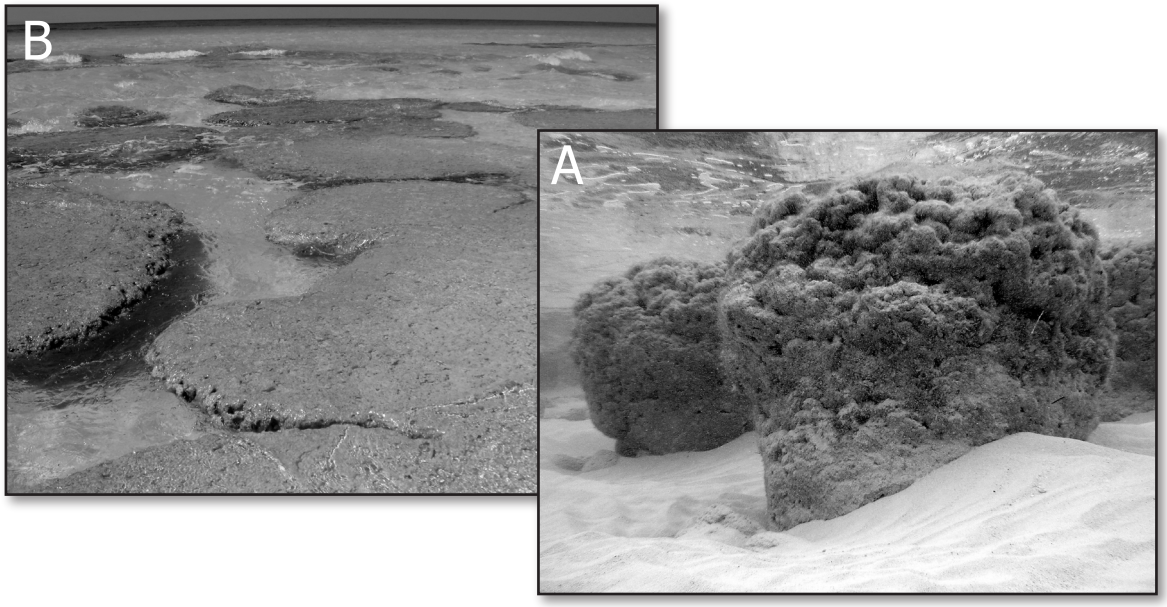


Figure 3. A. Thrombolites forming in shallow-inshore, heavily sand-inundated areas. B. Surface view of thrombolites (formed by irregular internal microstructures) showing their irregular shape and often flattened top.

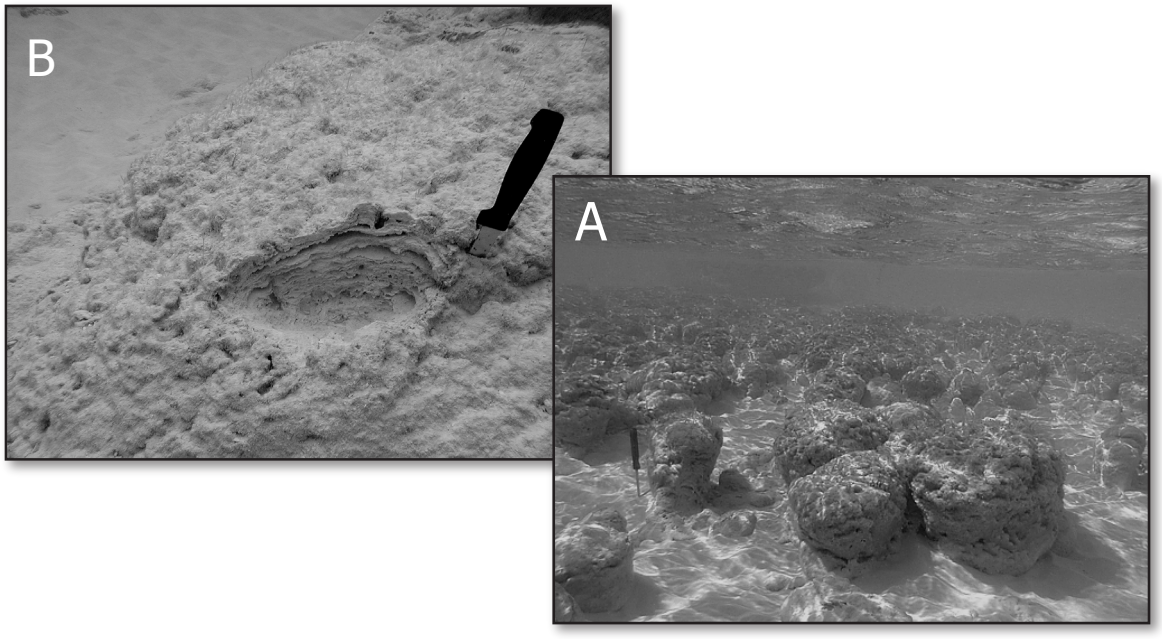


Figure 4. A. Stromatolites (formed by laminated internal microstructure) generally occurring in deeper water than the thrombolites. B. Close-up of a stromatolite showing the distinctly deferentiated layers that create the structure.

Oceanographic conditions are characterized by normal salinity, approximately 35 ‰, with sea-surface temperatures ranging from 20–28° C in winter and summer, respectively. The water is saturated with respect to both aragonite and calcite. Tides are diurnal with a range of ~1 m. The climate is dominated by the trade winds blowing on average 10–15 knots from a southeast to easterly direction.

Although the reef system extends along the entire length of the beach, it is most extensively developed in the southern to central sections and in the very northern part. For research purposes this part of the reef system is subdivided into sites, numbered Site 1 in the south to Site 10 in the north (Fig. 1).

The reef tract is divided into distinct morphological zones (Fig. 2): beach sand, thrombolite (irregular internal microstructure) zone (Fig. 3); stromatolite (laminated internal microstructure) zone (Fig. 4); reef flat (Fig. 5); reef crest (*Neogoniolithon* zone, Fig. 6); and fore reef. Whereas most of these zones are found throughout all transects, the thrombolite zone occurs only at a few sites. Furthermore, the individual width and lateral extension of these zones is highly variable. In overview, this reef system is widest in the southern part of the eastern beach extending over 20–50 m with a maximum width of 54 m within Site 2 (Fig. 1). The *Neogoniolithon* zone is more shoreward at Site 3, resulting in decreased width to 25–35 m at Sites 3 and 4, narrowing further to 10 m and less at Sites 5–8. Although interrupted by cuts and channels, the outer reef edge is continuously traceable from Sites 1–6, whereas Sites 7 and 8 comprise a series of discontinuous narrow reefs. Sites 9 and 10 are isolated crescent-shaped reefs with extensive open sand areas in between (Fig. 1).

METHODS

From 30 January to 2 February 2005, Emily Bowlin and Ian G. Macintyre collected the dominant macroalgae from 10 established research transects across the Highborne Cay stromatolite fringing reef complex. Samples were collected from the *Neogoniolithon strictum* zone, the reef flat, the stromatolite zone, and finally the thrombolite zone, which did not occur in some transects (Fig. 1).

Samples were then taken to the laboratory in the R/V Walton Smith where they were photographed and then pressed and dried. Both photographs and pressed material were transferred to the Smithsonian Institution's National Museum of Natural History where the macroalgae were studied, identified and described by Diane S. Littler and Mark M. Littler. Highborne Cay photographs were sharpened and cropped in Adobe Photoshop but otherwise remain untouched. In air photographs of the Highborne Cay specimens were taken by Emily Bowlin with the assistance of Ian G. Macintyre. Drawings of internal structures and *in situ* photographs are from "Caribbean Reef Plants", used with the permission of the publisher and are not specifically from Highborne Cay or Highborne Cay material. However, they provide a representation of comparable *in situ* plants that occurred in the transects.

