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Original Research Article

New records of green algae (Chlorophyta) for the Caribbean coast of Costa Rica

[*1]Rubén Cabrera, [2]Jhoana Díaz-Larrea, [3]Yusimi Alfonso and [2]Laura Georgina Núñez-García

[1]Gabinete de Arqueología, Oficina del Historiador de la Ciudad, Habana Vieja, Cuba.

[2]Departamento de Hidrobiología, Universidad AutónomaMetropolitana-Iztapalapa. Av. San Rafael Atlixco 186, Col. Vicentina. 09340, Ciudad de México.

[3]AcuarioNacional de Cuba, Departamento de Colecciones Marinas, Cuba.

***Corresponding Author's E-mail: cabreraalgas@gmail.com**

Abstract

The Caribbean coast of Costa Rica is an area of significant floristic diversity. Five new records of the occurrence of marine green algae (Chlorophyta) are reported for this region, namely, *Ulva rotundata*, *Derbesia vaucheriformis*, *Avrainvillea asarifolia*, *Halimeda pumila* and *Penicillus capitatus* f. *laxus*. Each taxon is described, and their principal diagnostic characters are contrasted with those of other members of the genus present in the area of study. With the exception of the *Avrainvillea asarifolia*, all the species reported here are new occurrences for the Central American region.

Keywords: Central America, distribution, green algae, new records

INTRODUCTION

The Chlorophyta are distributed in the intertidal and the subtidal zones of the world's oceans, and they occur from tropical to temperate zones (Lüning, 1990). The ranges of bathymetric distribution are also very variable, with depths having been recorded to 120 m (Ballantine and Aponte, 2003). According to Bernecker (2009), the greatest depth for the occurrence of green algae on the Atlantic coast of Costa Rica does not exceed 70 m.

The zone of the southern Caribbean coast, where this research was carried out, is characterized by different biotopes, emphasizing the coral reef community and the seagrass community in the subtidal zone. The latter one is dominated by the seagrass *Thalassia testudinum* and conspicuous members of the genus *Halimeda*.

The biotope of the rocky intertidal zone is prominent especially in the region of Puerto Limon, which is one of the less studied areas (Cabrera et al. 2019). The most abundant genus in this area is *Chaetomorpha*, with coverage values remaining constant during all the year, in comparison with *Ulva*, that has remarkable sporadic peaks of abundance (Cabrera, unpublished results).

The most conspicuous genera of Chlorophyta on the basis of their diversity in the Caribbean of Costa Rica are species of the genera *Ulva*, *Caulerpa* and *Cladophora*. The objective of the present work is to report the presence of five taxa of green macroalgae (Chlorophyta) previously unknown for the Caribbean coast of Costa Rica, as well as presenting data on their distribution.

MATERIALS AND METHODS

Collection zone

The biological materials were collected at two localities of the southern Caribbean coast of Costa Rica (Fig. 1). To take the samples, we used frames of 25 x 25 cm to determine the extent of coverage. The samples were taken from the substrate with the assistance of spatulas, or they were found as epiphytes on the macroalgae that were previously removed from the substrate.

Methodology

We removed the excess particulate matter, such as sand and sediments, from the algal collections, which were

