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LISTS OF SPECIES

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An updated list of marine green algae (Chlorophyta, Ulvophyceae) from the Biosphere Reserve of Sian Ka'an, Quintana Roo, Mexico

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Abstract: In spite of it is baseline importance for comparative studies with the past and present data, an updated list of marine green algal taxa for the Biosphere Reserve of Sian Ka'an is not yet available. The aim of this paper is to present an updated list of marine green algal taxa for the Sian Ka'an Reserve based on literature and collections made by the authors in 17 localities during 2011–2012. Fifty-five taxa are new records for the study area and thus the list has increased to 129. Additionally five taxa are reported for the first time to Quintana Roo, and 11 to Mexican Atlantic coast. These results contribute to the knowledge of green seaweed diversity and also support the relevance of the Sian Ka'an Reserve as a high priority area for conservation due to their high level of algal biodiversity.

Key words: inventory; new records; seasonality; epiphytism; substrate; Caribbean

INTRODUCTION

Marine green algae, also known as green seaweeds, are among the most important primary producers in tropical benthic ecosystems of the world's oceans, but they also provide shelter, nursery grounds, and food sources for marine organisms. Some calcareous species contribute to the formation of sand on the beaches, and consolidate and avoid erosion of the bottom (Fukunaga 2008; Lee 2008; Beidenger et al. 2013). Green algae can be useful bioindicators of PAH pollution (polycyclic aromatic hydrocarbons) (Calva and Torres 2008) and, some species produce algal blooms related to the increase in concentration of nutrients (Cano-Malla et al. 2007). Quintana Roo state is one of the coastal regions with the highest green seaweed diversity in Mexico (Cetz-Navarro et al. 2008). Although the Biosphere Reserve of Sian Ka'an (BRSK) has not been well explored, this may suggest that the species richness of green seaweeds is underestimated. There are few phycological surveys for the study area, and most of the phycological knowledge occurred during 1989–1992 and, the last contribution was reported fifteen years ago (Aguilar-Rosas et al. 2001). Until the present, 74 infrageneric taxa of marine green algae have been cited (Taylor 1960; Aguilar-Rosas et al. 1989; Aguilar-Rosas 1990; Aguilar-Rosas et al. 1992; Aguilar-Rosas et al. 1998; Aguilar-Rosas et al. 2001). Currently, aquatic ecosystems of BRSK are seriously threatened by both an inadequate management of resources and the urban development (Cepeda-González et al. 2007). In response to these threats, the project "Sian Ka'an Ecological Integrity Analysis" contemplates the use of algae as an essential biologic element in the monitoring of such systems; however, its application is still pending due to lack of reliable and updated inventory (Cepeda-González et al. 2007). In this context, the aim of this paper is to present an update of the species list of marine green algae (Chlorophyta, Ulvophyceae) of the BRSK, with information of their seasonality, distribution, epiphytism, and affinity to substrate.

MATERIALS AND METHODS

Study site

The BRSK is located in the eastern part of the Yucatan Peninsula, between 19°05′ N, 087°22′ W and 20°07′ N, 088°02′ W (Figure 1), it comprises about 110 km of coastline of Quintana Roo state, in the region known as Mexican Caribbean (Instituto Nacional de Ecología 1995). The climate is warm subhumid (Aw2), three seasons may be distinguished by fluctuations in rainfall and ambient temperature: rainy season from May to October, windy season since November to February and dry season from February to May (Garcia 2004). The coastal region of the BRSK is characterized by rocky intertidal areas that not

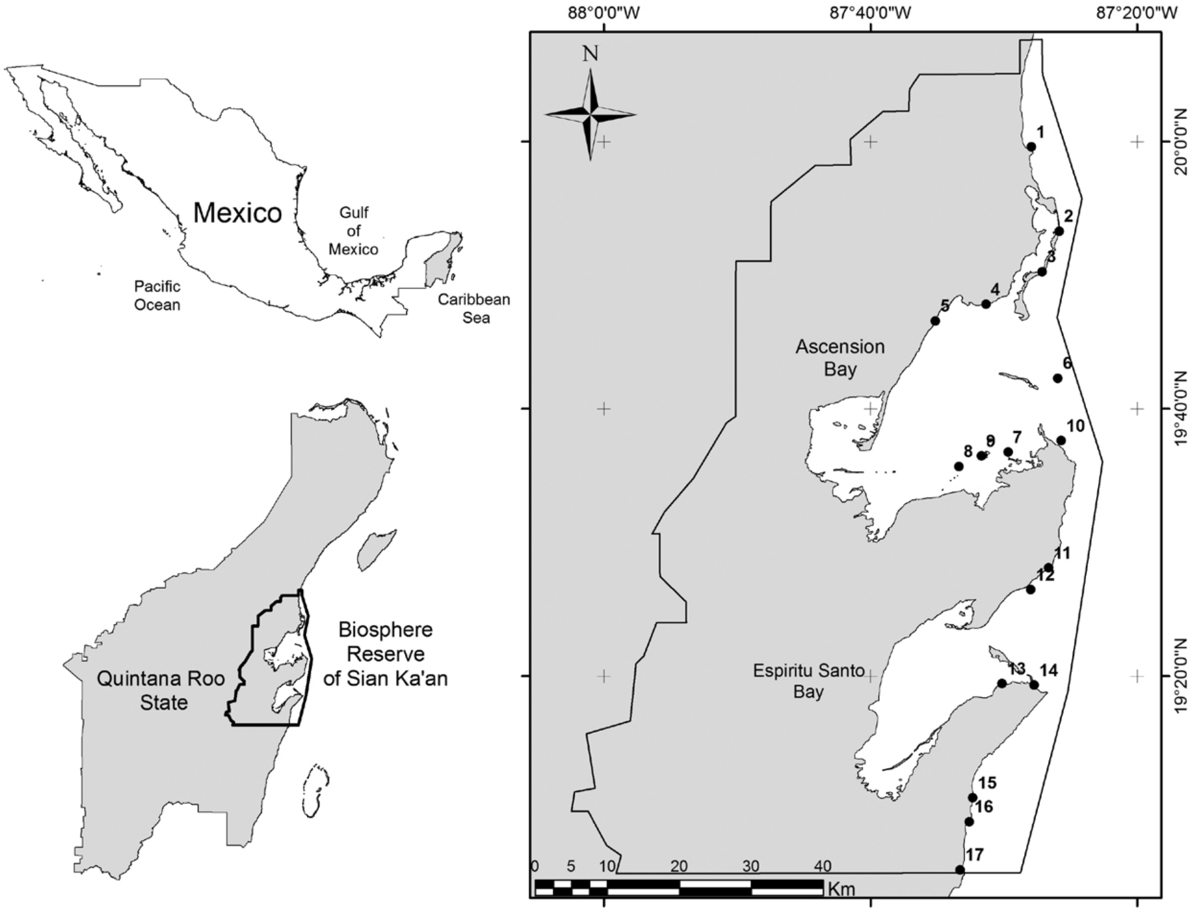


Figure 1. Area of study and sampling sites. 1) Punta Pelicanos, 2) Hualapich, 3) Punta Xoquem, 4) Punta Gorda, 5) Vigía Chico, 6) Cayo Valencia, 7) Cayo Cedro, 8) Cayo Tres Marías, 9) Cayo Lagartijas, 10) Hualastok, 11) Punta Sacrificios, 12) Tres cocos, 13) Golfito, 14) Punta Herrero, 15) Punta Mosquitero, 16) Playa Dei, 17) Pulticub.

exceed one meter elevation and by the presence of rocky and sandy beaches with sea grass meadows consisting mainly of *Thalassia testudinum* Banks ex König. This zone is under the influence by marine water of the Yucatan Current that moves along the coast from south to north with an average temperature of 27.9°C. Other regions in BRSK are the Ascension and Espiritu Santo bays: the first has a wide mouth of 12.5 km bounded on the north by Punta Allen and on the south by Punta Hualastok and an average depth of 4 m; inside this bay there are a several cays of different extension covered by Red Mangrove, *Rhizophora mangle* Linnaeus; the second bay has a narrow mouth of 2.5 km from Punta Niluc to Techal Island, and an average depth of 2 m (Espejel-Montes 1983). In the external zone of both bays, the bottom is rocky and sandy with sea grass meadows, in the central parts the substrate is sandy with/without sea-grass meadows and inside of the bays, the bottom is muddy associated with Red Mangrove (Aguilar-Rosas et al. 1989; Aguilar-Rosas 1990). The bays are considered brackish environments, resulting from the mixing of fresh and marine water, the fresh water comes from the channel marshes and wellsprings located in the bottom of the bays, and the marine water enters to these by currents and tides; maximum salinity values (34–35 psu) are recorded in areas near the mouth of the bays, while the lower (13–25 psu) are documented into the internal portion of the bays (Herrera-Silveira 2006).