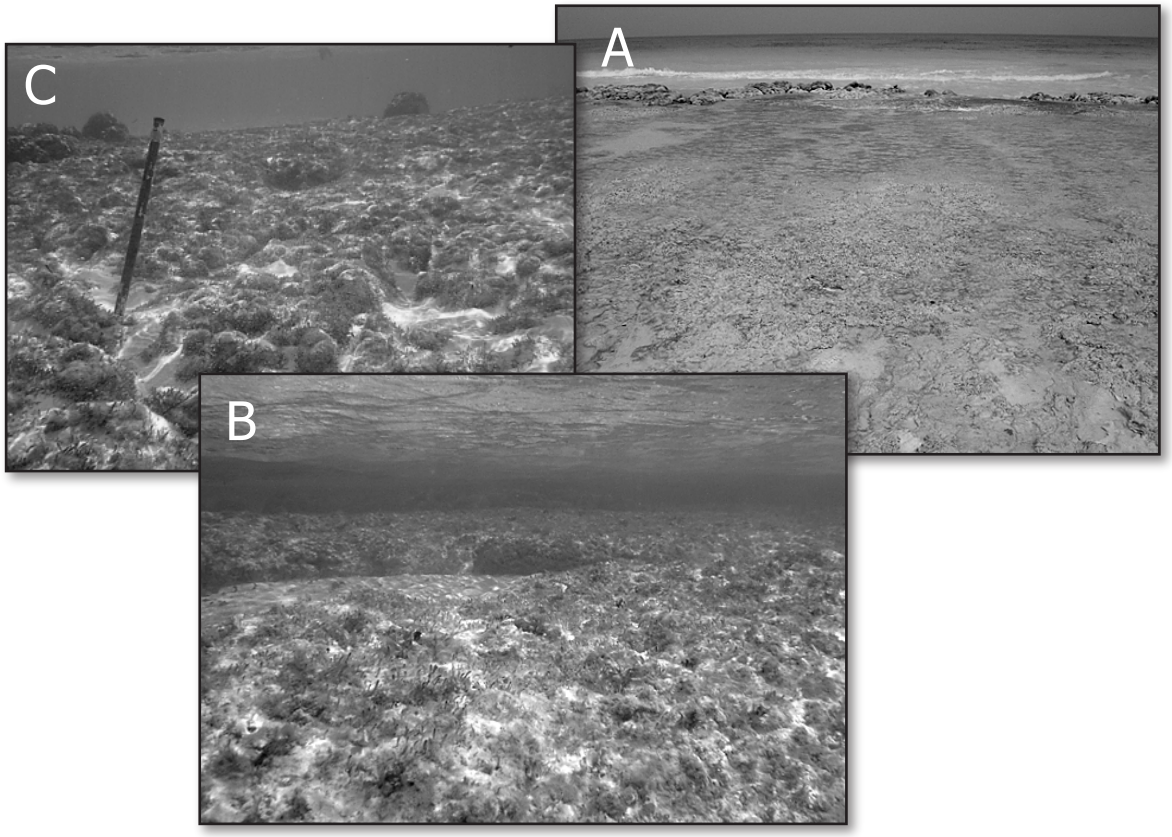


Figure 5. A. Surface view of the reef flat at low tide. B. Underwater view of the reef flat showing the sparse algal and seagrass cover presumably due to the turbulant sand scouring and intermittent sand inundation. C. Closer view of reef flat habitat.

Figure 6. The reef crest zone dominated by large heads of the sediment tolerant crustose coralline algal *Neogoniolithon strictum*.

RESULTS AND DISCUSSION

The marine flora of the Bahamas has been extensively studied over a long time period beginning at the turn of the 19th century when M.A. Howe began focusing his efforts on collecting there (e.g., Howe, 1904, 1905a, 1907, 1909, 1920, 1924). The myriad of algal habitats have not been intensively investigated in terms of coverage. Historical treatments in the past 75 years are limited to mostly ecologcial works and more limited floras and monographs (e.g., Jensen, 1985; Littler et al., 1985, 1986, 1988, 1991; Littler and Littler, 1990a, 1990b, 1991, 1992, 2000, 2004; Lapointe et al., 1992, 2004, in press a, in press b). Bahamian specimens and distributional records were also used to produce field guides such as Littler et al. (1989) and Littler and Littler (2000). Consequently, the present work adds a floristic dimension to a unique Bahamian ecosystem.

Twenty-two marine macroalgae commonly occurred on the stromatolite reefs of Highborne Cay. Of these, 10 were Rhodophyta (red algae), with 9 Chlorophyta (green algae), 2 Phaeophyta (brown algae) and 1 Cyanobacteria (blue-green algae). The often overlooked brown algal species *Padina haitiensis* was present. This species is commonly mistaken for *P. sanctae-crucis* and, consequently, has been rarely reported.

The reef crest was the most diverse site with 13 species present (Fig 7). The reef flat had 12 species while the stromatolite zone maintained 11 species. The thrombolite zone was the most depauperate in terms of species richness with only five species present. The latter paucity is presumably due to the constant and turbulent sand inundation in the shallow subtidal adjacent to the beach.

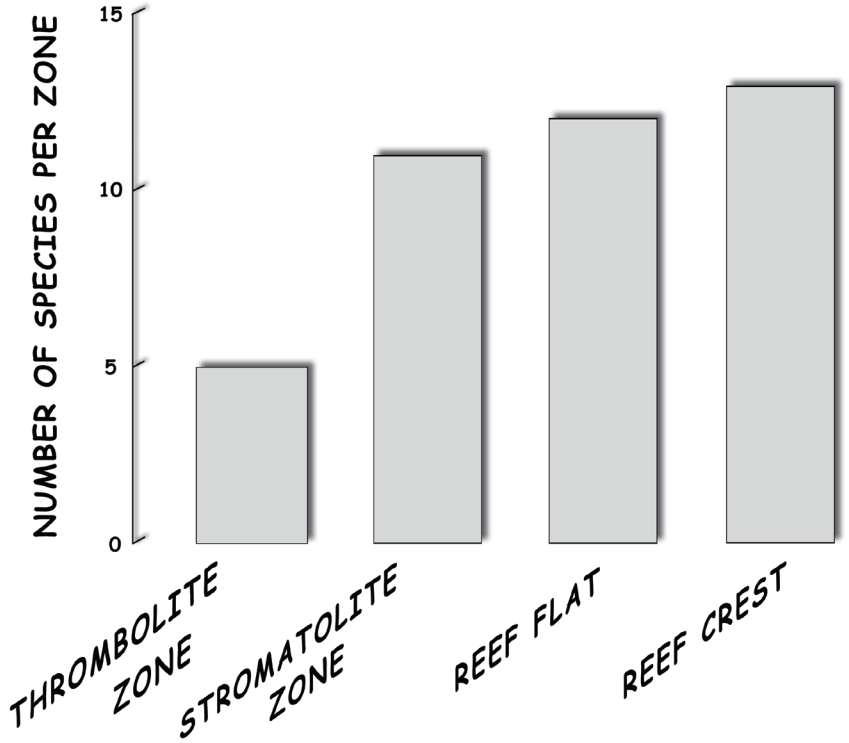


Figure 7. Histogram showing the number of species for the four zones.

The green alga *Batophora occidentalis* was the only species that occurred in every transect (Table 1). This species was the dominant macroalga in the thrombolite and/or the stromatolite zone and occasionally appeared on the reef crest and reef flat. The red alga *Laurencia obtusa* was present in all 10 transects on the reef crest or reef flat except at site 3 but was never found in either the stromatolite or thrombolite zones. The red alga *Lophosiphonia obscura* and the blue-green alga (cyanobacteria) *Dicothrix fucicola* were only present in the thrombolite zone, while *Neosiphonia sphaerocarpa* was present in the thrombolite and stromatolite zone; none of the three were found on the reef flat or reef crest. Two samophytes, the green algae *Udotea flabellum* and the closely related *U. norrisii,* were found only in the stromatolite zone. The brown alga *Dictyota cervicornis* is a common species on the reef flat and reef crest and is also present in the northernmost stromatolite zone. Species that were restricted to the reef flat and reef crest were *Avrainvillea digitata, Caulerpa paspaloides* var. *compressa, Chondrophycus gemmifera, Halimeda incrassata, Jania capillaceae, Laurencia obtusa* and *Rhipocephalus phoenix*, presumably species that are more susceptible to damage by sand scouring and inundation (Table 1).

ACKNOWLEDGEMENTS

We gratefully acknowledge Ana Patricia Gaspar for providing precise locations of the 10 transects in Figure 1. Funding for field work was provided from National Science Foundation Grant EAR-0221796 and funding for laboratory work was provided by the Smithsonian Marine Station at Fort Pierce, Florida (SMSFP Contr. No. 622). RIBS Contr. No. 34. HBOI Contr. No. 1609.

Table 1. List of species occurring at Highborne Cay study area according to Transect Sites 1–10. Sites show where individual species occurred on the RC = reef crest, RF = reef flat, SZ = stromatolite zone and TZ = thrombolite zone. The epiphyte *Pneophyllum fragile* is not included since it occurs on various species.