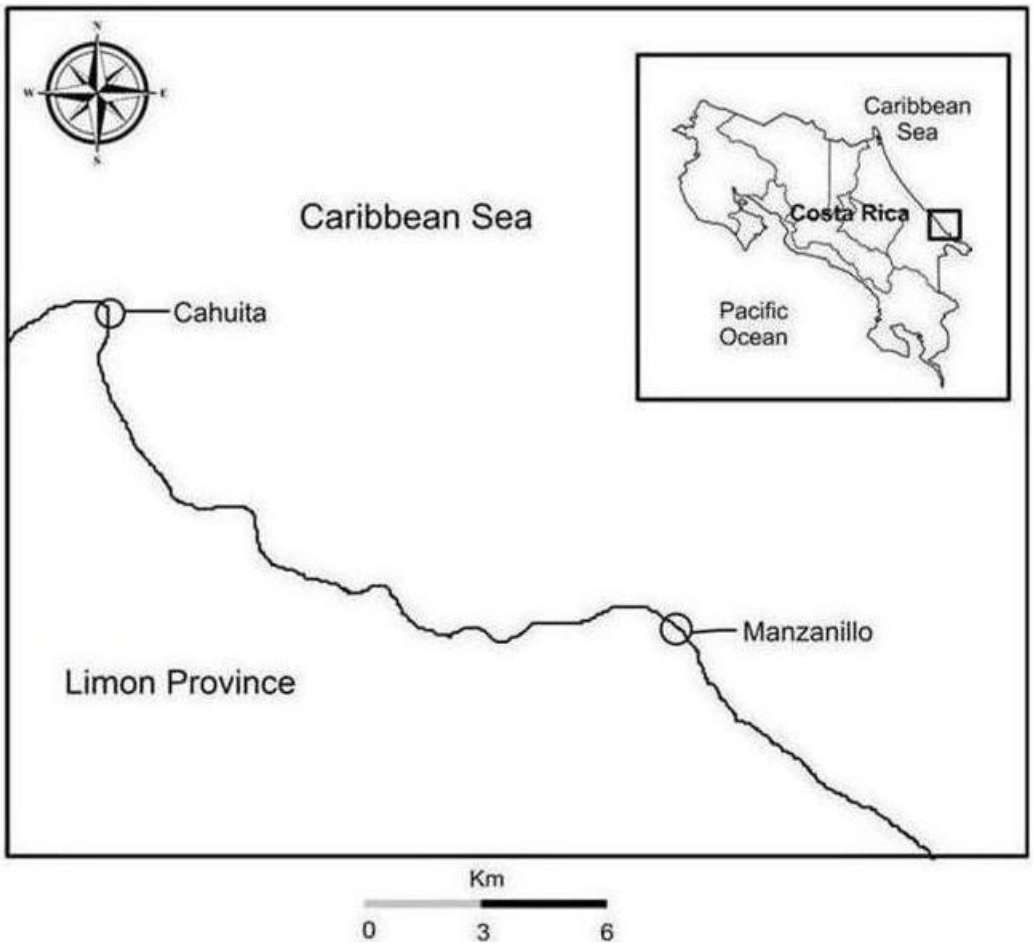

Figure 1. Sampling sites along the Caribbean coast of Costa Rica, Central America.

then fixed in alcohol and later pressed as herbarium specimens.

The calcified samples were decalcified by placing them in diluted hydrochloric acid (20%). For the non-calcified specimens, microscopic slides were prepared by teasing apart the strands of the examined material with the assistance of dissecting needles and razor blades.

We used a Leica © - Zoom 2000 stereoscopic microscope and an Olympus © - CX compound light microscope.

Morphological identification

For the identification of taxa at the infrageneric level, we observed aspects of the external and internal morphology of the vegetative and reproductive structures, where they are present. We consulted the original descriptions as well as the publications of Taylor (1960), Littler and Littler (1992, 2000), and Littler et al. (2008). For obtaining images of the identified algae, we used *a lucida camera* attached to the microscope.

For the taxonomic classification, we followed Wynne (2017), while information on the type localities and the references to the original descriptions were obtained from the site AlgaeBase (Guiry and Guiry, 2020).

Voucher herbarium specimens were deposited in the University of Michigan Herbarium (MICH) and in the herbarium Dr. Luis A. Fournier Origgi of the Universidad de Costa Rica, San Jose (USJ).

We cite the first references that we have of each genus of interest, and we contrast their principal characters diagnostics with the species that are being reported. Abbreviations of herbaria follow *Index Herbariorum* (Thiers, continuously updated).