Data collection

Marine green algae were collected from 17 localities sites along the BRSK, at Quintana Roo state (Figure 1), during windy (December 2011), dry (March 2012) and rainy seasons (September 2012). Due to the adverse weather conditions during the windy season was not possible to collect biological material in four of the 17 localities proposed in this study (Table 1). Algae were collected and preserved according to the techniques established by Abbott and Dawson (1978). Permission to collect specimens was granted by the Dirección General de Ordenamiento Pesquero y Acuícola de México (No. DGOPA 08980.011111.3063).

Data analysis

Phycological material were determined using Taylor (1960, 1962), Littler and Littler (1990, 1991, 1992, 2000), Schneider and Searles (1991) and, Dawes and Mathieson (2008). Reference specimens were deposited at herbarium ENCB. The list of species was prepared from both, data collection and previous records; follows

Table 1. Substrate characteristic, wave exposure, region and maximum depth collection of the 17 sampling sites in the BRSK, Quintana Roo, Mexico. AB: Ascension, EB: Espiritu Santo bays.

Sample sites		Characteristic	Coordinates	
			Latitude N	Longitude W
1	Punta Pelicanos	Rocky with sandy area and sea grass meadows. Exposed. Coastal 1.5 m	19°59′38″	087°27′55″
2	Hualapich	Rocky. Exposed Coastal. 1 m	19°53′20″	087°25′50″
3	Punta Xoquem	Rocky with sandy area with sea grass meadows. Exposed Coastal.1.0 m	19°50′05″	087°27′07″
4	Punta Gorda	Sandy associated to mangrove. Protected. Inside AB. 1 m	19°47′51″	087°31′20″
5	Vigia Chico	Sandy associated to mangrove. Protected. Inside AB. 1 m	19°46′36″	087°35′07″
6	Cayo Valencia	Sandy associated to sea grass meadows and mangrove. Protected. Outside AB. 1 m	19°42′19″	087°25′56″
7	Cayo Cedro	Sandy associated to mangrove. Protected. Inside AB. 1 m	19°36′46″	087°29′40″
8	Cayo Lagartijas		19°36′29″	087°31′40″
9	Cayo Tres Marias		19°35′42″	087°33′21″
10	Hualastok	Sandy with sea grass meadows. Protected. Outside AB. 4 m	19°37′28″	087°25′41″
11	Punta Sacrificios	Rocky. Exposed Coastal. 2 m	19°28′06″	087°26′38″
12	Tres Cocos	Sandy with sea grass meadows. Protected. Outside EB. 1.5 m	19°26′28″	087°27′59″
13	Golfito	Sandy. Protected. Inside EB. 1 m	19°19′26″	087°30′08″
14	Punta Herrero	Sandy with sea grass meadows. Protected. Outside EB. 2 m	19°19′19″	087°27′43″
15	Punta Mosquitero	Sandy with some rocks. Exposed Coastal. 1 m	19°10′53″	087°32′20″
16	Playa Dei	Sandy with sea grass meadows. Protected. Coastal. 1.5 m	19°09′05″	087°32′35″
17	Pulticub	Rocky with sea grass meadows. Exposed Coastal. 1.5 m	19°05′29″	087°33′16″

the classification proposed by Wynne (2011) and the nomenclature was updated following Guiry and Guiry (2015). The list of species includes data with new records, seasonality, distribution, and affinity to substrate. Furthermore the total number of species it is estimated by localities and climatic station.

RESULTS

A total of 129 infrageneric taxa of marine green algae (108 species, eight varieties and 13 forms) were determined from the references and collection, distributed in 19 families; the best represented families were: Udoteaceae (21) and Cladophoraceae (20), besides Caulerpaceae with 19, Halimedaceae with 11 and Dichotomosiphonaceae with 12. The best represented genera regarding taxa richness were: *Caulerpa* with 19, *Cladophora* 13, *Udotea* 12, *Avrainvillea* 12, *Halimeda* 11, and *Chaetomorpha* 7 (Table 2). Most infrageneric taxa were found during rainy (88) and dry seasons (71), and a lower number during windy season (68 species). The data suggest seasonality in the flora of green algae in BRSK given by an increase of number of species of Cladophoraceae, Bryopsidaceae and Ulvaceae during the rainy season. The highest number of infrageneric taxa was found in sample sites constituted by rocky and sandy substrates in the coastal region, like Punta Sacrificios (52 taxa), Punta Pelicanos (50 taxa), Pulticub (47 taxa), Hualapich (46 taxa), Punta Mosquitero (47 taxa) and Punta Xoquem (44taxa). In the localities with sandy bottom and associate with sea-grass meadows and mangroves located in the external region of the bays, the number of taxa varies from 18 to 34. The lower richness was ubicated in those localities with sandy substrates

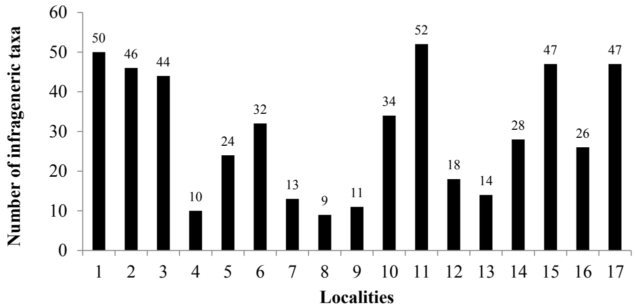


Figure 2. Total taxa richness in the localities of Biosphere Reserve of Sian Ka'an: 1) Punta Pelicanos, 2) Hualapich, 3) Punta Xoquem, 4) Punta Gorda, 5) Vigía Chico, 6) Cayo Valencia, 7) Cayo Cedro, 8) Cayo Tres Marías, 9) Cayo Lagartijas, 10) Hualastok, 11) Punta Sacrificios, 12) Tres cocos, 13) Golfito, 14) Punta Herrero, 15) Punta Mosquitero, 16) Playa Dei, 17) Pulticub.

without seagrass, inside the bays, like Punta Gorda (10 taxa) and Cayo Tres Marias (94 taxa) (Figure 2). The most common taxa regarding their occurrence over the three seasons were: *Anadyomene stellata* (Wulfen) C. Agardh, *Cladophoropsis membranacea* (Hoffman Bang ex C. Agardh) Børgesen, *Avrainvillea longicaulis* (Kützing) G. Murray & Boodle, *A. nigricans* Decaisne, *Dictyosphaeria cavernosa* (Forsskål) Børgesen, *Halimeda incrassata* (J. Ellis) J.V. Lamouroux, *H. monile* (J. Ellis & Solander) J.V. Lamouroux, *Halimeda opuntia* (Linnaeus) J.V. Lamouroux, *Penicillus capitatus* Lamarck, *P. dumetosus* (J.V. Lamouroux) Blainville, *P. lamourouxii* Decaisne, *P. pyriformis* A. Gepp & E. Gepp, *Rhipocephalus phoenix* (J. Ellis & Solander) Kützing, *Udotea conglutinata* (J. Ellis & Solander) M.A. Howe, *U. cyathiformis* f. *sublitorallis* (W.R. Taylor) D.S. Littler & M.M. Littler, and *U. flabellum* (J. Ellis & Solander) M.A. Howe, (Table 2). The marine green algae were grow on three types of substrate: 1) rocky

(54%), 2) sandy (34%), and 3) on other plants (50%). Some species were present on two of the three types of substrates, for example *Caulerpa cupressoides* (Vahl) C. Agardh, *Cladophora catenata* (Linnaeus) Kützing, *D. ocellata* (M.A. Howe) Olsen-Stojkovich, *Halimeda opuntia* (Linnaeus) J.V. Lamouroux and, *Siphonocladus rigidus* M.A. Howe. On the other hand, some taxa were found only on rocky substrate, like *Avrainvillea rawsonii* (Dickie) M.A. Howe, *Caulerpa. racemosa* (Forsskål) J. Agardh, *Cladophora sericea* (Hudson) Kützing, *Codium intertextum* Collins & Hervey, *Neomeris annulata* Dickie, *Udotea caribaea* D.S. Littler & M.M. Littler, and *Ulva compressa* Linnaeus. In contrast, *Caulerpa paspaloides* (Bory de Saint-Vincent) Greville, *C. sertularioides* (S.G. Gmelin) M.A. Howe , *Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux, *Rhipocephalus oblongus* Decaisne, and *Udotea luna* D.S. Littler & M.M. Littler were found on sandy bottoms. Finally, the epiphytic algae were

