MARINE MACROALGAE RESEARCH IN HISPANIOLA ISLAND [First Draft]

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RESUMEN. El presente trabajo actualiza, desde una perspectiva insular y con un enfoque histórico, el conocimiento de la riqueza taxonómica de las macroalgas marinas bentónicas de la isla Hispaniola. Se documentan 393 taxones infragenéricos: 375 especies, 1 subespecie, 6 formas y 11 variedades distribuidos en 5 clases, 27 órdenes y 61 familias; con 41 taxones en Ochrophyta, 221 en Rhodophyta y 131 en Chlorophyta. Para República Dominicana se compilan 294 taxones y 284 para Haití (con 185 compartidos). Catorce taxones tienen localidades tipo en la isla: 5 dominicanas y 9 haitianas. Se ofrece una lista de instituciones que albergan material colectado en Hispaniola y el mapa de distribución con las localidades de colecta. En la ecorregión de las Antillas Mayores el conocimiento de las macroalgas marinas de Hispaniola muestra cierto avance pero son necesarias nuevas investigaciones que puedan elevar nuestros inventarios a las cifras de Cuba y Puerto Rico.

ABSTRACT. The present paper updates, from an insular perspective and with a historical approach, the knowledge of the species taxonomic richness of the benthic marine macroalgae of Hispaniola Island. Here, 393 infrageneric taxa are documented: 375 species, 1 subspecies, 6 forms and 11 varieties distribute in 5 classes, 27 orders and 61 families; with 41 taxa in Ochrophyta, 221 in Rhodophyta y 131 in Chlorophyta. For Dominican Republic 294 taxa are compiled and 284 for Haiti (with 185 shared). Fourteen taxa have type localities on the island: 5 Dominican and 9 Haitian. A list of institutions that house material collected in Hispaniola and the distribution map with the collection locations, are offered. In the context of the Greater Antilles ecoregion, the knowledge of marine macroalgae from Hispaniola shows some progress, but new research is needed to raise our inventories to the figures for Cuba and Puerto Rico.

Introduction

The island of Hispaniola is located between 17º36'15" and 19º56'39" north latitude and 68º19'22" and 74º28'58" west longitude. The Atlantic Ocean, that bathes it to the north and the Caribbean Sea to the south, are connected to the east of the island at the Mona Channel, which separates it from Puerto Rico; and to the west at the Windward Passage, which separates it from Cuba (Fig. 1). With an area of 76,480 km² (including islands and islets), it is one of the many islands whose territory is shared by more than one country, in this case: Haiti which occupies 36% of the west and the Dominican Republic the remaining 64% to the east, separated by 360 km of border. Haiti has an area of 27,750 km², which includes the territory of its various islands and islets such as Gonave (743 km²), Tortue (180 km²), Vache (52 km²), Cayemites (45 km²) and Navassa (5.2 km²). The Dominican Republic has an area of 48,442 km² including its islands and islets such as Saona (117 km²), Beata (27 km²) and Catalina (9.6 km²). It also has the oceanic banks of Navidad (650 km²) and La Plata (1,680 km²) located to the northeast in the Atlantic Ocean.

Hispaniola's coastline extends for 3,059 km: 1,288 km belong to sixteen Dominican coastal provinces and 1,771 km to nine Haitian coastal departments (Fig. 2). Coastal ecosystems include muddy to sandy beaches (depending on terrigenous or biogenic influence), low rocky or cliffy shores, estuaries, coastal lagoons and mangrove forests. The insular shelf up to about 200 m depth is 6,683 km² on the Haitian side and is more extensive on the Dominican side with about 10,738 km² and on average, wider. Marine ecosystems include sandy or muddy bottoms, com-

monly with abundant macrophytobenthos, especially seagrasses, followed by different types and configurations of coral reefs: coastal, patch or barrier reefs. This chapter provides a summary of research on the benthic marine macroalgae of Hispaniola Island with updated information from the most recent inventory (Betancourt and Herrera-Moreno, in press). This work is a result of the Programa EcoMar/GBIF IDB-CA2020-012-INS project "Assessment and update of data on marine macroalgae in Hispaniola" (PROECOMAR, 2022).

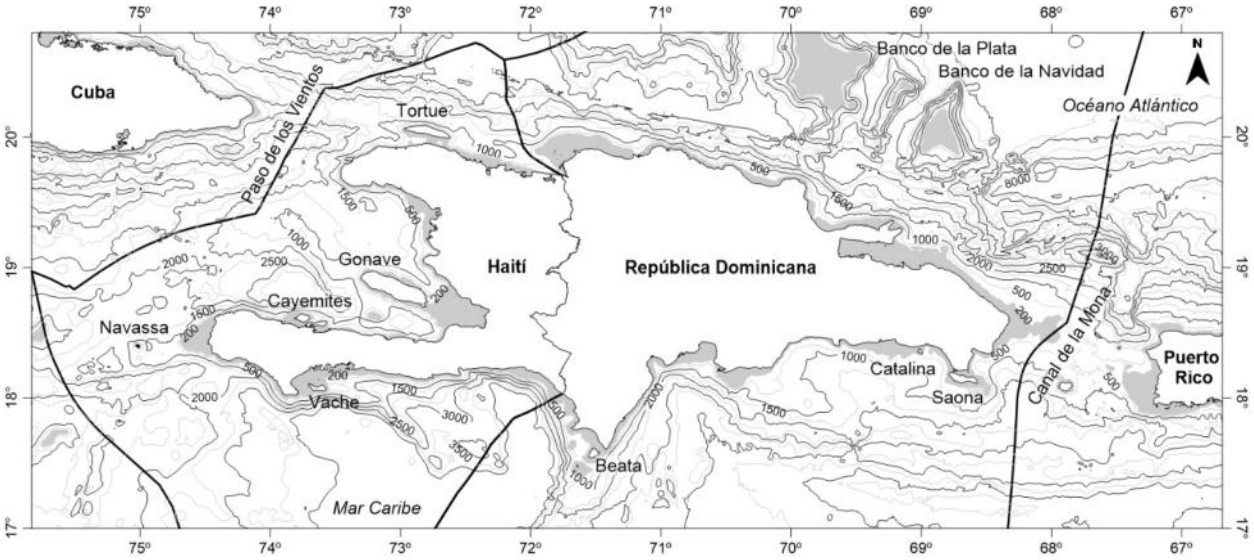

Figure 1. Map of the island of Hispaniola with the two nations that make it up: Haiti and the Dominican Republic. Part of the EEZs of both countries are indicated, plus the claim space for Navassa Island (black lines), the marine areas and some peculiarities of the submarine topography, highlighting the insular platform up to 200 m depth in gray. Source: Herrera-Moreno (2021).

