

Valuing Caribbean Biodiversity Knowledge

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Abstract

Valuing Caribbean biodiversity for health and wealth requires knowledge of the bio-resource so as to better appreciate the myriad of uses and services it provides. Increasing the knowledge base provides increasingly accurate valuation, which hopefully will lead to better management and sustainable use of this biodiversity. The Caribbean region comprises 229,540 km² of land (only 10% of which is still in original forest cover) and 2,754,000 km² of ocean. In the region there are about 13,000 identified plant species of which 205 genera and 6500 species are endemic. The marine area, with a maximum depth of 7686 m, includes the world's second largest barrier reef. It is estimated that the region has 25.6% marine endemic species. Multiple uses have been found for both terrestrial and marine organisms of the Caribbean. Mass extinctions have occurred for Peoples, associated traditional knowledge, terrestrial and marine biodiversity. Sea level rise and increasing temperature are global problems that threaten this area. All this information cannot be covered in one chapter so this review, based on a wide range of publications including our own research, is to raise awareness of these issues and the need to know more while suggesting solutions for discussion.

Keywords: biotechnology, conservation, ethnobotany, hotspot, marine, medicinal plants, Nagoya protocol, terrestrial, traditional knowledge

1. Introduction

The greatest challenge facing Caribbean biodiversity is the relative lack of knowledge and analysis. Caribbean scientists have been and continue to be heavily engaged in gathering information on regional biodiversity. However, the region is large and diverse and there is much that is still unknown. Also, there is a need to synthesize and evaluate these findings, to set goals for future research and managed utilization. The biodiversity resource of the Caribbean is very rich but under threat, so the concern is real. While increasing population densities with associated issues of agriculture and urbanization, and climate change are important, lack of knowledge trumps them. Why? Because if we do not know what the Caribbean has and the worth of it, will we protect while sustainably using this bioresource? How can we protect what we do not even know we have?

Let us start with the fundamentals. When we say 'Caribbean', where in the world are we? Actually, there are two names for this area—'West Indies' and 'Caribbean'. The West Indies was so named to differentiate this area from the East Indies and includes all the islands in the Atlantic Ocean southeast of the Gulf of Mexico. The



Figure 1.

Map showing the West Indies (all the islands in the Caribbean Sea), the Caribbean region (includes islands and bordering countries) and the Greater/Wider Caribbean (also includes the Gulf of Mexico, Florida, Bahamas and Bermuda). Source: https://www.cia.gov/library/publications/the-world-factbook/attachments/images/large/central_america-physical.jpg?1547145649.

Caribbean region encompasses a wider area, it includes the islands and the mainland countries whose shores are washed by the Caribbean Sea (eastern coast of Central America and northern coast of South America). Another term, the Greater or Wider Caribbean, is used to include the Gulf of Mexico, Florida, Bahamas and Bermuda (**Figure 1**).

What is better known is that the Caribbean is a tourist destination full of beautiful and rare plants and animals, many being unique to the region or parts thereof. Extensive work has been done to determine the biodiversity of this region. The Caribbean region comprises 229,540 km² of land (with only 10% of original forest cover remaining) and 2,754,000 km² of ocean. In this region, there are at least 13,000 identified plant species of which 205 genera and 6500 species are endemic [1]. Cuba, for example, has 6500 vascular plants of which 40% are endemic, and Jamaica has 2888 vascular plants and 28% endemism (**Figure 2**). Vertebrates also have a high rate of endemism of between 25 and 100% [2]. Marine endemism is estimated to be 25.6% [3]. The marine area of the Caribbean is extensive, is 7686 m at its maximum depth and includes the world's second largest barrier reef, the Mesoamerican Barrier Reef, which runs 1000 km along the coasts of Mexico, Belize, Guatemala and Honduras. Many studies have been undertaken to determine and monitor the health of the Caribbean Sea. Multiple uses have been found for both terrestrial and marine organisms. All this information cannot be summarized in one chapter so the purpose here is to highlight the main points, to give awareness to issues of mass extinctions, biodiversity and global problems affecting this area, and to provide a SWOT analysis and valuation exercise, so as to suggest future research needs to strengthen our knowledge base for sustainable development.