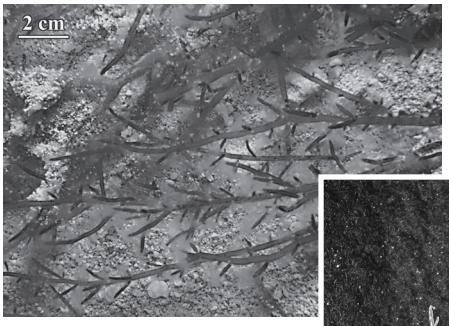
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Acetabularia crenulata				RF,SZ	RF	RF				
Avrainvillea digitata		RC								
Batophora occidentalis	SZ	RF,SZ	RC,SZ	RC,RF,SZ	RC,RF,SZ, TZ	RC,RF,SZ, TZ	TZ	RF,SZ	SZ	TZ
Caulerpa paspaloides	RC									
Chondria littoralis		RC	SZ	SZ	RF	RF,SZ		RF,SZ	RF,SZ	RC,RF
Chondrophycus gemmifera		RF			RC	RC			RC	
Dichothrix fucicola					TZ					
Dictyota cervicornis	RC,RF	RC	RC,RF	RC,RF		RC,RF	RF,SZ	SZ	RF,SZ	SZ
Digenia symplex			RF,SZ							
Halimeda incrassata			RC							RF
Jania capillaceae	RC		RF	RC	RF					
Laurencia obtusa	RF	RC,RF		RF	RC	RC,RF	RC	RC,RF	RC,RF	RC,RF,SZ
Lophosiphonia obscura				TZ	TZ	TZ	TZ	TZ		
Neogoniolithon strictum	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC
Neosiphonia sphaerocarpa				TZ	SZ		TZ			SZ
Padina haitiensis	RF			RC,RF,SZ			RC,RF			
Rhipocephalus phoenix			RC							
Udotea flabellum			SZ						SZ	SZ
Udotea norrisii			SZ							
Valoniopsis pachynema	RC,RF	RF	RF	RC				RC,RF		RC,RF,TZ
Wrangelia penicillata			SZ		RF		RC,RF,SZ			RC,SZ

Chondria littoralis Harvey 1853: 22

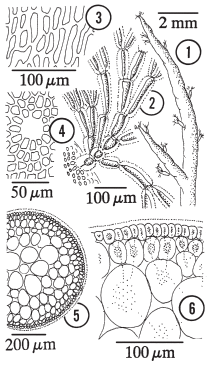
Thallus: sparsely branched, to 35 cm high, brown-yellow or pale to dark red; branching irregular. *Branches* cylindrical, to 2.0 mm diam. proximally (main axis to 2.2 mm diam.), tapering to 0.8 mm distally; pericentral cells 5–6. *Branchlets* only present on outer branches, to 0.5 mm diam., tapered at both ends, mainly unbranched, decidedly pinched at base; apices pointed; apical filaments fine, to 1.5 mm long, dichotomously branched (often at every segment for first 5–6 divisions), densely tufted, persistent; apical cell exposed. *Surface cells* to 18 µm diam., rectangular, 1–4 diameters long.

Common: firmly attached to coral, rock fragments or other hard surfaces on shallow sand or mud flats, occasionally intermingled with other small algae in short turfs; to 15 m deep.

Highborne Cay distribution: generally found on the reef flat and in the stromatolite zone; only once was it found on the reef crest.



Highborne Cay US# 209060



1. Branch with branchlets abruptly thinner than main axis.
2. Persistent apical filaments.
3. Surface cells of mature branch.
4. Surface cells of branchlet with filament scar.
5. Transverse section of branch.
6. Transverse section of cortex.

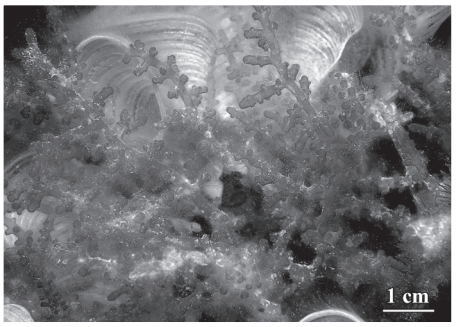
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

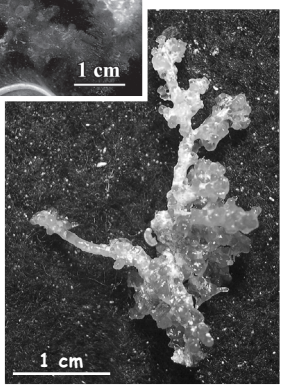
Chondrophycus gemmiferus (Harvey) Garbary & Harper 1998: 194

Thallus: bushy, sti , wiry, 2–5(–15) cm high, yellow-brown, occasionally with red-brown tips; branching dense, alternate to irregular. Branches cylindrical, somewhat flattened with age, 1.0–2.2 mm diam., tapering to 0.5 mm diam. at apices. Branchlets numerous, cylindrical, 0.2–0.9 mm diam., 0.2–1.0(–3.0) mm long, blunt, wart-like, often swollen; apices tufted with fine deciduous, dichotomously branched filaments extending just beyond rim of terminal depression. Surface cells oval to angular, 40–50(–130) µm diam., with surface projection near apices, deeply pigmented; medullary cells large, colorless; apical cell sunken in terminal depression. Holdfast disc-like or spreading to pad-like.

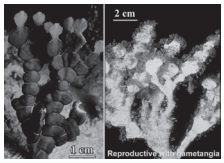
Uncommon: on hard surfaces of shallow reef flats or attached to dead coral rubble on shallow sand plains; to 20 m deep.

Highborne Cay distribution: in most stations limited to the reef crest, in one instance on the reef flat.





Highborne Cay US# 209056



1. Habit.
2. Transverse section of immature branchlet showing pointed surface cells.
3. Branchlet apex.
4. Surface cells of mature branch.

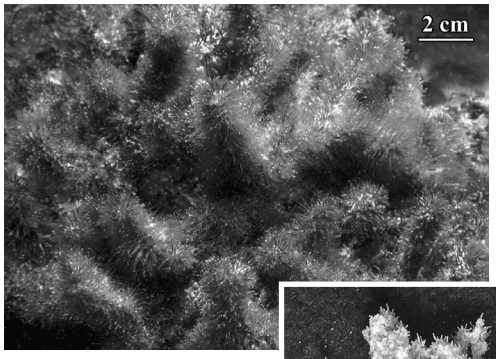
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

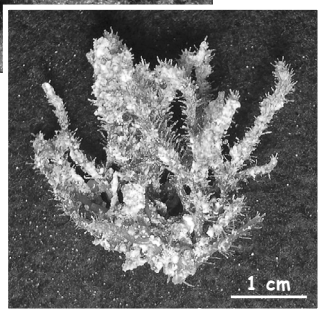
Digenea simplex (Wulfen) C. Agardh 1822 [1822–1823]: 389

Thallus: sti , wiry, often gregarious, to 8(–25) cm high, light pink to dull, dark brown-red; branching dichotomous to irregular. *Branches* naked proximally, covered with numerous short branchlets distally; in transverse section, large central cells grading smaller toward surface. *Branchlets* 3–5(–15) mm long, unbranched, sti , wiry, often with fine, deciduous hairs near apices. *Surface cells* of branchlet 25–35 µm diam., in 20–24 longitudinal cylinders; pericentral cells 10–12, 25–38 µm diam.; central filament distinct, 40–55 µm diam. *Holdfast* of coarse, short rhizoids descending from thicker disc-like base.

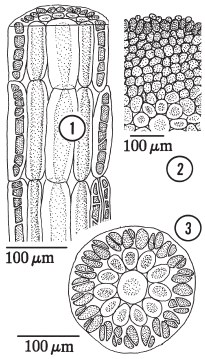
Common: on hard surfaces, often overgrown by filamentous epiphytes, abundant in heavy-surf conditions, when buried by sand dwarfed and denuded; lower intertidal to 20 m deep.

Highborne Cay distribution: only present at Site #10 both on the reef flat and in the stromatolite zone; generally a species commonly occurring throughout the Bahamas.





Highborne Cay US# 209062



1. Schematic longitudinal section of branchlet showing tube-like cylinder of surface cells.
2. Transverse section of mature branch.
3. Transverse section of branchlet.