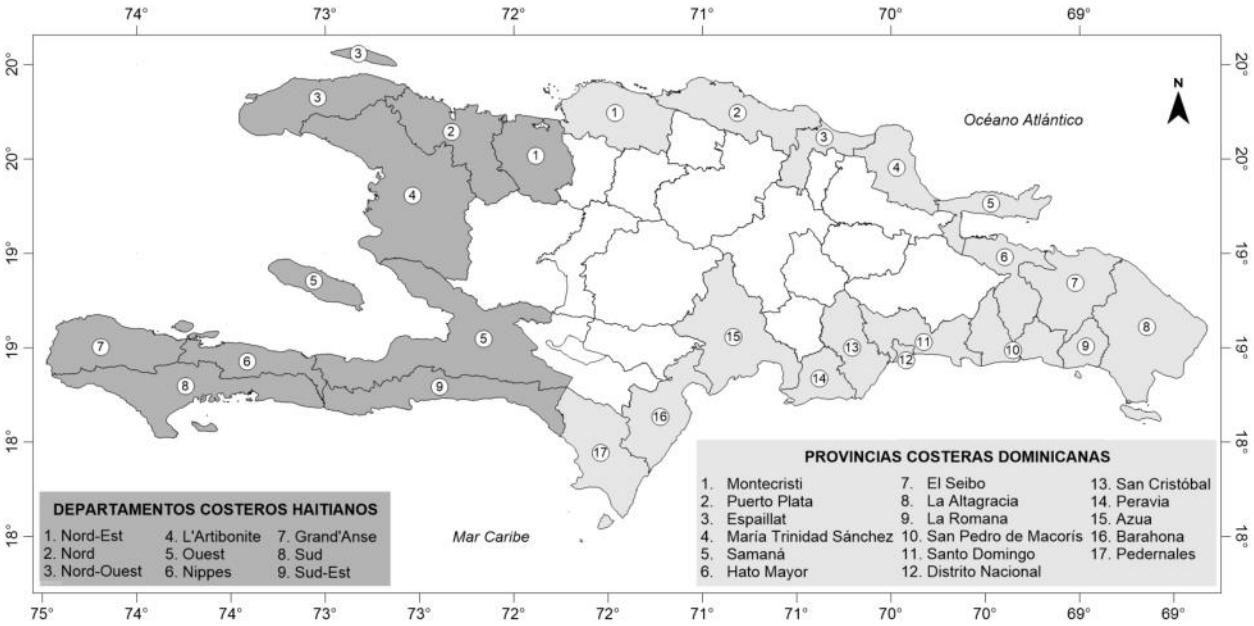

Figure 2. Haitian departments and Dominican provinces in the coastal zone.

Historical background and research

The chronology of the scientific knowledge about the benthic marine macroalgae of Hispaniola seems to begin at the beginning of the 19th century with the dissertations of Lamouroux (1805) on several new or not well-known species of the genus *Fucus*, where he reports the ochrophytes *Fucus pseudociliatus* (currently *Taonia pseudociliata*), *Fucus poitei* (currently *Yuzurua poiteaui*) and *Fucus zonalis* (currently *Stypopodium zonale*), for "Sancti Dominici". This location refers to some type locality on the coast of the former French colony of Saint-Domingue, in Haiti, where, according to J. V. Lamouroux's own words, his friend the French botanist Pierre-Antoine Poiteau (to whom he dedicates one of these species), made the collections.

The next record could be found in the famous *Systema algarum* of C. A. Agardh (1824) if we assume that the locality, he indicates for the rhodophyte *Hutchinsia macrocarpa* (currently *Polysiphonia macrocarpa*) from "In mari Antillarum ad 'Port au Pray'" refers to Port-au-Prince or Port-de-Paix in Haiti (which would be its type locality), as interpreted by Kapraun and Norris (1982). Subsequently, for Haitian waters we find several records of rhodophytes in the monograph of exotic cellular plants of Montagne (1842) and the botanical additions of Endlicher (1843) with *Dasya lophoclados* (currently *Lophocladia trichoclados*); in the descriptions of J. G. Agardh (1851) with *Rhabdonia tenera* (currently *Solieria filiformis*) and in the phycological tables of Kützing (1869) with *Sphaerococcus domingensis* (currently *Gracilaria domingensis*) with type locality in "Ins. St. Domingo", probably in the Dominican Republic.

In 1871, the United States Congress sent a special commission (Commission of Inquiry to Santo Domingo) to the Dominican Republic –with openly annexationist purposes– which included the botanists C. C. Parry, C. Wright and H. Brummel (Wade *et al.,* 1871), who made the first collections of algae in different marine localities of the country. About twenty species were identified and deposited in various museums, mainly in the United States National Herbarium of the Smithsonian Institution. This museum also houses a small collection of algae collected by William More Gabb in 1877 during his travels through Dominican territory (NMNH, 2022). Murray (1889) in his catalog of West Indian seaweeds lists several species for the island.

For the Dominican Republic the 20th century opens with the notes of Foslie (1906; 1907) on the non-geniculate coralline algae of the genus *Lithothamnion* with a species with type locality in Puerto Plata: *Lithothamnion ruptile*, deposited in the herbarium of the museum of the University of Norway. In 1911, preast Miguel Fuertes y Lorens collected algae in Barahona (Sáez, 1989) and in 1913, John N. Rose of the Carnegie Institution of Washington collected algae in Azua and San Pedro de Macorís (Zanoni and Read, 1989), with deposits in the herbariums of the United States National Museum and the New York Botanical Garden. But the study that marks the beginning of phycological research in Dominican waters was done by Børgesen (1924), who identified part of the specimens collected by C. H. Ostenfeld in Beata Island, during the expedition of the Oceanographic Ship Dana, in 1922. His paper offers the first inventory with 63 infrageneric taxa, including a new species and a new variety with type locality in this island of the southwestern Dominican Republic: *Ceramium comptum* and *Ceramium brevizonatum* var. *caraibicum.*

Five years later, Taylor and Arndt (1929), based on collections made between 1925 and 1929 by the second author in Haiti, listed more than ninety species, a variety, a form and a subspecies and

described *Actinothamnion antillarum* (currently *Dohrniella antillara*) with type locality in Aquin Bay. Taylor (1933) continued to expand the phycological knowledge for Haitian waters, identifying the material collected by C. R. Orcutt, which covered a much larger area in the west of this country, with the result of about one hundred species listed. In February of that year the Johnson-Smithsonian Deep-Sea Expedition made collections of algae in Dominican waters of Samaná Bay (Bartsch, 1933) which are preserved in the New York Botanical Garden. Post (1936) in his systematic notes of the *Bostrychia-Caloglossa* association mentions three species for Port-au-Prince and Port Saluit in Haiti.

The collections of W. L. Schmitt and G. R. Lunz during the 1937 Smithsonian-Hartford Expedition to Tortuga Island on the north coast of Haiti served as material for the work of Taylor (1940), who listed about twenty species. H. H. Barlett, in 1941 also collected phycological material in the Haitian part of Hispaniola, with which Taylor (1943) recorded about eighty taxa and described three new species: *Pterocladia bartlettii* (currently *Pterocladiella bartlettii*), *Gloiophloea caribaea* (currently *Scinaia caribaea*) and *Wurdemannia miniata* var. *planicaulis* (currently *Ceratodictyon planicaule*) with type localities at Saint Louis du Sud, Trou Cochon, and Jérémie, respectively. Taylor (1960), in his monograph of the benthic marine algae known for the Western Atlantic, considered one of the most important contributions to Caribbean and Atlantic marine botany, summarizes much of the phycological knowledge on Hispaniola up to that date with more than two hundred taxa for the island (including species, varieties, forms and subspecies) and new species such as *Padina haitiensis* with type locality at Tortuga Island. In this same locality, Segonzac (1969) later adds new records.