RESULTS

PHYLUM **CHLOROPHYTA**

FAMILY **ULVACEAE**
Ulva rotundata Bliding

Fig. 2.1-2

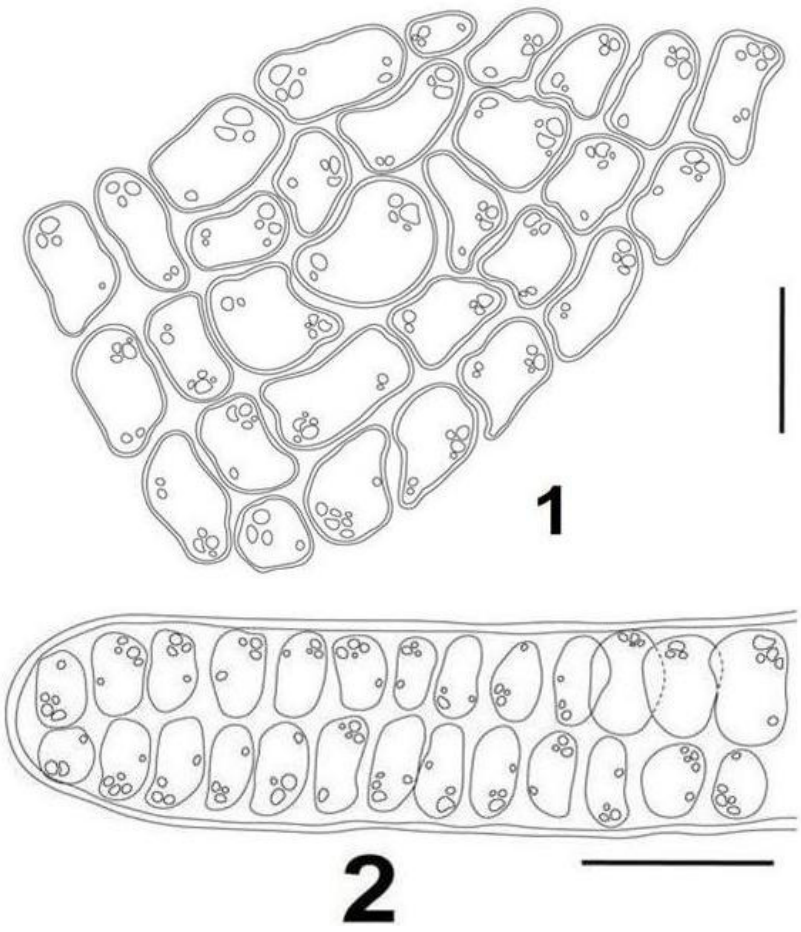

Figure 2. 1-2. ***Ulva rotundata***, 1 surface cells of blade containing gametes, 2 transverse section of blade margin, scale bars [1] = 40 µm, scale bars [2] = 25 µm

Shiny green thalli formed of very thin sheets with a uniform aspect or very wavy; the margins are rounded, lobed and without microscopic teeth. Cells in surface view are polygonal, large, 30-38 (-45) µm in their largest dimension, and they are not organized in of thallus. In a transverse section, the thallus shows two layers of cells. The plant is distinguished easily from the closely related species of *Ulva* by the same shape of their basal disk. In the lower part is a well-developed stipe, and it usually has longitudinal ridges out of which new disks are developed, which can become joined with the original disk. We observed fertile stages in the examined material.

Type locality: Naples, Italy. Bliding (1969: 566).

Examined materials: Limón Province: National Cahuita Park, on steel pier and over rocks (9˚4'19.0", 82˚27'37.9"), 0.5 m of depth, collected by RC (260), May 27, 2019 (MICH 1210825).

Distribution in western Atlantic: Wynne (2017), Central America, southern Caribbean coast of Costa Rica.

Comments

Ulva includes foliose and tubular species (Hayden et al. 2003), while *Ulva rotundata* is a species that has a laminar thallus, similar to *Ulva lactuca* Linn., which now includes *U. fasciata* Delile as a taxonomic synonym (Hughey et al. 2019).

The shape and color of the thalli of *Ulva lactuca* make it clearly distinct from *U. rotundata.* Bliding (1969) distinguished this species largely on the basis of the shape of the superficial cells and the reproductive stages, attributes that make it clearly different from *Ulva lactuca* and other species of *Ulva* occurring on the Caribbean coast of Costa Rica.

FAMILY **DERBESIACEAE**

Derbesia vaucheriformis (Harvey) J. Agardh
Fig. 2.3-4

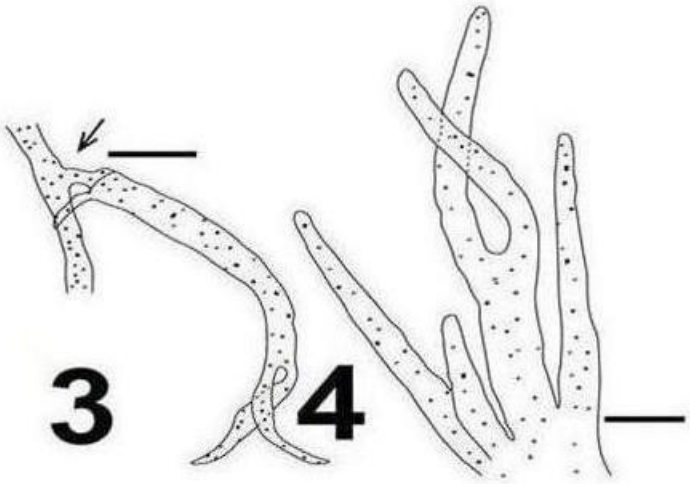

Figure 2. 3-4. ***Derbesia vaucheriformis***. 3 double cell wall at junction of parent siphon, 4 dichotomous branching near siphons apex, scale bars [3] = 70 µm, scale bars [4] = 50 µm.