Table 2. List of marine green algal taxa Biosphere Reserve of Sian Ka'an, Quintana Roo, Mexico. Seasonality: M: March (dry), D: December (windy), S: September (rainy). Distribution: 1: Punta Pelicanos, 2: Hualapich, 3: Punta Xoquem, 4: Punta Gorda, 5: Vigía Chico, 6: Cayo Valencia, 7: Cayo Cedro, 8: Cayo Tres Marías, 9: Cayo Lagartijas, 10: Hualastok, 11: Punta Sacrificios, 12: Tres cocos, 13: Golfito, 14: Punta Herrero, 15: Punta Mosquitero, 16: Playa Dei, 17: Pulticub. Substrate: R: Rocky, S: Sandy, Ep: Ephyphite. Type of algae: A: Anual, P: Perennial. References: 1: Taylor (1972), 2: Aguilar-Rosas et al. (1989), 3: Aguilar-Rosas (1990), 4: Aguilar- Rosas et al. (1992), 5: Aguilar-Rosas et al. (1998), 6: Aguilar-Rosas et al. (2001). New records: SK: Sian Ka'an, NRM: Mexican Atlantic Coast.

Chlorophyta	Seasonality/ Distribution	Substrate	Type of algae	References	Herbarium number	New record
Class Ulvophyceae						
Order Ulotrichales						
Family Ulotrichaceae						
Ulothrix flacca (Dillwyn) Thuret	M/11	Ep-79	A		20610	SK
Order Ulvales						
Family Phaeophilaceae						
Phaeophila dendroides (P.L. Crouan & H.M. Crouan) Batters	D, M/2, 3, 5, 14	Ep-99	A		19838 20470	SK
Family Ulvellaceae						
Ulvella viridis (Reinke) R. Nielsen, C.J. O'Kelly & B. Wysor	M/5	Ep-82	A		20764	SK
Family Ulvaceae						
Ulva chaetomorphoides (Børgesen) Hayden, Blomster, Maggs, P.C. Silva, M.J. Stanhope & J.R. Waaland	M, S/5, 11	Ep-105	A		20611 20714	SK
U. compressa Linnaeus	D, S/1, 15	R	A		20360	SK
U. flexuosa Wulfen	D, M, S/1, 5, 11, 14, 15	Ep-96	A	2, 3	20468 20861	
U. lactuca Linnaeus			A	2, 3		
U. prolifera O.F. Müller	S/13	R	A		20875	SK
U. rigida C. Agardh				2, 3		
Order Cladophorales						
Family Anadyomenaceae						
Anadyomene saldanhae A.B. Joly & E.C. Oliveira	M, S/9, 17	Ep-MR	A		20835	SK
A. stellata (Wulfen) C. Agardh	D, M, S/2, 4, 5, 6, 7, 8, 9, 11, 13, 14, 17	R, Ep-80	A	1, 2, 3, 5	20374 20866	
Family Cladophoraceae						
Chaetomorpha aerea (Dillwyn) Kützing	S/14, 15	Ep-98	A	3	20866	
C. antennina (Bory de Saint-Vincent) Kützing	S/3	Ep-17	A		20758	SK
C. brachygona Harvey	S/3	Ep-16	A		20893	SK
C. crassa (C. Agardh) Kützing	S/11, 14, 15	Ep-*Sargassum*	A		20751	SK
C. gracilis Kützing	M, S/1, 2, 3, 11, 14, 15	R, Ep-98	A		20829	SK
C. linum (O.F. Müller) Kützing	D, M, S/1, 2, 315, 17	Ep-83	A	2, 3, 5	20758	
C. minima F.S. Collins & Hervey	M/3	Ep-97	A		20496	SK
Cladophora albida (Nees) Kützing	M/11	Ep-73	A		20824	SK
C. catenata (Linnaeus) Kützing	D, M, S/1, 2, 3, 10, 11, 14, 15, 16, 17	R, Ep-86	A	1, 2, 3	19843 19844	
C. coelothrix Kützing	D/11	Ep-33	A		20862	SK
C. constricta F.S. Collins	S/15	Ep-98	A		20874	SK
C. flexuosa (O.F. Müller) Kützing	D, S/12, 17	Ep-86	A		20761 20883	SK
C. glomerata var. *crassior* (C. Agardh) Hoek	S/3	Ep-16	A		20881	SK
C. jongorium C. van den Hoek				4		
C. laetevirens (Dillwyn) Kützing	D/11	Ep-73	A		20610	SK
C. liebetruthii Grunow	M, S/11, 15, 17	Ep-33	A		20760	SK

Continued

Table 2. *Continued.*

Chlorophyta	Seasonality/ Distribution	Substrate	Type of algae	References	Herbarium number	New record
C. sericea (Hudson) Kützing	D/1	R	A	5	20610	
C. submarina P.L. Crouan & H.M. Crouan	D, M, S/2, 14, 15, 16	Ep-62	A		19846	SK
C. vagabunda (Linnaeus) Hoek	M, S/2, 15	Ep-47	A	2, 3, 5	20759	
Rhizoclonium riparium (Roth) Harvey	M/11	Ep-73	A	3	20610	
Family Boodleaceae						
Boodlea composita (Harvey) F. Brand				1		
Cladophoropsis fasciculata (Kjellman) Wille	D, M, S/2, 3, 8, 11, 14, 15, 16, 17	R, Ep-83	A		20715 20760	NRM
C. macromeres W.R. Taylor				1, 3, 5		
C. membranacea (Hoffman Bang ex C. Agardh) Børgesen	D, M, S/1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17	R, Ep-106	A	2, 3, 5	20754 20755	
Family Siphonocladaceae						
Chamaedoris peniculum (J. Ellis & Solander) Kuntze	S/10	Ep-*Neogoniolithon*	A		20762	SK
Dictyosphaeria cavernosa (Forsskål) Børgesen	D, M, S/1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 14, 15, 16, 17	R, Ep-96	A	1, 2, 3, 5	20590 20719 20722	
D. ocellata (M.A. Howe) Olsen-Stojkovich	D, M, S/1, 5, 6, 10, 11, 12, 13, 14, 15, 16	R, Ep-116	A	2, 3, 5	20720 20721 20753	
D. versluysii Weber-van Bosse				1, 2, 4		
Ernodesmis verticillata (Kützing) Børgesen	D/1	R	A	3, 5	20874	
Siphonocladus rigidus M.A. Howe	D, M, S/1, 2, 3, 4, 9, 10, 11, 13, 17	R, Ep-83	A	4, 5	20716 20752	
S. tropicus (P.L. Crouan & H.M. Crouan) J. Agardh				4		
Family Valoniaceae						
Petrosiphon adhaerens M.A. Howe				3, 5		
Valonia aegagropila C. Agardh				3, 5		
V. macrophysa Kützing	D, M, S/1, 3, 6, 9, 10, 11, 13, 14, 15, 17	R, Ep-88	A	2, 3, 5	20379 20717	
V. utricularis (Roth) C. Agardh	D, S/2, 5	R	A	3, 5	20889	
V. ventricosa J. Agardh	D, M, S/1, 2, 3, 5, 6, 10, 11, 14, 15, 16, 17	R, Ep-83	A	1, 2, 3, 5	20718 20859	
Valoniopsis pachynema (G. Martens) Børgesen	S/15	R, Ep-97	A		20869	SK
Order Bryopsidales						
Family Bryopsidaceae						
Bryopsis halliae W.R. Taylor				4		
B. pennata J.V. Lamouroux	S/15	Ep-*Digenea*	A		20890	SK
Pseudobryopsis blomquistii Díaz-Piferrer	S/15	R, Ep-116	A		20868	SK
P. cf. *venezolana* (W.R. Taylor) K.D. Henne & R. Schnetter	D/1	R	A		20867	
Trichosolen duchassaingii (J. Agardh) W.R. Taylor	S/5, 15	R, Ep-MR	A		20891	SK
T. longipedicellatus (H.L. Blomquist & Díaz-Piferrer) D.M. John	S/6	Ep-MR	A		20375	NRM
Family Derbesiaceae						
Derbesia vaucheriformis (Harvey) J. Agardh	S/6	Ep-MR	A		20757	SK
Pedobesia simplex (Meneghini ex Kützing) M.J. Wynne & Leliaert	M/12	Ep-105	A		20714	SK
Family Codiaceae						
Codium decorticatum (Woodward) M.A. Howe				4		
C. intertextum Collins & Hervey	M, S/17	R	A		20376 20777	SK
Family Caulerpaceae						
Caulerpa ambigua Okamura				3, 5		
C. cupressoides (Vahl) C. Agardh	D, M, S/1, 6, 10, 11, 15, 17	A, Ep-96	P	3, 5	19955 20376	
C. cupressoides var. *lycopodium* Weber-van Bosse	M/2, 11, 17	S	P			SK
C. cupressoides var. *mamillosa* (Montagne) Weber-van Bosse	D, M, S/1, 2, 3, 6, 11, 15, 16, 17	S	P	2, 3	20745 20746 20821	
C. cupressoides var. *turneri* Weber-van Bosse				2, 3		
C. mexicana Sonder ex Kützing	D, M, S/2, 6, 7, 15, 16	Ep-105	P	3, 5	20823	

