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# Updated list and new records of macroalgae from the Gulf of Morrosquillo, Colombian Caribbean

## Listado actualizado y nuevos registros de macroalgas para el Golfo de Morrosquillo, Caribe colombiano

Humberto Luis Quintana-Manotas<sup>1,4</sup> , Diego Alexander Hernández-Contreras<sup>2</sup> , Brigitte Gavio<sup>3</sup> 

### Abstract:

**Background and Aims:** Macroalgae are primary producers of marine ecosystems, so the information regarding their species composition and distribution is necessary to develop conservation strategies and sustainable use of the coastal coastlines they inhabit. However, in different marine regions of Colombia, such as the Gulf of Morrosquillo, this knowledge is scarce, requiring a greater sampling effort and constant updating of data. Therefore, this work aims to provide an updated list of the macroalgae in the aforementioned region, based on published and unpublished biological records and recent sampling.

**Methods:** Bibliographic information was compiled from historical records from 1976 to the present and complemented with sampling in one location in the Gulf of Morrosquillo. The taxa were organized and updated based on the most recent nomenclature, and the geographical affinity of the algal flora was determined using the Cheney index.

**Key results:** The occurrence of 97 taxa classified in three classes, 15 orders, 32 families and 54 genera. Red algae, with 48 taxa, were the group that contributed the largest number of species, and the phycoflora of the region was of a mixed type according to the Cheney index. Six new annotated and illustrated records were reported for the Gulf: *Antithamnionella breviramosa*, *Centroceras gasparrinii*, *Bostrychia tenella*, *Melanothamnus sphaerocarpus*, *Agardhiella ramosissima* and *Feldmannia mitchelliae*.

**Conclusions:** The inventory of macroalgae in the evaluated region was updated, showing a clearer historical panorama of the sampled areas, which suggests an extraordinary potential in the future discovery of new records that would increase the knowledge about the phycoflora of the Colombian Caribbean, particularly because the records of encrusting red algae, epiphytic and epizoic species are non-existent.

**Key words:** biodiversity, Chlorophyta, Heterokontophyta, review, Rhodophyta, taxonomy.

### Resumen:

**Antecedentes y Objetivos:** Las macroalgas son productores primarios de los ecosistemas marinos, por lo que la composición de especies y su distribución es información necesaria para establecer estrategias de conservación y uso sostenible de los litorales costeros que habitan. Sin embargo, en diferentes regiones marinas de Colombia, como el Golfo de Morrosquillo, este conocimiento es escaso, requiriendo de un mayor esfuerzo de muestreo y actualización constante de datos. Por lo tanto, este trabajo tiene como objetivo proporcionar una lista actualizada de las macroalgas de la región mencionada, basada en registros biológicos publicados, inéditos y muestreos recientes.

**Métodos:** Se recopiló información bibliográfica de registros históricos desde 1976 al presente y se complementó con muestreos en una localidad del Golfo de Morrosquillo. Los taxa se organizaron y actualizaron con base en la nomenclatura más reciente, y se determinó la afinidad geográfica de la flora algal mediante el índice de Cheney.

**Resultados clave:** Se determinó la presencia de 97 taxa agrupados en tres clases, 15 órdenes, 32 familias y 54 géneros. Las algas rojas, con 48 taxa, fueron el grupo que aportó un mayor número de especies, y la ficoflora de la región es de tipo mixto de acuerdo con el índice de Cheney. Se reportan seis nuevos registros comentados e ilustrados para el Golfo: *Antithamnionella breviramosa*, *Centroceras gasparrinii*, *Bostrychia tenella*, *Melanothamnus sphaerocarpus*, *Agardhiella ramosissima* y *Feldmannia mitchelliae*.

**Conclusiones:** Se actualizó el inventario de macroalgas en la región evaluada, mostrando un panorama histórico más claro de las zonas muestreadas, lo que sugiere un extraordinario potencial en el hallazgo futuro de nuevos registros que incrementarían el conocimiento sobre la ficoflora del Caribe colombiano, particularmente porque los registros de algas rojas incrustantes, especies epífitas y epizoicas son nulos.

**Palabras clave:** biodiversidad, Chlorophyta, Heterokontophyta, revisión, Rhodophyta, taxonomía.

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## Introduction

Seaweeds play a prominent role in coastal marine ecosystems as primary producers (Peña-Salamanca, 2008; Tuya et al., 2014); even so, despite their ecological importance, many regions in the world still have a limited knowledge of the biodiversity, physiology, and taxonomy of macroalgae along their coasts (Hu and Fraser, 2016). These benthic organisms fix carbon through photosynthetic processes, producing organic matter which is exported to other environments and contribute to the nutrient cycle in marine systems (Goreau, 1963; Bykova et al., 2020), and to blue carbon sequestration (Ortega et al., 2019; Queirós et al., 2019). Macroalgae are used as a refuge by larval stages of commercial fish and invertebrates (Vandendriessche et al., 2007; Tano et al., 2016). Several seaweed taxa are an important economic resource of phycocolloids and other active compounds used in food, cosmetic and pharmaceutical industries (Zerrifi et al., 2018; Hurtado et al., 2019). These characteristics, together with their ability to structure complex biological communities, convert them in bioengineer organisms in intertidal ecosystems (Umanzor et al., 2019).

In the history of Marine Ecology and Phycology of Colombia, one of the first floristic lists of seaweeds in the Colombian Caribbean was made by Germán A. Bula Meyer, who listed 472 species inhabiting this ecoregion of the country (Bula-Meyer, 1998). However, he did not record macroalgae from the Gulf of Morrosquillo. Subsequently, Díaz-Pulido and Díaz-Ruíz (2003) reported 29 species of macroalgae for the Gulf, and this species list has not been updated since then.

The studies of the marine algal flora of the Caribbean coast of Colombia have been focused on the eastern area towards Santa Marta (Schnetter, 1969; Bula-Meyer and Díaz-Pulido, 1995; Díaz-Pulido and Díaz-Ruíz, 2003; Vega-Sequeda et al., 2008; Camacho and Montaña-Fernández, 2012; Gómez-Cubillos, 2018; Cabarcas and García-Ureña, 2020), Rosario islands near Cartagena (Salazar-Foreiro et al., 2021), and La Guajira peninsula (Díaz-Pulido, 2000; Mendoza-Castro and Suarez-Acuña, 2018; Vasquez-Carrillo and Sullivan, 2018; Puccini and Molina, 2022; Gavio et al., 2022b). Phycological research in the International Biosphere Reserve Seaflower, oceanic archipelago located in the western Caribbean, has been extensive (e.g., Díaz-Puli-

do and Bula-Meyer, 1997; Ortiz and Gavio, 2010; Albis-Salas and Gavio 2011, 2015; Rincón-Díaz, 2014; Gavio et al., 2015; Rincón-Díaz and Ramos, 2016; Rincón-Díaz et al., 2018; Reyes-Gómez et al., 2021; Gavio et al., 2022a; Daza, 2023).

In contrast, the western part of the Caribbean coast of the country (with exception of work done by López-Jiménez et al. (2021) in the Capurganá Bay, who reported 61 species of macroalgae inhabiting this region) and especially the Gulf of Morrosquillo, located between the departments of Córdoba and Sucre (Castaño, 2002), has been overlooked and is lacking adequate knowledge of its phycoflora (Gavio, 2023), as shown by the low number of reported species by Díaz-Pulido and Díaz-Ruíz (2003). However, some authors have reported macroalgal species for both rocky (Quirós-Rodríguez et al., 2010, 2013; Sampedro-M. et al., 2012) and sandy shores (Quintana-M. and Mercado-Gómez, 2017) of the Gulf following the list of 2003. In Colombia, this lack of knowledge of the phycoflora of its coasts is due to several factors: first of all, despite having coasts on both the Atlantic and the Pacific Ocean, the country does not value its marine ecosystems as it should (Garnica, 2021); second, historically the study of marine algae does not rank high in the interest of the national scientific community, although, at present, this tendency is changing (Gavio, 2023); third, the access to several areas of coastline is still difficult and expensive, either due to lack of infrastructure (roads and highways), or security problems due to the presence of paramilitary groups or other illegal associations in some territories (Garnica, 2021; Palencia et al., 2023).

In accordance with the ecological importance of seaweeds and the lack of updated information on the phycoflora that inhabits the Gulf of Morrosquillo, the purpose of this paper was to provide an updated list of the macroalgae of the Gulf, through the review of existing and unpublished literature, along with recent samplings. It is intended that this information contributes to better decision-making in marine-coastal management of the Colombian Caribbean.

## Materials and Methods

Macroalgal samples were collected in January, April, and September 2019 and January 2020 around the town of Coveñas (department of Sucre) in the Gulf of Morrosquillo (Fig.