In the Dominican Republic, the following two decades counted with the results of the collaboration between the Department of Marine Sciences of the University of Puerto Rico and the Center for Marine Research of the Autonomous University of Santo Domingo, which resulted in the inventories of Almodóvar and Bonnelly de Calventi (1977), Almodóvar and Álvarez (1978), Díaz-Piferrer (1978), which is still preserved in the Herbarium of the Botanical Garden of Santo Domingo; Álvarez and Bonnelly de Calventi (1978), Montero *et al.* (1983) and Williams *et al.* (1983). These contributions added new records which can be seen in several museums of the Macroalgae Herbarium Consortium Portal, and expanded the known geographic distribution of some species to new localities in several provinces, mostly in the southern Dominican Republic. For Haiti we have the study by Gabrielson and Hommersand (1982) on the vegetative and reproductive morphology of two species of the genus *Solieria* using Haitian material from Anse a Drick. Fredericq and Norris (1986) describe a new species for Haiti: *Dasya haitiana*, with type locality at Caracol Bay. Wilcox *et al.* (1989) report several species of macroalgae at different depths and reef zones, in their inventory of the coral reefs of Les Arcadins.

In Dominican Republic, during the following two decades began the collaboration between the Department of Marine Sciences of the University of Puerto Rico and the Center for Marine Research (CIBIMA) of the Autonomous University of Santo Domingo, which resulted in the inventories of Almodóvar and Bonnelly de Calventi (1977), Almodóvar and Álvarez (1978), Díaz-Piferrer (1978) Álvarez and Bonnelly de Calventi (1978), Montero *et al.* (1983) and Williams *et al.* (1983). These contributions added new records and expanded the known geographical distribution of some species to new localities in several provinces, mostly in the south of the country. Gabrielson and Hommersand (1982) in their study of the vegetative and reproductive morpholo-

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In the 1990s, the knowledge of the Dominican macroalgae advances with the results of the expeditions of the University of East Carolina in Montecristi (Luczkovich *et al.,* 1991); from the Jaragua Group and the University of Puerto Rico in Pedernales (Rosenberg *et al.,* 1995); the reviews of the genera *Anadyomene* (Littler and Littler, 1991) and *Avrainvillea* (Littler and Littler, 1992) and the first report of *Yamadaella caenomyce* (Wynne and Huisman, 1998). New records are published for Haitian waters in the review of the genus *Udotea* (Littler and Littler, 1990) and in the report of the oceanographic expedition to Navassa Island with the participation of the National Museum of Natural History of Santo Domingo and the Center for Marine Conservation (Littler *et al.,* 1999).

Beginning 2000, we found inventories of algae in Cotubamaná National Park (formerly Parque del Este) in Dominican Republic (Chiappone *et al.,* 2001). Leliaert *et al.* (2003) use Dominican material in the study of the phylogeny of the Cladophorophyceae, as do Verbruggen and Kooistra (2004) in the morphological characterization of lineages within the genus *Halimeda*. The review of the catalog of the coralline red algae of M. Foslie by Woelkerling *et al.* (2005) reported a new coralline algal variety: *Lithothamnion occidentale* var. *effusum*. Leliaert *et al.* (2007) in in their systematic study of the genus *Chamaedoris* include samples from Puerto Plata and Río San Juan. For Haiti, Begin and Steneck (2003) mention five species of crustose coralline algae (genera *Harveylithon, Lithophyllum* and *Neogoniolithon*) for Navassa reefs. In the description of two new species: *Crouania elisiae* and *Chondracanthus saundersii*, Schneider (2004) and Schneider and Lane (2005) use Haitian material from the Michigan University. Santelices and Flores (2004) in their observations of *Gelidiella acerosa* spermatangia examine Haitian specimens.

Martin-Lescanne *et al.* (2010) in their phylogenetic analysis of the *Laurencia* complex validate *Yuzurua poiteaui* as a new combination based on Lamouroux's (1805) description of the basonym *Fucus poitei* from Saint-Domingue, Haiti, which we have already mentioned. Moreira and Cabrera (2011) include Dominican material from the Ficoteca Antillana de Oriente (FAUO) in the study of the anatomy of the reproductive structures in two varieties of the genus *Sargassum*; Dreckmann (2012) in his study of the genera *Gracilaria* and *Hydropuntia* mention material from both countries and Tronholm *et al.* (2013) in the taxonomic reevaluation of the *Dictyota ciliolata–crenulata* complex uses material from the Herbarium of the University of La Laguna (TFC) in Spain. Bucher *et al.* (2014), in their description of *Wrangelia gordoniae* as a new species examine Dominican material from Isla Saona and Haitian material from Caracol Bay. Also, Dominican material is present in the phylogenetic and molecular analyses of the genus *Dictyota* by Lozano-Orozco *et al.* (2016) and in the description of two new species of the *Hypnea musciformis* complex by Nauer *et al.* (2019) with *Hypnea schneideri* with type locality on Saona Island in the Dominican Republic. The study of sargassum arrivals on Dominican coasts reports the presence of a new variety: *Sargassum polyceratium* var. *ovatum* (Méndez-Tejeda and Rosado, 2019) already known for Haiti since Taylor and Arndt (1929). Finally, Vieira *et al.* (2020) in their review of the genus *Lobophora* include Dominican material collected in El Portillo.

Thus, from the first explorations at the beginning of the 19th century to the present, the number of macroalgae species known for Hispaniola has increased progressively (Fig. 3). In this progress, the contributions of F. Børgesen in the Dominican Republic in the 1920s and especially those of R. W. Taylor and collaborators in Haiti, which lasted until the 1960s, should be highlighted, as together they contributed more than 60% of the species known today for the island. In the late 70's and early 80's there was an important contribution to the knowledge of Dominican macroalgae with the research of CIBIMA and the University of Puerto Rico in the work of L. R. Almodóvar, I. Bonnelly de Calventi, M. Díaz-Piferrer, V. Álvarez and E. H. Williams. H. Williams. From the late 1980s to the present there are several contributions from well-known specialists in macroalgal taxonomy in Haiti (S. Fredericq, J. N. Norris, D.S. Littler and M.M. Littler) and the Dominican Republic (K.E. Bucher, F. Nauer, G. Rosenberg, G., M.J. Wynne and J.M. Huisman) and inventories derived from several expeditions.