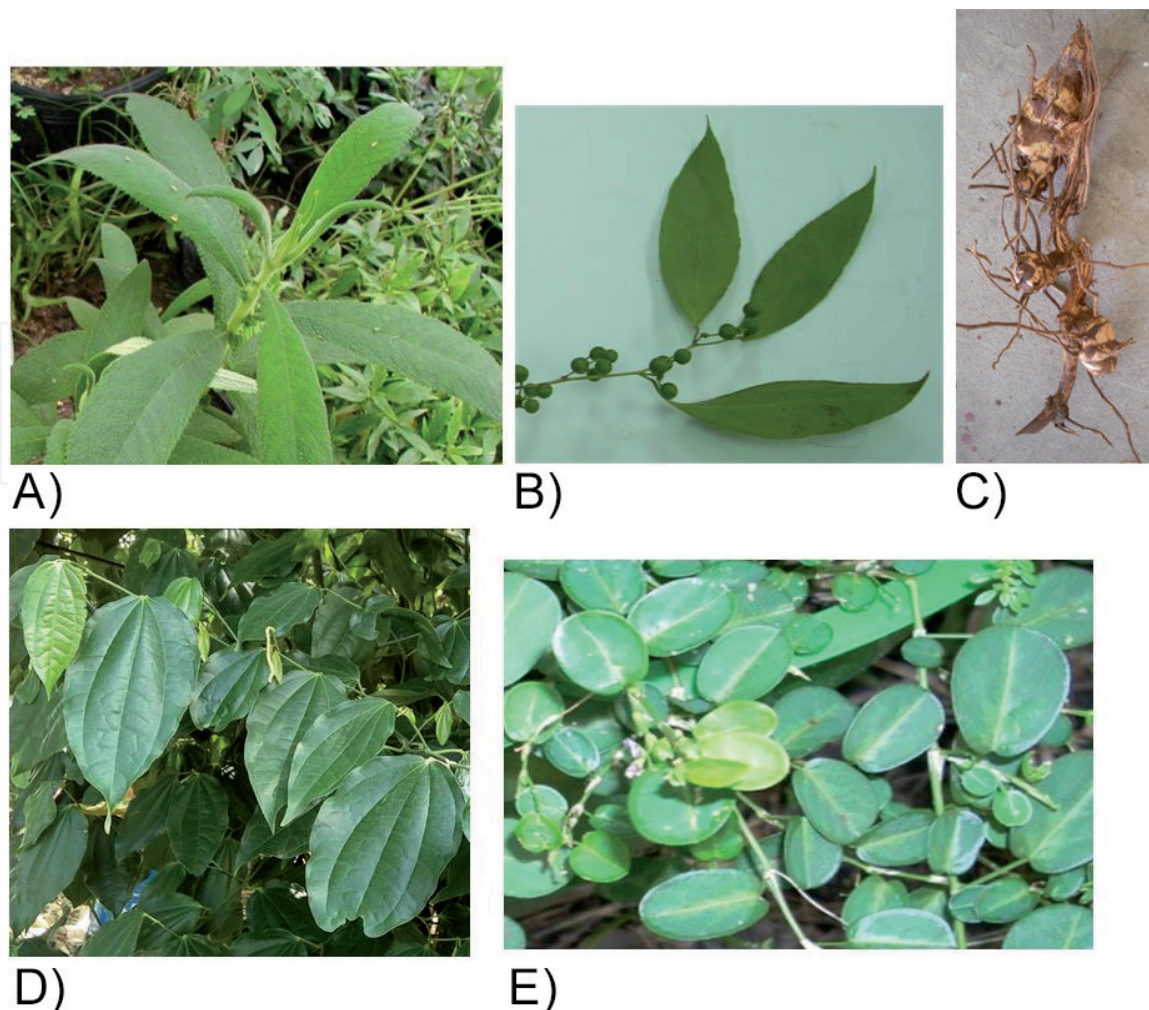


Figure 2.
Endemic plants of the Caribbean: (A) search-mi-heart, Rhytidophyllum tomentosum; (B) leaf and fruit of Chaney root, Smilax balbisiana; (C) rhizome of Chaney root; (D) black jointer, Piper amalago; (E) medina, Alysicarpus vaginalis (plant not endemic but tonic use is endemic to the Caribbean). Pictures taken by Dr. Sylvia Mitchell.

2. Methodology

In the face of incomplete yet extensive data on Caribbean biodiversity, focus in this chapter is given to medicinal plants in order to estimate the extent of the resource, problems being experienced and some suggestions of what needs to be done to improve the situation. For Extinctions, the literature was searched for any estimates of extinctions. For Biodiversity, four areas were explored: (1) the Caribbean hotspot, (2) Caribbean medicinal plants where country of origin is mentioned, (3) Caribbean medicinal plant research and development highlighting commercial potential, (4) case studies to highlight different issues. For Global Problems, we consider the Caribbean as a region of a planet under pressure, to highlight what needs to be considered globally.