Thalli forming dense strands of tightly arranged siphonous filaments, 3 to 5 cm in height and the individual siphons 25 - 50 µm in diameter; with a dark green color; limited ramifications, dichotomous, rarely lateral. Walls sometimes present in pairs across the segments above a fork, about 30 - 35 µm apart. Holdfast inconspicuous, of tightly knit contorted siphons.

Type locality: Key West, Florida, United States (Harvey 1858: 30).

Examined material: Limón Province: National Cahuita Park, over trunks and rocks (9˚4'19.0", 82˚27'37.9"), 1.5 m of depth, collected by RC (362), May 27, 2019 (MICH 1210834).

Distribution in Western Atlantic: Wynne (2017), **Central America**, Southern Caribbean coast of Costa Rica.

Comments

Bernecker and Wehrtmann (2009) reported three species of *Derbesia* for the Caribbean coast of Costa Rica *D.fastigiata* W.R. Taylor, *D. marina* (Lyngbye) Solier and *D. turbinate* M. Howe and Hoyt. However, *D. vaucheriformis* is distinguished by the presence of the double cell walls at the unions of the branches of the siphons.

FAMILY **DICHOTOMOSIPHONACEAE**

Avrainvillea asarifolia Børgesen
Fig. 2.5-6

This species can be identified by its large thallus showing surface zonation and with a deeply rounded lower margin and by its appearance as individuals or as a group of 2-5 fronds of the same group. Internally, the fronds have thin, slightly moniliform siphons and a distinctive crust composed of strongly intertwined siphon apices. This is a deep-water form (10-20 m).

Syntype localities: Danish West Indies (Børgesen, 1909); Lectotype locality: Water Island, St. Thomas, US Virgin Islands (Littler and Littler, 1992: 377).

Examined material: Limón Province: Manzanillo in sand (9˚63'65.7", 82˚65'23.4"), 15 m of depth, collected RC (650), Dec 10, 2019 (USJ).

Distribution in western Atlantic: Wynne (2017), Central America: Belize (Littler and Littler, 1997), Southern Caribbean coast of Costa Rica.

Comments

Even though *Avrainvillea* is very similar to the genera *Rhipilia*, *Flabellia* and *Cladocephalus*, it is distinguished from those genera because of the presence of moniliform siphons and the lack of lateral branches (Littler and Littler, 1992). *Avrainvillea* is also similar to *Udotea* in the disposition of the siphons, but the thallus of *Avrainvillea* lacks calcification, unlike *Udotea* thalli, which are calcified and with siphons that are not moniliform (Murray and Boodle, 1889; Littler and Littler, 1992). By showing the discrete morphological differences, and anatomically the lack of appendages in the siphons, the species of this genus present a difficult taxonomy.

