

# New records of benthic marine algae and Cyanobacteria for Costa Rica, and a comparison with other Central American countries

Andrea Bernecker · Ingo S. Wehrtmann

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**Abstract** We present the results of an intensive sampling program carried out from 2000 to 2007 along both coasts of Costa Rica, Central America. The presence of 44 species of benthic marine algae is reported for the first time for Costa Rica. Most of the new records are Rhodophyta (27 spp.), followed by Chlorophyta (15 spp.), and Heterokontophyta, Phaeophyceae (2 spp.). Overall, the currently known marine flora of Costa Rica is comprised of 446 benthic marine algae and 24 Cyanobacteria. This species number is an under estimation, and will increase when species of benthic marine algae from taxonomic groups where only limited information is available (e.g., microfilamentous benthic marine algae, Cyanobacteria) are included. The Caribbean coast harbors considerably more benthic marine algae (318 spp.) than the Pacific coast (190 spp.); such a trend has been observed in all neighboring countries. Compared to other Central American countries, Costa Rica has the highest number of reported benthic marine algae; however, Panama may have a similarly high diversity after unpublished results from a Rhodophyta survey (Wysor, unpublished) are included. Sixty-two species have been found along both the Pacific and Caribbean coasts of Costa

Rica; we discuss this result in relation to the emergence of the Central American Isthmus.

**Keywords** Marine macroalgae · Cyanobacteria · Costa Rica · Central America

## Introduction

The marine benthic flora plays an important role in the marine environment. It forms the basis of many marine food chains and harbors an impressive variety of organisms. Fish, decapods and mollusks are among the most prominent species associated with the marine flora, which serves these animals as a refuge and for alimentation (Hay 1981; Fletcher 1987; Littler and Littler 1988; Ruitton et al. 2000). Despite their ecological importance, our knowledge about the taxonomic diversity of the marine benthic flora in Central America is far from complete. Apart from the basic works of Taylor (1945, 1960) and Dawson (1960) on the marine flora of Central America and adjacent regions, several publications provide annotated species lists for marine algae from Panama (Earle 1972; Wysor and De Clerck 2003; Wysor and Kooistra 2003; Wysor 2004), Belize (Norris and Bucher 1982; Littler et al. 1995, 2000; Littler and Littler 1997), Guatemala (Bird and McIntosh 1979), Nicaragua (Dawson 1962; Phillips et al. 1982), El Salvador (Dawson 1961), and Honduras (Ogden 1998). However, most of these studies concern the Caribbean coast of Central America, while information on the diversity of the benthic marine flora remains scarce for the eastern tropical Pacific coast of the region (Dawson 1957, 1960; Wysor 2004).

Soto (1983) summarized the prior phycological studies carried out in Costa Rica. Subsequently, Bernecker (2008)

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A. Bernecker  
Escuela de Biología, and Centro de Investigaciones en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica  
e-mail: aberneck@biologia.ucr.ac.cr

I. S. Wehrtmann (✉)  
Unidad de Investigación Pesquera y Acuicultura (UNIP) of the Centro de Investigaciones en Ciencias del Mar y Limnología (CIMAR), and Escuela de Biología, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica  
e-mail: ingowehrtmann@gmx.de

provided an extensive overview of available publications and the species of benthic macroalgae and Cyanobacteria from both coasts of Costa Rica that have been reported. According to her publication, which is based exclusively on data obtained from the literature and AlgaeBase (Guiry and Guiry 2008), a total of 396 species of benthic marine algae, and 24 species of Cyanobacteria have been reported from Costa Rica. Two hundred and eighty-seven species of algae and ten species of Cyanobacteria are from the Caribbean, and 156 species of algae and 19 species of Cyanobacteria are from the Pacific. Forty-seven species of algae and five species of Cyanobacteria occur on both the Caribbean and the Pacific coast. Additionally to those species listed in Bernecker (2008), one species [*Dermatolithon saxicola* (M. Lemoine) Setchell & L.R. Mason] has been previously mentioned by Setchell and Mason (1943). Two other species, already known from the Caribbean coast, have been recently reported also from the Pacific coast of Costa Rica (*Caulerpa sertularioides* (S.G. Gmelin) M. Howe; Fernández and Cortés (2005), and from Cocos Island (*Dictyopteris delicatula* J.V. Lamouroux; Fernández 2008). A list of new records from Cocos Island (Fernández 2008) include five species of Chlorophyta new to Costa Rica: *Ulva intestinalis* Linnaeus, *Cladophora panamensis* W.R. Taylor, *Codium picturatum* F. F. Pedroche et P. C. Silva, *Caulerpa serrulata* (Forsskål) J. Agardh, and *Parvocaulis parvulus* (Solms-Laubach) S. Berger, U. Fettweiss, S. Gleissberg, L. B. Liddle, U. Richter, H. Sawitsky & G.C. Zuccarello (cited as its synonym *Acetabularia parvula* Solms-Laubach).

Between the years 2000 and 2007, intensive field work along both coasts of Costa Rica was carried out to enhance our knowledge about the diversity of the marine flora in Costa Rica. As a result of this effort, we present here new records of algae and Cyanobacteria, and discuss the species diversity of Costa Rica in comparison with that of neighboring Central American countries.