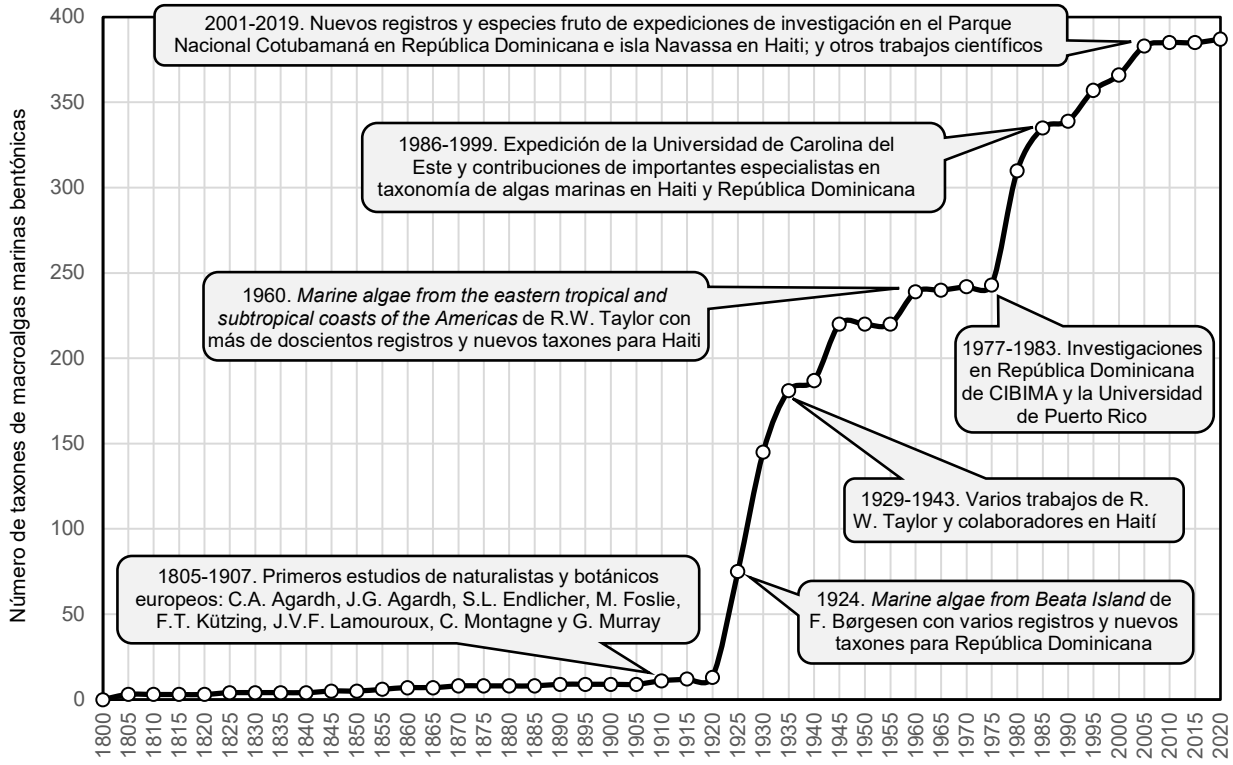

Figure 3. Cumulative curve by years of the number of macroalgae species known for Hispaniola. Some events, expeditions and publications that are milestones in the development of phycological knowledge are indicated.

At present, specimens collected in more than one hundred localities of Hispaniola are housed in 38 museums around the world in: Australia, Belgium, Brazil, Cuba, Spain, United States, France, Hawaii, Netherlands, England, Norway, Dominican Republic and Sweden with an estimated number of records in the order of 4000. Of these, at least twenty-one U.S. museums grouped in the Macroalgae Herbarium Consortium Portal contain some 2,824 records with the largest numbers in the herbaria of the University of Michigan (MICH), the New York Botanical Garden (NY) and the University of California (UC) with 784, 676 and 393 records, respectively. The United States National Museum holds about 871 records.

Taxonomic richness

The present inventory documents 393 taxa of benthic marine macroalgae for Hispaniola with 41 in Ochrophyta, 221 in Rhodophyta and 131 in Chlorophyta. In the taxonomic categories compiled there are 375 species, one subspecies, 6 forms and 11 varieties. distributed in 5 classes, 27 orders and 61 families (Appendix 1). The richest family was Rhodomelaceae with 43 taxa; followed by Dictyotaceae, Cladophoraceae and Caulerpaceae, between 20 and 25 taxa; and Ceramiaceae, Corallinaceae, Dasyaceae Gracilariaceae, Halimedaceae Udoteaceae and Wrangeliaceae, between 10 and 16 taxa. A total of 294 taxa are compiled for the Dominican Republic and 284 for Haiti (Table 1), with 185 shared. Fourteen taxa have type localities on the island: nine Dominican and five Haitian (Table 2). The records of 339 taxa are supported by scientific literature with or without reference to collections in national or international institutions (Appendix 2), but in 54 cases the record could only be supported by museum material.

Table 1. Summary of the number of benthic marine macroalgal taxa known for Haiti (H), Dominican Republic (D) and Hispaniola (HA).

Phyla	**Ochrophyta**			**Rhodophyta**			**Chlorophyta**			**Total**		
Category	**D**	**H**	**HA**	**D**	**H**	**HA**	**D**	**H**	**HA**	**D**	**H**	**HA**
Species	34	31	41	155	156	216	93	85	118	281	275	375
Subspecies	0	0	0	1	0	1	0	0	0	1	0	1
Form	0	0	0	0	1	1	3	2	5	3	3	6
Variety	0	0	0	3	2	3	5	5	8	8	7	11
Total	34	31	41	158	160	221	102	93	131	294	284	393

Table 2. Summary of taxa with type localities in Dominican Republic (D) or Haiti (H).

Current scientific name [Original scientific name]	**Country. Locality**	**Reference**
Yuzurua poiteaui (J.V.Lamouroux) Martin-Lescanne, 2010 [*Fucus poitei*]	H. Sancti Dominici	Lamouroux, 1805
Stypopodium zonale (J.V.Lamouroux) Papenfuss, 1940 [*Fucus zonalis*]	H. Sancti Dominici	Lamouroux, 1805
Polysiphonia macrocarpa (C.Agardh) Sprengel, 1827 [*Hutchinsia macrocarpa*]	H. Port-au-Prince?	C.A.Agardh, 1824
Gracilaria domingensis (Kützing) Sonder ex Dickie, 1874 [*Sphaerococcus domingensis*]	D. St. Domingo	Kützing, 1869
Lithothamnion ruptile (Foslie) Foslie, 1907	D. Puerto Plata	Foslie, 1907
Ceramium brevizonatum var. caraibicum H.E.Petersen y Børgesen, 1924	D. Isla Beata, Pedernales	Børgesen, 1924
Ceramium comptum Børgesen, 1924	D. Isla Beata, Pedernales	Børgesen, 1924
Dohrniella antillara (W.R.Taylor) Feldmann-Mazoyer, 1941 [*Actinothamnion antillarum*]	H. Baie Anglais, Aquin	Taylor y Arndt, 1929
Pterocladiella bartlettii (W.R.Taylor) Santelices, 1998 [*Pterocladia bartlettii*]	H. Saint Louis du Sud	Taylor, 1943
Ceratodictyon planicaule (W.R.Taylor) M.J.Wynne, 2011 [*Wurdemannia miniata var. planicaulis*]	H. Jérémie	Taylor, 1943
Scinaia caribaea (W.R.Taylor) Huisman, 1985 [*Gloiophloea caribaea*]	H. Trou Cochon,	Taylor, 1943
Padina haitiensis Thivy, 1960	H. Isla Tortuga	Taylor, 1960
Dasya haitiana S.Fredericq y J.N.Norris, 1986	H. Caracol Bay	Fredericq and Norris, 1986
Hypnea schneideri Nauer, Cassano y M.C.Oliveira, 2019	D. Isla Saona, La Romana	Nauer *et al.,* 2019