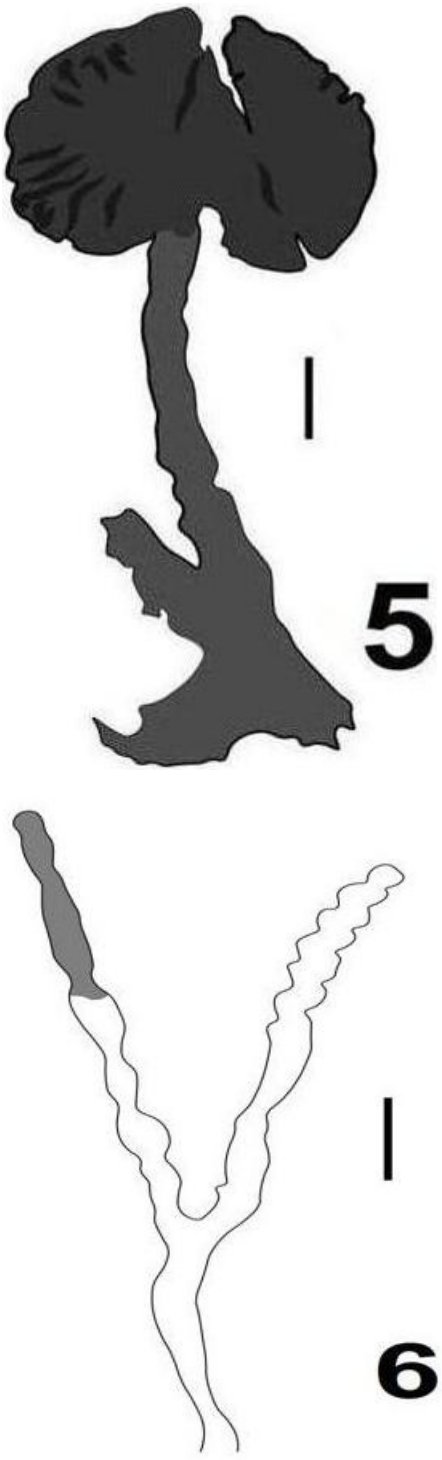

Figure 2. 5-6. ***Avrainvillea asarifolia***, 5 habit, 6 siphons slightly moniliform and/or tortuous, with rounded apices; distal portion of siphon at growing margins slightly moniliform scale bars [5] = 1 cm, scale bars [6] = 100 µm

Nonetheless, the entity reported here as *A. asarifolia* can be distinguished from other species of *Avrainvillea* present in Costa Rica. *A. digitata* D.S. Littler and Littler (Vega-Álvarez et al. 2018, has a fingerlike thallus and a

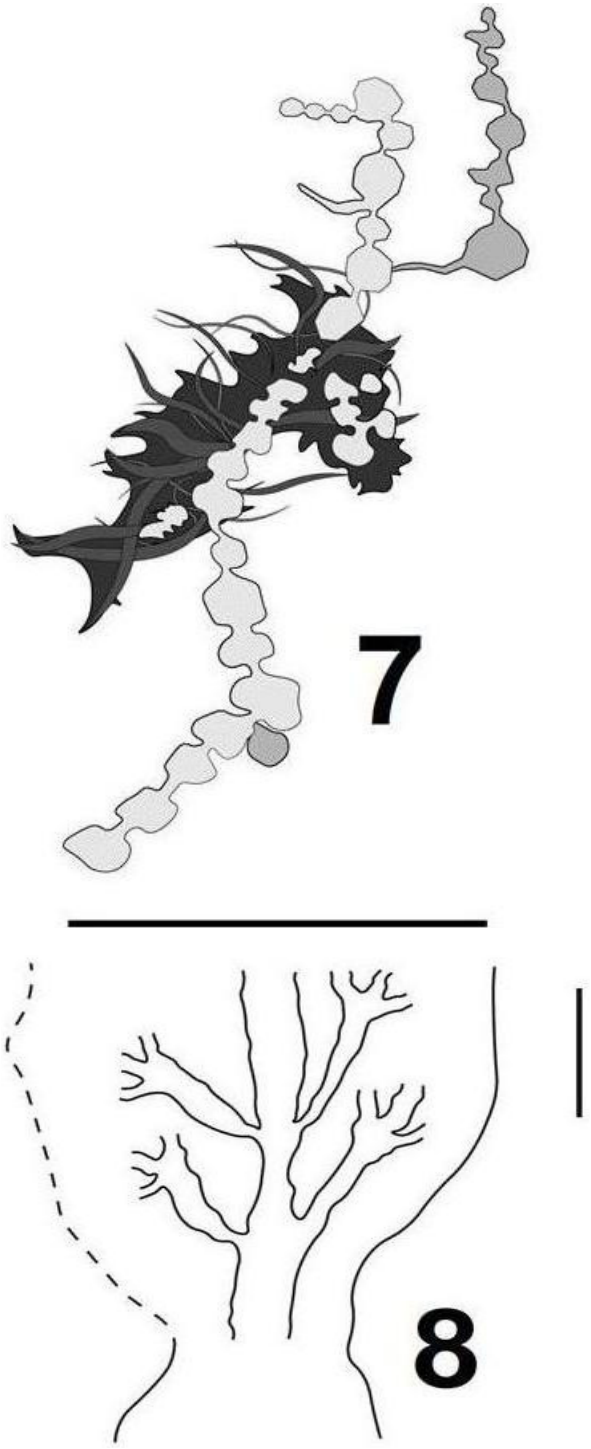

Figure 2. 7-8. *Halimeda pumila*, 7 habit; *Cladophora* sp., growing epiphytically on *Halimeda*, 8 structure of the medullary, scale bars [7] = 2.5 cm, scale bars [8] = 30 µm