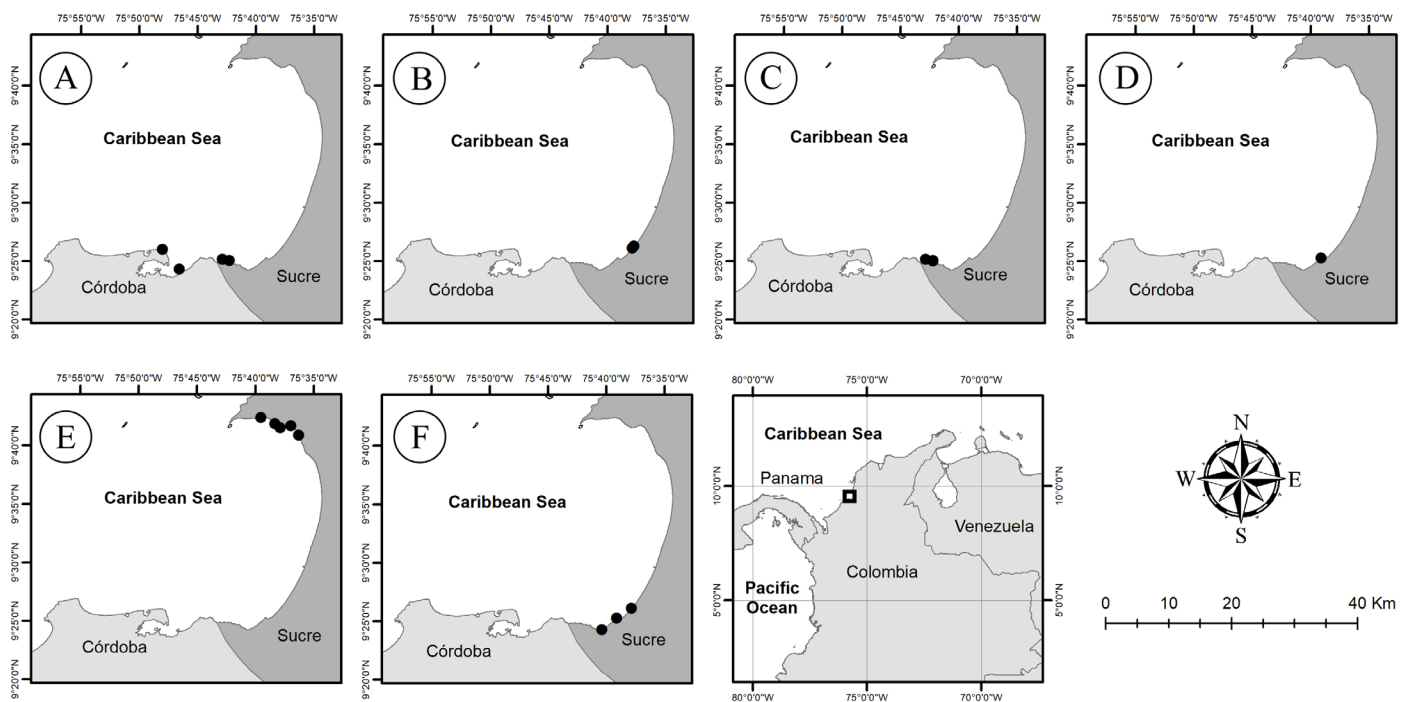


1, the square on the last map indicates the study zone. The Gulf lies in a warm dry climate, with a mean annual temperature of 27.4 °C and annual precipitation ranging between 82.9 and 131 mm (Aguilera-Díaz, 2005). The Gulf harbors sandy substrate and coral patches, while the shore is characterized by the presence of mangrove and coastal lagoons (Díaz-Merlano and Puyana, 1994).

Macroalgae were sampled in inter- and subtidal environments to a depth of about 2 m. Specimens were preserved in a formalin-seawater solution at 5% (Gavio et al., 2015) until their identification, and were deposited with inclusion codes (IC), or vouchers, in the Pacific Oceanographic and Hydrographic Research Center biological collection (CB-CCCP), Tumaco, Colombia, Single National Collection Registry under number 138 of the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. For some specimens, transverse and longitudinal sections were made by hand with a razor blade and stained with aniline blue at 1% (Florez-Leiva et al., 2010). The specimens

were identified with specific literature (e.g., Taylor, 1960; Littler and Littler, 2000; Dawes and Mathieson, 2008; Littler et al., 2008; Won et al., 2009) under an optical microscope (Labomed LX 400, Fremont, USA). The photographs were taken in the biology laboratory of the Pacific Oceanographic and Hydrographic Research Center, and in the Imaging Laboratory of the Postgraduate program in Sciences-Biology, Universidad del Valle (Cali, Colombia).

Records from published papers were included to prepare the species list from Schnetter (1976) to the most recent work in the Gulf by Quintana-M. and Mercado-Gómez (2017), and books and theses available in the libraries of the following national institutions were consulted: Instituto de Investigaciones Marinas y Costeras José Benito Vives de Andrés (INVEMAR), Universidad de Córdoba, Universidad Jorge Tadeo Lozano, Universidad del Magdalena and Universidad de Sucre. Additionally, the online site macroalgae.org (Macroalgal Herbarium Portal, 2024) and the data available in the Global Biodiversity Information Facility



**Figure 1:** Sampling sites in different studies in the Gulf of Morrosquillo, Colombia. A. Quirós-Rodríguez et al. (2010); B. Sampedro-M. et al. (2012); C. Quirós-Rodríguez et al. (2013); D. Meneses and Rivera (2014); E. Quintana-M. and Mercado-Gómez (2017); F. new records for this study. The works by Schnetter (1976; 1978), Patiño and Flórez (1993), and Díaz-Pulido and Díaz-Ruiz (2003) were not added to the map because they do not have the coordinates, making their location in the Gulf uncertain.



(GBIF) from the virtual Herbarium of Universidad Nacional de Colombia (COL) (Raz and Agudelo-Zamora, 2023) were consulted. The scientific names were corroborated in AlgaeBase (Guiry and Guiry, 2024) and ITIS (2024). The taxonomic categories in the checklist were organized according to Wynne (2022). Nevertheless, the list does not include the name Ochrophyta, given the recent validation of the phylum Heterokontophyta (Guiry et al., 2023).

The information was filtered with the tool “*taxon match*” in the world record of marine species (WoRMS, 2023) and the software OpenRefine v. 3.4.1 (Verborgh and De Wilde, 2013). Taxonomic notes were provided, when necessary, regarding the nomenclatural updates or the new records. The geographical map was elaborated with the software QGIS v. 3.34 (QGIS, 2023) (Fig. 1). In order to determine the geographical affinity of the phycoflora, the Cheney index was calculated:

$$R+C/P$$

where R is the number of red algal taxa, C is the number of green algae, and P is the number of brown algae. Values <3 indicate cold temperate flora, while values >6 indicate tropical flora. Intermediate values indicate mixed flora (e.g. warm temperate flora) (Cheney, 1977).

## Results

### Phycoflora diversity

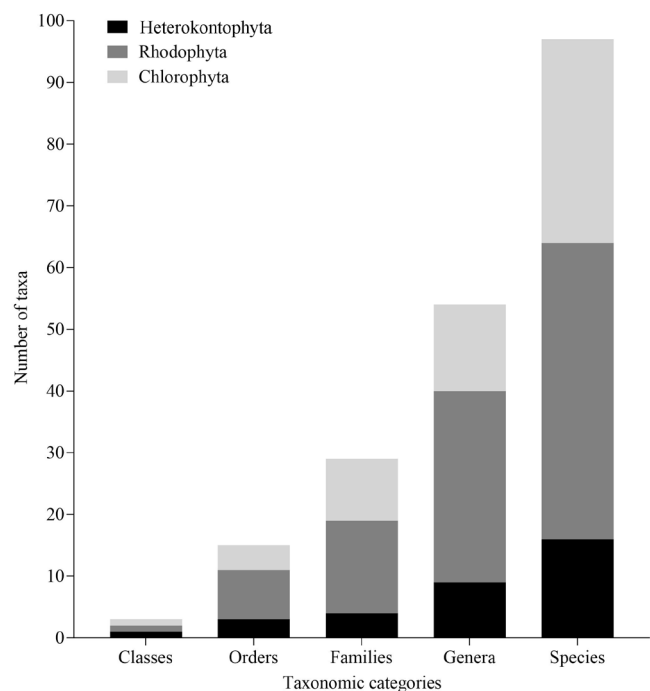
A total of nine publications with macroalgal reports for the Gulf of Morrosquillo were retrieved (Table 1, Fig. 1A-E): five published articles, one thesis and three books. Among these works, Schnetter (1976; 1978), Díaz-Pulido and Díaz-Ruíz (2003), and Quirós-Rodríguez et al. (2010) were the only ones that have the objective of presenting a floristic list for the Caribbean coast of Colombia or the coast of Córdoba, including the Gulf of Morrosquillo. The other works, namely Patiño and Flórez (1993), Sampedro-M. et al. (2012), Quirós-Rodríguez et al. (2013), Meneses and Rivera (2014), and Quintana-M. and Mercado-Gómez (2017) had other study objectives (ecological), and macroalgal species records were an additional result.