Taxa not included

During the present review several taxa reported for Hispaniola appeared that were not included in the inventory for one of the following reasons: (i) they did not appear in Wynne's (2022) review for the tropical and subtropical western Atlantic, (ii) they were not present or appeared as "uncertain" in the WoRMS Editorial Board (2022), (iii) they appeared as doubtful taxa in the AlgaeBase (Guiry and Guiry, 2022), or (iv) geographic information on their ranges in various sources did not include the Greater Antilles. Since these taxa need to be investigated further, both taxonomically and in terms of the quality of the information (e.g., probable typographical errors by museums) their inclusion was beyond the time available for the present project so they were grouped in Table 3 pending the development of an appendix to the present inventory at a later date, if necessary.

Table 3. List of benthic marine macroalgae taxa reported for Hispaniola not included in the present inventory.

Amphibia moritziana (Sonder ex Kützing) Kuntze H[Taylor qnd Arndt, 1929]
Bryothamnion seaforthii f. *distichum* J.Agardh, 1863 H[NBC L.4033424]
Caulerpa elongata Weber Bosse, 1898 D[USNM 13597252]
Ceramium tenuicorne (Kützing) Waern, 1952 H[NRM A19587]
Cladophora fracta (O.F.Müller ex Vahl) Kützing, 1843 H[USNM 52351, 52352]
Codium dichotomum H[Taylor, 1943; USNM 33891, 70952; WNC-A-0006808, 0006809]
Enteromorpha flexuosa subsp. *flexuosa* Bliding H[NBC L.4139509]
Gayliella flaccida (Harvey ex Kützing) T.O.Cho & L.J.McIvor, 2008 D[MICH 622976]
Gelidium inagakii Yoshida, 1997 H[FH00907122]
Gelidium rigidum var. *radicans* (Bory) J.Agardh, 1851 D[F C0502910F; YPM:YU 245987]
Gongolaria abies-marina (S.G.Gmelin) Kuntze 1891 D[MNHN-PC0596589]
Goniolithon decutescens (Heydrich) Foslie ex M.A.Howe, 1918 H[Taylor, 1943; MICH 737703; USNM 32987]
Gracilaria dura (C.Agardh) J.Agardh, 1842 D[FH01170125]
Haraldiophyllum sinuosum (A.H.S.Lucas) A.J.K.Millar, 1990 H[Taylor, 1933; FC0505666F; UC1835847]
Heterosiphonia gunniana (Harvey) Reinbold, 1899 H[FH01171737]
Lithothamnion corallioides (P.Crouan & H.Crouan) P.Crouan y H.Crouan, 1867 D[Foslie, 1906]
Rhizoclonium hieroglyphicum (C.Agardh) Kützing, 1845 D[UC689104; USNM 153144]
Sargassum howellii Setchell, 1937 D[FH00883362]
Sargassum liebmannii J.Agardh, 1847 D[BCN 2322]
Turbinaria ornata (Turner) J.Agardh, 1848 D[NRM A14844]
Ulva fenestrata Postels & Ruprecht, 1840 H[MICH 733730]
Ulva lactuca var. *rigida* (C.Agardh) Hariot H[USNM 54995]
Ulva rigida C.Agardh, 1823 H[DUKE 202894; MICH 735234, 735263; NY 02140584]

Geographic distribution

Collections have been made in about forty Haitian localities and seventy Dominican localities covering all its departments and provinces (Appendix 3), many of which have been mentioned in the historical background section. The coast of Haiti was systematically visited from 1925 to 1943 by W.R. Taylor and his collaborators (C.H. Arndt, C.R. Orcutt, W.L. Schmitt, G.R. Lunz and H.H. Barlett), with major visits to localities in the Sud, Ouest and Grand'Anse (Fig. 4), although virtually all Haitian departments had some collection site. Subsequent work in Haiti reported new records or contributed with the description of new taxa but without significantly expanding the geographic area of study, with the exception of the World Wildlife Fund expeditions in 1988 that studied the coral reef of Les Arcadins for the first time (Wilcox et al., 1989); and of the National Museum of Natural History of Santo Domingo and the Center for Marine Conserva-

tion in 1998 (Littler et al., 1999) and of NOAA in 2002 (Begin and Steneck, 2003) that opened the knowledge of the macroalgae of Navassa Island in western Haiti. Here we must highlight Caracol Bay, a type locality that has been intensively sampled and where 58 taxa are reported with 91 records in the National Museum of Natural History of the United States.