Continued

Table 2. *Continued.*

Chlorophyta	Seasonality/ Distribution	Substrate	Type of algae	References	Herbarium number	New record
C. mexicana f. *laxior* (Weber-van Bosse) W.R. Taylor	D/1	R	P		20387	SK
C. paspaloides (Bory de Saint-Vincent) Greville	D, M/2, 5, 10	S	P	2, 3, 5	19959	
C. paspaloides var. *laxa* Weber-van Bosse	D, S/1, 2, 6, 10	S, R	P		20747 20865	SK
C. prolifera (Forsskål) J. Agardh	D, S/1, 2, 3, 11	R	P	3, 5	20489 20779	
C. prolifera f. *obovata* J. Agardh			P	3		
C. racemosa (Forsskål) J. Agardh	D, M, S/1, 11, 16, 17	R	P	1, 2, 5	20827 20853	
C. racemosa var. *macrophysa* (Sonder ex Kützing) W.R. Taylor	D, M, S/1, 2, 3, 11, 15, 17	Ep-96, R	P		20486 20827	SK
C. sertularioides (S.G. Gmelin) M.A. Howe	D, M, S/1, 7, 11, 14, 15	S	P	2, 5	20822	
C. sertularioides f. *farlowii* (Weber-van Bosse) Børgesen	D, M, S/1, 2, 3, 11, 15, 16, 17	R, S	P	3	20610 20824 20825	
C. sertularioides f. *brevipes* (J. Agardh) Svedelius				3		
C. sertularioides f. *longiseta* (Bory de Saint-Vincent) Svedelius	D, M, S/2, 5, 7, 11, 14	S, Ep-MR	P	3, 5	20780	
C. verticillata J. Agardh	D, M, S/5, 6, 7, 11, 13, 14	Ep-MR	P	1, 3, 5	20150 20826	
C. verticillata f. *charoides* Weber-van Bosse	S/11	Ep-MR	P		20744	NRM
Family Dichotomosiphonaceae						
Avrainvillea asarifolia Børgesen				2, 3		
A. asarifolia f. *olivacea* D.S. Littler & M.M. Littler	D, M, S/3, 5, 16, 17	S, R	P		20711 20832	NRM
A. digitata D.S. Littler & M.M. Littler	D, M, S/10, 12, 16, 17	R, S	P		20710 20763 20766	NRM
A. ellioti A. Gepp & E. Gepp				6		
A. fenicalii f. *flabellifolia* D.S. Littler, M.M. Littler & M.E. Hay	D, M, S/1, 2, 3, 10, 11, 15, 16, 17	S	P		20764 20765	NRM
A. longicaulis (Kützing) G. Murray & Boodle	D, M, S/1, 2, 3, 5, 10, 11, 12, 14, 15, 17	R, S	P	1, 2, 3, 5	20378 20709	
A. longicaulis f. *laxa* D.S. Littler & M.M. Littler	D, M, S/10, 11, 12, 14, 15	R, S	P		20857 20858	NRM
A. mazei G. Murray & Boodle				6		
A. nigricans Decaisne	D, M, S/1, 2, 11, 16, 17	R, S	P	1, 2, 3, 5, 6	19662 20708	
A. nigricans f. *floridana* D.S. Littler & M.M. Littler	D, M, S/1, 2, 3, 10, 11, 15, 17	R, S	P		19963 20830 20831	NRM
A. rawsonii (Dickie) M.A. Howe	D/10	R	P	1, 3, 5	20749	
A. silvana D.S. Littler & M.M. Littler	M, S/3, 17	S	P		20879	NRM
Family Halimedaceae						
Halimeda discoidea Decaisne	M/2	R	P	6	20409	
H. favulosa M.A. Howe	S/1	R	P		20871	SK
H. gracilis Harvey ex J. Agardh	S/2, 17	R, S	P		20364	SK
H. goreaui W.R. Taylor				6		
H. incrassata (J. Ellis) J.V. Lamouroux	D, M, S/1, 2, 3, 5, 6, 10, 11, 12, 14, 15, 17	S, R, Ep-83	P	1, 2, 3, 5, 6	20454 20456 20634	
H. lacrimosa M.A Howe	S/17	R	P	6	20888	
H. monile (J. Ellis & Solander) J.V. Lamouroux	D, M, S/1, 2, 3, 5, 6, 7, 10, 11, 12, 14, 15, 16, 17	S, R	P	1, 2, 3, 5, 6	20523 20468 20437	
H. opuntia (Linnaeus) J.V. Lamouroux	D, M, S/1, 2, 3, 11, 12, 14, 15, 16, 17	R, S, Ep-103	P	1, 2, 3, 5, 6	20404 20496 20494	
H. scabra M.A. Howe	D, M, S/1, 2, 3, 10, 11, 15, 16, 17	R, S	P	1, 2, 3, 5, 6	20439 20499 20498	
H. simulans M.A. Howe	D, M, S/1, 3, 5, 6, 15, 17	S	P		20471 20470 20413	SK
H. tuna (J. Ellis & Solander) J.V. Lamouroux	D, S/6, 15	S	P	2, 3, 5, 6	20185 20360	

Continued

Table 2. *Continued.*

Chlorophyta	Seasonality/ Distribution	Substrate	Type of algae	References	Herbarium number	New record
Family Rhipiliaceae						
Rhipilia tomentosa Kützing	D, M, S/1, 2, 3, 10	R	P	2, 3, 5	19964	
Family Udoteaceae						
Cladocephalus luteofuscus (P.L. Crouan & H.M. Crouan) Børgesen				1, 3, 5		
Penicillus capitatus Lamarck	D, M, S/1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17	S, R	P	1, 2, 3, 5, 6	19850 19857	
P. dumetosus (J.V. Lamouroux) Blainville	D, M, S/1, 2, 3, 6, 10, 11, 12, 14, 15, 16, 17	S, R	P	2, 3, 5	19858 20820	
P. lamourouxii Decaisne	D, M, S/1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	S, R	P	1, 2, 3, 5, 6	19853 19854	
P. pyriformis A. Gepp & E.S. Gepp	D, M, S/1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 14, 15, 17	S, R	P	1, 5, 6	20611 20714	
Rhipocephalus oblongus Decaisne	D, M, S/1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 16	S	P	3, 5	19833 19835	
R. phoenix (J. Ellis & Solander) Kützing	D, M, S/1, 2, 3, 10, 11, 15, 16, 17	R, S	P	5, 6	19834 19841	
R. phoenix f. *brevifolius* A. Gepp & E. Gepp	D, M, S/1, 3, 10, 11	R, S	P	2, 3, 5	20712 20713 20856	
R. phoenix f. *longifolius* A. Gepp & E. Gepp	D, M, S/3, 10, 17	S	P	2, 3, 5, 6	20819	
Udotea caribaea D.S. Littler & M.M Littler	D, M, S/1, 2, 3, 6, 11, 15, 16, 17	R	P		20750 20817	SK
U. conglutinata (J. Ellis & Solander) M.A. Howe	D, M, S/1, 2, 3, 6, 10, 11, 15, 17	S, R	P	2, 3, 5, 6	19839 19840 20855	
U. cyathiformis f. *sublitorallis* (W.R. Taylor) D.S. Littler & M.M. Littler	D, M, S/1, 2, 3, 6, 15, 16, 17	S	P	2, 3, 5	19961 20707 20854	
U. cyathiformis var. *flabellifolia* D.S. Littler & M.M. Littler	S/6	S	P		20887	NRM
U. dixonii D.S. Littler & M.M. Littler	S/1	R	P		20818	SK
U. fibrosa D.S. Littler & M.M. Littler	D/3	R	P		20866	NRM
U. flabellum (J. Ellis & Solander) M.A. Howe	D, M, S/1, 2, 3, 6, 10, 11, 12, 14, 15, 16, 17	S, R	P	1, 2, 3, 5, 6	19837 19838 20864	
U. looensis D.S. Littler & M.M. Littler	D/17	R	P			SK
U. luna D.S. Littler & M.M. Littler	D, S/1, 2, 11, 17	S	P		20851 20852	SK
U. occidentalis A. Gepp & E.S. Gepp				5		
U. unistratea D.S. Littler & M.M. Littler	M/17	R	P		20880	SK
U. wilsonii A. Gepp, E.S. Gepp & M.A. Howe	S/14	S	P			SK
Order Dasycladales						
Family Dasycladaceae						
Batophora oerstedii J. Agardh	D, M, S/1, 6, 7, 8, 9, 10, 13, 17	R, Ep-96	P		19960	
B. occidentalis var. *largoensis* (J.S. Prince & S. Baker) S. Berger & Kaever ex M.J.Wynne	D, M, S/2, 3, 4, 5, 6, 7, 8, 10, 13	R, Ep-96	P	1, 2, 3, 5	20748 20776 20834	SK
Cymopolia barbata (Linnaeus) J.V. Lamouroux	M, S/10, 11	R	P		20886	SK
Dasycladus vermicularis (Scopoli) Krasser in Beck & Zahlbruckner	D, M, S/1, 2, 3, 12, 15, 17	R, Ep-112	P	2, 3, 5	19954 20833	
Neomeris annulata Dickie	M, S/15, 17	R	P	3, 5	20884 20885	
Family Polyphysaceae						
Acetabularia caliculus J.V. Lamouroux	D, M, S/5	Ep-MR	P		20872 20873	SK
A. crenulata J.V. Lamouroux	M, S/1, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14	R, Ep-MR	P	1, 2, 3, 5	20259 20272 20276	