A total of 97 taxa are reported, corresponding to 96 species and one infraspecific name (Appendix). Species are

distributed in three classes, 15 orders, 32 families and 54 genera (Fig. 2). The brown algae (Heterokontophyta) present the lowest number of species (16), of which twelve are members of the family Dictyotaceae. Red algae (Rhodophyta) are composed of 48 taxa. The family Gracilariaceae is the most representative within the red algae with 11 species. Finally, the green algae (Chlorophyta) contribute with 33 taxa. The most diverse family is the Caulerpaceae with eight taxa (seven species and one form). Twenty-one years later, the present work adds 68 records not included in the species list by Díaz-Pulido and Díaz-Ruíz (2003).

### New records for the Gulf of Morrosquillo

From the species presented, six correspond to new records for the Gulf of Morrosquillo (Fig. 1F), five red algae: *Antithamnionella breviramosa* (E.Y. Dawson) Wollaston, *Centroceras gasparrinii* (Meneghini) Kützinger, *Bostrychia tenella* (J.V. Lamouroux) J. Agardh, *Melanothamnus sphaerocarpus* (Børgesen) Díaz-Tapia & Maggs, *Agardhiella ramosissima* (Harvey) Kylin, and the brown alga *Feldmannia mitchelliae* (Harvey) H.-S. Kim. Their description and illustrations are presented hereafter.



**Figure 2:** Number of records in the Gulf of Morrosquillo, Colombia, according to different taxonomic levels.

**Table 1:** Data from sampling sites in the Gulf of Morrosquillo, Colombia, included in the present study, both from literature and own sampling.

Locality (Department)	Collection date	Source	Geographic coordinates	Substrate
Punta San José, Coveñas (Sucre)	1976 and 1978	Schnetter (1976, 1978)	Unknown	Rocky shore
Punta Piedra, Tolú (Sucre)	1976 and 1978	Schnetter (1976, 1978)	Unknown	Rocky shore
Santiago de Tolú (Sucre)	1976 and 1978	Schnetter (1976, 1978)	Unknown	Rocky shore
Berrugas, San Onofre (Sucre)	1978	Schnetter (1978)	Unknown	Rocky shore
San Antero (Córdoba)	1993	Patiño and Flórez (1993)	Unknown	Not reported
Coveñas (Sucre)	1993	Patiño and Flórez (1993)	Unknown	Not reported
Santiago de Tolú (Sucre)	1993	Patiño and Flórez (1993)	Unknown	Not reported
Playa el Francés, Santiago de Tolú (Sucre)	1993	Patiño and Flórez (1993)	Unknown	Not reported
Playa Berrugas, San Onofre (Sucre)	1993	Patiño and Flórez (1993)	Unknown	Not reported
Gulf of Morrosquillo	2003	Díaz-Pulido and Díaz-Ruiz (2003)	Unknown	Not reported
Punta Bolívar, San Antero (Córdoba)	Between June 2004 and May 2005	Quirós-Rodríguez et al. (2010)	9°25'02.7"N, 75°42'16.1"W	Calcareous rock
Punta Bello, San Antero (Córdoba)	Between June 2004 and May 2005	Quirós-Rodríguez et al. (2010)	9°25'08.1"N, 75°42'51.4"W	Calcareous rock
Punta Resguardos (Córdoba)	Between June 2004 and May 2005	Quirós-Rodríguez et al. (2010)	9°25'12.1"N, 75°58'27.8"W	Calcareous rock
Punta Mestizos (Córdoba)	Between June 2004 and May 2005	Quirós-Rodríguez et al. (2010)	9°25'19.3"N, 76°04'12.5"W	Calcareous rock
Playas Boca la Caimanera, Coveñas (Sucre)	Between June 2010 and May 2011	Sampedro-M. et al. (2012)	9°26'6.66"N, 75°37'52.07"W	Breakwater
Playas Boca la Caimanera, Coveñas (Sucre)	Between June 2010 and May 2011	Sampedro-M. et al. (2012)	9°26'16.99"N, 75°37'43.92"W	Breakwater
San Antero (Córdoba)	Between September 2006 and June 2007	Quirós-Rodríguez et al. (2013)	9°25'01.0"N, 75°42'14.1"W	Calcareous rock
San Antero (Córdoba)	Between September 2006 and June 2007	Quirós-Rodríguez et al. (2013)	9°25'02.2"N, 75°42'15.1"W	Calcareous rock
San Antero (Córdoba)	Between September 2006 and June 2007	Quirós-Rodríguez et al. (2013)	09°25'08.1"N, 75°42'51.4"W	Calcareous rock
Punta Piedra, Coveñas (Sucre)	2014	Meneses and Rivera (2014)	9°25'15.9"N, 75°39'06.6"W	Breakwater
San Onofre (Sucre)	February to May 2015	Quintana-M. and Mercado-Gómez (2017)	9°40'52.97"N, 75°36'17.29"W	Rocky shore and sandy beaches
San Onofre (Sucre)	February to May 2015	Quintana-M. and Mercado-Gómez (2017)	9°42'24.27"N, 75°39'31.34"W	Rocky shore and sandy beaches
San Onofre (Sucre)	February to May 2015	Quintana-M. and Mercado-Gómez (2017)	9°41'41.5"N, 75°36'56.6"W	Rocky shore and sandy beaches
San Onofre (Sucre)	February to May 2015	Quintana-M. and Mercado-Gómez (2017)	9°41'31.7"N, 75°37'51.6"W	Rocky shore and sandy beaches



Table 1: Continuation.

Locality (Department)	Collection date	Source	Geographic coordinates	Substrate
San Onofre (Sucre)	February to May 2015	Quintana-M. and Mercado-Gómez (2017)	9°41'51.1"N, 75°38'20.0"W	Rocky shore and sandy beaches
Punta Piedra, Coveñas (Sucre)	Between February 2019 and January 2020	Present study	9°25'16.6"N, 75°39'05.6"W	Breakwater
Punta Piedra, Coveñas (Sucre)	Between February 2019 and January 2020	Present study	9°24'17.8"N, 75°40'22.6"W	Breakwater
Boca Ciénaga la Caimanera, Coveñas (Sucre)	Between February 2019 and January 2020	Present study	9°26'7.08"N, 75°37'50.363"W	Breakwater

## Taxonomy

ching the apex and its sporangia are mainly sessile (not stalked) and plurilocular.

## Heterokontophyta

## Phaeophyceae

Distribution in Colombian Caribbean: Guajira, Tayrona National Natural Park (Tayrona-NNP), Magdalena, Darién, Archipelago of San Andres, Old Providence and Sainte Cataline and Gulf of Morrosquillo.

## Ectocarpales

## Acinetosporaceae

Material examined: COLOMBIA. Sucre, Coveñas, Boca Ciénaga la Caimanera, depth 1 m, 9°26'7.08"N, 75°37'50.363"W, 10.I.2020, H. L. Quintana-M. Macroalg-CCCP-07 (CB-CCCP).

*Feldmannia mitchelliae* (Harvey) H.-S. Kim, Algal flora of Korea 2(1): 3-137. 2010. Figs. 3A-C.

## Rhodophyta

TYPE: UNITED STATES OF AMERICA. Massachusetts, Nantucket, no depth and coordinate information available, 1987, H. B. S. Womersley 52 (holotype: TCD).

## Florideophyceae

## Ceramiales

Thallus filamentous, brown, 8 cm tall, entirely uniseriate, branching irregular, axial cells 15-25 µm diameter, 30-80 µm long, branches tapering towards apex, roundish (Fig. 3A); cell divisions in intercalary meristem (Fig. 3B); plurilocular gametangia cylindrical, 15-30 µm diameter, 70-130 µm long, sessile, inserted laterally on branches (Fig. 3C).