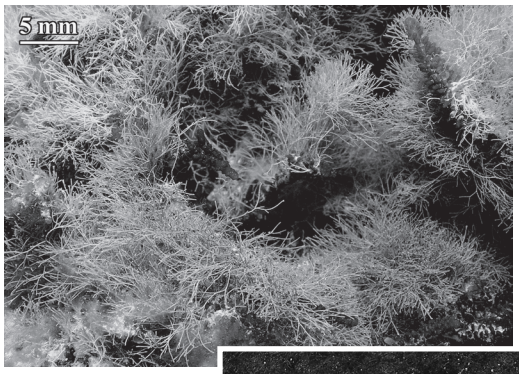
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

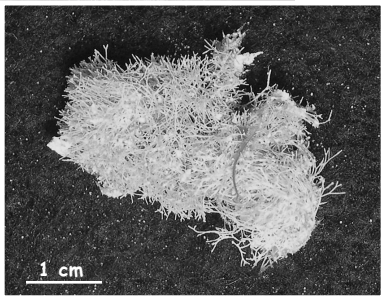
Jania capillacea Harvey 1853: 84–85

Thallus: delicate, as tightly packed clumps or small cushions, 4–10 mm high, rose-red; branching widely dichotomous (angled 30°–45°). *Branches* cylindrical, 45–100 µm diam., often recurved; apices pointed to occasionally rounded. *Segments* calcified, 300–600 µm long; medullary cells tiered, parallel, elongated, 26–42 µm long; cortical cells roundly rectangular, 5–8 µm diam., densely pigmented. *Joints* flexible, uncalcified; occurring at base of branches and at regular intervals between branches; cells elongated, 42–77 µm long, parallel, in one tier; cortex lacking. *Holdfast* crust-like or disc-like. *Tetrasporangial conceptacles* solitary, vase-shaped, with central pore, formed in swollen apical segments, eventually initiating new branchlets; tetrasporangia oval, zonately divided.

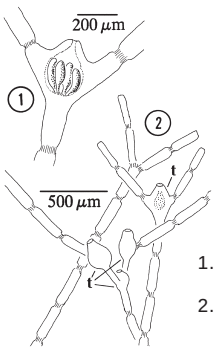
Common: epiphytic on other marine plants, in calm waters; to 15 m deep.

Highborne Cay distribution: on the reef crest or reef flat.





Highborne Cay US# 209067



1. Longitudinal section of tetrasporangial conceptacle containing tetrasporangia.
2. Branching pattern with tetrasporangial segments (t) often initiating branchlets.

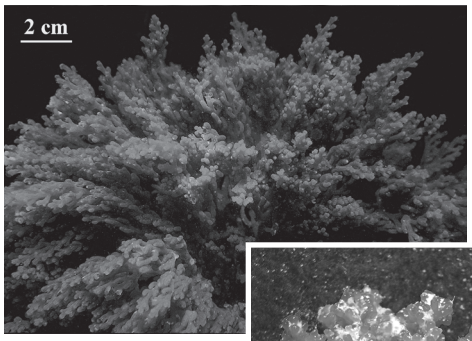
Phylum Rhodophyta Class Florideophyceae Order Corallinales Family Corallinaceae

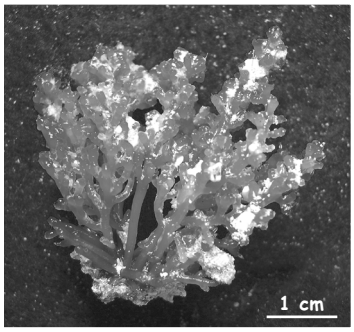
Laurencia obtusa (Hudson) J.V. Lamouroux 1813: 130

Thallus: compact, often clumped, 8–15(–26) cm high, dark to olive-green with maroon tips; branching alternate, sparse below, numerous and crowded above. *Branches* cylindrical, proximally 0.7–1.8 mm diam. *Branchlets* generally spiral to occasionally opposite, 0.5–0.8 mm diam., 1–2 mm long; apices tufted with fine deciduous filaments forming in shallow terminal depression. *Surface cells* 24–30 µm diam., somewhat spherical, heavily pigmented, with distinctive colorless spherical bodies ("corps en cerise") present in live or recently preserved specimens only; medullary cells large, colorless; apical cell sunken in shallow terminal depression. *Tetrasporangia* tetrahedrally divided.

Common: in shallow wave-dashed habitats or areas of strong currents; to 8 m deep.

Highborne Cay distribution: extremely common on the reef crest and reef flat in shallow water near low tide mark, found only once in the stromatolite zone.





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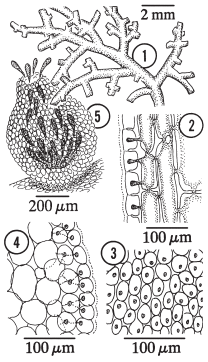


1. Typical branch.
2. Longitudinal section of cortex.
3. Surface view showing surface cells with distinctive microscopic spots.
4. Transverse section of branch cortex.
5. Cystocarp releasing carpospores.

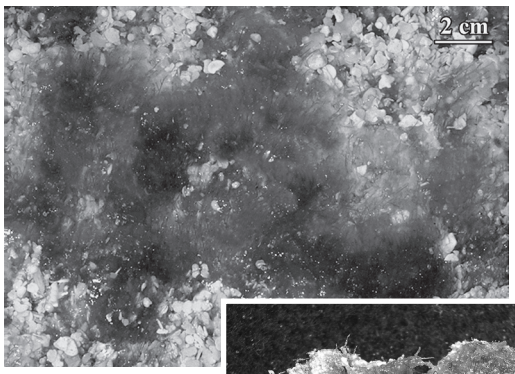
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

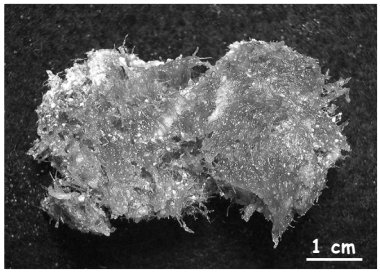
Lophosiphonia obscura (C. Agardh) Falkenberg in Schmitz & Falkenberg 1897: 46

Thallus: as filamentous turfs, to 1.5(–2) cm high, of indeterminate area, red-brown; prostrate branching irregular; branching of erect filaments infrequent, lateral. Prostrate axis to 140 µm diam., bearing single upright every (4–)8–10 or more joints; apices upcurved. Erect branchlets to 100 µm diam., tapering at apices; mature segments slightly longer than wide; pericentral cells (6–)9– 13, thick-walled; apices downturned. Apical filaments crested on outer margin, slightly alternately o set on every segment when mature, soon deciduous, pseudodichotomously branched; basal cell often spherical. Rhizoids single-celled, 30–50 µm diam., as extension of pericentral cell, partitioning cell wall absent, terminating in finger-like attachment pad.

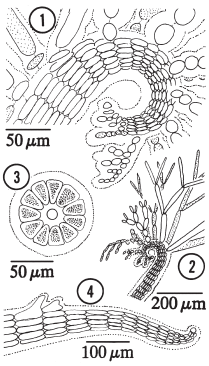
Uncommon: inconspicuous, on hard surfaces, in calm protected areas; lower intertidal to 2 m deep.

Highborne Cay distribution: only recorded from the thrombolite zone adjacent to the beach in very shallow water.





Highborne Cay US# 209055



1. Downturned apex with apical filaments slightly o set alternately at every segment.
2. Downturned apex showing dichoto-mously branching filaments.
3. Transverse section of erect filament.
4. Apex of prostrate filament.

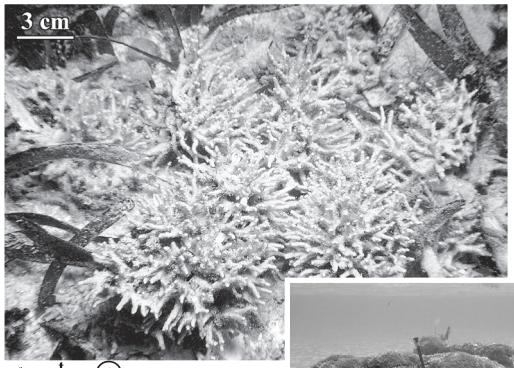
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

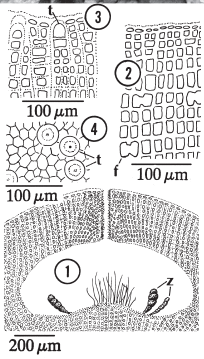
Neogoniolithon strictum (Foslie) Setchell & L.R. Mason 1943: 92

Thallus: stony, heavily calcified, forming brittle clumps or nodules, to 14(–20) cm diam., chalky rose-pink; branching abundant, irregular, often cervicorn. *Branches* cylindrical, rigid, to 1.5 mm diam., tapered, roughened with reproductive structures when fertile. *Cells* of surface layer lens-shaped to oval, 15–20 µm diam., synchronous sloughing of surface layer common; subsurface stratum of many layers, gently curving to medulla, lateral pit connections absent, lateral fusions common; medullary cells thick-walled, rectangular, tiered, 15–20 µm wide, 20–40 µm thick. *Trichocytes* large, thick-walled, solitary or in vertical clusters, scattered in surface layer.