3. Extinctions

Extinctions in the Caribbean have to be considered in terms of Peoples, traditional knowledge and biodiversity—terrestrial and marine—whether endemic, native, indigenous, or imported. Extinction is a threat to every living organism on these small island development states (SIDS). Species considered abundant can suddenly become

hard to find if they become commercially important to an island state. Such was the case of Cerasee (*Momordica charantia*) in Jamaica when it became a lucrative export crop. Species can also become overabundant and cause extinction of other species as happened to Coralita (*Antigonon leptopus*) on St. Eustatius and other islands. By review of literature, this was thought to be caused by: overgrazing by free-roaming livestock (16), anthropogenic disturbance (19) and climate change (six papers) [4].

Botanical work began early in the West Indies [5] but this historical data is not easily available. Not knowing what or how many species existed in the first place, makes analysis of extinction very difficult. When that question is asked of thousands of organisms, survival of all is often the best option. Extinction also has to be considered for the marine environment, as experienced when multiple consecutive coral bleaching events occurred in the mid to late-2000s. Warmer oceans are also implicated in the recent spread of coral diseases (**Figure 4B**) [6].

3.1 Extinction of Caribbean peoples

Due to the influx of many nations into the Caribbean, whether coerced or by free will, the earlier inhabitants of the Caribbean were thought to be extinct. However, in spite of tremendous forces against them, there are still pockets of Caribs and Tainos in the Caribbean [7]. In addition, DNA analyses have shown how the various nations have mingled in the region especially between Amerindian (from South America and the Yucatan Peninsula), African and European tribes [8, 9].

3.2 Traditional knowledge (TK)

Traditional knowledge (TK) of the early inhabitants (Tainos, Caribs) has been retained in pockets, and via intermingling of Amerindians, Europeans and Africans [7]. Such a connection was confirmed by analysis of a database of 2350 Afro-Surinamese plant names—20% of the Sranantongo and 43% Maroon names were similar to those used in Gabon, Angola and Benin for related plants showing that the link between the Caribbean and Africa is strong [10].

A study comparing plants used in 35 African and the 117 Caribbean tonic mixtures indicated that few of the 324 ingredients (plant parts such as leaves, seeds, rhizomes, roots) were the same on both continents and the difference in genera and family increased with increasing distance from Africa indicating that new, unrelated plants with similar taste or properties were used; and while this suggests an African heritage, it also points to Amerindian and European influences [11]. Another study of 38 indigenous Jamaican root tonics indicates that the main forest plant ingredient is endemic to the island (*Smilax balbisiana*) suggesting that the Africans could utilize local plants to obtain the health outcome they desired [12]. This study uncovered several issues—there was no database to compare the common names to, there were no herbarium samples, and no scientific names for 20 of the 94 forest plants used in the root tonics. The only reference was the common name given on the tonic bottle [12] so the actual plants used are still unknown to science.

Caribbean traditional knowledge (TK) is extensive and includes both terrestrial and marine species [7]. Protection of biodiversity and its associated traditional knowledge is supported by the Nagoya Protocol. This is an international agreement which aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way; it entered into force in 2014 (<https://www.cbd.int/abs/>). Continued efforts to document Caribbean TK and associated plant knowledge, in order to preserve and sustainably use it for the benefit of the Caribbean, is strongly recommended.

3.3 Analysis of risk of extinction of Caribbean biodiversity

The Caribbean region includes 35 island territories (17 independent and 18 dependent countries comprising about 700 islands, reefs and cays) and 12 continental bordering countries. The Caribbean population is estimated to be about 42.5 million while the region has over 27+ million stay-over tourists each year. The risk of extinction of its biodiversity is due to several factors. Threats to flora, freshwater and marine biodiversity will be reviewed. These include the actions of waves of people starting from Amerindians who appear to have brought plant and animal species with them but who also lived in harmony with the natural world; through colonial times when great tracts of land were denuded of trees such as pimento (*Pimenta dioica*), logwood (*Haematoxylon campechianum* L), mahogany (*Swietenia mahagoni*) and bitterwood (*Picrasma excelsa*) to establish sugarcane plantations with immense associated damage to native biodiversity (to terrestrial and freshwater habitats) and who also imported new plant species; to the present time where destruction of local biodiversity and importation of new biodiversity has continued [7, 13]. Tourism, though needed, has to be managed to reduce its threat to local biodiversity. More recent 'natural' threats include stronger hurricanes, rising ocean temperatures, drought, unpredictable seasons and rising sea levels. Local anthropogenic threats include increasing population densities in rural and urban areas, agriculture, roads (leading to habitat defragmentation and new settlements) and over-harvesting.