## Methods

The present update is based upon collections carried out principally by the first author during the years 2000 and 2007. Sampling included both coasts and all months. During the field trips, all major habitats (sandy beach, stones on beaches, rocks, dead and living coral reefs, intertidal, subtidal down to 20 m) were examined. Algae collected by colleagues and donated to the Herbarium of the Universidad de Costa Rica were also studied. Sampling was done by means of Scuba-diving, snorkeling and wading, and covered coastal areas up to a depth of 30 m. Specimens were obtained from both coasts of Costa Rica, and although the material was collected along the entire

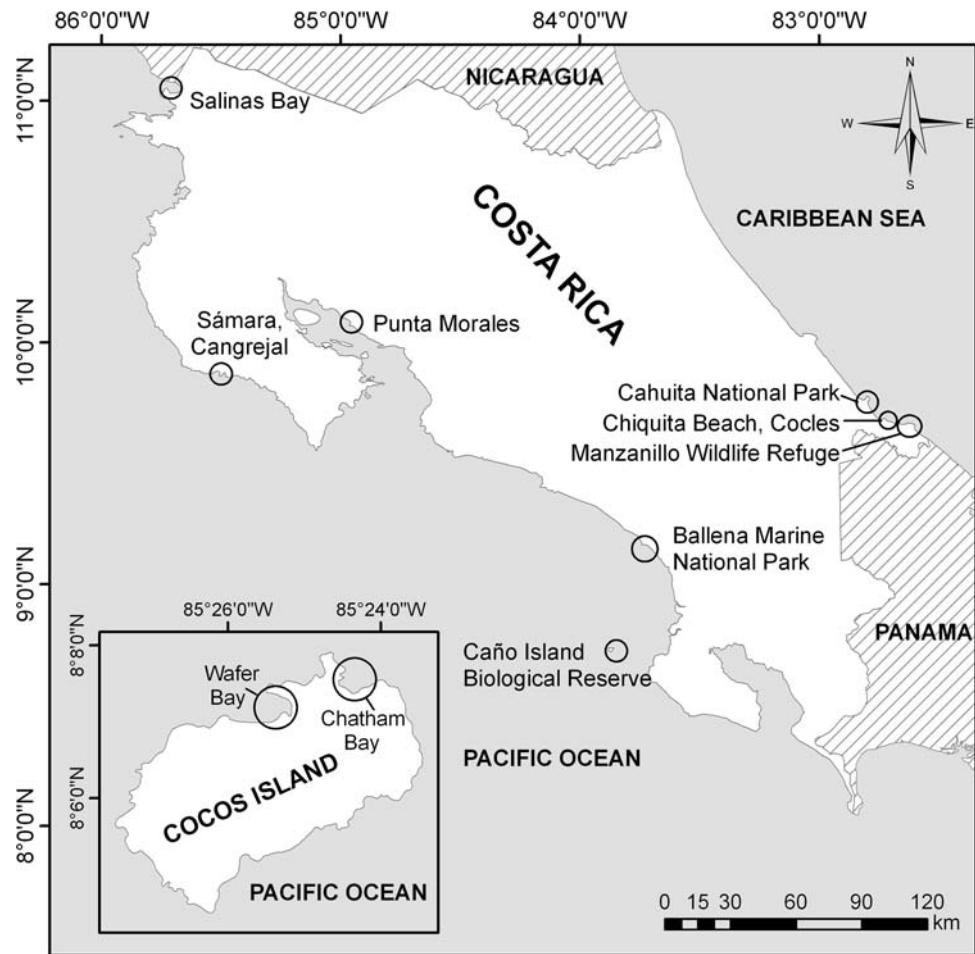
coasts, the main sampling location on the Caribbean coast was Cahuita, and along the Pacific coast were Bahía Salinas, Samara and Caño Island (Fig. 1). Samples were preserved in a mixture of 3% buffered formalin/seawater, and subsequently, the specimens were pressed and air-dried on herbarium sheets for archiving. When specimens were fertile, a subsample with reproductive structures was preserved in 70% ethanol for future morphological study. All samples and subsamples of the collected material have been deposited in the Herbarium (USJ) of the Universidad de Costa Rica.

Dawson (1957, 1960) and Taylor (1945) were principally used for the identification of Pacific species. Caribbean species were mainly identified using Littler and Littler (2000) and Taylor (1960). Moreover, original descriptions were consulted when ever possible. Additional information about the species, especially type localities, was obtained from AlgaeBase (Guiry and Guiry 2008) and the Index Nominum Algarum (2008).

## Results

Overall, a total of 44 benthic marine algae species (15 Chlorophyta, 2 Heterokontophyta, Phaeophyceae, and 27 Rhodophyta) are reported for the first time from Costa Rica (Table 1). These 44 species represent 34 genera, including eight new for Costa Rica (Heterokontophyta, Phaeophyceae: *Canistrocarpus*; Rhodophyta: *Trichogloea*, *Dichotomaria*, *Kallymenia*, *Ethelia*, *Polystrata*, *Seirospora*, *Thuretia*). A total of 25 algal species (7 Chlorophyta; 4 Heterokontophyta, Phaeophyceae; 14 Rhodophyta) are newly reported from the Pacific mainland; however, nine of these have been found previously along the Caribbean coast (Chlorophyta: *Caulerpa racemosa*; Heterokontophyta, Phaeophyceae: *Hincksia mitchelliae*, *Rosenvingea intricata*, *Sphaecelaria tribuloides*, *Spatoglossum* sp.; Rhodophyta: *Porphyra* sp.; *Galaxuara rugosa*, *Tricleocarpa cylindrical*, *Laurencia* sp.) or from Cocos Island (Fernández 2008: Chlorophyta: *Caulerpa racemosa*; *Rosenvingea intricata* as *R. intricata*). Thirty-one benthic marine algae (10 Chlorophyta; 2 Phaeophyceae; 19 Rhodophyta) and one species of Cyanobacteria are reported for the first time from the Caribbean. Two of these, *Boodlea composita* (Chlorophyta), and *Lyngbya confervoides* (Cyanobacteria) have been previously reported from the Pacific coast (Dawson 1957). *Bryopsis pennata* without varietal specification was found for the first time on both the Pacific and the Caribbean coasts, but does not represent a new species record for Costa Rica because a variety, *Bryopsis pennata* var. *lepreurii* (Kützing) Collins & Hervey has been previously reported (Dawson 1957; Bernecker 2008). Additionally, two species (*Ulva flexuosa* and *Boodleopsis verticillata*), formerly