Common: often lying free in shallow seagrass beds on reef flats, occasionally fusing to create massive reef structures on turbulent reefs; to 3 m deep.

Highborne Cay distribution: dominant alga of the reef crest zone.





1. Transverse section of tetrasporangial conceptacle with zonately divided tetrasporangia (z).
2. Transverse section showing several lateral fusions (f).
3. Transverse section showing cell arrangement with trichocytes (t).
4. Surface view of cells and large trichocytes (t).

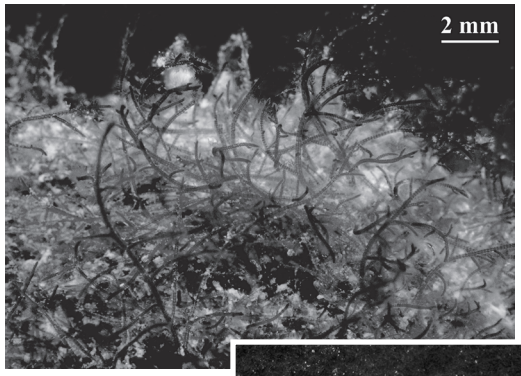
Phylum Rhodophyta Class Florideophyceae Order Corallinales Family Corallinaceae

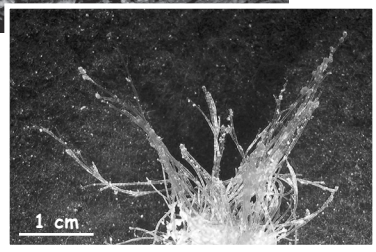
Neosiphonia sphaerocarpa M.S. Kim & I.K. Lee 1999: 280

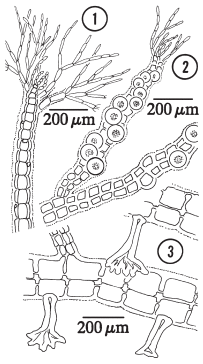
Thallus: filamentous, fine, tufted, bushy, to 2 cm high, light brown to rose-red to maroon; branching alternate to somewhat dichotomous. *Prostrate axis* 100–210 µm diam. *Erect axis* 60–150 µm diam., of four pericentral cells; lateral branches 60–125 µm diam., often basally constricted, replacing apical filaments; cortication absent; filament scar cells common; segments 0.5–1.5(–3.0) diameters long. *Apical filaments* deciduous, rarely to 800 µm long. *Holdfast* initially disc-like, later attached by unicellular rhizoids; rhizoids separated from parent cell by wall, distal on pericentral cells, commonly attaching to nearby branches creating mesh-like net which traps sand. *Tetrasporangia* spherical, 50–60 µm diam., tetrahedrally divided, as swollen spiral series in outer branchlets.

Common: inconspicuous, epiphytic on larger plants or on hard surfaces, in wave-exposed areas; lower intertidal to 8 m deep.

Highborne Cay distribution: only occurring in the stromatolite and thrombolite zones.







1. Apex of erect axis.
2. Axis with spirally arranged tetrasporangia.
3. Prostrate axes showing commonly occurring rhizoidal attachment to adjacent axis.

Highborne Cay US# 209053

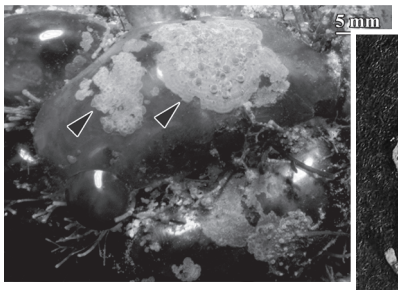
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Rhodomelaceae

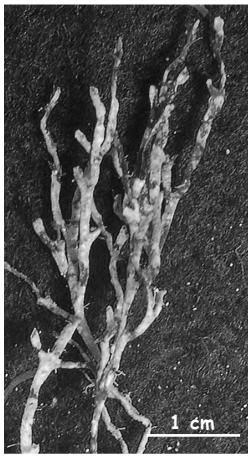
Pneophyllum fragile Kützing 1843: 385

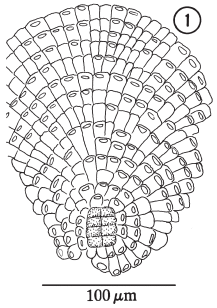
Thallus: prostrate, fragile, forming thin calcified crusts, 0.5–2.0 mm diam., 15–30 µm thick, with older thalli often merging together, rose, pale pink to white. *Cells* square to rectangular, 5–10 µm wide, 5–20 µm long, radiating from original eight-celled structure; one cell thick, older crusts up to four cells thick; surface cells 6.5–12.0 µm wide, 3.5–11.5 µm long, 17–20 µm thick; cap cells wider than long, 3.4–8.0 µm wide, 1.5–3.5 µm long, 2–3 µm thick, at distal ends of surface cells. *Trichocytes* intercalary, rare, 8.5–13.5 µm diam., 11–16 µm long. *Conceptacles* flat or slightly raised, with central pore; cystocarpic and sporangial conceptacles (60–)150–250(–300) µm diam.; spermatangial conceptacles (13–)7 5–100 µm diam.

Common: inconspicuous, epiphytic on macroalgae or seagrasses; to 10 m deep.

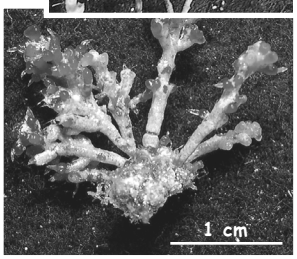
Distribution: common epiphyte on most species occurring on the reef crest and reef flat.







1. Organization of cells from original eight-celled cluster (shaded).



Highborne Cay US# 209071

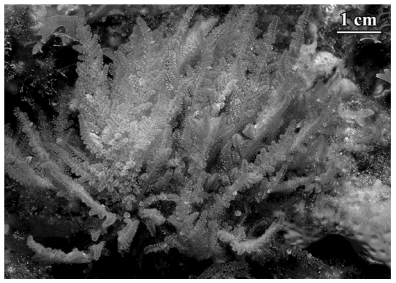
Phylum Rhodophyta Class Florideophyceae Order Corallinales Family Corallinaceae

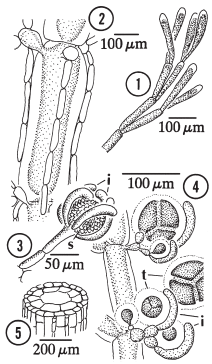
Wrangelia penicillata (C. Agardh) C. Agardh 1828: 138

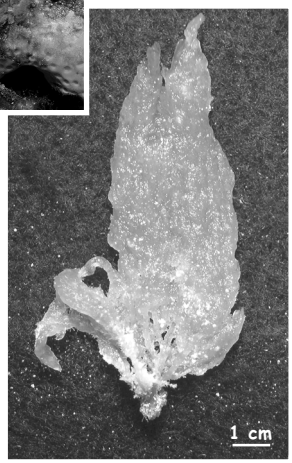
Thallus: finely branched, bush-like, to 8 cm high, light pink; main branching alternate or irregular; secondary branching alternate at every segment, mainly in one plane. *Main filaments* cylindrical, 180–200 µm diam., completely corticated proximally; cells to 800 µm long. *Branchlets* soft, thin, in whorls at joints, dichotomously divided; apical cells blunt tipped, often deciduous. Rhizoids clustered, finely branched. *Tetrasporangia* abundant, spherical, 75–100 µm diam., tetrahedrally divided, at joints near branchlet tips, loosely clasped by short, slender, involucral filaments. *Spermatangia* similar to above but clustered, 55–60 µm diam. *Cystocarps* to 400 µm diam., terminal on short branchlets, surrounded by many short, slender, incurved filaments.

Common: generally epiphytic on seagrasses or other larger algae; to 15 m deep.

Highborne Cay Distribution: on the reef crest, reef flat and stromatolite zones.







Highborne Cay US# 209061

1. Branchlet apices.
2. Main branch segment showing descending corticating filaments.
3. Spermatangial cluster (s) loosely surrounded by involucral cells (i).
4. Tetrasporangia (t) clasped by solitary involucral filaments (i).
5. Transverse section of main branch in oblique view.