The Caribbean region is one of the world's hottest hot spots, with only just over 10% of its original forest cover remaining [14]. This aggravates the vulnerability of the region to hurricanes and other natural disasters. Of the 187 endemic mammals and birds in the Caribbean, at least 43 have become extinct over the last 500 years. Currently, it is estimated that 755 plants and vertebrate species are at risk of extinction [2]. A Lesser Antilles analysis found that of 263 seed plant taxa unique to these islands, 70% are threatened [15]. Of these endemics, most were found on only 1 (37%), 2 (14%) or 3 (13%) islands while 25% were spread over 5 or more islands.

Globally, freshwater biodiversity accounts for 10% [16] of all documented species, with about 167 freshwater fish occurring within the Caribbean [17]. Freshwater biodiversity is threatened by over-exploitation, water pollution, flow modification, destruction and degradation of habitat and invasion of exotic species [18]. Run-off from freshwater drainage leads to mangrove forests on the coast of Caribbean islands. These forests support more than 2000 species of fish, shellfish, invertebrates, and plants [19]. Suggested solutions to reduce risk of extinction for terrestrial ecosystems include protected areas that are well-managed and joined by 'corridors' of wild forest. Also there should be planned botanical collections (in situ, ex situ and in vitro)—held by farmers, institutions and government—recorded in a database registry. Databases and associated seed banks are needed for conservation of plant genetic material for food and agriculture (PGRFA) and for wild species (especially endemics). This information will help the region to determine species most at risk. Another recommendation is the development of an online, up-to-date, addable and searchable database for all Caribbean organisms—flora, fauna, microbes—and associated traditional knowledge—that is in the control of the Caribbean, for the benefit of its inhabitants. The time to act is now.

Marine biodiversity is also at risk. The Caribbean region is 92% sea and contains the largest concentration of marine species in the Atlantic Ocean [3]. The coastal area includes territorial waters up to 12 nautical miles from shore, some areas of these exclusive economic zones (EEZs) are still in dispute. The marine ecosystems in the Caribbean have three critical transboundary issues: (a) illegal, unreported and unregulated (IUU) fishing, (b) habitat degradation and (c) pollution. These are being exacerbated by climate variability and change. The Association of Marine

OBIS entries for Caribbean Sea biodiversity

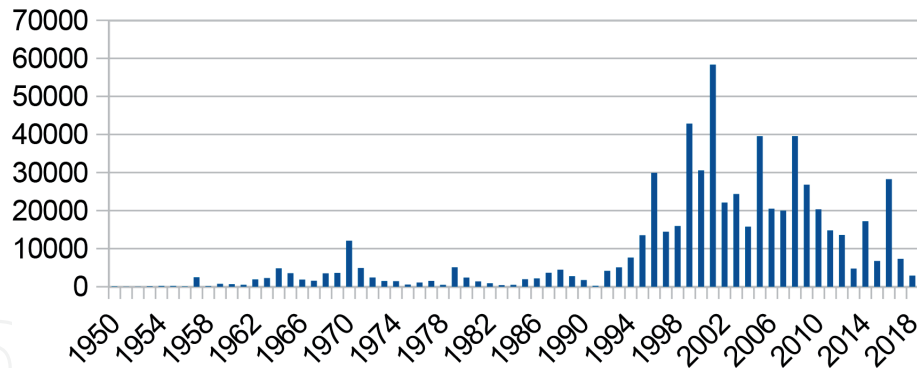


Figure 3.
Number of OBIS entries for species found in the Caribbean Sea.

Laboratories of the Caribbean was established in 1957 to facilitate regional collaboration and now includes 30 labs and over 300 members. Collection of data increased after mass mortality of the formerly ubiquitous sea urchin *Diadema antillarum* in 1983–1984 prompted several monitoring programs [20]. The census of marine life (CoML) became involved with the Caribbean in 2004. All the information gathered over the years has been fed into the Ocean Biogeographic Information System (OBIS), a dynamic, global, 4-dimensional (space and time) digital atlas [21]. Through these efforts, knowledge of marine biodiversity in the Caribbean is coming of age. OBIS has 663,339 records, 11,175 species and 15,659 taxa for the “Caribbean Sea” region (accessed August 02, 2019)—most of these were collected since 1992 (<https://mapper.obis.org/?areaid=40012#>, **Figure 3**). The most well-known marine ecosystems in the Caribbean are: coral reefs (26,000 km²), seagrass beds (66,000 km²), and mangroves (11,560 km²). Offshore and deep-sea habitats are slowly being documented as well [21].

In the last 30–40 years, anthropogenic impacts have led to degradation of water and land resources, increased sediment run-off, invertebrate extinction and habitat loss. The coverage of mangroves has decreased by an average of 1% per year since 1980. Coral cover in Jamaica was reduced to 10% by 2016, as a result of the concurrent effects of Hurricane Allen (1980), white band disease, reduced herbivory due to over-fishing and mass mortality of the urchin (*Diadema antillarum*) thus allowing algae overgrowth, and a major bleaching event in 2005 [22, 23]. For the future, here is a sobering thought—with blue biotechnology looking to the oceans for medical value—these marine species might be extinct before we even know they were there!