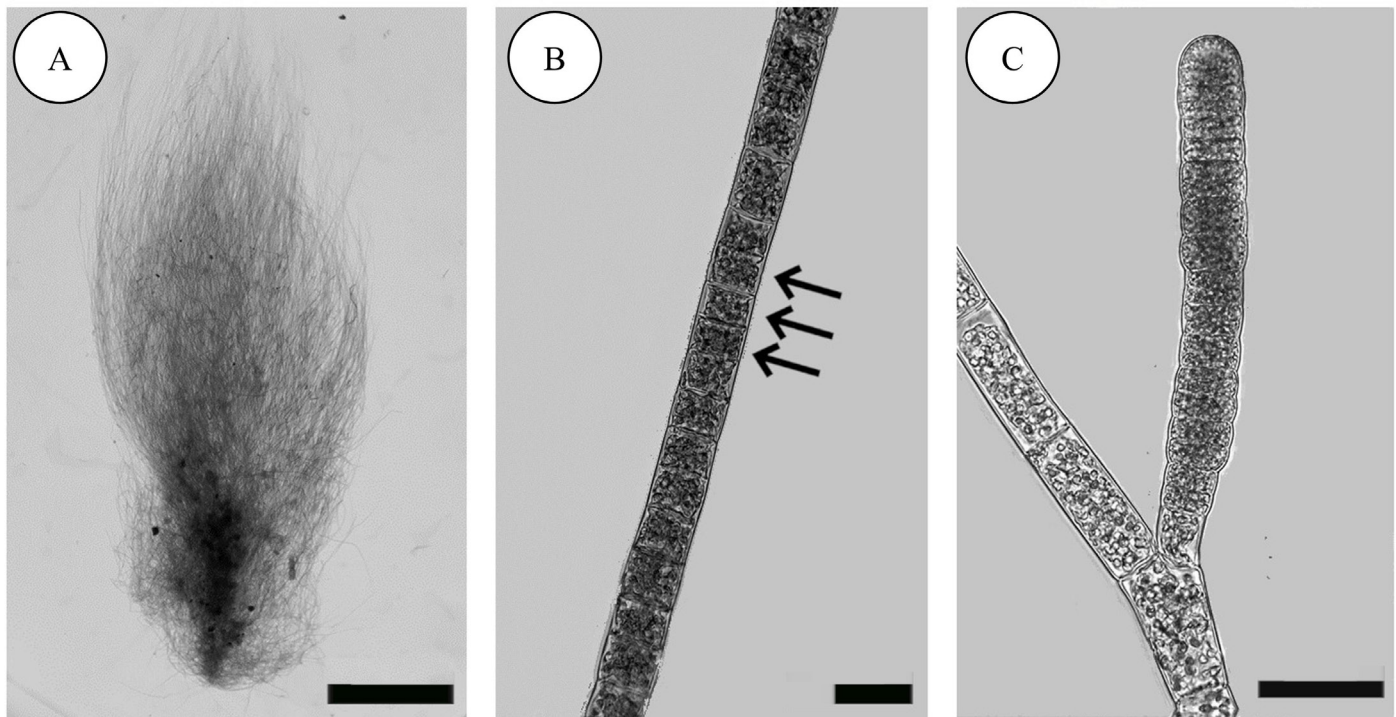
## Ceramiaceae

*Antithamnionella breviramosa* (E.Y. Dawson) Wollaston, Philosophical Transactions of the Royal Society of London, B. Biological Sciences 259: 257-352. 1970. Fig. 4A.

Taxonomic notes: it can be differentiated from other species of the genus by not presenting branches at an 90° angle, the filaments gradually decrease in size until rea-

TYPE: UNITED STATES OF AMERICA. California, Santa Catalina Island, Pebbly Beach, near Avalon, no depth and coordinate information available, 24.III.1948, E. Y. Dawson 26521 (holotype: AHFH).





**Figure 3:** A-C. *Feldmannia mitchelliae* (Harvey) H.-S. Kim. A. habit; B. intercalary meristem (arrows); C. plurilocular gametangium. Scale bars: A=2 mm, B=20  $\mu$ m, C=50  $\mu$ m.

Thallus filamentous, delicate, 1.5 mm tall, rose-pink in color; prostrate axes uniseriate, 20-30  $\mu$ m diameter, bearing rhizoids; erect axes uniseriate, 15-30  $\mu$ m diameter, 5-22 cells long, cells 25-35  $\mu$ m long; branchlets in whorls of three, at the upper end of axial cells, tapering from base toward apex, each branchlet 10-12  $\mu$ m diameter, divided pseudodichotomously; gland cells oval, 10-12  $\mu$ m diameter, in contact with only one cell of branchlets (Fig. 4A).

**Taxonomic notes:** Kim and Lee (1990) determined that the number of whorl branchlets arising from each axial cell is a good character to identify this species. For *Antithamnionella breviramosa*, they observed that the alga always forms three branchlets per axial cell; this character was observed in our specimen.

**Distribution in Colombian Caribbean:** Guajira, Tayrona-NNP, Darién, Archipelago de San Andrés, Old Providence and Sainte Cataline and Gulf of Morrosquillo.

**Material examined:** COLOMBIA. Sucre, Coveñas, Punta Piedra, depth 2.5 m, 9°25'16.6"N, 75°39'05.6"W, 5.I.2019,

epiphytic on *Halimeda opuntia* (L.) J.V. Lamouroux, H. L. Quintana-M. Macroalg-CCCP-02 (CB-CCCP).

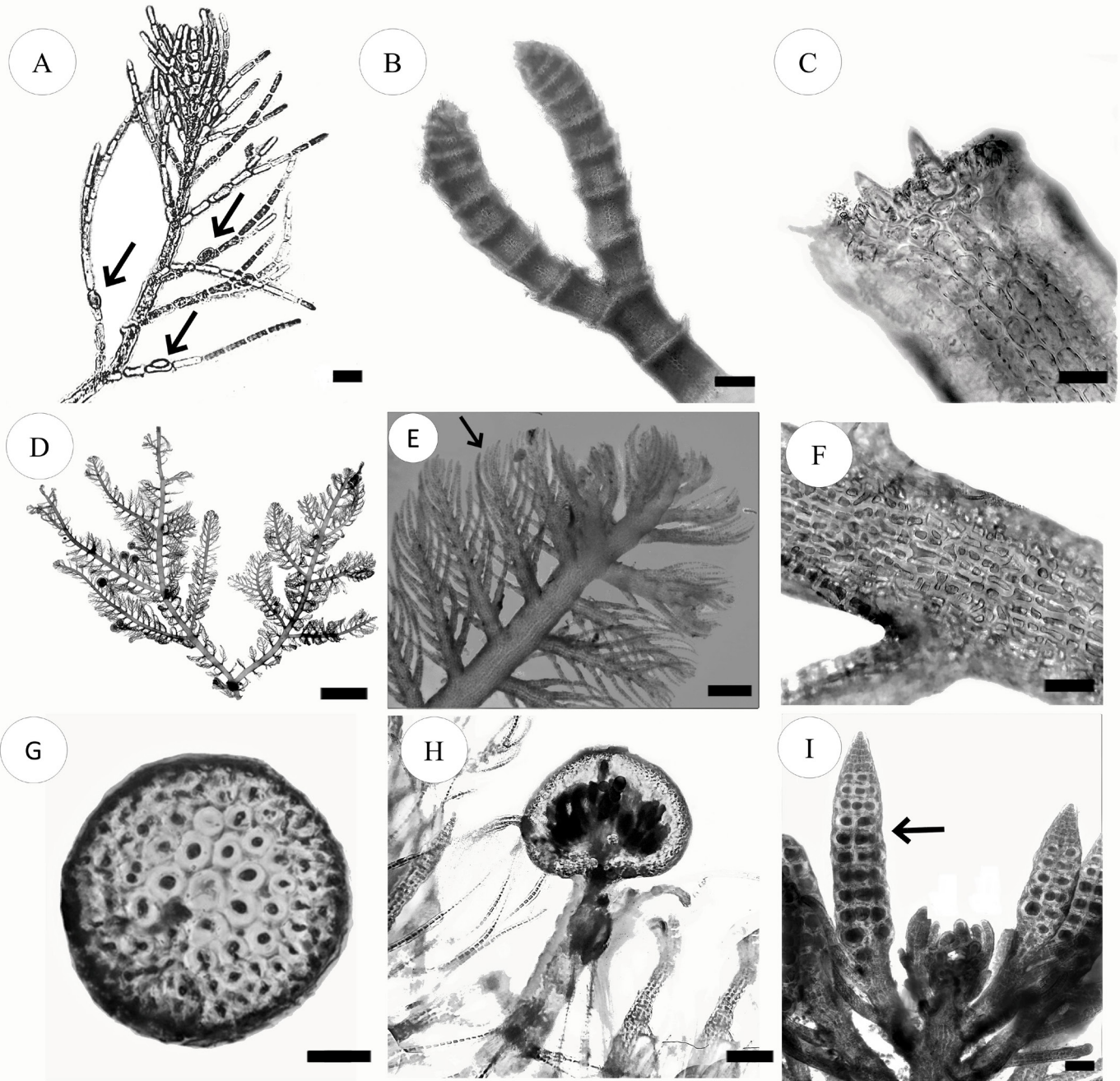
***Centroceras gasparrinii*** (Meneghini) Kützing, Lipsiae: F.A. Brockhaus (i)-vi, 1-922. 1849. Figs. 4B, C.

**TYPE:** ITALY. Sicilia, Palermo, no depth and coordinate information available, 1844, G. Meneghini 186 (holotype: L-0193946, isotype: L-0193946, #940264-102).