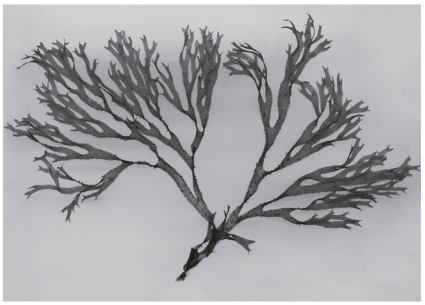
Phylum Rhodophyta Class Florideophyceae Order Ceramiales Family Ceramiaceae

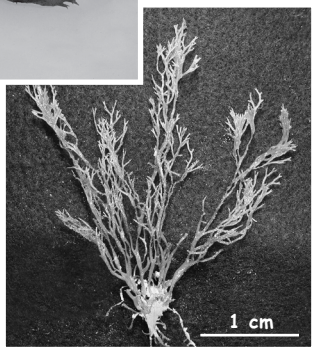
Dictyota cervicornis Kützing 1859: 11, pl. 24, fig. 2

Thallus: bushy, to 20 cm high, olive-brown; branching dichotomously asymmetrical, cervicorn. *Branches* 1.0–2.5 mm wide (very old thalli with proliferating blades to 3 mm wide); 180–220 µm thick, 10–25 medullary cells wide, often twisted or spiral, small surface hooks often present in Indian River Lagoon specimens; apices pointed. *Medullary cells* in one layer, rectangular, 140–180 µm thick, arranged in longitudinal rows. *Surface cells* rectangular, 15–20 µm thick. *Surface hairs* in tufts, scattered near central axis. *Holdfast* fibrous, mat-like; marginal rhizoids common. *Sporangia* scattered, solitary, to 120 µm dian., surrounded by paraphyses. *Oogonial sori* scattered.

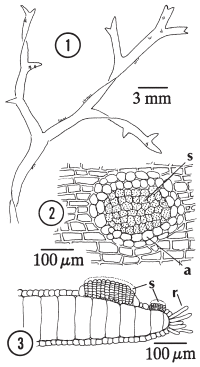
Common: attached to rocks, shell fragments or large plants in sandy shallow areas; to 3 m deep.

Highborne Cay distributin: common on the reef crest and reef flat, occasionally in the stromatolite zone.





Highborne Cay US# 209065



1. Habit of blade.
2. Surface view of antheridial sorus (s) surrounded by paraphyses (a).
3. Transverse section of blade margin showing antheridial sori (s) and marginal rhizoids (r).

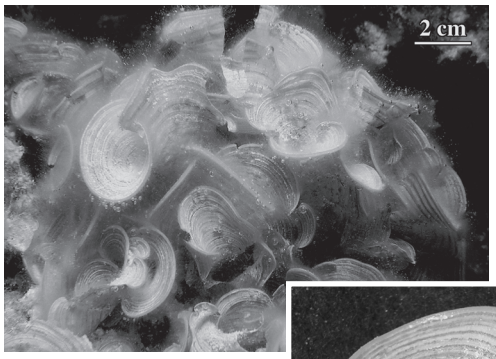
Phylum Heterokontophyta Class Phaeophyceae Order Dictyotales Family Dictyotaceae

Padina haitiensis Thivy in W.R. Taylor 1960: 235, 632, pl. 75, fig. 1

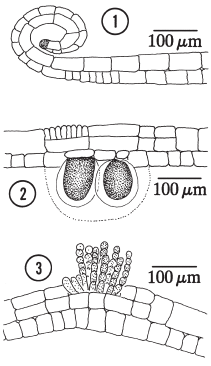
Thallus: in leaf-like clusters, ru ed, to 6 cm high, upper surface chalky white alternating with light yellow-brown bands, lower surface less calcified with darker brown bands. *Blades* fan-shaped, to 8 cm broad, concentrically zoned, substantially calcified; to 65 µm thick distally, 105 µm thick proximally, generally of two cell layers, three cell layers only where surface hairs are produced or reproductive structures are formed; dorsal cells rectangular, 30–80 µm wide, to 60 µm thick; ventral cells smaller, rectangular, 20–60(–80) µm wide, to 30 µm thick; margins inrolled. *Surface hairs* to 15 µm diam., 130 µm long, in concentric zones. *Rhizoidal base* matted. *Reproductive sori* alternating with bands of sterile hairs.

Rarely reported: in the Bahamas, often misidentified as *Padina sanctae-crucis*, on hard substrates such as beach rock; lower intertidal to 3 m deep.

Highborne Cay distribution: generally on the reef crest and reef flat, only collected once from the stromatolite zone.



Highborne Cay US# 209068



1. Longitudinal inrolled margin of blade.
2. Longitudinal section of blade with oogonial sorus.
3. Longitudinal section of blade with immature hairs.

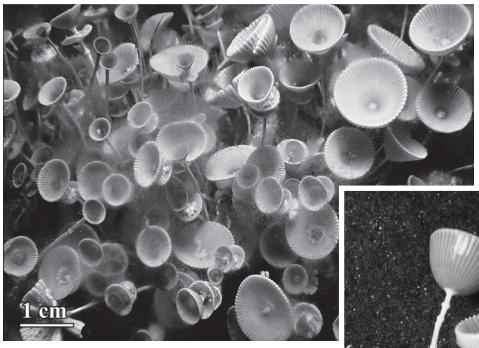
Phylum Heterokontophyta Class Phaeophyceae Order Dictyotales Family Dictyotaceae

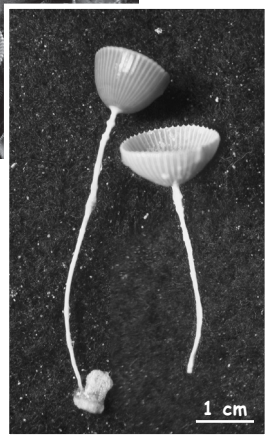
Acetabularia crenulata J.V. Lamouroux 1816: 249, pl. 8, fig. 1

Thallus: solitary or in clusters, parasol-shaped, moderately calcified, 2–8 cm high, white-green. *Axes* 200–300 µm diam., heavily calcified, occasionally bearing several whorls of filaments; filaments colorless, pale green when young, rapidly deciduous. *Discs* one or more in succession, flat or cup-shaped, 12–20 mm diam., of 30–80 rays; outer margin of ray with centered tooth or spine; corona superior (at base of rays) of short inconspicuous projections, with rounded or slightly lobed apices and two exceedingly faint hair scars; corona inferior (underside, base of rays) of short inconspicuous projections with forked apices. *Gametangia* are mature rays, producing up to 500 cysts per ray; cysts spherical, 65–80 µm diam.

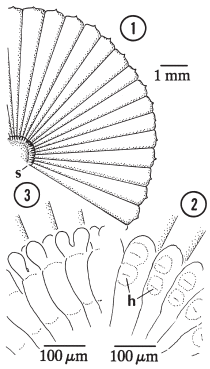
Common: growing on mangrove prop roots, rocks, shells or coral fragments in protected areas; to 3 m deep.

Highborne Cay Distribution: mainly found on the reef flat, only found once in the stromatolite zone.





Highborne Cay US# 209054



1. Disk of rays with corona superior (s) at base.
2. Corona superior with two hair scars (h).
3. Corona inferior.

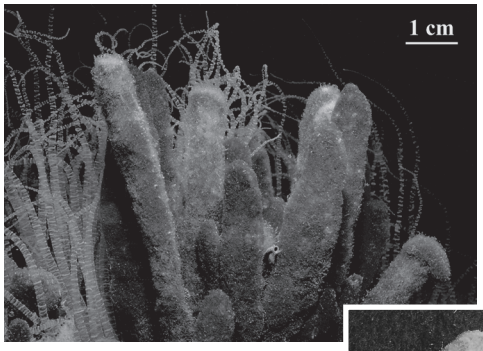
Phylum Chlorophyta Class Ulvophyceae Order Dasycladales Family Polyphysaceae

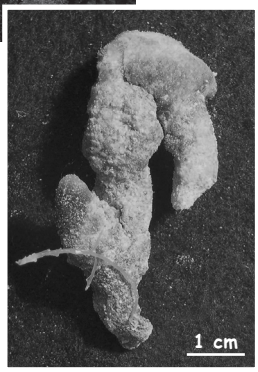
Avrainvillea digitata D.S. Littler & M.M. Littler 1992: 379, fig. 3

Thallus: gregarious, finger-like, occasionally club-shaped or pointed, to 6 cm high, 1.5 cm diam., dull dark brown-green. *Blades* loosely woven, spongy; zonation absent; interior and surface siphons strong-walled, 40–55 µm (to 75 µm at growing margins) diam., slightly moniliform (bead-like), apices bulbous or rounded. *Stipe* absent. *Rhizoidal mass* large, prostrate.