**Fig. 1** Main collection sites along both coasts of Costa Rica, including the offshore Cocos Island



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 Lat/Long Geographical coordinates, Datum WGS84

**Table 1** New records of benthic marine algae and Cyanobacteria for Costa Rica

	Chlorophyta	Heterokontophyta (Phaeophyceae)	Rhodophyta	Cyanobacteria	Total	Caribbean	Pacific	Both coasts
New to Costa Rica	15	2	27	0	44	31	25	1
New to Pacific mainland, Costa Rica	7	4	14	0	25	–	–	–
New to Caribbean of Costa Rica	10	2	19	1	32	–	–	–
New to Cocos Island	2	–	–	–	2	–	–	–

known from Costa Rica mainland (Dawson 1957, 1962; Kemperman and Stegenga 1986; Soto and Ballantine 1986; Tejada Rivas 2002; Bernecker 2008), were identified in a small collection from Cocos Island.

The following list is divided into species from the Caribbean, the Pacific mainland, and reports for Cocos Island (Pacific). Each section is organized according to the classification system used by AlgaeBase (Guiry and Guiry 2008). Species are labeled according to the following criteria: first record for Costa Rica, and new for either Caribbean or Pacific coast (\*); first record for Costa

Rica, and new for both coasts (●); new record for the Caribbean coast, but already known from the Pacific (■); new record for the Pacific coast, but previously reported from the Caribbean coast (▲). Records without a label are either new forms or varieties of already reported species.

New records for the Caribbean coast

Phylum: CHLOROPHYTA  
 Class: ULVOPHYCEAE

Order: CLADOPHORALES

Family: CLADOPHORACEAE

\* *Cladophora albida* (Nees) Kützing 1843: 267

Type locality: Island of Selsey, England

Collections: USJ-A-73503, Punta Cahuita, reef lagoon, on hard substrate, subtidal, 0.5–1 m depth, March 2005.

\* *Cladophora laetevirens* (Dillwyn) Kützing 1843: 263

Type locality: Swansea, Glamorgan, Wales

Collections: USJ-A-73492, Punta Cahuita, reef lagoon, on hard substrate, subtidal, 0.5 m depth, September 2006; USJ-A-73513, Punta Cahuita, reef lagoon, epiphytic, subtidal, 0.5 m depth, June 2006; USJ-A-71471, Cahuita National Park, in front of Perezoso river, subtidal, 0.5–2.0 m depth, September 2001; USJ-A-73030, Lagoon of Uvita Island, November 2002.

Family: BOODLEACEAE

■ *Boodlea composita* (Harvey) F. Brand 1904: 187–190, pl. 6, figs. 28–35

Type locality: Mauritius

Collections: USJ-A-73471, Punta Cahuita, reef lagoon, on dead coral, subtidal, 0.5–1 m depth, August 2003.

Comments: already known from the Pacific coast of Costa Rica (Dawson 1957; Bernecker 2008).

Order: DASYCLADALES

Family: POLYPHYSAEAE

\* *Acetabularia myriospora* A.B. Joly & Cordeiro-Marina 1965: 80, pl. 2, figs. 1–10

Type locality: Brazil, Bahia: Amaralina, Salvador

Collections: USJ-A-73389, Punta Cahuita, at the reef crest, on hard substrate, subtidal, 0.5–1.5 m depth, October 2005.

Comments: identified as *Polyphysa myriospora* (A. B. Joly and Cordeiro-Marinha) Bula-Meyer. *P. myriospora* is a synonym for *A. myriospora* (Berger et al. 2003).

Class: BRYOPSIDOPHYCEAE

Order: BRYOPSIDALES

Family: BRYOPSIDACEAE

*Bryopsis pennata* J.V. Lamouroux 1809: 333

Type locality: Antilles, West Indies.

Collections: USJ-A-71484, USJ-A-73070, Punta Cahuita, reef lagoon, subtidal, 0.5–1.0 m depth, September 2001, and September 2003; USJ-A-73086, USJ-A-73192, USJ-A-73206, USJ-A-73383, the same locality, October 2003, the latter one October 2005; USJ-A-73423, Punta Cahuita, at reef crest, subtidal, May 2005; USJ-A-73468, drift at the beach, March 2004

Comments: this species has been previously recorded for Costa Rica by its variety *Bryopsis pennata* var. *leprieurii* (Kützing) Collins & Hervey (Dawson 1957), and also listed by Fernández (2008) for Cocos Island.

\* *Derbesia fastigiata* W.R.Taylor 1928: 94, pl. 11, figs. 1–3

Type locality: Dry Tortugas, FL, USA.

Collections: USJ-A-73518, Punta Cahuita, reef lagoon, epiphytic, subtidal, 0.5 m depth, June 2006.

\* *Derbesia marina* (Lyngbye) Solier 1846: 452

Type locality: Denmark

Collections: USJ-A-71418, USJ-A-71429, Punta Cahuita, reef lagoon toward Puerto Vargas, subtidal, 0.5–1.5 m depth, October 2001.

Comments: Also mentioned for Cocos Island by Fernández (2008) as *Derbesia* cf. *marina* (Lyngbye) Solier.

\* *Derbesia turbinata* M.Howe et Hoyt 1916: 106, pl. 11, figs. 10–16

Type locality: Beaufort, NC, USA.

Collections: USJ-A-71403, Punta Cahuita, reef lagoon toward Puerto Vargas, subtidal, 0.5–1.5 m depth, October 2001.

Family: CODIACEAE

*Caulerpa verticillata* f. *charoides* Weber-van Bosse 1898: 267–268

Lectotype locality: Tonga

Collections: USJ-A-71493, Punta Cahuita, outside reef crest, subtidal at 8–10 m depth, October 2001.