Incomplete information is still an issue. The known taxa for Caribbean coral reefs have been estimated to be only about 5–10% of total species inhabiting these communities. This hinders investigation into population dynamics and other studies [3]. Other issues highlighted were: heterogeneity of sampling effort, variability in collecting methods, relatively less sampling from off-shore and deep sea sites, under-sampling even of more accessible coastal areas, insufficient expert taxonomists, insufficient information guides, with many new species being discovered yearly, so while research and data collection has continued, marine biodiversity knowledge is still insufficient which hampers planning efforts. Another issue highlighted was that collected specimens remain scattered worldwide, with data largely in unavailable formats and sources with limited and inconsistent effort of some external researchers to make this data available. OBIS, is changing this narrative for the better and should be commended [3].

Yet another issue is marine invasive species that may enter the region via direct and indirect routes, possibly with multiple introductions. Most of these transfers

are unintentional such as ballast water transfer and hull-fouling of international vessels [24–27]. Intentional releases usually entail the release of an animal one can no longer care for into the wild [28]. The invasive marine species gain access to resources needed by the native marine populations to survive. Without the usual checks and balances in their own native range, they often outcompete and overpopulate their new habitat, causing a nuisance. The zebra mussel, *Dreissena polymorpha* (Figure 4A), native to Europe, entered the USA Great Lakes in 1988 and then grew in numbers far greater than the native mussels causing substantial damage to industrial waterways with an annual maintenance cost of ~US\$ 1 billion [29]. The Caribbean wants to prevent such a disaster in its waters.

With increased movement of goods and people across oceans, the risk increases. If introduced species successfully establish, they begin to interrupt nature's delicate balance causing a cascading effect that can change entire ecosystems over time.

Halophila stipulacea, a seagrass species native to the Red Sea and Indo-Pacific, was first observed in the Caribbean in 2002 and has rapidly spread [30–32]. *H. stipulacea*