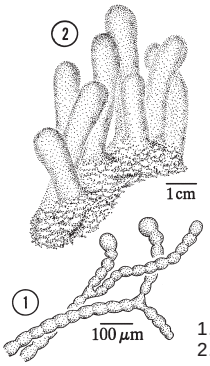
Common: on carbonate sediments or mangrove peat, growing as large mats in shallow waters (less than 1 m), often interspersed among *Thalassia testudinum* or at the edges of mangrove islands; deeper forms (greater than 3 m) have narrow uprights with bluntly pointed apices, Puerto Rican specimens have more club-shaped uprights; to 5 m deep.

Highborne Cay Distribution: only encountered on the reef flat.





Highborne Cay US# 209059



1. Surface siphons of blade.
2. Habit.

Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Udoteaceae

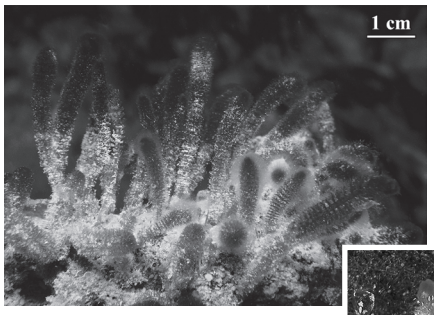
Batophora occidentalis var. *largoensis*

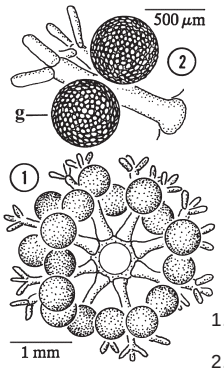
(J.S. Price & S. Baker) S. Berger & Kaever ex M.J. Wynne 1998: 108

Thallus: fuzzy, soft, cylindrical, solitary or most-often gregarious, 4–6 mm diam., 3–4(–6) cm high, green to brown-green, releasing bright yellow stain when crushed. *Main axis* of loosely whorled branchlets every 1 mm or less; whorls of 8–13 branchlets; branchlets dichotomously forked 1–7 times, initial branch to 400 µm diam., dw eciduous on older fertile thalli, lower 0.5 cm of axis often naked. *Gametangia* spherical, 500–800 µm diam., bright yellow-green, clustered near base of branchlet; reproductive bodies oval to oblong, 40–60 µm diam.

Common: in lagoons, especially around mangroves, also in brackish-water habitats, often on rubble or dead seashells; to 8 m deep.

Highborne Cay Distribution: common and most abundant species, occurring throughout the study area. A dominant on stromatolites and thrombolites.





Highborne Cay US# 209066

1. Transverse section of gametangial thallus.
2. Gametangia (g) on branchlet.

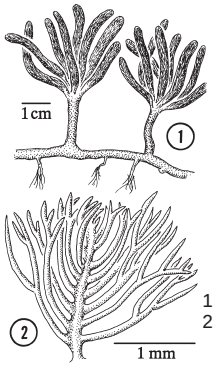
Phylum Chlorophyta Class Ulvophyceae Order Dasycladales Family Dasycladaceae

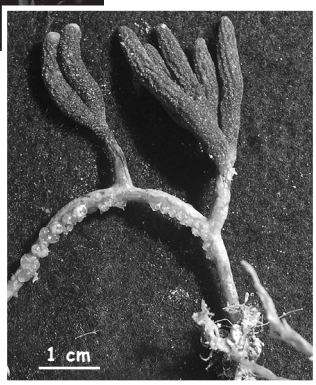
Caulerpa paspaloides var. compressa (Weber-van Bosse) M. Howe 1920: 609

Thallus: erect, to 8 cm high; summit branches 3–5 mm diam., 3–4 cm long, dark green, densely covered with fine branchlets not set in vertical rows, cylindrical in configuration when viewed from tip. *Branchlets* cylindrical, 80–100 µm diam., 1–2 mm long, angling 75–90° from axes, sti ; branching opposite to alternate in two rows opposite one another; ultimate branchlets alternate or irregular, angling 45° or more from one another. *Stalk* naked, green, generally unbranched, to 4 mm diam., to 2 cm long; summit whorled with 3–12 branches. *Stolons* creeping, to 4 mm diam.; rhizoids numerous, white-yellow, stalked, to 2 mm diam. at stolons, branching to slender apices.

Uncommon: in shallow seagrass communities; to 12 m deep.

Highborne Cay Distribution: found only once on the reef crest in the study area, but a species commonly occurring the Bahamas.





Highborne Cay US# 209063

1. Habit.
2. Branchlets showing opposite branching with alternate or irregular ultimate branchlets.

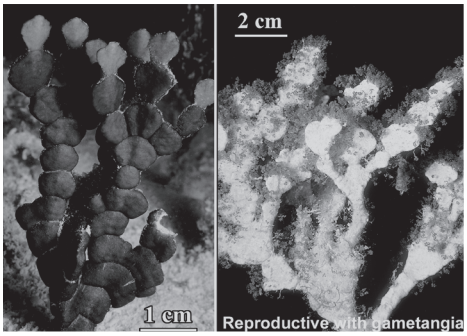
Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Caulerpaceae

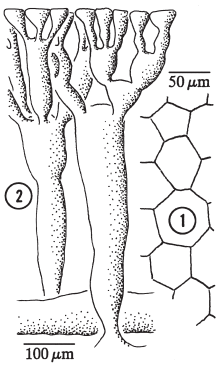
Halimeda incrassata (J. Ellis) J.V. Lamouroux 1816: 307

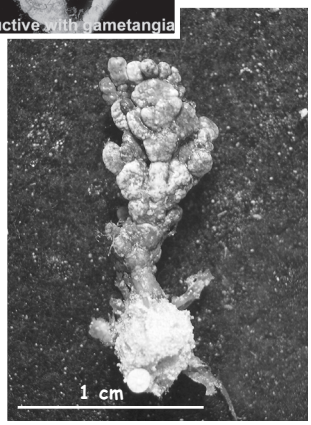
Thallus: erect, to 25 cm high, light to dark green; branching somewhat dichotomous, initial branching in one plane. *Segments* heavily calcified, hard, brittle, disc-like, oval to kidney-shaped, to 14 mm wide, 10 mm long, 0.7–1.5 mm thick, often ribbed and/or lobed; basal segments fused. *Utricles* in 3–5 layers; surface utricles 34–90(–105) µm diam., 40–125 µm long, 2–4 supported by each subsurface utricle; subsurface utricles oval, swollen, 23–90 µm diam., 30–115 µm long. *Joint siphons* uniting as single group, uncalcified. *Rhizoidal mass* bulbous. *Sporangia* spherical to oval, bright green, 200–380 µm diam. on dichotomously forked stalk, densely clustered at margins of fertile segments.

Common: associated with seagrasses or on shallow sand flats; to 12(–65) m deep.

Highborne Cay Distribution: common on the reef flat.







Highborne Cay US# 209051

1. Surface view.
2. Surface utricles in longitudinal section.

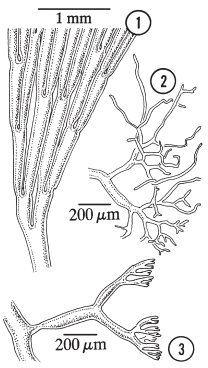
Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Halimedaceae

Rhipocephalus phoenix (J. Ellis & Solander) Kützing 1843: 311

Thallus: lightly calcified, to 10 cm high, dark green. *Cap* oval, of small blades in close proximity to main stalk. *Blades* 2–3 cm long, concentric, flattened, symmetrical; siphons cylindrical, parallel, fused laterally, 200–250 µm diam. proximally, 50–100 µm diam. distally; dichotomies equal distances from base, lower one or two dichotomies not constricted after decalcification, others evenly constricted. *Stipe* cylindrical, 3–5 mm diam., 2–5 cm long; cortical appendages tightly packed, repeatedly branched with blunt, finger-like apices. *Rhizoidal mass* compact.

Common: on rock or sand, often among seagrasses; to 20 m deep.

Highborne Cay Distribution: only found on the reef crest.



Highborne Cay US# 209057

1. Siphon of blade base showing basal dichotomy lacking deep constriction.
2. Lower lateral appendage initiating rhizoids.
3. Lateral appendage of upper stipe cortex.