Comments: *C. verticillata* already reported (Dawson 1962; Bernecker 2008), but new form.

\* *Caulerpa prolifera* f. *zosterifolia* Børgesen 1907: 359, fig. 6

Type locality: West Indies (St. John, St. Croix, St. Thomas).

Collections: USJ-A-73850, Punta Cocles, Chiquita beach, on rocks, subtidal, 1 m depth, April 2003; USJ-A-73855, Punta Uva, in sand, subtidal, 1–3 m depth, October 2003.

Family: UDOTACEAE

*Avrainvillea longicaulis* f. *laxa* D.S. Littler & M.M. Littler 1992: 397, fig. 3

Type locality: Tobacco Range, Belize

Collections: USJ-A-73087, USJ-A-73326, USJ-A-73327, Punta Cahuita, reef lagoon, subtidal, 0.5–1.0 m depth; October 2003, September 2003, and June 2003, respectively.

Comments: *A. longicaulis* already reported (Dawson 1962; Bernecker 2008), but new form.

\* *Avrainvillea mazei* G. Murray & Boodle 1889: 70

Type locality: Guadeloupe, West Indies

Collections: USJ-A-73175, USJ-A-73375, USJ-A-73440, Punta Cahuita, reef lagoon, in seagrass beds, 0.5 m depth, June 2006, September 2005, and April 2004, respectively.

\* *Udotea dixonii* D.S. Littler & M.M. Littler 1990: 220, fig. 8

Type locality: east side of Curlew Cay, Belize

Collections: USJ-A-73254, USJ-A-73089, Manzanillo National Park, reef close to the beach, subtidal, 1–6 m depth, September 2000 and October 2003, respectively.

## PHYLUM: HETEROKONTOPHYTA

Class: PHAEOPHYCEAE

Order: DICTYOTALES

Family: DICTYOTACEAE

\* *Dictyota menstrualis* (Hoyt) Schnetter, Hörning & Weber-Peukert 1987: 195, figs. 5, 6

Type locality: NC, USA

Collections: USJ-A-73363, Punta Cahuita, reef lagoon, subtidal, 0.5–1.0 m depth, April 2004; USJ-A-73718, Punta Cahuita, reef crest, subtidal, May 2005.

\* *Canistrocarpus crispatus* (J.V. Lamouroux) De Paula & De Clerck in De Clerck et al. 2006: 1285

Type locality: [Antilles] Caribbean Sea

Collections: USJ-A-73129, Punta Cahuita, outside reef crest, subtidal at 5–9 m depth, September 2003; USJ-A-73427, Punta Cahuita, at the reef crest, subtidal, May 2005. (both as *Dictyota crispata* J.V. Lamouroux)

## PHYLUM: RHODOPHYTA

Class: FLORIDEOPHYCEAE

Order: CORALLINALES

Family: CORALLINACEAE

● *Amphiroa rigida* J.V. Lamouroux 1816: 297, pl. 9: fig. 1

Type locality: Mediterranean Sea

Collections: USJ-A-71406, USJ-A-73301, USJ-A-73435, Punta Cahuita, reef lagoon, subtidal, 0.5–1.5 m depth, October 2001, September 2004, and June 2006, respectively; USJ-A-73228, Cahuita National Park, in seagrass beds in front of Perezoso river, subtidal, 1 m depth, May, 2004.

Comments: hitherto reported for the Caribbean of Costa Rica only as *A. rigida* var. *antillana* (Dawson 1962; Bernecker 2008)

\* *Lithophyllum congestum* (Foslie) Foslie 1900: 20

Type locality: St. Barthelemy, West Indies

Collections: USJ-A-73061, Punta Cahuita, outside reef crest, subtidal at 8–10 m depth, September 2003; USJ-A-73178, Punta Cahuita, drift at the beach, March 2004; USJ-A-73232, USJ-A-73238, Punta Cocles, Reef of Chiquita beach, subtidal, 0.5–1 m depth, May 2004. All specimens identified by R. Steneck.

\* *Neogoniolithon affine* (Foslie & M.A. Howe) Setchell & L.R. Mason 1943: 91

Type locality: Culebra Island, Puerto Rico.

Collections: USJ-A-73236, USJ-A-73237, USJ-A-73239, USJ-A-73240, Punta Cocles, reef of Chiquita beach, wave exposed, subtidal at 1.5 m depth, May 2004 (identified by R. Steneck).

● *Neogoniolithon fosliei* (Heydrich) Setchell & L.R. Mason 1943: 90

Type locality: Tor, Sinai Peninsula, Egypt

Collections: USJ-A-73189, USJ-A-73210, USJ-A-73211, Punta Cahuita, reef lagoon, subtidal, 0.5–1 m depth, November 2003.

Comments: All specimens identified by R. Steneck as *Paragoniolithon solubile* (Foslie & M. A. Howe) Adey, Townsend & Boykins). According to Mateo-Cid and Pedroche (2004) *P. solubile* is a synonym of *N. fosliei*.

\* *Neogoniolithon strictum* (Foslie) Setchell & Mason 1943: 92

Type locality: Florida

Collections: USJ-A-73059, Punta Cahuita, outside reef crest, subtidal at 8–10 m depth, October 2003; USJ-A-73179, USJ-A-73186, Punta Cahuita, reef lagoon, subtidal, 0.5–1 m depth, October and November 2003 (all specimens identified by R. Steneck).

Order: NEMALIALES

Family: LIAGORACEAE

\* *Trichogloea requienii* (Montagne) Kützing 1847: 54

Type locality: “Mari Rubro” [Red Sea]

Collections: USJ-A-73255, Manzanillo National Park, reef close to the beach, subtidal, 1–6 m depth, September 2000.