Epiphytic (Ep): The numbers or genera listed in this column correspond to seaweed on which the epiphytic species were found. Some specimens were found on mangrove roots (MR).

Chaetomorpha brachygona Harvey was epiphyte on *C. gracilis* Kützing, *Bryopsis pennata* J.V. Lamouroux on the red algae *Digenea simplex* (Wulfen) C. Agardh, and *Chaetomorpha crassa* (C. Agardh) Kützing on the brown alga *Sargassum* sp. (Table 2). In this survey 55 taxa are reported for the first time to BRSK, and the number of known taxa increases to 129 for the study area. Of these new records *Cladophora coelothrix* Kützing, *C. constricta* F.S. Collins, *C. flexuosa* (O.F. Muller) Kützing, *C. laetevirens* (Dillwyn), *C. liebetruthii* Grunow are new records for Quintana Roo state. In addition 11 taxa are new records for the Mexican Atlantic Coast (Table 2), which are described below.

New records for Mexican Atlantic Coast

Avrainvillea asarifolia* f. *olivacea D.S. Littler & M.M. Littler (Figures 3–5)

Thallus is composed by fronds up to 5 cm tall, gregarious and dark green, several stipes upright from a single rhizoid. Stipe compressed and blades with little zonation and lower margin truncate (< 2mm thick). Medullary siphons of blade 25 μm in diameter, slightly moniliform and dichotomously branching. Medullary siphons of the stipes 25 μm in diameter, slightly moniliform. Thallus occurs on hard substrate associated to coral reef and soft bottom with mangrove. Internally, *Avrainvillea asarifolia* f. *olivacea* is virtually identical to *Avrainvillea asarifolia* f. *asarifolia* but externally, plants differ greatly, especially because the blade of *A. asarifolia* f. *olivacea* has a truncated base, while that of *A. asarifolia* f. *asarifolia* has a cordate base.

Avrainvillea digitata D.S. Littler & M.M. Littler (Figures 6–8)

Thallus is composed by fronds up to 8 cm tall and 1.5 cm in diameter, gregarious and dark brownish-green. Loosely woven siphons producing a spongy texture, finger like without differentiation stipe, occasionally clavate, not zonate, attached by a large prostate rhizoidal mass. Surface siphons 20 μm in diameter, slightly moniliform. Apices of the siphons rounded and curved. This species is distinguished to *A. rawsonii* (Dickie) M.A. Howe by its digitate upright growth form and its often bulbous apex on moniliform blade siphons.

Avrainvillea fenicalii* f. *flabellifolia D.S. Littler, M.M. Littler & M.E. Hay (Figures 9–11)

Thallus is composed by fronds up to 10 cm tall, dark green but appearing whitish due to entrapped carbonate sediments. Stipe unbranched terete, arising in clusters from a large rhizoidal support. Blade entire, broadly, lobed margin, zonate. Blade siphons 20 μm in diameter, slightly moniliform, and enlargement. Surface siphons are forming cortex in the blade, tapering to 10 μm, with rounded apices. Siphons stipe 20 μm in diameter, with rounded and hooked apices. This form differs from f. *fenicalii* in the shape of its blade; f. *flabellifolia* has an entire lobed margin in contrast to the deeply incised blades off *fenicalii*. Thallus occurs in soft bottoms associated to seagrass *Thalassia testudinum*.

Avrainvillea longicaulis* f. *laxa D.S. Littler & M.M. Littler (Figures 12–15)

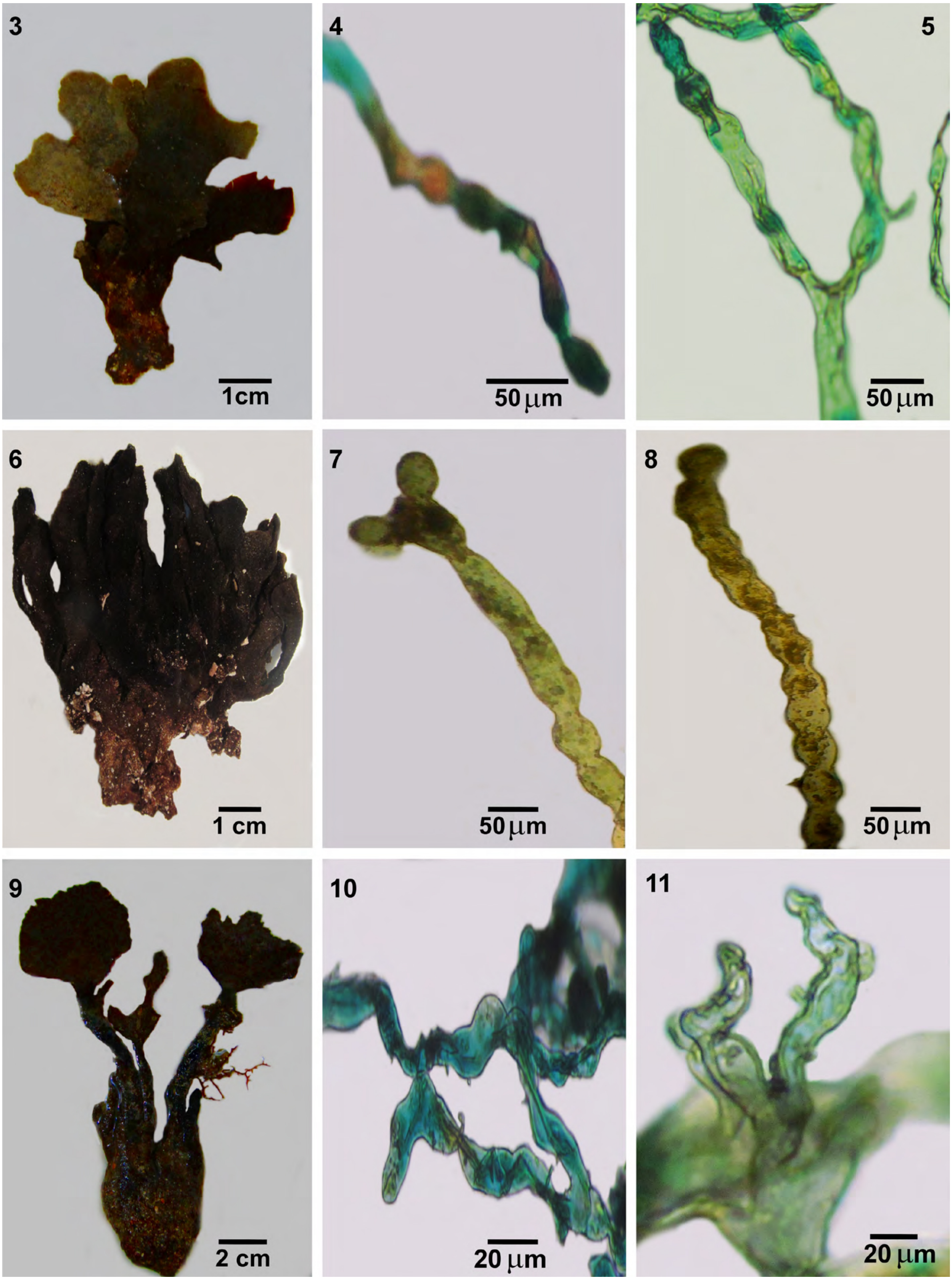
Thallus is up to15 cm tall, dark green-brown, solitary. Blade spatulate and not zonate with cuneate base. Stipe to 10 cm long, 1 cm in diameter, slightly flattened, not branched. Blade siphons mainly cylindrical to 35 μm in diameter with rounded apices. Siphons of stipe 35 μm in diameter tapering to 10 μm, moniliform, and tortuous. Thallus occurs on sandy bottoms with seagrass *Thalassia testudinum*. *Avrainvillea longicaulis* f. *laxa* differs from f. *longicaulis* by a long stipe, while f. *longicaulis* presents a short stipe.