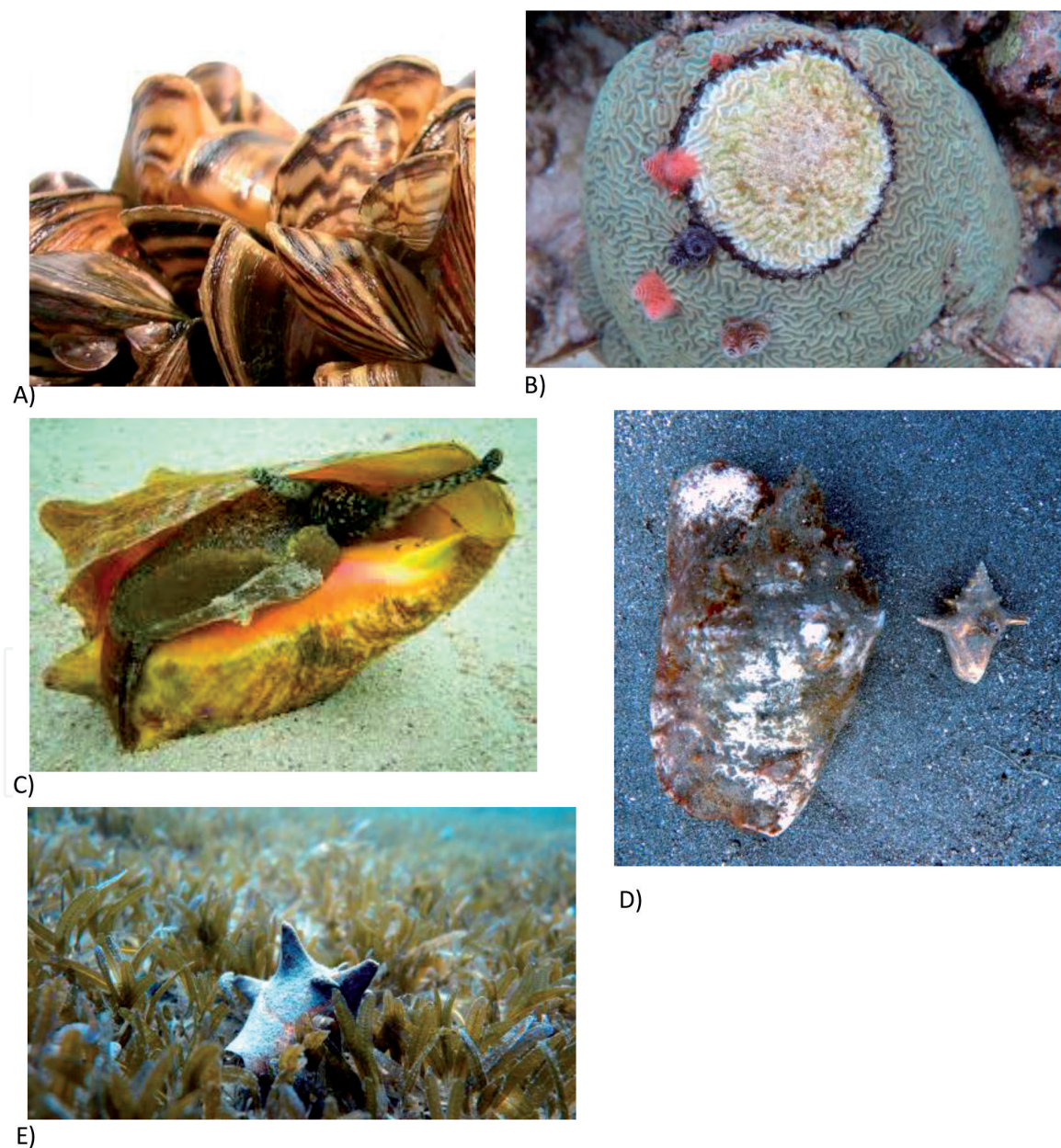


Figure 4.

Marine pictures: (A) Zebra mussels (<https://www.healthylake.ca/zebra-mussels>), (B) *Pseudodiploria strigosa* brain coral infected with black band disease, (C) queen conch (<https://www.keywestaquarium.com/queen-conch>), (D) juvenile and adult conch, (E) juvenile queen conch in invasive seagrass *Halophila stipulacea*. Pictures (B, D, E) by Dr. Kimani Kitson-Walters.

outcompetes Caribbean native seagrasses through its ability to rapidly expand and form dense mats which impacts native fish and epibenthic species [33]. The invasive seagrass has impacted the endangered queen conch (*Lobatus gigas*), a giant mollusk endemic to the Caribbean region, as it limits access of the juvenile conch to the sediment [34]. This has detrimental implications for this important species and countless others that use native seagrass meadows as a nursery habitat (**Figure 4C–E**).

Biotechnology is helping us better understand the magnitude of the marine bioresource and to monitor it, and thus propose solutions. Using DNA barcoding to identify Caribbean reef fish allowed processing of 3400 specimens of 521 reef fishes collected from six areas across the Caribbean between 2004 and 2009. By using these advanced methods, it is clear that tropical reef diversity has been under-detected and therefore underestimated [35]. This method was found especially useful for matching juveniles with adults and barcoding unknown specimens. This effort also resulted in the naming of new genera and resolution of taxonomic issues. Importantly, this database grows with each new set of barcodes making the information more and more robust [36].

The continued advancement of biotechnology provides new perspectives to age-old questions, providing solutions to problems that were unsolvable less than a decade ago. For example, the use of microsatellite DNA technology allowed for accurate distinction of populations and of individuals within populations and subsequently their genetic connectivity across temporal and spatial scales [37, 38]. This is especially useful in informing management strategies of important species on a local and regional level, whether the goal is commercial or for conservation. In the case of the over-harvested queen conch, biotechnology has helped with both these goals. The multi-million US dollar conch trade has declined significantly throughout the Caribbean with little known about whether it can recover. It was found that genetic connectivity of the species across the region was limited by oceanic distance [39], making recovery of specific populations difficult due to complete reliance on self-recruitment or on upstream populations in the territorial waters of neighboring countries. The management practices, or lack thereof, on upstream populations therefore have a significant impact on the recovery of downstream populations [39, 40]. This serves as another reminder, that in the Caribbean we do not, and cannot, survive alone. This technology is applicable to all species and can be used to guide local and regional management and conservation, safeguarding biodiversity.

The use of single nucleotide polymorphisms (SNPs), another advanced genomics technique, can provide deeper insight into the connectivity of key species. SNPs allow for targeted research into specific aspects of a species' ecology on the molecular level. Questions about the effectiveness of marine protected areas, organism's response to climate change and anthropogenic stressors as well as identification of genetically distinct populations, can be answered using SNPs technology [41, 42]. SNP libraries can and have been developed for numerous species for conservation and management purposes. In the Caribbean, SNP technology has been applied across various taxa including endangered corals (*Acropora palmata* and *Orbicella faveolata*), fish (Nassau grouper), invertebrates (spiny lobster) and an invasive angiosperm (*Halophila stipulacea*) [42–46].