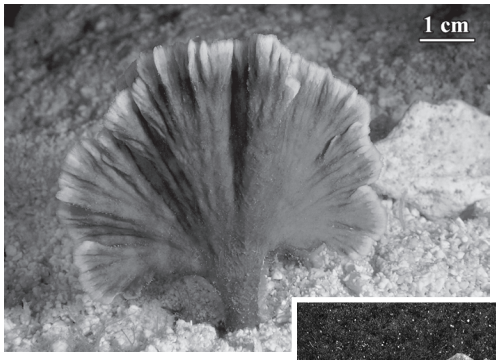
Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Udoteaceae

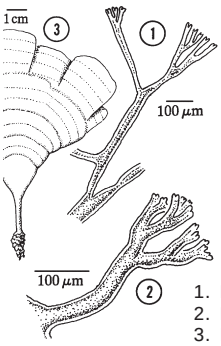
Udotea flabellum (J. Ellis & Solander) M. Howe 1904: 94

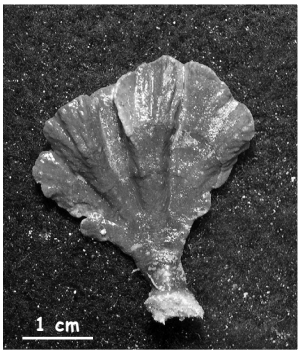
Thallus: fan-shaped, moderately calcified, solitary, to 30 cm high, pale green to dark green. *Blade* variable, undivided to highly divided, size variable, 0.8–1.5 mm thick, leathery, corticated; zonation distinct; siphons 30–50 µm diam., constrictions above infrequent dichotomies absent or slightly uneven; lateral appendages irregularly spaced, long stemmed, dichotomously branched with crowded, short, rounded apices, apices appear shrunken or flat when dried. *Stipe* cylindrical below, flattened above, 5–7 mm diam., 2–4 cm long, unbranched; surface unmodified in transition to blade; siphons 20–80 µm diam.; lateral appendages similar to blade. *Rhizoidal mass* bulbous to elongated.

Common: widespread, occurring in sandy areas or seagrass beds; to 10 m deep.

Highborne Cay Distribution: only in the stromatolite zone.







Highborne Cay US# 209058

1. Blade siphon with lateral appendages.
2. Blade lateral appendage.
3. Habit.

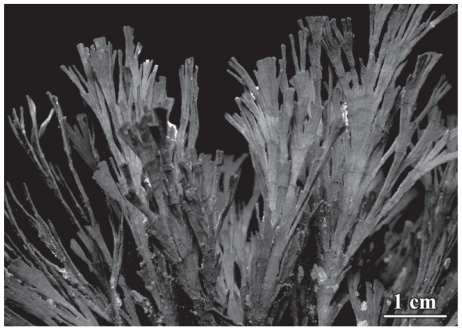
Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Udoteaceae

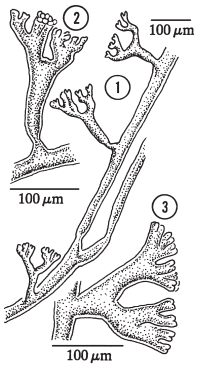
Udotea norrisii D.S. Littler & M.M. Littler 1990a: 235, fig. 17

Thallus: coarse, bushy, heavily calcified, to 11 cm high, gray-green. *Blades* irregularly dissected into long linear segments, 1–3 mm wide, 1–2 mm thick, corticated; zonation distinct; siphons 40–80 µm diam., unevenly constricted above dichotomies; lateral appendages widely spaced, irregular, long-stemmed, apices flattened or rounded. *Stipe* often branched, 2–3 mm diam., 1–2 cm long, surface unmodified in transition to blade; lateral appendages repeatedly branched with flattened, blunt apices. *Rhizoidal mass* bulbous, tangled.

Rare: on sand plains or sandy patches around coral pinnacles; 3–30 m deep.

Highborne Cay Distribution: only in the stromatolite zone.





Highborne Cay US# 209069

1. Blade siphon with lateral appendages.
2. Blade lateral appendage.
3. Stipe lateral appendage.

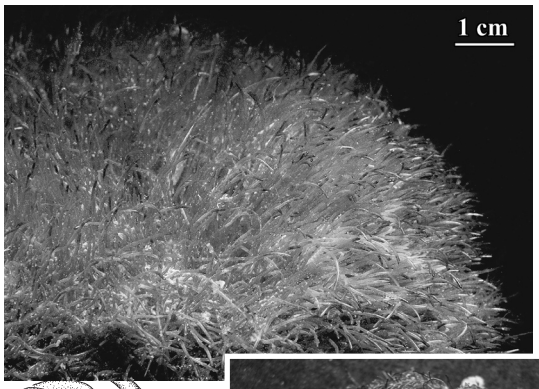
Phylum Chlorophyta Class Bryopsidophyceae Order Bryopsidales Family Udoteaceae

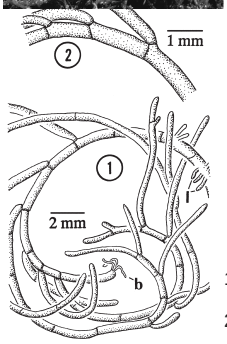
Valoniopsis pachynema (G. Martens) Børgesen 1934: 10, figs. 1, 2

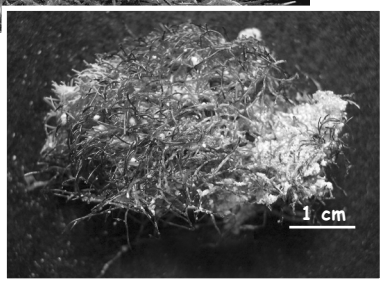
Thallus: filamentous, coarse, stiff, loose, forming pad-like cushions, to 10 cm diam., 5 cm thick, glossy green; branching generally unilateral. *Filament cells* cylindrical, (0.3–)0.5–1.0 mm diam., 2–10 or more diameters long. *Branchlets* cylindrical, with no or little taper, originating from upper ends of parent cells; wall formation basal to main filament. *Rhizoids* short, sparse; older branches often secondarily attached by short lateral rhizoids.

Common: forming sti masses or clumps in calm shallow habitats; to 5 m deep.

Highborne Cay Distribution: on the reef crest, reef flat and thrombolite zones, but not present in the stromatolite zone.







Highborne Cay US# 209064

1. Habit showing basal rhizoids (b) and lateral rhizoids (l).
2. Unilateral branching pattern.

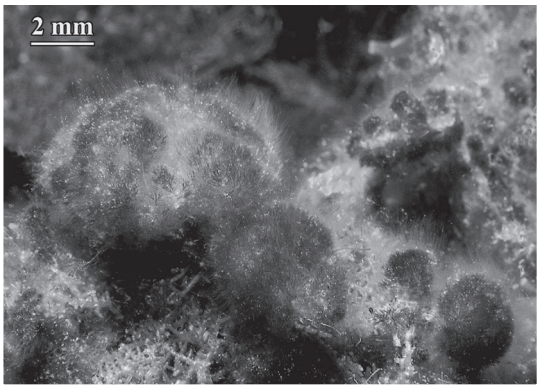
Phylum Chlorophyta Class Ulvophyceae Order Cladophorales Family Anadyomenaceae

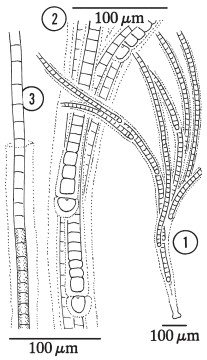
Dichothrix fucicola (Kützing) Bornet & Flahault 1886: 379

Thallus: forming small erect tufts or soft fuzzy patches, to 8 mm high, lavender-red to dark olive-green. *Filaments* 20–40 µm diam., forming false branching. *Trichomes* one per sheath, merging with age, tapering from base, ending in a long hair. *Cells* 9–13 µm diam., swollen base 13–22 µm diam., 10–60 µm long; not constricted at cross walls. *Sheaths* clear, colorless or yellowish, striated, 8–20 µm thick. *Heterocytes* spherical, cone-shaped to elongated, 20–25 µm diam., 20–60 µm long, basal or intercalary.

Common: generally epiphytic on other marine plants, forming small pads or fuzzy clumps; intertidal to 2 m deep.

Highborne Cay Distribution: found intermixed with other species in all zones.





1. Habit.
2. Typical filaments showing trichomes with basal heterocytes.
3. Filament with sheath at apex.

Phylum Cyanophyta Class Cyanophyceae Order Nostocales Family Rivulariaceae

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