Avrainvillea nigricans* f. *floridana D.S. Littler & M.M. Littler (Figures 16–18)

Thalli to 10 cm tall, brown dark, mainly solitary. Blades 6 cm long, 6 cm wide, thick 5 mm, margins smoothly lacerate and ragged, cuneate base and not zonate. Stipe 3 cm long, shorter, terete. Blade siphons 35 μm in diameter, moniliform, with rounded apices. Siphons of stipe deeply moniliform, 40 μm in diameter, and not taper toward the surface. The surface siphons can be separated easily by dissection. The thallus is growing on hard substrate associated to coral reef and soft bottom with seagrass *Thalassia testudinum*. This form is most easily confused with f. *nigricans*, from which it differs in having a blade that is thicker and coarse than the papery blade f. *nigricans*. The blades of both forms also differ in shape and appearance; while in f. *floridana* the blade is cuneate and not zonate, in f. *nigricans* it often tends to be reniform.

Avrainvillea silvana D.S. Littler & M.M. Littler (Figures 19–21)

Thallus is up to 6 cm tall, olive green, solitary. Ovate blades are 3.5 cm long, 5 cm wide, not zonate, with upper margin lacerate, lower margin cuneate. Stipe is terete 3 cm long and 0.5 cm in diameter. Thalli are anchored by small fibrous rhizoidal system. Siphons of blades 20 μm in diameter, moniliform, tapering abruptly to 5 μm in diameter, with wide spreading dichotomies and rounded, hooked apices forming a tight cortex. Siphons of stipe 20 μm in diameter, tapering, cylindrical with hooked apices forming a cortex. Thallus occurs on hard substrate, shallow waters. *Avrainvillea silvana* is easily recognizable by the distinctive lacerate margin of its blade and by the cortex of the stipe is so tightly intertwined that is difficult to separate during the dissection.



Figures 3–5. *Avrainvillea asarifolia* f. *olivacea*. 3. Habit of thalli. 4. Medullary siphons of blade. 5. Medullary siphons of stipe. **Figures 6–8.** *A. digi*tata. 6. Habit of thalli. 7. Surface siphons of blade. 8. Surface siphons of proximal blade. **Figures 9–11.** *A. fenicalli* f. *flabellifolia*.9. Habit of thalli. 10. Surface siphons of blade. 11. Siphons of stipe.

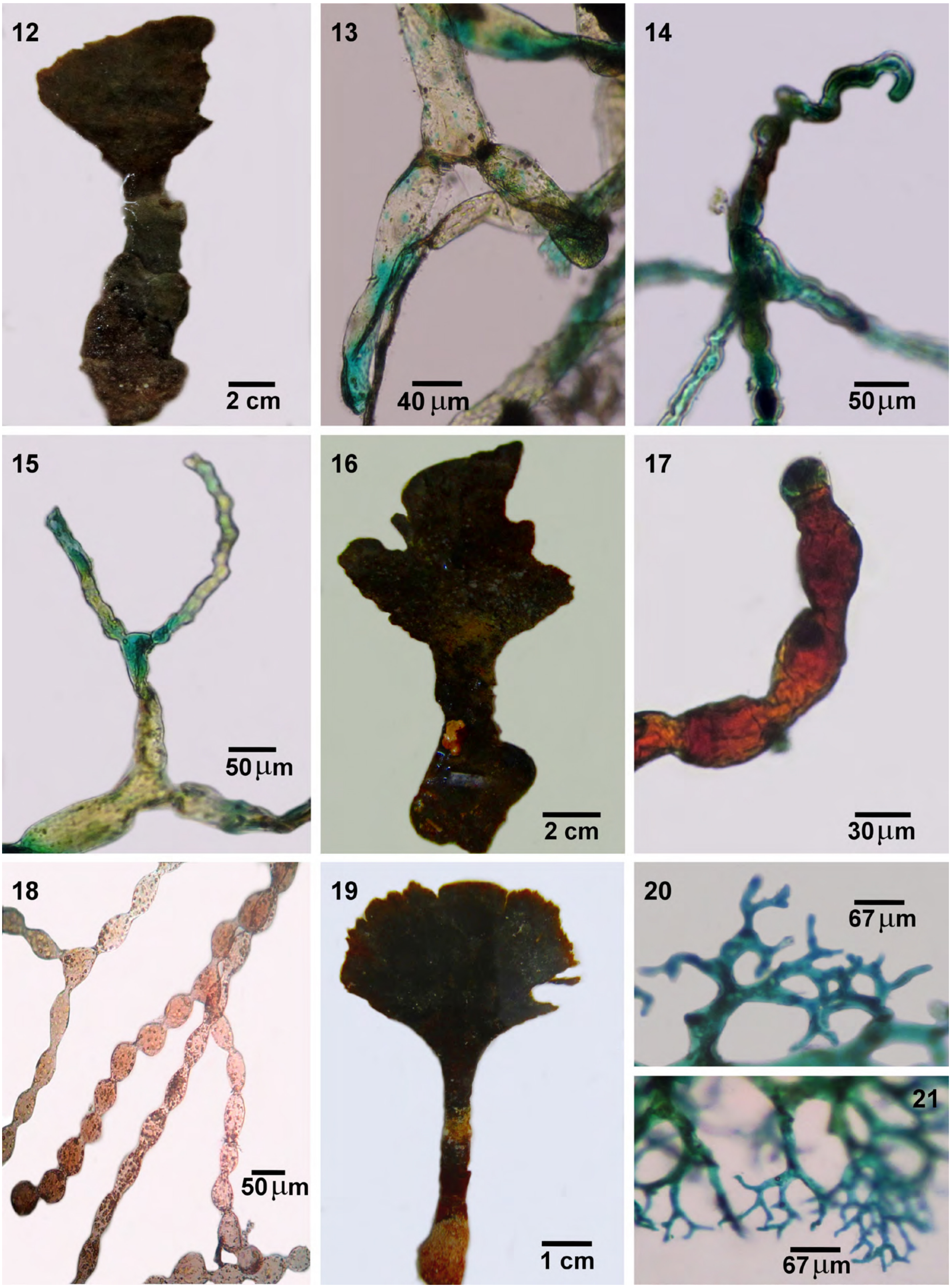


Figure 12–15. *Avrainvillea longicaulis f. laxa*. 12. Habit of thalli. 13. Siphons of blade. 14-15. Siphons of stipe. **Figure 16.** *A. nigricans* f. *floridana*. Habit of thalli. 17. Blade siphons. 18. Stipe siphons. **Figures 19–21.** *A. silvana*. 19. Habit of thalli. 20. Siphons of blade. 21. Siphons of stipe.

Caulerpa verticillata* f. *charoides Weber van Bosse (Figures 22–24)

Thallus fine, felt like mats, 2 cm high, green. Fronds delicately whorled, whorls 2–4, closely placed, distal on stalk, mat-forming aggregations having up to 12 whorls, generally 0.1 cm apart. Branchlets slightly constricted at forks. Apices often abruptly forked, pointed. It occurs on roots of mangrove. This form differ from *C. verticillata* by the constrictions at forks and the abruptly forked at apices.

Cladophoropsis fasciculata (Kjellman) Wille (Figures 25–27)

Thallus light to medium green, forming compact spongy cushions mats, firmly attached to the substrate, often sand or sediment trapping. Thallus is anchored to the substratum by branched multicellular rhizoids. Cylindrical filaments curved to slightly tapering, 40 μm in diameter. It occurs on rocky intertidal zone. This species differ from the other species of *Cladophoropsis* by the small diameter of the filament (40 μm), while the other species having more than 100 μm in diameter.