Thallus filamentous, red to brown in color, 5 cm tall; axial filament completely corticated by small rectangular cells in vertical row; branching dichotomous or occasionally trichotomous, apices weakly incurved (Fig. 4B); branches 100-120  $\mu$ m diameter; nodes bearing spines formed by two or three cells, acropetal cells ovoid: gland cell spherical at nodes (Fig. 4C); nodes 120-150  $\mu$ m diameter, 12-15 pericentral cells.

**Taxonomic notes:** distinguishable among other species of this genus by the presence of ovoid terminal acropetal cells.





**Figure 4:** A. *Antithamnionella breviramosa* (E.Y. Dawson) Wollaston. A. close up of erect axis with gland cells (arrows) touching only one branch cell; B-C. *Centroceras gasparrinii* (Meneghini) Kützing. B. forcate apices; C. close-up of nodes with spines; D-I. *Bostrychia tenella* (J.V.Lamouroux) J.Agardh. D. habit; E. branch, showing monosiphonic branchlets (arrow); F. cortication of axes; G. transverse section of thallus; H. urn-shaped cystocarp; I. branch with stichidia (arrow). Scale bars: A=20  $\mu$ m, B, C=50  $\mu$ m, D=2 mm, E=0.25 mm, F=150  $\mu$ m, G=100  $\mu$ m, H=300  $\mu$ m, I=100  $\mu$ m.

Distribution in Colombian Caribbean: Tayrona-NNP, Magdalena and Gulf of Morrosquillo.

Material examined: COLOMBIA. Sucre, Coveñas, Boca Ciénaga la Caimanera, depth 1 m, 9°26'7.08"N,

75°37'50.363"W, 05.I.2019, *H. L. Quintana-M. Macroalg-CCCP-03* (CB-CCCP).

#### Rhodomelaceae

***Bostrychia tenella*** (J.V. Lamouroux) J. Agardh, Lundae (Lund): C. W. K. Gleerup 2(3): 787-1138, 1158-1291. 1863. Figs. 4D-I.

TYPE: UNITED STATES OF AMERICA. Virgin Islands, Saint Croix, no depth and coordinate information available, 1998, *T. Yoshida 672309A* (syntype: MEL).

Thalli forming mats up to 2 cm tall, purple, or brown in color, growing on mangrove roots (Fig. 4D); abundant branching, pinnate branches emerging in alternating fashion, branchlet apices upturned, branches 170-300 µm diameter, without cortication, superficial cells small, pit connection present, branchlets 80-120 µm diameter, branches uniseriate at the apex, 20-50 µm diameter (Fig. 4E); main axes with light cortication (Fig. 4F); single central cell surrounded by 5-9 pericentral cells in main axes, two tier cells per pericentral cell (Fig. 4G); cystocarps urn-shaped, sessile, 600-650 µm diameter (Fig. 4H); stichidia 500-600 µm high, 100-150 µm diameter (Fig. 4I).

Taxonomic notes: this species forms a cryptic complex with the taxon *Bostrychia binderi* Harvey (Zuccarello et al., 2015), and its morphological differentiation is rather difficult (Saengkaew et al., 2016; Zuccarello et al., 2015). However, authors such as Hernández-Contreras (2017) suggested that these two species could be distinguished by the fact that *B. tenella* has completely monosiphonous branchlets, with upturned apices and light cortication.

Distribution in Colombian Caribbean: Tayrona-NNP, Islas del Rosario National Natural Park, Darién, and Gulf of Morrosquillo.

Material examined: COLOMBIA. Sucre, Coveñas, Boca Ciénaga la Caimanera, depth 0 m, 9°26'7.08"N, 75°37'50.363"W, 05.I.2019, epiphytic on *Rhizophora mangle* L. roots *H. L. Quintana-M. Macroalg-CCCP-04* (CB-CCCP).

***Melanothamnus sphaerocarpus*** (Børgesen) Díaz-Tapia & Maggs, European Journal of Phycology 52(1): 1-20. 2017. Figs. 5A-E.

TYPE: UNITED STATES OF AMERICA. Virgin Islands, Store Nordsidebugt (Magens Bay), St. Thomas, no depth and coordinate information available, 1918, *F. Børgesen* (holotype: C?, isotype: US, C).

Thallus filamentous, dark red, forming mats up to 1 cm tall on the substrate, prostrate (60-85 µm diameter, segments 1-2 diameter long) and erect axes, dichotomously branched, 40-50 µm diameter (Fig. 5A); axes not corticated, with four pericentral cells (Fig. 5B); trichoblasts at the apices (Fig. 5C); apex with monosiphonic cells (Fig. 5D); rhizoids unicellular, cut off from pericentral cell (Fig. 5E).

Taxonomic notes: this species is characterized by its pseudodichotomous branching and thallus with a small size of no more than 2 cm high.

Distribution in Colombian Caribbean: Darién, Gulf of Morrosquillo, Archipelago of San Andres, Old Providence and Sainte Cataline.

Material examined: COLOMBIA. Sucre, Coveñas, Boca Ciénaga la Caimanera, depth 0 m, 9°26'7.08"N, 75°37'50.363"W, 05.I.2019, growing on limestone rock *H. L. Quintana-M. Macroalg-CCCP-05* (CB-CCCP).

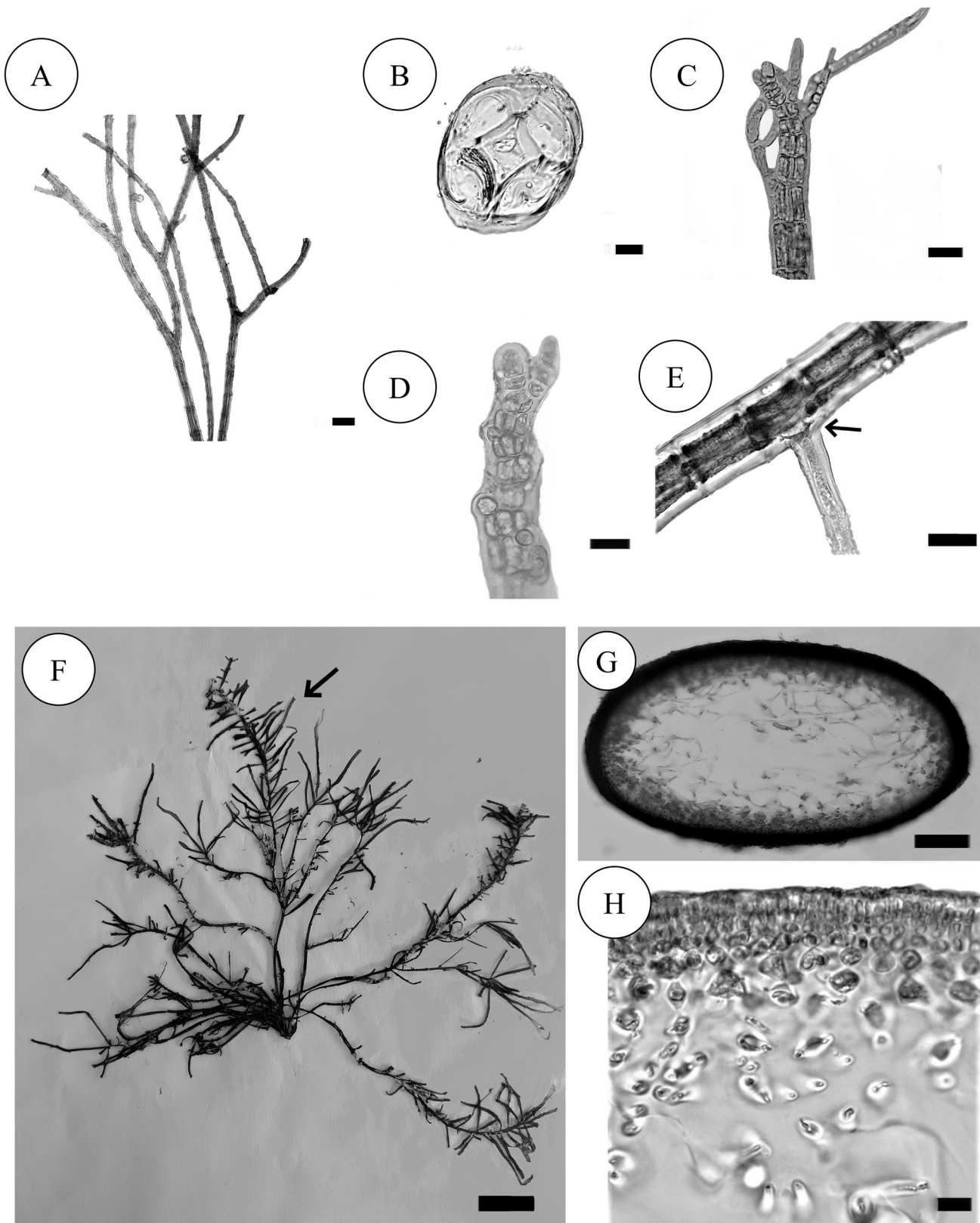
#### Gigartinales

##### Solieriaceae

***Agardhiella ramosissima*** (Harvey) Kylin, Acta Universitatis Lundensis 28(8): 1-88. 1932. Figs. 5F-H.

TYPE: UNITED STATES OF AMERICA. Florida, Key West, no depth and coordinate information available, 1853, *W.H. Harvey* (holotype: TCD?).