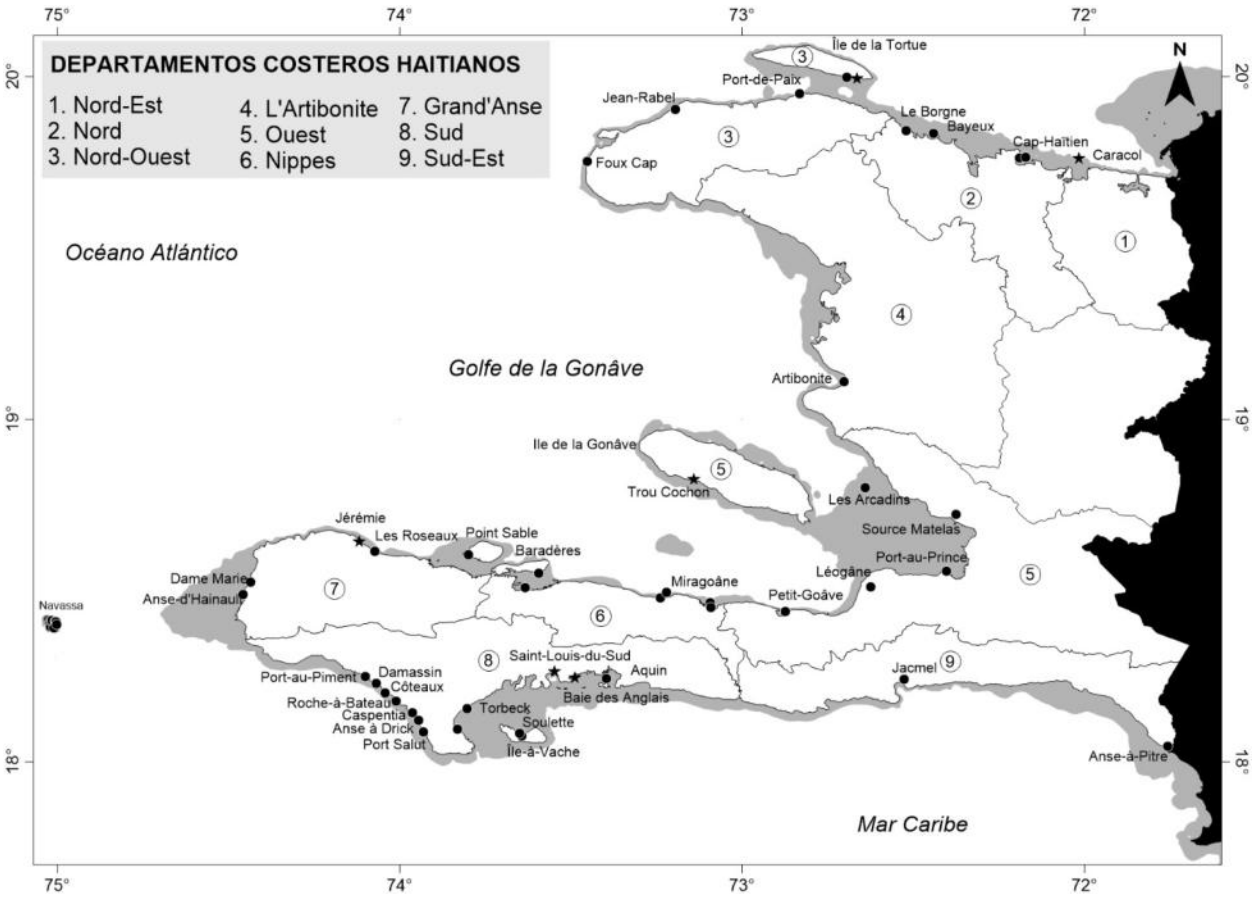

Figure 4. Main collection locations (black circles) of marine macroalgae by Haitian coastal departments. The stars provide a geographic reference to the type localities.

About forty species have a wide distribution in all Haitian regions, including: *Acanthophora spicifera, Alsidium triquetrum, Amphiroa fragilissima, Anadyomene stellata, Canistrocarpus cervicornis, Caulerpa sertularioides, Ceramium nitens, Cladophoropsis membranacea, Coelothrix irregularis, Dictyopteris delicatula, Dictyosphaeria cavernosa, Dictyota ciliolata, Digenea simplex, Galaxaura rugosa, Gelidiella acerosa, Gracilaria cervicornis, Halimeda opuntia, Hypnea musciformis, Jania adhaerens, Lobophora variegata, Ochtodes secundiramea, Padina sanctae-crucis, Palisada perforata, Penicillus capitatus, Sargassum platycarpum, Sargassum polyceratium, Spyridia filamentosa, Tricleocarpa fragilis* and *Turbinaria turbinata.*

In the Dominican Republic (Fig. 5) the coastline was visited between 1871 and 1877 by several botanists and naturalists (among them C.C. Parry, C. Wright, H. Brummel and W. Gabb) with research interests but their collection sites are not clearly identified. The first known collection localities are in Barahona, Azua and San Pedro de Macorís visited by Father Miguel Fuertes y Lorens in 1911 (Sáez, 1989) and John N. Rose in 1913 (Zanoni and Read, 1989). With Børgesen

(1924), collections expanded to the western Dominican Republic to Pedernales and with the Johnson-Smithsonian Deep-Sea expedition, several stations in Samaná Bay were sampled (Bartsch, 1933). Between 1977 and 1983, with the investigations of the Department of Marine Sciences of the University of Puerto Rico and the Marine Research Center, the study area was extended to new provinces and localities: Azua, Distrito Nacional, La Altagracia, La Romana, María Trinidad Sánchez, San Cristóbal, San Pedro de Macorís and Santo Domingo.

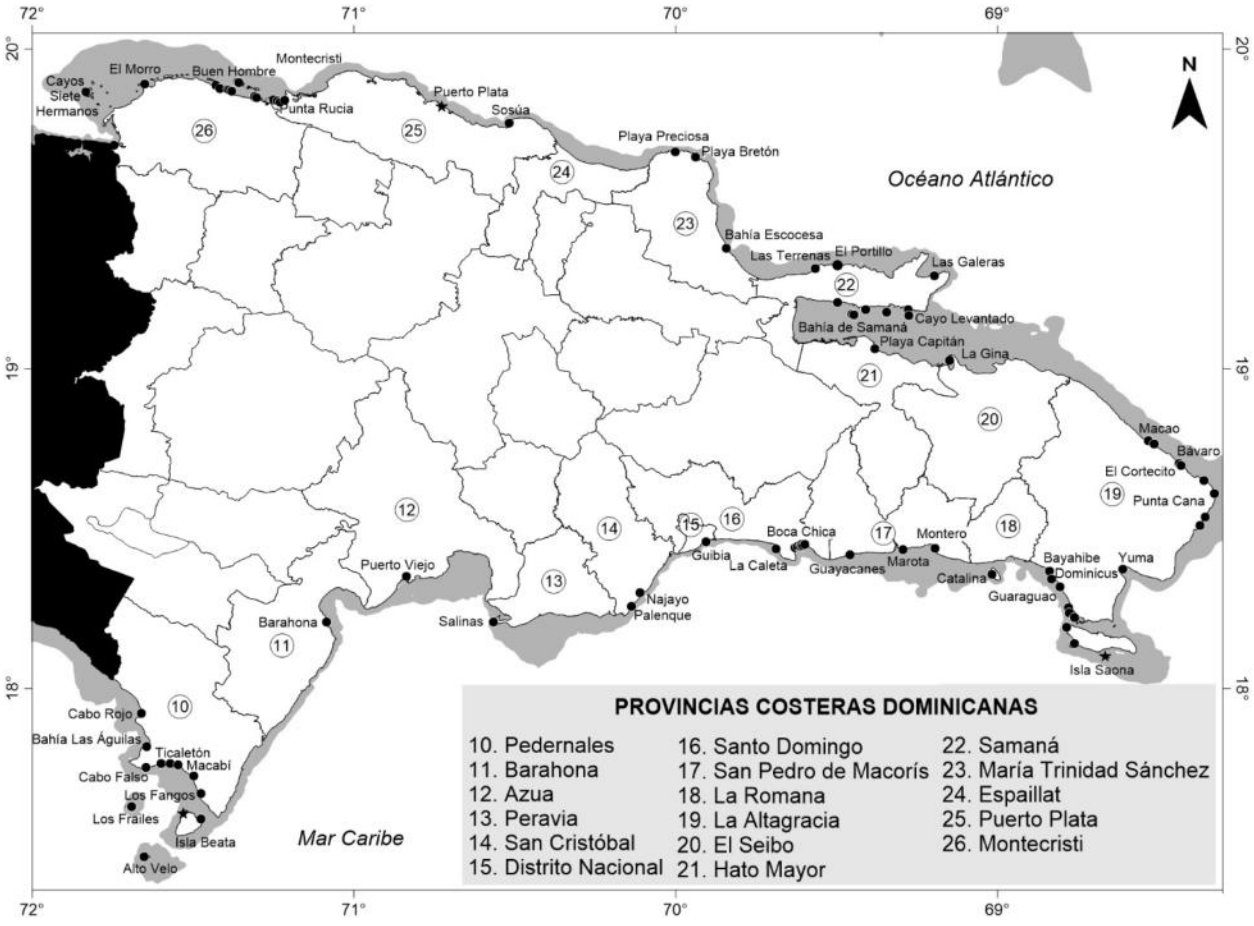

Figure5. Main collection locations (black circles) of marine macroalgae by Dominican coastal provinces. The stars provide a geographic reference to the type localities.