Along with gathering and analyzing knowledge, various methods are being used as counter-measures against possible extinctions. These include but are not limited to:

- Creating protected areas for biodiversity hotspots within the CIBH
- Establishing protected heritage sites

- In situ, ex situ (**Figure 5**) and in vitro plant collections (**Figure 6**)
- Wildcrafting, polyculture and permaculture practices
- Botanical gardens and seed banks
- Plant breeding and conservation efforts including by local communities
- Removal of top grazers (rats and goats)—see Redonda Island—the before and after pictures are awesome! [47]
- Reforestation/replanting of forest trees inland and mangroves along the coast
- Establishment of fish sanctuaries
- Coral reef restoration through multiple methods including micro-fragmentation, fertilization and coral larvae propagation [48, 49]



Figure 5.
Ex situ medicinal plant collection by a local community in Quickstep, Trelawny, Jamaica.



Figure 6.
In vitro medicinal plant collection at the Biotechnology Centre, UWI, Mona Campus, Jamaica.

4. Biodiversity

4.1 Caribbean island biodiversity hotspot (CIBH)

The Caribbean is one of 25 biodiversity hotspots worldwide (**Table 1**) [2]. Together these hotspots contain about 50,000 endemic species. As many as 44% of all known vascular plant species, and 35% of all species in four vertebrate groups, are confined to these 25 hotspots covering only 1.4% of the Earth's land surface. An area is designated as a hotspot when it contains at least 0.5% of the world's endemic plant species [50]. The Caribbean Islands are a known biodiversity hotspot (**Figure 7**), but this amazing biodiversity has been and is still being threatened by humans.

To further characterize the Caribbean Island Biodiversity Hotspot (CIBH): 294 Key Biodiversity Areas (KBA) were identified, these cover over 50,000 km² or roughly 22% of the hotspot [2]. Of these, 144 (or 51%) overlap partially or completely with protected areas. Cockpit Country, Litchfield Mountain—Matheson's Run, Blue Mountains (all Jamaica) and Massif de la Hotte (Haiti) were found to support exceptionally high numbers of globally threatened taxa, with more than 40 such species at each site. In total, 409 globally threatened plants and vertebrate species (trigger species) determined the vulnerability criterion to define KBAs. No data were available for the other 346 globally threatened species, most of which were plants [2].

The CIBH exhibits high endemism. It is seventh of the 25 global hotspots in terms of known plant species, and 6th in terms of known plant endemic species (**Table 1**). A total of 180 genera and 727 species are unique to this hotspot, these are the Caribbean endemics [51]. Type species of most of these were published between 1854 and 1928, but although molecular phylogeny has been available for 63, only 21 have robust data. Much work remains to be done. Conservation and management of resources requires an understanding of their taxonomy. This paper concluded that there is urgent need for (1) additional field studies to learn the conservation status of these genera, (2) effective protection of the habitats where the most endangered genera occur, and (3) additional biological and systematic studies of the least understood genera [51].

Hotspots	Plant species number	Endemic plants	% of global plants	Vertebrate species	Endemic Vertebrates	% of global vertebrates
1. Tropical Andes	45,000	20,000	6.7	3389	1567	5.7
2. Sundaland	25,000	15,000	5.0	1800	701	2.6
3. Mediterranean Basin	25,000	13,000	4.3	770	235	0.9
4. Mesoamerican forests	24,000	5000	1.7	2859	1159	4.2
5. Brazil's Atlantic Forest	20,000	8000	2.7	1361	567	2.1
6. Indo-Burma Eastern Himalayas	13,500	7000	2.3	2185	528	1.9
7. Caribbean	12,000	7000	2.3	1518	779	2.9
8. Madagascar	12,000	9704	3.2	987	771	2.8
9. South-Central China	12,000	3500	1.2	1141	178	0.7
10. Brazil's Cerrado	10,000	4400	1.5	1268	117	0.4

Table 1. Top 10 global biodiversity hotspots (in terms of plant species number) [2].



Figure 7.
Caribbean Island Biodiversity Hotspot (CIBH) showing its extent. Source: https://www.cepf.net/sites/default/files/final_caribbean_ep.pdf.

In terms of biodiversity under threat, Conservation International identified 10 global priority regions in need of targeted funding, in order to build resilience and help adaptation to the impacts of climate change [52]. This would provide the greatest benefits to people and natural ecosystems necessary for life on Earth. These 10 areas intersect known global biodiversity hotspots and cover 13% of cultivated tropical land. The 10 areas include Central America, Caribbean, Andes and Atlantic coast of Brazil (South America), Guiana Highlands, Albertine Rift, Madagascar, Ghats (India), Philippines and Java (Indonesia) [52, 53]. However, there is no corresponding global fund or program to protect these resources at the level at which they need to be protected.