Thallus cartilaginous, 20 cm tall, pink, green, main axes flat, 2-3 mm wide, 1 mm thick, branching irregular



**Figure 5:** A-E. *Melanothamnus sphaerocarpus* (Børgesen) Díaz-Tapia & Maggs. A. habit, showing dichotomous and pseudodichotomous branching; B. transverse section of thallus showing four pericentral cells; C. apical portion with trichoblast; D. apical portion showing primordial arrangement; E. prostrate axis with rhizoid cut off from pericentral cells (arrow); F-H. *Agardhiella ramosissima* (Harvey) Kylin. F. habit, showing opposite branching (arrow); G. transverse section of thallus showing compressed axis, with transverse filament in the center; H. close up transverse section of thallus showing cortical cells. Scale bars: A=100  $\mu$ m, B=10  $\mu$ m, C=50  $\mu$ m, D=10  $\mu$ m, E= 50  $\mu$ m, F=2 cm, G=300  $\mu$ m, H=10  $\mu$ m.

proximally and pinnate distally, branchlets tapering toward the apices and at the base (Fig. 5F); medulla formed by dispersed filaments 1-2  $\mu\text{m}$  diameter in a mucilaginous matrix, cortex formed by three to four layers of deeply pigmented cells (Figs. 5G, H).

Taxonomic notes: this taxon is easily distinguishable from *Agardhiella subulata* (C. Agardh) Kraft & M.J. Wynne due to its flattened thallus and the pinnate branching.

Distribution in Colombian Caribbean: Darién and Gulf of Morrosquillo.

Material examined: COLOMBIA. Sucre, Coveñas, Punta piedra, depth 1 m, 9°24'17.8"N, 75°40'22.6"W, 05.I.2019, growing on limestone rock *H. L. Quintana-M. Macroalg-CCCP-06* (CB-CCCP).

### Climate affinity of the marine flora of Gulf of Morrosquillo

The Cheney index was calculated with the updated list of species for the Gulf of Morrosquillo. The value of the index was 5.02, indicating a mixed flora, in transition between temperate and tropical affinities.

## Discussion

### Richness of species

This work contributes to the marine-coastal management of the Gulf of Morrosquillo with an updated taxonomic list that records the presence of at least 97 taxa of seaweeds for the region, since Díaz-Pulido and Díaz-Ruiz (2003), in the first checklist of the Gulf, previously reported the existence of 29 species (this list and others that precede it include some records in personal collections, which was common practice at that time, since the legalization of biological collections in Colombia was an incipient policy). This represents an increase of 235% in the reported species between the two works, which indicates that during 21 years the generation of new phycological knowledge for the region, despite logistical and security difficulties, has been expanded. To date, seaweed sampling in the Gulf shows a greater effort in its southern portion (Fig. 1, Table 1), around the municipalities of San Antero and Coveñas.

This might be associated with better access facilities, vicinity to towns and lack of guerrilla activity in these areas. On the contrary, the middle and northern parts of the Gulf lack access roads, towns on the coast, and there is the presence of paramilitary groups still controlling the territory, all of which complicate sampling.

The majority of the works reported in the present paper were not focused on macroalgae, reporting algal species as additional results, reinforcing the evidence that algal species richness in the Gulf is underestimated. Furthermore, the lack of records of incrusting red algae, epiphytic, epizotic species and cyanobacteria is noteworthy. These organisms constitute a relevant portion of macroalgal diversity, especially in tropical regions (Mateo-Cid et al., 2020; Reyes-Gómez et al., 2021) and have been ignored in the Gulf of Morrosquillo as well as in the Colombian Caribbean in general. Moreover, most recent works (e.g., Quirós-Rodríguez et al., 2010; Sampedro-M. et al., 2012; Meneses and Rivera, 2014; Quintana-M. and Mercado-Gómez, 2017) focused exclusively on shallow environments (to 4 m depth); hence, there is no information on seaweeds at greater depths in the Gulf.

### New records of seaweeds

The new records of this work and other comments on some species of interest for the coastal management of the Gulf of Morrosquillo considered the current nomenclature and taxonomic changes reported by different authors. Until 2009, the most common species of the genus *Centroceras* Kützing reported for the Caribbean was *C. clavulatum* (C. Agardh) Montagne. However, Won et al. (2009) showed that the distribution of this species is restricted to the Southern Pacific Ocean. To date, at least nine different species are present in the Western Atlantic Ocean, according to Wynne's most recent review (2022): *C. arcii* C.W. Schneider, Cianciola & Popolizio, *C. gasparrinii* (Meneghini) Kützing, *C. hyalacanthum* Kützing, *C. illaqueans* C.W. Schneider, Cianciola & Popolizio, *C. internitens* S.G. Gallagher & Humm, *C. micracanthum* Kützing, *C. minutum* Yamada, *C. rhizophorum* Montagne, *C. tetrachotomum* Won, T.O. Cho & Fredericq (Schneider et al., 2015; Wynne, 2022). Considering these studies, we propose discounting reports of the species *C. clavulatum* from the species list of the Gulf of Morrosquillo

(and the country). Recent samplings in other regions of the Colombian coast have shown that *C. gasparrinii* is the most common species of the genus (Gavio, unpublished results).

Other records for the Gulf, such as *Bostrychia tenella*, stand out due to the complexity of their identification. Given its great phenotypic plasticity, Zuccarello and West (2011) group the species into complexes, the *Bostrychia tenella* / *B. binderi* complex being one of them. Zuccarello et al. (2015) and Hernández-Contreras (2017) have elucidated some characters that are useful to differentiate these taxa using molecular tools and comparing the morphology of the species.

The sample found in the Gulf of Morrosquillo (*H. L. Quintana-M. Macroalg-CCCP-04*) belongs to the mentioned complex, due to the presence of two characters that helped to identify this species. First, the presence of numerous monosiphonous branches; this character has been one of the most prominent to differentiate the species of this complex since *B. binderi* presents few or no monosiphonous branches, while *B. tenella* presents a large number of these branches arranged in a revolute fashion giving it a feather-like appearance (Fig. 4E shows the presence of these structures being similar to images 7, 8 and 9 of Zuccarello et al. (2015) and figure B of image 5 in Saengkaew et al. (2016). Second, the level of cortication of the thallus: *B. tenella* has moderate cortication in the main axes (Fig. 4F), while in lateral branches and immature axes there is no presence of cortical cells. On the contrary, *B. binderi* presents dense cortication both in main axes and in branches and branchlets, see Figs. 1-6 in Zuccarello et al. (2015), figures F and G in Saengkaew et al. (2016) and figure I of Hernández-Contreras (2017).

Hernández-Contreras (2017) highlighted the absence of cladophylls in *B. tenella* as an important feature to differentiate this species from *B. binderi*, in which cladophylls usually are present. Nevertheless, Zuccarello et al. (2015), Saengkaew et al. (2016), and Hernández-Contreras (2017) did not always report the absence or presence of cladophylls in their specimens (which depends on the sampling conditions), which makes this character less informative than expected for the differentiation between the two species, compared to the number of monosiphonous branches, and especially, the cortication of the thallus. This

is so, not only because of the typical crypticism observed in the genus *Bostrychia* Montagne (Zuccarello and West, 2011), but also because *B. tenella* is a species with high genetic diversity, and complex phylogeographic patterns, which have been explained by the effect of geological history and marine surface currents (Zuccarello et al., 2015; Bulan et al., 2022), which can eventually make it very susceptible to generating morphological variations that complicate its identification by classical taxonomical studies.

Regarding the other new records for the Gulf of Morrosquillo, apart from some sporadic and discontinuous records for *Agardhiella ramosissima* in the Darién (Díaz-Pulido and Díaz-Ruíz, 2003), and for *Feldmannia mitchelliae* in the north of La Guajira peninsula (Díaz-Pulido and Díaz-Ruíz, 2003; Vasquez-Carrillo and Sullivan, 2018), little is known about the biology or ecology of these species in the Colombian Caribbean context. Nevertheless, *Antithamnionella breviformis* has a relatively greater number of records concentrated in the International Biosphere Reserve Seaflower (Díaz-Pulido and Bula-Meyer, 1997; Rincón-Díaz, 2014; Rincón-Díaz and Ramos, 2016; Gavio and Daza, 2022), and some occasional reports in Darién (Díaz-Pulido and Díaz-Ruíz, 2003), Santa Marta (Bula-Meyer and Díaz-Pulido, 1995; Díaz-Pulido and Díaz-Ruíz, 2003), and La Guajira Peninsula (Díaz-Pulido, 2000). *Melanothamnus sphaerocarpus* has only been reported on the island of San Andrés by Ortiz and Gavio (2010) in the drift, and Albis-Salas and Gavio (2015) in Thalassia grasslands, who described it based on a specimen in a reproductive state and named it *Neosiphonia sphaerocarpa* (Børgesen) M.-S. Kim & I.K. Lee, a name that is currently considered synonymous of *M. sphaerocarpus* (Wynne, 2022; Guiry and Guiry, 2024).