Expeditions have played an important role in expanding the geographic space for phycological research. Montecristi had not been studied until the 1990s when the University of East Carolina expedition took place (Luczkovich et al., 1991). In 1995, the Jaragua Group and the University of Puerto Rico expedition sampled new localities in Pedernales (Rosenberg *et al.,* 1995). The Nature Conservancy's research in Cotubamaná National Park (formerly Parque del Este), summarized in part by Chiappone *et al*. (2001), expanded the phycological knowledge of this protected area. At present, the most studied provinces have been La Altagracia, Montecristi, Pedernales, Samaná and Santo Domingo, although practically all the Dominican provinces have some collection localities.

The most intensively sampled locality is Boca Chica with more than fifty taxa and 88 records in the Macroalgae Herbarium Consortium Portal and 32 in the National Museum of Natural History of the United States. The species with the widest distribution in all Dominican regions are: *Caulerpa cupressoides, Caulerpa racemosa, Dictyosphaeria cavernosa, Digenea simplex, Halimeda tuna, Hypnea musciformis, Lobophora variegata, Penicillus dumetosus, Stypopodium zonale* and *Valonia ventricosa.*

Distribution by habitat and depth

Sampling of the benthic marine macroalgae of Hispaniola has covered the mesolittoral zone both in natural environments (beach, low rocky or cliffy shore, tide pools and roots of the red mangrove *Rhizophora mangle*) and in built structures (piers and jetties); and the sublittoral zone from the shore up to 50 m depth, on particulate substrates (from mud to gravel) with or without seagrass cover (mainly *Thalassia testudinum* and *Syringodium filiforme*) or rocky and coral reefs in all its zones: lagoon, back reef, reef flat, reef crest, spurs and grooves and fore reef. Macroalgae have been collected in open or semi-enclosed coasts of bays and inlets, protected or exposed, under fluvial influence or with high oceanic influence. Because of logistical facilities, most of the studies, especially the first ones, have focused on the intertidal zone or the near shallow sublittoral (< 3 m), but as research progressed, the bathymetric interval was extended with sampling in Dominican coral reefs up to 10 m in Montecristi (Luczkovich *et al.,* 1991) or 23 m at Los Frailes (Rosenberg *et al.,* 1995); and Haitian up to 25 m at Navassa (Begin and Steneck, 2003), 33 m at Les Arcadines (Wilcox *et al.,* 1989) or 48.8 m at Caracol (Bucher *et al.,* 2014), which is the greatest depth of collection on record.

Regional comparison

According to the figures of number of taxa of benthic marine macroalgae reported by Suárez and Martínez-Daranas (2020) for the islands of the Greater Antilles, Hispaniola with 393 is only slightly above Jamaica, which reports 359, and below Cuba and Puerto Rico, which report 536 and 567, respectively. In the context of the Antillean ecoregion, knowledge of the marine macroalgae of Hispaniola shows some progress but it is necessary to develop Dominican and Haitian specialists and implement new researches that can raise our inventories to the figures of Cuba and Puerto Rico. Suarez and Martinez-Daranas (2020) also indicate that the similarity of the Hispaniolan benthic phycoflora with its Antillean counterparts ranges from 65 to 71% (Table 3) with differences explained by the influence of the variety of environments and depths of collection, or differences in sampling effort. It should be clarified that these results offer only a general comparative framework because the taxonomic lists of the countries compared have changed, as well as the classification criteria, particularly after the advent of molecular phylogenetics. Wynne (2022) summarizes 1,707 taxa forthe tropical and subtropical western Atlantic.

Table 3. Similarity matrix (%) between islands of the Greater Antilles using Sørensen's index, according to Suárez and Martínez-Daranas (2020).

Hispaniola	**Cuba**	**Puerto Rico**	**Jamaica**	
100	65,8	65,2	70,7	**Hispaniola**
	100	70,2	65,2	**Cuba**
		100	64,6	**Puerto Rico**
			100	**Jamaica**

Aquaculture- Biotechnology – and Macroalgal uses

In Dominican Republic, Díaz-Piferrer (1978) was the first to begin to assess the actual and potential seaweed resources in the country. In his inventory of San Pedro de Macorís he identified the marine algae species of economic commercial value as producers of agar, agaroids, carrageenan and alginates; explained their economic potential and offered ideas for its use, but we have not found any subsequent application. In Haiti, the red algae *Hypnea musciformis*, which produces kappa carrageenan, was exported once to Denmark for carrageenan extraction (Renoux-Meunier, 1978), but there is apparently no commercial use of the species in the region at present.

Marine macroalgae threats

Since 2011 the coasts of Hispaniola, as well as the entire Caribbean region, have experienced an unusual increase in the arrival of *Sargassum*, with significant economic losses in the tourist sector. Saharan dust clouds, warming temperatures and the growing human nitrogen footprint, are among the likely causes of seaweed invasions. In Dominican Republic the search for solutions to the sargassum problem has focused on two large areas (Desrochers *et al.*, 2020). On the one hand, to solve the problem of algae accumulations on the beach and in the sea; and, on the other, to seek a rational use to the accumulated biomass (Table 1).

Table 1. Summary of actions that offer management options for different aspects of the sargassum problem accumulation on the Dominican coasts. Source: Adapted from Desrochers *et al.* (2020).

Use	**End product/ service**	**Participants**	**Additional Information**
Collection and processing	Sargassum-free beaches	AlgeaNova Grupo Punta Cana	Anti-sargassum floating barriers and innovative solutions for collecting sargassum at sea, maintenance, processing, valorization and marine protection.
Environmental restoration	Carbon sequestration	SOS Carbon	Development of a system to pump and effectively sink sargassum into the deep ocean before it impacts the coastlines
Agricultural and crop production	Compost, mulch & bioplastic	AlgaeNova	Production of a compost made of 60% sargassum and 40% river tamarind (*Leucaena leucocephala*), which takes approximately 70 days to mature; and also, a 100% sargassum mulch.
Biofuels	Biogas and digestate	EnergyAlgae APEC Grupo Punta Cana	Pilot Project in Punta Cana to experiment five small-scale anaerobic digestors, using sargassum and organic waste as feedstock, looking for develop a larger 1 MW co-digestion model biogas facility.
Bioplastics	Bioplastics, compost and mulch	AlgaeNova Bionova	Development of single-use plates made with 50% sargassum and 50% cassava, which is fully compostable (no industrial composting required) within 30 days
Bioremediation and purification	Activated carbon	NBC TECMALAB	Working to develop and commercialize a sargassum-based activated carbon for use in water and wastewater treatment and air purification applications.
Bioremediation and purification	Activated carbon	INTEC	Sargassum-based activated carbon for water treatment and other applications

In eight beaches in the Dominican south coast: Monte Río (Azua), Ojeda, La Saladilla (Barahona), Boca Chica, La Caleta, San Andrés (Santo Domingo), Guayacanes and Juan Dolio (San Pedro de Macorís) the content of heavy metals (As, Be, Cu, Co, Cr, Cd, Hg, Mo, Ni, Pb, Se and Zn) and lanthanides in sargassum samples (*Sargassum natans* and *S. fluitans*) have been analyzed

(Fernández *et al.,* 2017; Tejada-Tejada *et al.*, 2021) In general, the concentrations of heavy metals are within acceptable limits, but some slightly high values of Hg highlights that the ability of macroalgae to bioaccumulate toxic metals must be considered in any proposal of solutions for their use in agriculture or industry.