Family: GALAXAURACEAE

\* *Dichotomaria obtusata* (J. Ellis & Solander) Lamarck 1816: 145

Type locality: Bahamas

Collections: USJ-A-73534, Manzanillo National Park, subtidal, October 2005; USJ-A-73582, Cahuita National Park, drift at the beach, May 2003.

Order: GIGARTINALES

Family: KALLYMENIACEAE

\* *Kallymenia westii* Ganesan 1976: 169, figs. 1–12, 14, 16–21

Type locality: Venezuela: Isla de Margarita: El Farallon, 20 m deep

Collections: USJ-A-73564, Manzanillo National Park, Longshoal, subtidal, 20 m deep, on dead coral, October 2006.

Family: PEYSSONNELIACEAE

*Ethelia* (Weber-van Bosse) Weber-van Bosse 1921: 297.

\* *Ethelia* sp.

Collections: USJ-A-71494, Cahuita National Park, in front of Perezoso river, subtidal, 0.5–2.0 m, October 2001.

Comments: species could not be identified—first record of this genus for the Caribbean coast of Costa Rica.

Order: HALYMENIALES

Family: HALYMENIACEAE

\* *Halymenia echinophysa* F.S. Collins & M.A. Howe 1916: 180

Type locality: Bermuda, dredged

Collections: USJ-A-71474, Punta Cahuita, outside reef crest, subtidal at 8–10 m depth, October 2001.

Order: GRACILARIALES

Family: GRACILARIACEAE

\* *Hydropuntia caudata* (J. Agardh) Gurgel & Fredericq 2004: 155

Type locality: Virgin Islands: St. Croix; Gulf of Mexico

Collections: USJ-A-73170, Cahuita National Park, Puerto Vargas, in front of the old Ranger station, subtidal, 0.5 m,

April 2004; USJ-A-71478, Cahuita National Park, in front of Perezoso river, subtidal, 0.5–2.0 m, October 2001; USJ-A-73762, Punta Cahuita, reef lagoon, subtidal, 0.5–1.0 m, September 2003 (rev. F. Gurgel).

\* *Hydropuntia cornea* (J. Agardh) M.J. Wynne 1989: 476  
Type locality: Brazil: Pernambuco [Recife]

Collections: USJ-A-73106, Cahuita National Park, Puerto Vargas, in front of the old Ranger station, subtidal, 1–3 m, October 2003.

\* *Hydropuntia usneoides* (C. Agardh) Gurgel & Fredericq 2004: 156

Type locality: Brazil

Collections: USJ-A-73146, Cahuita National Park, subtidal, without collecting date (rev. F. Gurgel).

Comments: in Soto and Ballantine (1986) and Bernecker (2008) mentioned as *H. aff. usneoides*. The presence of the species can be confirmed by the identification of the above-mentioned material.

Order: RHODYMENIALES

Family: CHAMPIACEAE

\* *Champia salicornioides* Harvey 1853: 76, 77, pl. 19.B

Type locality: Key West, FL, USA

Collections: USJ-A-73229, USJ-A-73381, Punta Cahuita, seagrass beds in reef lagoon, epiphytic, subtidal, 0.5–1.0 m, April 2004 and October 2005, respectively.

Family: LOMENTARIACEAE

\* *Botryocladia pyriformis* (Børgesen) Kylin 1931: 18

Type locality: Virgin Islands: north of St. Jan (St. John) (off America Hill, W. of Thatch Island)

Collections: USJ-A-71462, Cahuita National Park, in front of Perezoso river, subtidal, 0.5–2 m, October 2001.

Order: CERAMIALES

Family: CERAMIACEAE

\* *Seirospora occidentalis* Børgesen 1909: 14

Type locality: West Indies

Collections: USJ-A-71431, Punta Cahuita, reef lagoon, subtidal, 0.5–1.5 m, October 2001.

*Ceramium brevizonatum var. caraibicum* H. E. Petersen & Børgesen 1924: 29, fig. 11

Type locality: Beata Island, Dominican Republic

Collections: USJ-A-73227, USJ-A-73821, Punta Cahuita, seagrass beds in reef lagoon, epiphytic, subtidal, 0.5–1.0 m, April 2004 and October 2005, respectively.

Comments: *C. brevizonatum* already known from the Caribbean coast of Costa Rica (Kemperman and Stegenga 1986; Bernecker 2008), but new variety.

Family: DASYACEAE

\* *Thuretia borneyi* Vickers 1905: 63

Type locality: Barbados

Collections: USJ-A-71396, Punta Cahuita, reef lagoon, subtidal, 0.5–1.5 m, October 2001.

Family: RHODOMELACEAE

\* *Chondrophyucus poiteaui* (J.V. Lamouroux) K.W. Nam 1999: 463

Type locality: Santo Domingo, Dominican Republic

Collections: USJ-A-71392, Punta Cahuita, reef lagoon, subtidal, 0.5–1.5 m, October 2001; USJ-A-73090, Punta Cahuita, reef lagoon, subtidal, 0.5–1.0 m, October 2003; USJ-A-73448, Punta Cahuita, reef lagoon, subtidal, 0.5 m, June 2006; USJ-A-73758, Punta Cahuita, drift on the beach, December 2005.

\* *Dipterosiphonia rigens* (Shousboe ex C. Agardh) Falkenberg 1901: 325

Type locality: Gulf of Neapel

Collections: USJ-A-71404, Punta Cahuita, reef lagoon, subtidal, 0.5–1.5 m, October 2001.