Trichosolen longipedicellatus (H.L. Blomquist & Díaz-Piferrer) D.M. John (Figures 28–32)

Thalli consisting of a few erect central siphon to 3 cm tall, originating from a common rhizoidal base. The central siphon 30 μm in diameter, sparingly dichotomous branching, abruptly inflated above the fork. Gametangia arise on ramuli, pedicel 64 μm long, not septate at base, gametangium ovate 90 μm broad and 114 μm long. Thallus occurs on mangrove roots. This species differ from *T. duchassaingii* by the arrangement and shape of gametangium and ramification, in *T. longipedicellatus* the gametangium is ovate, while gametangium in *T. duchassaingii* is pyriform. Also, in *T. longipedicellatus* branching is dichotomous and in *T. duchassaingii* is alternate.

Udotea cyathiformis* f. *flabellifolia D.S. Littler & M.M. Littler (Figures 33–35)

Thallus is to 6 cm tall, yellow-green. Form the blade is fan-shaped. Blade is multistratose and lightly zonate. Stipe is terete and a sharp junction occurring when the blade is connected with stipe. Thalli are anchored in sand by a mass of fibrous rhizoids. Siphon of blades 40μm in diameter, lacking appendages, interwoven. Siphons of stipe 40 μm in diameter, lateral appendages irregularly branched, terminating in asymmetrical dichotomies, with distorted digitate apices. It occurs on sandy bottom associated to seagrass *Thalassia testudinum*. This variety differs from var. *cyathiformis* only in having a fan-shaped rather than a cup-shaped blade and by the apices of the siphons of stipe.

Udotea fibrosa D.S. Littler & M.M. Littler (Figures 36–40)

Frond to 8 cm tall, green and heavily calcifies. Blade typically longer than wide often convoluted, multistratose and lacking zonation bands. Stipe hard and heavily calcified, flattened above, 2 cm long to 0.5 cm wide. Blade siphons lacking appendages, 50 μm in diameter, slightly moniliform, deep supra dichotomous constrictions, there is a quit sharp distinction between the surface of the blade and stipe. Siphons of blade 45 μm in diameter, lateral branchlets terminate in short, dichotomously divided rounded or bulbous tips. Thallus occurs on rocky bottom, shallow water. *Udotea fibrosa* can be confused with *U. cyathiformis* f. *sublittorallis* (W.R. Taylor) D.S: Littler & M.M. Littler, since both have a coarse fibrous texture. However, the blade siphons of *U. fibrosa* lack the alternating zonation bands characteristically exhibited by *U.cyathiformis* f. *sublittoralis*.

DISCUSSION

The BRSK presents a typical tropical flora from the Caribbean Sea, represented mainly by species of the families Udoteaceae, Caulerpaceae, Dichotomosiphonaceae, Bryopsidaceae, Dasycladaceae, Polyphysaceae and, Cladophoraceae (Taylor 1960; Norris and Bucher 1982; Littler and Littler 2000; Wysor and Kooistra 2003; Suárez 2005; Duncan and Lee 2006; Dawes and Mathieson 2008). The results obtained in this study suggest a seasonal variation of species richness, mainly due to the life cycle presented by these organism, for example Cladophoraceae and Ulvaceae species are annual type algae since they are present in one season of the year, and on the other side Udoteaceae, Caulerpaceae, Dichotomosiphonaceae, Dasycladaceae and, Polyphysaceae species are perennial type since year-round presence (Feldmann 1951). The localities with rocky and sandy substrate associated to seagrass meadows on marine water influence current present high taxa richness. This fact may be related to the hard and stable substrate, which allows the establishment of green algae (Santelices 1977), an appropriated environment for the development of a great number of tropical seaweeds like Bryopsidales and Dasycladales (Lüning 1990). Moreover, sites with sandy substrate without sea-grass are lower richness; this may be because this type of bottom is unstable because the removal of substrate by mechanical force of water can inhibit the establishment and development of new thalli of marine green algae (Santelices 1977; Garduño-Solórzano et al. 2005). In addition, these sample sites are in brackish areas (Herrera-Silveira 2006), which are less favorable for the development of marine green algae (Ulvophyceae) because such algae are better adapted to fully marine

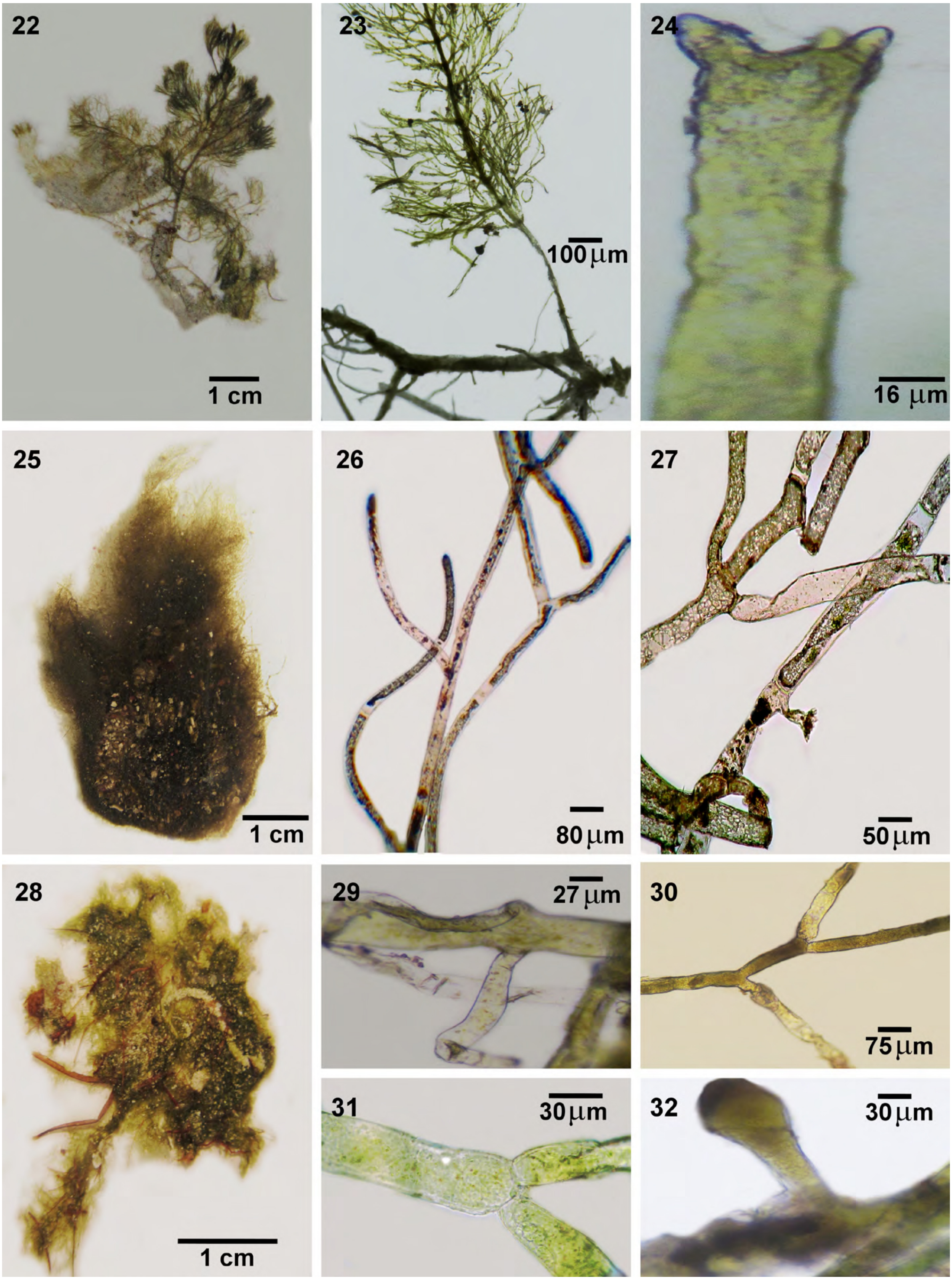
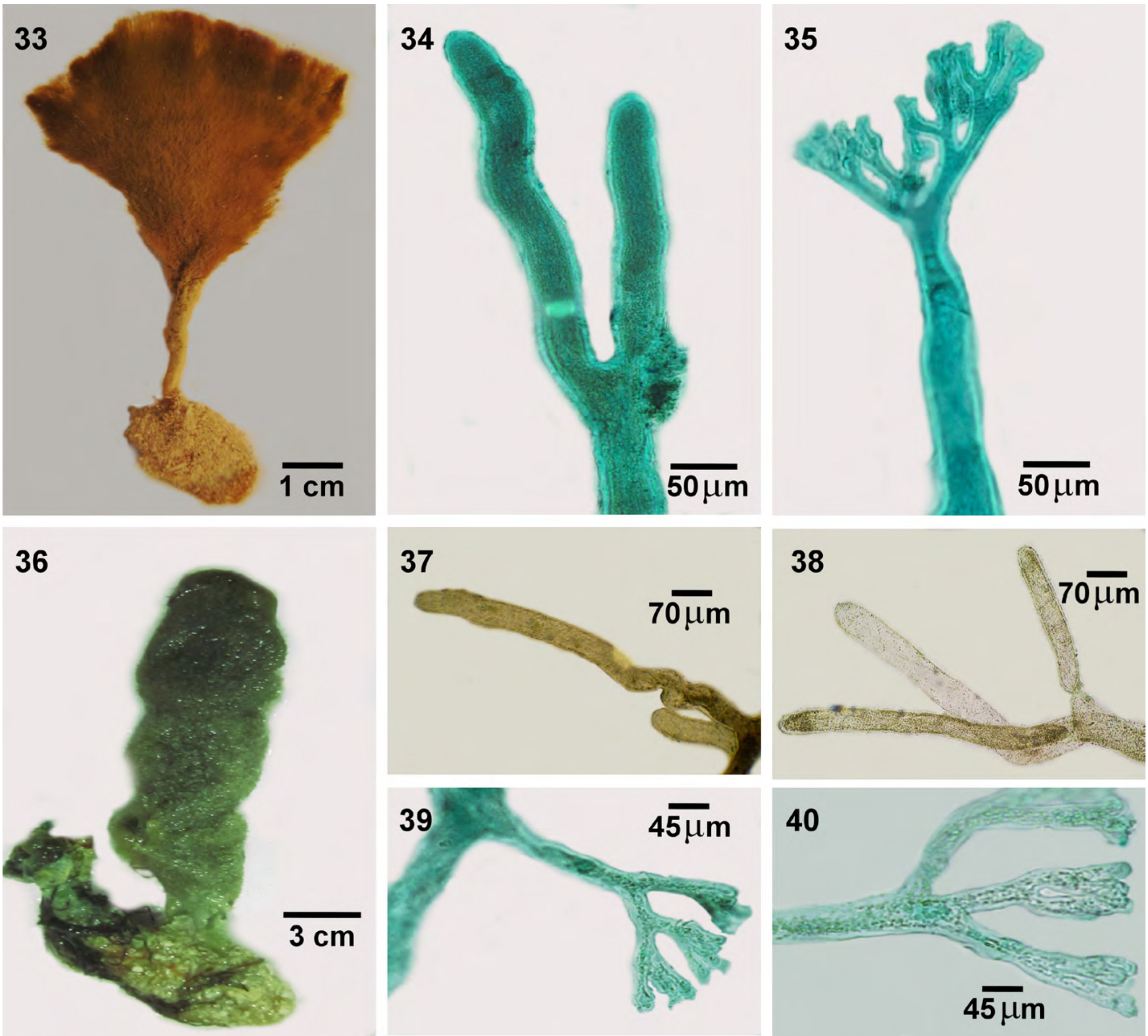