### Climate affinity

It is well-known that in the tropics the marine phycoflora is dominated by red algae, followed by green algae (Hu and Fraser, 2016). Brown seaweeds have a reduced diversity at low latitudes, while they are dominant in cold and temperate waters (Mathieson et al., 2009; Neiva et al., 2016). This knowledge is captured in the Cheney index, a simple way to calculate biogeographic affinities of a local/regional marine flora. According to Cheney (1977) and Mathieson et

al. (2009), this index is described as: “ $(R+C)/P$ , where R=the number of Rhodophyta, C=the number of Chlorophyta, and P=the number of Phaeophyceae, (or Heterokontophyta). A value of  $<3.0$  indicates a temperate or cold-water flora, while values of  $>6.0$  indicate a tropical flora”. Intermediate values are associated with flora of a mixed type that generally inhabits warm temperatures (Mathieson et al., 2009). The result of this ratio for the flora of Gulf of Morrosquillo is a mixed flora, despite the high temperatures of the Gulf waters (28-29.5 °C) and its location in the tropics (Bastidas-Salamanca and Ordóñez-Zúñiga, 2017). This indicates a low representation of red algae, which are mainly small, epiphytic, and therefore are easily overlooked. Since the majority of the recent literature was not especially focused on algae, the absence of these records is justified. The lack of specific and long-term studies is the most probable reason for the low representation of red algae.

### Research perspectives in the Gulf of Morrosquillo

*Caulerpa chemnitzia* (Esper) J.V. Lamouroux is a species with great phenotypic plasticity, and its characters may overlap with those of *Caulerpa racemosa* (Forsskål) J. Agardh (Belton et al., 2014), which is a very common and widespread species on the coast of Colombia. Patiño and Flórez (1993) reported *C. chemnitzia* for the Gulf of Morrosquillo; however, there is no herbarium material to corroborate the presence of the species, and it is considered a doubtful record. Future sampling campaigns could resume the search for this species in the localities previously reported by Patiño and Flórez (1993), such as the beaches of San Antero (Córdoba) and the mangrove ecosystems of Coveñas, Santiago de Tolú and San Onofre, in the department of Sucre.

The species *Polysiphonia subtilissima* Montagne has been reported on the basis of field photographs. Species in the genus *Polysiphonia* Greville are separated on the basis of the number of pericentral cells, type of connection between rhizoids and pericentral cells, and origin of branches, characters which are not distinguishable in the field and mostly require mounting and observation with an optical microscope (Stuercke and Freshwater, 2008). Therefore, in the present work the taxon is considered a doubtful re-

cord. Nevertheless, the complexity of the taxonomy of the genus *Polysiphonia* denotes the need to implement molecular tools to detect more species of the genus that are potentially inhabiting the Gulf of Morrosquillo and other regions of the Colombian Caribbean, as has already been done with other species of *Polysiphonia* in the Panamanian Caribbean (Mamoozadeh and Freshwater, 2012) and other regions of the world (Kim and Kim, 2014; Díaz-Tapia et al., 2020). In the Colombian context, it is essential to address the mentioned problem, not only to broaden the knowledge of the diversity of macroalgae in the Colombian Caribbean, but also because of the cryptic nature of *Polysiphonia* (Geoffroy et al., 2012; Hu and Fraser, 2016; Díaz-Tapia et al., 2020) and its classification as the world's most invasive non-native algae genus (Thomsen et al., 2016). The latest report by Wynne (2022), which indicates the presence of 27 species of the genus (including native and foreign species) in the tropical and subtropical Western Atlantic Ocean, is a wake-up call for the environmental authorities of the country to generate local policies on the knowledge, prevention and control of invasive algae, which eventually, as indicated by Thomsen et al. (2016), can drive changes in the structure of marine biological communities. Based on current knowledge, it is not possible to affirm that *Polysiphonia subtilissima* or other *Polysiphonia* species represent a management problem (invasion) for the coasts of the Gulf of Morrosquillo, but it does show the need to increase the sampling effort and the investment of public and private funds that promote more specific research that helps to measure the impact that some of these species (and others) may have on the communities of the estuary and coral ecosystems of the region.

Considering that at the moment the macroalgae reported for the Caribbean coast of Colombia reach a number of 619 taxa (Rincón-Díaz and Gavio, 2020), and that the list of species of the tropical and subtropical Western Atlantic Ocean has recently been updated, with 1861 taxa, of which four are new names (Wynne, 2022), it is evident that the integrated report of 97 taxa in the Gulf of Morrosquillo is an indicator that shows a low knowledge of the algal diversity of this region, and we expect a large number of species yet to be recorded. However, of the total species registered for the Colombian Caribbean (619), 14% are represented



in the Gulf of Morrosquillo, projecting it as a relevant ecosystem for the survival of Colombia's algal biodiversity. This potential diversity can be used by the new generations of researchers interested in Phycology, so that, together with the environmental authorities, valuable and quantitative information can be provided allowing more precise decision-making in the management, sustainable use, and marine-coastal conservation of the Colombian Caribbean.

## Author contributions

HLQM conceived the idea of this work, collected, and identified the new species records, compiled information, and analyzed data. DAHC compiled and analyzed data, verified the taxonomy of *Bostrychia tenella* by taking photographs at the Universidad del Valle, and adjusted editorial formatting details. BG analyzed the information and confirmed the taxonomy of the new records. All authors made substantial contributions to the writing, discussion, data review, photography, text translation, and final approval of this article. The map has been prepared by DAHC and HLQM.

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**Appendix:** Updated list of macroalgal species in the Gulf of Morrosquillo, Colombia. References: 1 (Schnetter, 1976), 2 (Schnetter, 1978), 3 (Patiño and Flórez, 1993), 4 (Díaz-Pulido and Díaz-Ruíz, 2003), 5 (Quirós-Rodríguez et al., 2010), 6 (Sampedro-M. et al., 2012), 7 (Quirós-Rodríguez et al., 2013), 8 (Meneses and Rivera, 2014), and 9 (Quintana-M. and Mercado-Gómez, 2017). Description of acronyms: Observations (OBS), Inclusion code (IC), doubtful record (?), \*new record for Gulf of Morrosquillo.

Taxa	References	IC
<b>HETEROKONTOPHYTA</b>		
<b>Phaeophyceae</b>		
<b>Dictyotales</b>		
<b>Dictyotaceae</b>		
<i>Canistrocarpus cervicornis</i> (Kützinger) De Paula & De Clerck	2, 4, 5, 9	
<i>Dictyota ciliolata</i> Sonder ex Kützinger	2, 3, 4, 5, 9	
<i>Dictyota implexa</i> (Desfontaines) J.V. Lamouroux	3	
<i>Dictyota jamaicensis</i> W.R. Taylor	3	
<i>Dictyota pulchella</i> Hörnig & Schnetter	9	
<i>Padina antillarum</i> (Kützinger) Piccone	5	
<i>Padina boergesenii</i> Allender & Kraft	5	
<i>Padina gymnospora</i> (Kützinger) Sonder	2, 3, 4, 5	
<i>Padina haitiensis</i> Thivy	5	
<i>Padina pavonica</i> (Linnaeus) Thivy	9	
<i>Spatoglossum schroederi</i> (C. Agardh) Kützinger	3	
<i>Stypopodium zonale</i> (J.V. Lamouroux) Papenfuss	5	
<b>Ectocarpales</b>		
<b>Acinetosporaceae</b>		
* <i>Feldmannia mitchelliae</i> (Harvey) H.-S. Kim		Macroalg-CCCP-07
<b>Ectocarpaceae</b>		
<i>Ectocarpus</i> sp.	5	
<b>Fucales</b>		
<b>Sargassaceae</b>		
<i>Sargassum natans</i> (Linnaeus) Gaillon	3, 9	
<i>Turbinaria turbinata</i> (Linnaeus) Kuntze	2, 4	
<b>RHODOPHYTA</b>		
<b>Florideophyceae</b>		
<b>Corallinales</b>		
<b>Corallinaceae</b>		
<i>Jania cubensis</i> Montagne ex Kützinger	3	
<b>Lithophyllaceae</b>		
<i>Amphiroa fragilissima</i> (Linnaeus) J.V. Lamouroux	4	
<b>Nemaliales</b>		
<b>Galaxauraceae</b>		
<i>Dichotomaria obtusata</i> (J. Ellis & Solander) Lamarck	5, 7	
<i>Tricleocarpa fragilis</i> (Linnaeus) Huisman & R.A. Townsend	5	
<b>Liagoraceae</b>		
<i>Titanophycus validus</i> (Harvey) Huisman, G.W. Saunders & A.R. Sherwood	4	
<b>Ceramiales</b>		
<b>Ceramiaceae</b>		