shape of dense conglomerates in the subtidal zone), the entities *A. longicaulis* (Kützing) Murray and Boodle (Dawson, 1962) and A. *longicaulis* f. laxa D.S. Littler and Littler (Bernecker and Wehrtman, 2009), their blades never have the shape of a kidney, and internally the siphons are very different: *A. nigricans* Decaisne (Bernecker, 2009, distinctly, the siphons are markedly moniliform); *A. rawsonii* (Dickie) M. Howe (Bernecker

and Wehrtmann, 2009, has a thallus in a knotty and irregular shape that makes its anatomy very distinctive); *A.mazei* Murray and Boodle (Bernecker and Wehrtmann, 2009, the stipe is unproportionally thick in comparison with its blade, which lacks a kidney shape).

Børgesen (1909) defined the heart-shaped blade as diagnostic for this species, which was also confirmed by Littler and Littler (1992) in their monographic treatment of the genus.

According to Santos and Nunes (2015), the most valuable criteria for the distinction between the species are the anatomical characteristics related to the shape and the diameter of the siphons in the different regions of the thallus. The morphology alone, however, is not conclusive to provide a reliable determination because the species exhibits a high level of phenotypic plasticity (Littler and Littler, 1992; Olsen-Stojkovich,1985).

Considering the consistent differences in the external morphology and supported by the lack of integrations with other taxa, these factors led Littler *et al.* (2004) to carry out experiments of reciprocal transplants with appropriate controls to define the taxonomic status of *A. asarifolia* f. *olivacea* D.S. Littler and Littler, the taxon closest to f. *asarifolia*. The results showed that f. *olivacea* is different only at the level of the shape of the thallus.Cabrera and Martinez-Daranas (2005) discussed partially the delimitation between *A. asarifolia* f. *asarifolia* and f. *olivacea* where they confirmed that the truncated shapes and cordate shapes of the thalli are very distinctive and consistent attributes.

FAMILY **HALIMEDACEAE**

Halimeda pumila Verbruggen, D.S. Littler and Littler
Fig. 2.7-8

Thallus 20 mm in height, barely ramified or occasionally with more than 2 or 3 secondary segments by each parent segment. Most of the segments are slightly wider than long and wider just over the center; the lower margins are generally smoothly rounded; meanwhile the upper and lateral margins have generally many lobes of shallow depth. The central siphon is trifurcate many times into each segment, and it is 75-100 µmin diameter. The interval between posterior trifurcations is short just over the node, and it gradually gets longer proceding into the center of the segment. The principal siphon does not contract above the first ramification; however, other siphons show deep constrictions above the trifurcations, and the two lateral branches are noticeably smaller than the primary siphon.

Type locality: SW side of San Salvador Island, Bahamas (Verbruggen *et al*. 2007: 516).

Examined material: Limón Province: National Cahuita Park, in steel pier, over rocks (9˚4'19.0", 82˚27'37.9"), 2 m of depth in seagrass of *Thalassia*, collected RC (255), May 27, 2019 (MICH 1210824).

Distribution in western Atlantic: Wynne (2017), Central America: Southern Caribbean coast of Costa Rica.

Comments

For the Atlantic coast of Costa Rica four species of *Halimeda* have been reported up to the present: *H.discoidea* Decaisne*, H. opuntia* (Linnaeus) Lamouroux, *H. tuna* (Ellis and Solander) Lamouroux(Dawson, 1962) and *H. hummii* D.L. Ballantine (Soto, 1983). Of these, only *H. hummii* might be confused with the *H. pumila* because of its dimensions.

According to Ballantine (1982), thalli of *Halimeda hummii* are very tiny, only to 2.5 cm in height. However, in contrast to *H. pumila* the thalli present many ramifications in irregular ways, and the shape of the segments is very variable from flattened to cylindrical.

FAMILY **UDOTEACEAE**

Penicillus capitatus f. ***laxus*** Børgesen
Fig. 2.9-11

Thallus moderately calcified, off-white, with the shape of a brush, erect, 3 - 7 cm in height. Cylindrical stipe, plain, without ramifications, to 2 cm of length, cap siphon of the capitulum lax, 2 mm wide thin, delicate, up to 2 cm of length, 2.5 mm in width. Thin capitulate siphons, of 150–180 µm of diameter. We did not observe fertile material.