PHYLUM: CYANOBACTERIA

Class: CYANOPHYCEAE

Order: OSCILLATORIALES

Family: OSCILLATORIACEAE

■ *Lyngbya confervoides* C. Agardh ex Gomont 1892: 136

Type locality: Spain, presumably Cádiz (Silva, Basson and Moe 1996: 35)

Collections: USJ-A-73122, Punta Cahuita, at reef crest, subtidal, but exposed to wave action, February 2003; USJ-A-73396, Cahuita National Park, reef at Eduardo, on dead coral, subtidal at 3–5 m depth, October 2005.

Comments: already known from the Pacific coast (Dawson 1957; Bernecker 2008).

New records for the Pacific coast

PHYLUM: CHLOROPHYTA

Class: ULVOPHYCEAE

Order: ULVALES

Family: ULVACEAE

\* *Ulva dactylifera* Setchell & N.L. Gardner 1920: 285–286, pl. 26: fig. 1

Type locality: San Pedro, CA, USA.

Collections: USJ-A-73587, Salinas Bay, Ruanilla Island, on rocks, subtidal at 3–4 m depth, April 2005.

\* *Ulva lobata* (Kützinger) Harvey 1855: 265

Type locality: Chile

Collections: USJ-A-73607, Salinas Bay, Bolaños Island, on rocks, subtidal at 1 m depth, February 2007; USJ-A-73690, Salinas Bay, Islands in front of Punta Descartes, on rocks and coral, subtidal, 5–8 m depth, April 2005.

Order: CLADOPHORALES

Family: CLADOPHORACEAE

\* *Rhizoclonium rhizophilum* W.R. Taylor 1945: 55

Type locality: Academy Bay, I. Santa Cruz, Galápagos Islands, Ecuador

Collections: USJ-A-73274, USJ-A-73275, Punta Morales, mangroves in front of the Biological Station, intertidal, on mangrove roots, May 2004.

Class: BRYOPSIDOPHYCEAE

Order: BRYOPSIDALES

Family: BRYOPSIDACEAE

***Bryopsis pennata*** J.V. Lamouroux 1809: 333

Type locality: Antilles, West Indies.

Collections: USJ-A-73566, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004.

Family: CODIACEAE

\* ***Codium isabelae*** W.R. Taylor 1945: 70, pl. 1: figs. 10–13; pl. 7: fig. 1

Type locality: Tagus Cove, I. Isabela, Galápagos Islands, Ecuador.

Collections: USJ-A-71518, Ballena Marine National Park, intertidal on rocks in tidepool, 2003, without exact collecting date (identified by P. Silva).

\* ***Codium geppiorum*** O.C. Schmidt 1923: 50, fig. 33 ('geppii')

Type locality: Kai Islands and Celebes, Indonesia

Collections: USJ-A-73553, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004.

Family: CAULERPACEAE

▲ ***Caulerpa racemosa*** (Forsskål) J. Agardh 1873: 35, 36

Type locality: Suez, Egypt.

Collections: USJ-A-73296, USJ-A-73297, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004.

Comments: already known from the Caribbean coast (Dawson 1962; Bernecker 2008), and also listed by Fernández (2008) for Cocos Island.

PHYLUM: HETEROKONTOPHYTA

Class: PHAEOPHYCEAE

Order: ECTOCARPALES

Family: ACTINOSPORACEAE

▲ ***Hincksia mitchelliae*** (Harvey) P.C. Silva 1987: 73, 130

Type locality: Nantucket, MA, USA

Collections: USJ-A-73739, Caño Island, on buoys in front of the Ranger Station, subtidal, 1 m, May 2006.

Comments: already known from the Caribbean coast (Dawson 1962; Bernecker 2008).

Family: SCYTOSIPHONACEAE

▲ ***Rosenvingea intricata*** (J. Agardh) Børgesen 1914: 26

Type locality: Veracruz, Mexico

Collections: USJ-A-73627, Salinas Bay, Bajo Rojo, on rocks, subtidal, 1.5 m depth, February 2007.

Comments: already known from the Caribbean coast (Kemperman and Stegenga 1986; Soto and Ballantine 1986; Bernecker 2008), and also listed by Fernández (2008, as *Rosenvingea intricata*) for Cocos Island.

Order: SPHACELARIALES

Family: SPHACELARIACEAE

▲ ***Sphacelaria tribuloides*** Meneghini 1840: 2

Type locality: La Spezia, Italy

Collections: USJ-A-73509, Samara, Cangrejal, intertidal on rocks, May 2004.

Comments: already known from the Caribbean coast (Kemperman and Stegenga 1986; Bernecker 2008).

Order: DICTYOTALES

Family: DICTYOTACEAE

***Spatoglossum*** Kützing 1843: 339

▲ ***Spatoglossum*** sp.

Collections: USJ-A-73590, Salinas Bay, Ruanilla Island, on hard substrate, subtidal at 3–4 m depth, April 2005.

Comments: species could not be identified; genus already known from the Caribbean coast (Dawson 1962; Bernecker 2008).

PHYLUM: RHODOPHYTA

Class: BANGIOPHYCEAE

Order: BANGIALES

Family: BANGIACEAE

***Porphyra*** C. Agardh 1824: xxxii, 190.

▲ ***Porphyra*** sp.

Collections: USJ-A-73657, Salinas Bay, on rocks, subtidal at 6–8 m depth, April 2005.

Comments: species could not be identified; genus already known from the Caribbean coast where the species could not be identified either (Soto and Bermudez unpublished; see also Bernecker 2008).

Class: FLORIDEOPHYCEAE

Order: CORALLINALES

Family: CORALLINACEAE

● ***Amphiroa rigida*** J.V. Lamouroux 1816: 297, pl. 9: fig. 1

Type locality: Mediterranean Sea

Collections: USJ-A-73554, USJ-A-73557, Caño Island, Playa India, platform in front of the beach, on rocks, 1 m depth, May 2006; USJ-A-73676, Caño Island, south side of island in rhodolith field, subtidal at 18 m depth, April 2006.