Recommendations and concluding remarks

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Appendix 1. Macroalgae taxa from Hispaniola (Excel file).

Appendix 2. Institutions that house material collected in Hispaniola. The access route to the collections is indicated in brackets when it comes to the Macroalgae Herbarium Consortium Portal [MHCP], the Global Biodiversity Information Facility [GBIF] or Sweden's Virtual Herbarium [SVH]

ABRU. Brown University, Providence, Rhode Island, Estados Unidos [MHCP]
BCN. CeDoc of Plant Biodiversity (CeDocBIV), Universidad de Barcelona, España [GBIF]
BISH. Herbarium Pacificum, Bernice P. Bishop Museum, Honolulu, Hawaii [MHCP, GBIF]
BR. Meise Botanic Garden, Bélgica [GBIF]
CHRB. Rutgers University, Chrysler Herbarium- Macroalgae Collection, Estados Unidos [MHCP]
DUKE. Duke University Herbarium Algae Collection, Durham, North Carolina, Estados Unidos [MHCP]
F. Field Museum of Natural History, Chicago, Illinois, Estados Unidos [MHCP]
FAUO. Ficoteca Antillana de Oriente, Academy of Sciences, Cuba
FH. Farlow Herbarium, Harvard University, Estados Unidos [MHCP]
GB. Herbarium GB, University of Gothenburg, Suecia [SVH]
GENT. Herbarium of the University of Ghent, Bélgica
GMS. Hopkins Marine Station, Stanford University, California, Estados Unidos [MHCP]
HNJBSD. Colección Díaz-Piferrer, Herbario Jardín Botánico Nacional, Santo Domingo, República Domi-nicana
INat. iNaturalist Research-grade Observations, Estados Unidos [GBIF]
LD. Lund Botanical Museum, Suecia [SVH]
MASS. University of Massachusetts, Estados Unidos [MHCP]
MGC. Herbario de la Universidad de Málaga, España
MH. M. Hay y S. Fredericq Haiti collections, Smithsonian´s R/V Marsys Resolute Caribbean expeditions.
MICH. University of Michigan Herbarium, Michigan, Estados Unidos [MHCP]
MNHN. Muséum National d'Histoire Naturelle, Paris, Francia
MSC. Michigan State University, Estados Unidos [MHCP]
MU. Miami University, Estados Unidos [MHCP]
NBC. Naturalis Biodiversity Center, Leiden, Países Bajos [GBIF]
NCU. University of North Carolina at Chapel Hill Herbarium, Estados Unidos [MHCP]
NHM Natural History Museum, London, Inglaterra
NRM. Swedish Museum of Natural History (Naturhistoriska Riksmuseet), Suecia
NTNU. Algae Herbarium TRH, NTNU University Museum, Noruega
NY. The New York Botanical Garden Herbarium, Estados Unidos [MHCP]
PERTH. Australasian Virtual Herbarium (AVH) Western Australian Herbarium, Australia [GBIF]
PH. Drexel University, Academy of Natural Sciences, Philadelphia, Estados Unidos [MHCP]
SPF. Herbário da Universidade de São Paulo - Coleção de Algas, Universidade de São Paulo
TFC Herbario de la Universidad de La Laguna, Islas Canarias, España
UC University Herbarium, University of California, Berkeley, Estados Unidos [MHCP]
Uni-DUE. Algal Herbarium of the University Duisburg-Essen, Alemania
USCH. University of South Carolina, A. C. Moore Herbarium, Estados Unidos [MHCP]
USF. University of South Florida, Estados Unidos [MHCP]
USNM. National Museum of Natural History, Smithsonian Institution, Washington, Estados Unidos
WNC. University of North Carolina Wilmington, David J. Sieren Herbarium, Estados Unidos [MHCP]
WTU. University of Washington, Estados Unidos [MHCP]
YPM:YU. Yale University Herbarium, Peabody Museum, New Haven, Estados Unidos [MHCP]

Appendix 3. Localities of macroalgae collections.

Departamento o provincia	Locality
01. Nord-Est	Caracol
02. Nord	Anse a Margot, Bayeux, Cap Haitien, Le Borgne
03. Nord-Ouest	Ile de la Tortue, Foux Cap, Jean Rabel, Port-de-Paix
04. Artibonite	Artibonite
05. Ouest	Léogane, Les Arcadines, Petit Goave, Port au Prince, Source Matelas, Trou Cochon
06. Nippes	Baraderes, Miragoane,
07. Grand'Anse	Anse d'Hainault, Dame Marie, Jérémie. La Pointe, Dames Point, Navassa
08. Sud	Aquin, Anse a Drick, Caspentia, Côteaux, Damassin, Ile a Vache, Port Salut, Port-au-Piment, Roche-a-Bateau, Saint Louis du Sud, Soulette, Ile a Vache, Torbeck
09. Sud-Est	Jacmel
10. Pedernales	Alto Velo, Bahía de las Águilas, Bucan de Tui, Trudillé, Cabo Falso, Cabo Rojo, Isla Beata, Los Fangos, Los Frailes, Macabí, Odin, Ticaetón
11. Barahona	Barahona
12. Azua	Isla de Pájaros Puerto Viejo
13. Peravia	Salinas
14. San Cristobal	Najayo, Palenque
15. Distrito Nacional	Guibia
16. Santo Domingo	Boca Chica, La Caleta, La Matica, isla La Piedra
17. San Pedro de Macorís	Guayacanes, Playa Marota, Playa Montero, San Pedro de Macorís
18. La Romana	Isla Catalina, Isla Saona
19. La Altagracia	Bávaro, Bayahibe, Boca de Yuma, Cabeza de Toro, Cabo Falso, Dominicus, El Cortesito, El Faro, El Peñón, El Toro, Guaraguao, La Raya, Los Cocos, Macao, Playa Borinquen, Punta Cana, Rubén
20. El Seibo	Bahía de la Gina, Playa Arriba, Miches
21. Hato Mayor	Playa Capitán
22. Samaná	Bahía de Samaná, Cayo Levantado, Las Flechas, Las Galeras, Las Terrenas, Los Corozos, Los Corrales
23. María Trinidad Sánchez	Bahía Escocesa, Nagua, Playa Bretón, Playa Preciosa
25. Puerto Plata	Puerto Plata, Sosúa
26. Montecristi	El Morro, Buen Hombre, Cayo Arena, Cayo Muertos, Higuerito, La Cordillera Afuera, La Pasa, La Pasita, La Piedra de Buen Hombre, La Posa, La Punta de la Cordillera de Afuera, Los Tocones, Pepillo Salcedo, Playa del Coco, Punta Rucia