Type locality:Antilles (Dawes and Mathieson, 2008: 96)

Examined material: Limón Province: Manzanillo,Thallus epiphyte of *Avrainvillea asarifolia* cf *olivaceae* (9˚63'65.7", 82˚65'23.4"), 15 m of depth, collected RC (650), Dec 10, 2019 (USJ).

Distribution in western Atlantic: Wynne (2017), Central America: Southern Caribbean coast of Costa Rica.

Comments:

Dawson (1962) referred for the first time to the genus *Penicillus* on the Caribbean coast of Costa Rica "*P. capitatus* Lamx". At the resent, we report for the first time f. *laxus* of *P. capitatus* for the Caribbean coast of Costa Rica. In general, this form has been reported to occur from the infralittoral zones to a depth of 10 m (Cabrera and Alfonso, 2010; Santo and Nunes, 2014).

The specimen was found as an epiphyte on *Avrainvillea asarifolia* in the infralittoral at a depth of 15m. This shape differs from the shape of the nominate

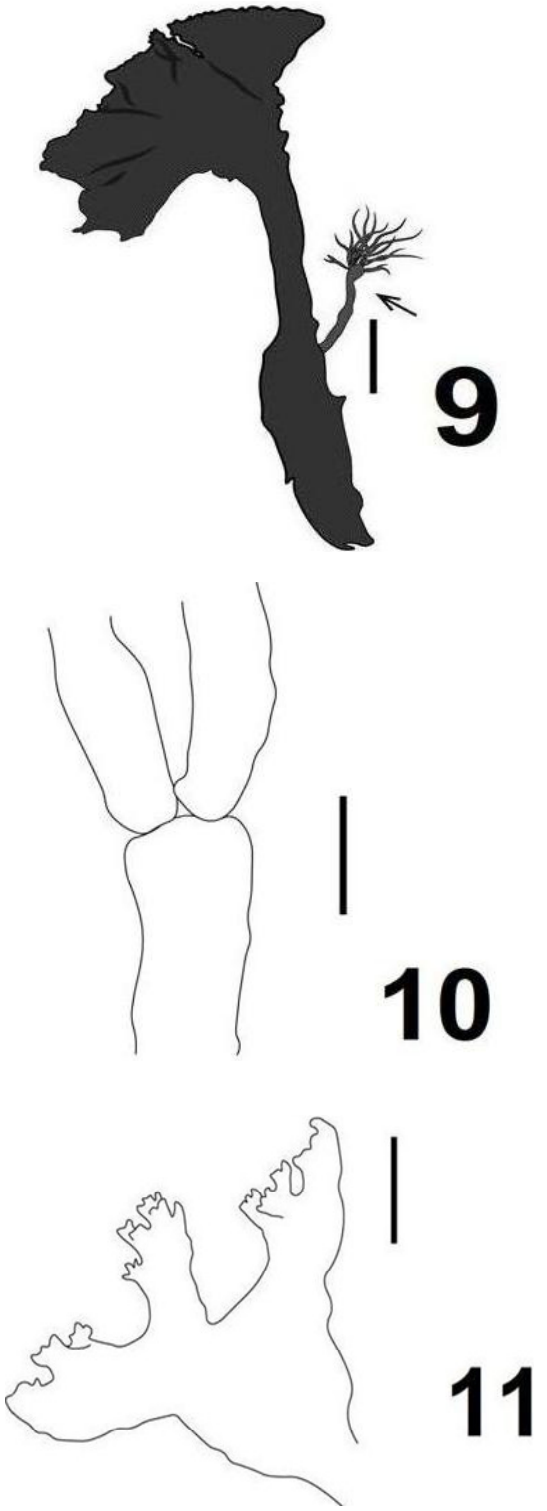

Figure 2. 9-11. Penicillus capitatus f. laxus, 9 Epiphytic habit in A.asarifolia cf. olivacea. 10, portion of one filament from terminal tuft,11, tips of a cortical filament from the stalk, scale bars [9] = 1 cm, scale bars [10] = 2mm, scale bars [11] = 100 µm

form of *Penicillus capitatus* (Bernecker, 2009) because it has smaller capitular filaments, and the capitular region is less dense, giving a lax appearance to the capitulate crest. The *laxus* shape is considered very rare throughout the tropical Western Atlantic according to Taylor (1960).

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