\* ***Amphiroa zonata*** Yendo 1902: 10, pl. 1: figs. 11–14; pl. 4: fig. 9

Type locality: Misaki, Shimoda and Sunosaki, Japan

Collections: USJ-A-73664, Caño Island, El Chorro, on rocks in front of the beach, subtidal, 2 m depth, April 2006.

\* ***Lithophyllum kotschyianum*** Unger 1858: 22, pl. 5: figs. 15, 16

Type locality: Gulf of Bahrain

Collections: USJ-A-73220, Samara, Cangrejal, in tide pools on rocks, always immersed between 0.2 and 0.8 m, May 2004 (identified by R. Steneck).

\* ***Lithothamnion crassiusculum*** (Foslie) L.R. Mason 1943: 93, '*Lithothamnium*'

Lectotype locality: White's Point, near San Pedro, CA  
 Collections: USJ-A-73223, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004 (identified by R. Steneck).

● *Neogoniolithon fosliei* (Heydrich) Setchell & L.R. Mason 1943: 90

Type locality: Tor, Sinai Peninsula, Egypt.

Collections: USJ-A-73220 Samara, Cangrejal, in tide pools on rocks but always immersed between 0.2 and 0.8 m, May 2004 (identified by R. Steneck).

Comments: According to Guiry and Guiry (2008), *N. fosliei* is a synonym of *N. brassica-florida*. Nevertheless, we prefer to follow Mateo-Cid and Pedroche (2004) to maintain the status of two different species

Order: NEMALIALES

Family: LIAGORACEAE

\* *Trichogloeopsis pedicellata* (Howe) I.A. Abbott & Doty 1960: 638, figs. 18–20

Type locality: Bahamas, Cockburn Harbor, South Caicos.

Collections: USJ-A-73541, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004.

Family: GALAXAURACEAE

▲ *Galaxaura rugosa* (J. Ellis & Solander) J.V. Lamouroux 1816: 263

Type locality: Jamaica

Collections: USJ-A-73445, USJ-A-73447, Caño Island, El Chorro, on rocks in front of the beach, subtidal, 2 m depth, April 2006.

Comments: hitherto known from the Caribbean coast of Costa Rica (Dawson 1962; Bernecker 2008), new to the Pacific.

\* *Scinaia latifrons* M.A. Howe 1911: 500, fig. 1; pl. 28

Type locality: La Paz, Baja California, México

Collections: USJ-A-73583, Bahia Salinas, drift on the beach in front of “Hotel Ecoplaya”, April 2005; USJ-A-73584, Salinas Bay, Ruanilla Island, on rocks, subtidal at 8 m depth, February 2007.

▲ *Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka 1990: 164–168, Figs. 40–45, 50–52

Type locality: West Indies

Collections: USJ-A-73446, Caño Island, El Chorro, on rocks in front of the beach, subtidal, 2 m depth, April 2006.

Comments: already known from the Caribbean coast (Dawson 1962; Bernecker 2008).

Order: GIGARTINALES

Family: HYPNEACEAE

\* *Hypnea valentiae* (Turner) Montagne 1841: 161

Type locality: Red Sea

Collections: USJ-A-73656, USJ-A-73685, Bahia Salinas, algae drift on the beach in front of “Hotel Ecoplaya”, April 2005.

Family: PEYSSONELIACEAE

\* *Polysrata dura* Heydrich 1905: 35, pl. 1

Type locality: Tami Island, Huon Gulf, Papua New Guinea  
 Collections: USJ-A-73533, Samara, Cangrejal, intertidal, November 2005 (identified by M. Baba and A. Kato).

Order: GRACILARIALES

Family: GRACILARIACEAE

\* *Gracilaria spinigera* E.Y. Dawson 1949: 24, pl. 8: figs. 1–3; pl. 9: figs. 1–3

Type locality: Ensenada de San Francisco, Sonora, Mexico.  
 Collections: USJ-A-73589, Salinas Bay, Ruanilla Island, on hard substrate, subtidal at 3–4 m depth, April 2005; USJ-A-73601, Salinas Bay, Islands in front of Punta Descartes, on rocks and coral, subtidal, 5–8 m depth, April 2005.

Order: CERAMIALES

Family: RHODOMELACEAE

*Laurencia* Lamouroux 1813: 130.

▲ *Laurencia* sp.

Collections: USJ-A-73600 Salinas Bay, Ruanilla Island, on hard substrate, subtidal at 3–4 m depth, April 2005; USJ-A-73636, Samara, Cangrejal, reef lagoon on dead coral, subtidal, 1–2 m depth, May 2004.

Comments: species could not be identified; already known by various species from the Caribbean coast (Dawson 1962; Kemperman and Stegenga 1986; Soto and Ballantine 1986; Bernecker 2008).

New reports for Cocos Island

PHYLUM: CHLOROPHYTA

Class: ULVOPHYCEAE

Order: ULVALES

Family: ULVACEAE

*Ulva flexuosa* Wulfen 1803: 1

Type locality: Duino (near Trieste), Adriatic Sea

Collections: USJ-A-73332, Cocos Island, Wafer Bay, algal drift on the beach, November 2001.

Comments: species already known from Pacific and Caribbean mainland coasts (Dawson 1957, 1962; Kemperman and Stegenga 1986; Soto and Ballantine 1986; Bernecker 2008).

Order: BRYOPSIDALES

Family: UDOTEACEAE

*Boodleopsis verticillata* E.Y. Dawson 1960: 32, figs. 1 a–d  
 Type locality: Bahía San Tlemos, Isla del Rey, Pearl Islands, Panama.

Collections: USJ-A-73330, Cocos Island, Chatham Bay, algal drift on the beach, December 2001.



Comments: species already known from Pacific mainland (Tejada Rivas 2002; Bernecker 2008).