Figure 22–32. *Caulerpa verticillata* f. *charoides*. 22. Habit of thalli. 23. Ramification. 24. Apice of branchlet. **Figure 25–27** *Cladophoropsis fasciculata*.25. Habit of thalli. 26. Apice of filaments. 27. Ramification of filament. **Figures 28–32.** *Trichosolen longipedicellata*. 28. Habit of thalli. 29. Rhizoids. 30. Ramification siphon. 31. Constrictions of siphons. 23. Gametangia.



Figures 33–35. *Udotea cyathiformis* var. *flabellifolia* . 33. Habit of thalli. 34. Siphon of balde. 35. Siphons of stipe. **Figures 36–40.** *Udotea fibrosa*. 36. Habit of thalli. 37. Blade siphons apice. 38. Blade siphon ramification. 39–40. Stipe appendages.

conditions (Lüning 1990; Lobban and Harrison 1997). In this sense, Santelices (1977) mentioned that there is a reduction in the number of species along a salinity gradient; this phenomenon is known as "depletion of brackish habitats". Finally, these results are in agreement with previous observations about the spatial variation of the seaweeds in the BRSK (Aguilar-Rosas et al. 1989; Aguilar-Rosas et al. 1998). However, more studies are necessary to determine the environmental factors that influence in the spatio-temporal variation of green algae. The most important factor for establishment of the algae is the substrate (Santelices 1977). Over half of the species was located on the rocky substrate, represented by subtidal calcareous platforms, rocks of different sizes and intertidal rocky areas with prominences and cavities. Several authors (Taylor 1960; Aguilar Rosas et al. 1998; Mateo-Cid and Mendoza-González 2007) indicated that on rocky substrates a great diversity of seaweed can develop. Garduño-Solórzano et al. (2005) referred to hardness and the degree of compactness of substrate has an important role in the distribution of algae. In contrast, the epiphytic flora is characterized by filamentous thalli, small size and short life cycles (Hoek 1982; Hoek et al. 1995). Perennial green algae like *Udotea*, *Halimeda* and *Penicillus* were the main hosts. It has been suggested that the longevity of the host must be long enough to allow the epiphyte to complete its life cycle (Santelices 1977), and this could be a reason for the absence of green algal epiphytes on the annual green algae. Mangrove roots are another available substrate to green algae such as *Anadyomene*, *Bryopsis*, and *Trichosolen*. Inclan-Rivadeneira (1989) found several species on mangrove roots at BRSK, some of them are recorded in this study (*Acetabularia crenulata* J.V. Lamouroux and *Caulerpa mexicana* Sonder ex Kützing). Inclan-Rivadeneira (1989) mentioned that there is high competition for space between the fauna and flora associated to mangrove roots. Another common substrate in the study area is the sandy bottom associated with seagrass meadows, where species of the family Udoteaceae, Caulerpaceae, Dichotomosiphonaceae and, Halimedaceae were located; these rhizophitic algae have a fixation system that allows them to live in unstable substrates and consolidate and prevent erosion of the sandy substrate. Rhizophitic algae are well-recognized as calcareous sediment producers, especially in tropical settings (Nelson 2009; Bedinger et al. 2013).

Most species recorded in this study have been also recorded in other places of Quintana Roo state (Taylor 1972; Huerta-Múzquiz et al. 1987; Mendoza-González and Mateo-Cid 1992; Diaz-Martín et al. 1998; Mateo-Cid and Mendoza-González 2007). However, 55 taxa are recorded for first time from BRSK, both preview records (74) (Taylor 1960; Aguilar-Rosas et al. 1989; Aguilar-Rosas 1990; Aguilar-Rosas et al. 1992; Aguilar-Rosas et al. 1998; Aguilar-Rosas et al. 2001), and the new records revealed that the taxonomic richness of marine green algae of the study area is of 129 taxa. These results reveal that BRSK is more rich in taxa than other sites in Quintana Roo where an extensive floristic surveys have been done (e.g., Puerto Morelos with 72 taxa (Dreckmann et al. 1996); Cozumel, 122 taxa (Mateo-Cid and Mendoza-González 2007); and Isla Mujeres, 85 taxa (Mendoza-González and Mateo-Cid 1992). It is also remarkable that 71% of green algae recorded to Quintana Roo (Cetz-Navarro et al. 2008) can be found in the BRSK. Of the 74 previous records of green seaweeds of BRSK, 21 taxa were not reported in this study; this may be due to several factors:

1) the use of incorrect names due to the ambiguous taxonomic characters required to delimit species. For example, Collado-Vides et al. (2009) mentioned that there is a *Udotea* complex in the Mexican Caribbean that requires taxonomic revision; the same difficulty is met with the genus *Caulerpa* (Fama et al. 2002).

2) The type of life cycle, for example *Bryopsis halliae* W.R. Taylor, presents a heteromorphic life cycle (Lee 2008), and possibly the macroscopic phase was not found during the survey months;

3) the time and survey sites, for example Aguilar-Rosas et al. (1989) conducted surveys during February, April and June 1986, while this study was conducted in December 2011, April, September 2012, also they did not mention if the collection were done in line parallel or perpendicular to the coast.

4) climatological events such as hurricanes, which can induce changes in marine habitats (Lugo 2000).

This information is relevant to the future monitoring of this marine ecosystem and also supports the importance of the BRSK as a priority area for the conservation of marine environments.

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