## Appendix: Continuation.

Taxa	References	IC
* <i>Antithamnionella breviramosa</i> (E.Y. Dawson) Wollaston		Macroalg-CCCP-02
* <i>Centroceras gasparrinii</i> (Meneghini) Kützing		Macroalg-CCCP-03
<i>Centroceras micracanthum</i> Kützing	9	
<i>Ceramium cimbricum</i> H.E. Petersen	5, 7	
<b>Delesseriaceae</b>		
<i>Hypoglossum hypoglossoides</i> (Stackhouse) Collins & Hervey	1, 3, 4	
<b>Rhodomelaceae</b>		
<i>Acanthophora muscoides</i> (Linnaeus) Bory	3, 4, 5, 7	
<i>Acanthophora spicifera</i> (M.Vahl) Børgesen	5, 7, 6, 9	
<i>Alsidium seaforthii</i> (Turner) J. Agardh	3, 4, 5, 7	
<i>Alsidium triquetrum</i> (S.G. Gmelin) Trevisan	3, 5, 7	
* <i>Bostrychia tenella</i> (J.V. Lamouroux) J. Agardh		Macroalg-CCCP-04
<i>Laurencia obtusa</i> (Hudson) J.V. Lamouroux	5, 7	
* <i>Melanothamnus sphaerocarpus</i> (Børgesen) Díaz-Tapia & Maggs		Macroalg-CCCP-05
<i>Palisada perforata</i> (Bory) K.W. Nam	3, 5, 7	
? <i>Polysiphonia subtilissima</i> Montagne	6	
<b>Gelidiales</b>		
<b>Gelidiaceae</b>		
<i>Gelidium americanum</i> (W.R. Taylor) Santelices	3, 5, 6	
<i>Gelidium pusillum</i> (Stackhouse) Le Jolis	3, 5, 7	
<b>Gelidiellaceae</b>		
<i>Gelidiella acerosa</i> (Forsskål) Feldmann & Hamel	4, 5, 7, 9	
<b>Pterocladaceae</b>		
<i>Pterocladia capillacea</i> (S.G. Gmelin) Santelices & Hommersand	3	
<b>Gigartinales</b>		
<b>Cystocloniaceae</b>		
<i>Hypnea musciformis</i> (Wulfen) J.V. Lamouroux	5, 7, 9	
<i>Hypnea spinella</i> (C. Agardh) Kützing	5, 7, 9	
? <i>Hypnea valentiae</i> (Turner) Montagne	8	
<b>Solieriaceae</b>		
* <i>Agardhiella ramosissima</i> (Harvey) Kylin		Macroalg-CCCP-06
<i>Agardhiella subulata</i> (C. Agardh) Kraft & M.J. Wynne	3	
<i>Solieria filiformis</i> (Kützing) P.W. Gabrielson	5, 7, 9	
<b>Gracilariales</b>		
<b>Gracilariaceae</b>		
<i>Gracilaria blodgettii</i> Harvey	5, 7	
<i>Gracilaria caudata</i> J. Agardh	3	
<i>Gracilaria crassissima</i> (P. Crouan & H. Crouan) P. Crouan & H. Crouan	3	
<i>Gracilaria cervicornis</i> (Turner) J. Agardh	5, 7	
<i>Gracilaria damicornis</i> J. Agardh	5, 7	
<i>Gracilaria domingensis</i> (Kützing) Sonder ex Dickie	4, 5	
<i>Gracilaria flabelliformis</i> (P. Crouan & H. Crouan) Fredericq & Gurgel	9	
<i>Gracilaria isabellana</i> Gurgel, Fredericq & J.N. Norris	4	



## Appendix: Continuation.

Taxa	References	IC
<i>Gracilaria mammillaris</i> (Montagne) M. Howe	5, 7	
<i>Gracilariopsis lemaneiformis</i> (Bory) E.Y. Dawson, Acleto & Foldvik	5, 7	
<i>Gracilariopsis longissima</i> (S.G. Gmelin) Steentoft, L.M. Irvine & Farnham	3	
<b>Halymeniales</b>		
<b>Grateloupeae</b>		
<i>Dermocorynus dichotomus</i> (J. Agardh) Gargiulo, Morabito & Manghisi	3	
<i>Grateloupea cuneifolia</i> J. Agardh	3	
<i>Grateloupea filicina</i> sensu auctorum, non (J.V. Lamouroux) C. Agardh	3, 4, 5	
<b>Halymeniaceae</b>		
<i>Cryptonemia atrocotalis</i> C.W. Schneider, C.E. Lane & G.W. Saunders	3	
<i>Halymenia duchassaingii</i> (J. Agardh) Kylin	4, 5	
<b>Rhodymeniales</b>		
<b>Rhodymeniaceae</b>		
<i>Botryocladia shanksii</i> E.Y. Dawson	4	
<b>Champiaceae</b>		
<i>Coelothrix irregularis</i> (Harvey) Børgesen	9	
<b>Lomentariaceae</b>		
<i>Ceratodictyon planicaule</i> (W.R. Taylor) M.J. Wynne	3, 9	
<b>CHLOROPHYTA</b>		
<b>Ulvophyceae</b>		
<b>Bryopsidales</b>		
<b>Derbesiaceae</b>		
? <i>Derbesia marina</i> (Lyngbye) Solier	4	
<b>Bryopsidaceae</b>		
<i>Bryopsis pennata</i> J.V. Lamouroux	3, 5, 9	
<i>Bryopsis plumosa</i> (Hudson) C. Agardh	5	
<i>Bryopsis ramulosa</i> Montagne	3	
<b>Caulerpaceae</b>		
? <i>Caulerpa chemnitzia</i> (Esper) J.V. Lamouroux	1, 3	
<i>Caulerpa cupressoides</i> (Vahl) C. Agardh	3, 9	
<i>Caulerpa mexicana</i> Sonder ex Kützing	3	
<i>Caulerpa racemosa</i> (Forsskål) J. Agardh	3, 9	
<i>Caulerpa sertularioides</i> (S.G. Gmelin) M. Howe	1, 3, 4, 5, 6, 9	
<i>Caulerpa sertularioides</i> f. <i>longiseta</i> (Bory) Svedelius	5	
<i>Caulerpa taxifolia</i> (M.Vahl) C. Agardh	1, 3, 4, 5, 9	
<i>Caulerpa verticillata</i> J. Agardh	3, 5, 9	
<b>Halimedaceae</b>		
<i>Halimeda discoidea</i> Decaisne	3	
<i>Halimeda incrassata</i> (J.Ellis) J.V. Lamouroux	3, 4	
<i>Halimeda opuntia</i> (Linnaeus) J.V. Lamouroux	3, 4, 5	
<i>Udotea conglutinata</i> (J. Ellis & Solander) J.V. Lamouroux	3, 4	
<i>Udotea flabellum</i> (J. Ellis & Solander) M. Howe	1, 4	
<i>Udotea occidentalis</i> A. Gepp & E.S. Gepp	4	
<i>Penicillus capitatus</i> Lamarck	3, 4	



## Appendix: Continuation.

Taxa	References	IC
<b>Cladophorales</b>		
<b>Cladophoraceae</b>		
<i>Chaetomorpha antennina</i> (Bory) Kützing	5	
<i>Chaetomorpha clavata</i> Kützing	1, 4	
<i>Chaetomorpha linum</i> (O.F. Müller) Kützing	5	
<i>Cladophora prolifera</i> (Roth) Kützing	3, 5	
<i>Cladophora vagabunda</i> (Linnaeus) C. Hoek	1, 4, 5	
<b>Siphonocladaceae</b>		
<i>Chamaedoris peniculum</i> (J. Ellis & Solander) Kuntze	3	
<b>Valoniaceae</b>		
<i>Valonia ventricosa</i> J. Agardh	3	
<b>Dasycladales</b>		
<b>Dasycladaceae</b>		
<i>Neomeris annulata</i> Dickie	3, 5	
<b>Polyphysaceae</b>		
<i>Acetabularia caliculus</i> J.V. Lamouroux	9	
<i>Acetabularia crenulata</i> J.V. Lamouroux	5	
<i>Parvocaulis pusillus</i> (M. Howe) S. Berger, U. Fettweiss, S. Gleissberg, L.B. Liddle, U. Richter, H. Sawitzky & G.C. Zuccarello	5	
<b>Ulvales</b>		
<b>Ulviceae</b>		
<i>Ulva clathrata</i> (Roth) C. Agardh	3	
<i>Ulva intestinalis</i> Linnaeus	5	
<i>Ulva lactuca</i> Linnaeus	3	