## Discussion

Here we report the presence of 42 additional benthic marine algae for the continental coasts of Costa Rica, and two new species for Cocos Island. Including the recently published reports of species from Cocos Island (Fernández 2008) as well as one previously report by Setchell and Mason (1943), the total number of species increases to 446. This represents an increase of 12.6% over the number (396 spp.) published by Bernecker (2008), who based her analyses exclusively on reports in the literature. When analyzing the different taxonomic groups of these algae (Table 2), the findings of our survey resulted in a considerable increase in the number of Chlorophyta species (23.8%; from 84 to 104 spp.), followed by Rhodophyta (10.8%; from 260 to 288 spp.), and Heterokontophyta, Phaeophyceae (3.8%; from 52 to 54 spp., including one species of Xanthophyceae). However, our additional records did not change the proportion of these groups when comparing their species number: the most specious group is Rhodophyta, followed by Chlorophyta and Phaeophyceae. Such a pattern can be found in all Central American countries (Table 2), and is typical for tropical zones (Strasburger et al. 1997).

Considerably more benthic marine algae species have been reported from the Caribbean coast of Costa Rica (318 spp.) when compared to the Pacific coast (190 spp.) (Table 2). This tendency is corroborated by our findings: we collected more new species along the Caribbean shore (Table 1) than at the Pacific side of Costa Rica (31 vs. 25 spp., respectively).

A recent assessment of the marine biodiversity of Costa Rica (Wehrmann and Cortés 2008) revealed that species

numbers are generally substantially higher along the Pacific coast when compared to the Caribbean side (Wehrmann et al. 2008). One of the few exceptions is the benthic marine algae, which are clearly more diverse along the Caribbean coast (Table 2). The same situation occurs in all Central American countries where data are available for both coasts (Table 2). The following two factors may contribute to such an unequal distribution of species diversity: (1) wide daily (tidepool heating) as well as seasonal (coastal upwelling) temperature fluctuations; (2) stressful physical conditions at the Pacific coast where there is an extreme tidal range, which allows the access of herbivores to the intertidal zone (Wysor 2004 and references cited therein). Typical indicators for stressful environments are algal turfs (Wysor 2004), which are very common along the Pacific coast. Moreover, unlike to the Pacific coast, the Caribbean provides more uniform and therefore more adequate conditions for settlement and growth of benthic marine algae (for references see Wysor 2004).

Compared to other countries in the region (Table 2), Costa Rica harbors substantially more species of benthic marine algae than any other country in Central America. Probably the two best-studied Central American marine floras are Panama and Costa Rica (for references, see “Introduction”). In both countries, there are strikingly similar numbers of Chlorophyta and Phaeophyceae species, but a substantial difference in total species numbers between these two countries is caused by the considerably higher number of Rhodophyta species reported for Costa Rica (288 vs. 103 spp.). Recent published studies on marine algae in Panama have been focused more on green and brown algae (Wysor and De Clerck 2003; Wysor and Kooistra 2003; Wysor 2004). According to Wysor (personal communication 2007), Rhodophyta have been collected in Panama as well; however, these results have not been published yet. It is expected that the number of

**Table 2** Updated species numbers of benthic marine algae and Cyanobacteria reported from all Central American countries (modified from Bernecker 2008, including also the data from Setchell and Mason (1943), Fernández and Cortés 2005, and Fernández 2008)

	Taxonomic groups				Benthic marine algae			
	Chlorophyta	Heterokontophyta (Phaeophyceae, (Xanthophyceae)	Rhodophyta	Cyanobacteria	Total	Caribbean	Pacific	Both coasts
Costa Rica	104	54	288	24	446	318	190	62
Panama	107	43	103	7	253	175	103	25
Belize	72	23	79	13	174	174	–	–
Honduras	38	19	58	5	115	115	–	–
El Salvador	18	8	67	na	93	–	93	–
Guatemala	11	1	23	11	35	27	10	2
Nicaragua	34	17	46	2	97	97	na	na

na information not available

red algae species reported from Panama will increase considerably, which may result in a similar overall number of benthic marine algae in both countries.

So far, 62 species of benthic marine algae have been documented from both coasts of Costa Rica (Table 2). This number is substantially higher than that reported for amphisthmian species from Panama (Wysor 2004: 15 spp.). According to Wehrtmann et al. (2008), 288 species of different groups of organisms have been found on both coasts of Costa Rica; thus, marine algae represent a considerable portion (roughly 22%) of these amphisthmian species. In this context, it is interesting that the number of amphisthmian benthic marine algae seems to greatly exceed the number of amphisthmian species from other groups of organisms, such as invertebrates and fishes (see Wysor 2004). This raises the question if this tendency is simply the result of inadequate algal taxonomy and a lack of information regarding current algal diversity along both coasts of Central America, or if this discrepancy is an indicator of reduced speciation in seaweeds. Further studies focusing on molecular genetic analyses of these species may help to clarify these questions, and may also reveal the presence of transisthmian sister species as documented for other groups of organisms (Weinberg and Starczak 1989; Knowlton and Weigt 1998; Knowlton et al. 1993; Wehrtmann and Albornoz 2002).

Considering the substantial effort to collect and document the diversity of the flora of benthic marine algae along both coasts of Costa Rica, we assume that the current number of reported species (446 spp.) is only fairly representative for the diversity of these organisms in Costa Rica, and is still an under estimation. However, our information about the diversity of marine benthic microfilamentous algae and Cyanobacteria in Costa Rica is far from complete, which may be related to the fact that the identification of most of these organisms requires culture studies and, preferably also the application of molecular-genetic techniques (e.g., O'Kelly et al. 2004). A detailed taxonomic analysis of these microfilamentous algae as well as of other diminutive-sized species (e.g., Verbruggen et al. 2007) will result in higher species numbers for Costa Rica and the region.

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