Understanding the biodiversity of the Caribbean is an ongoing process. Knowing where the hotspots are, where the KBAs are, where the global priority regions are, or even which organisms are endemic is not enough. Monographs for each species are needed. Understanding the life cycles, ecosystem interactions and the influences of threats such as population density and climate change are needed. Only then can viable management plans be made—for conservation and sustainable use.

Information for all 25 biodiversity hotspots can be found in source document [2].

4.2 Caribbean medicinal plants

An important part of biodiversity is the plants that have been found to be useful for health and wealth. The Caribbean medicinal plant industry is growing [54]. While there is still not a master list of all medicinal plants found in the Caribbean, an ethnobotanical database is being assembled. The first version of this database reviewed 21 books and included 2898 plant species and the country that identified them as being medicinal [6]. These books describe Caribbean medicinal plants and their folk uses, some are illustrated, and most have been published in the last 20 years (all since 1986 and 76% (16/21) since 2001). Twelve new literature sources have since been added [12, 55–65]. This database (Version2) now includes 3566 plants growing in the Caribbean that have been identified with at least one ethnomedicinal use—some as tonics, some

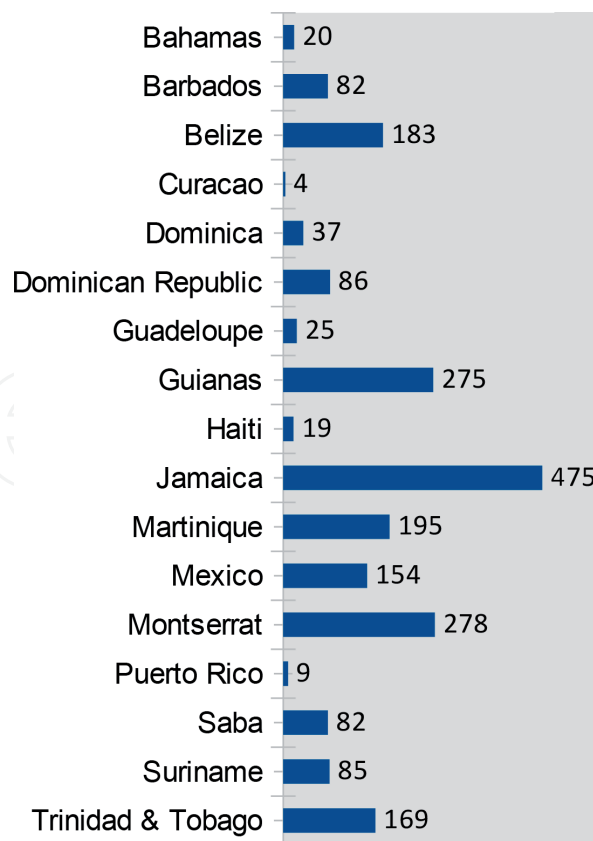


Figure 8.

Number of plants having at least one identified ethnomedicinal use in 17 Caribbean countries as enumerated in 34 source documents. Of the total, 353 said ‘Caribbean’ so were not included in this figure. Another 1034 were identified only in Guianas and so were excluded so as not to overwhelm the graph.

preventative, some curative—for health and wellness purposes (**Figure 8**). Most of these plants (639) were identified as medicinal in only one country although they might be found in others (**Table 2**). The highest number of medicinal plants were identified in Jamaica (475) for the islands and the Guianas (1309) for the coastal countries. ‘Guianas’ includes Suriname, Guyana and French Guiana [6]. However, any island not yet represented in this database does not imply that it has no plants with identified medicinal properties, but rather that their information has not yet been added. A problem arises if the books are in different languages, in local publications or if they are out of print [66, 67]. Not until the database is comprehensive will the comparative story of medicinal plants in the Caribbean be clearly seen.

4.3 Medicinal plant research in the Caribbean

The review of UWI research published between 1948 and 2001 listed 334 medicinal plants of which 194 had been studied in the lab [62]. Aphrodisiac root tonics described 152 mixtures from five Caribbean Islands, four South American and seven African countries that used ingredients from 324 plant species [11]. TRAMIL, which started in 1982 and under whose aegis several ethnobotanical studies have been carried out in the Caribbean, has monographs for 397 plant species (<http://www.tramil.net>). The second edition of the TRAMIL Caribbean Herbal Pharmacopeia had 99 species with 315 REC (recommended) and 5 TOX (found to be toxic) recipes [68]. The job now is to integrate these sources of Caribbean medicinal plant information into a searchable master database that acknowledges the countries from which this traditional knowledge emanates and returns benefit to the particular Caribbean ecosystem that needs this support to survive for perpetuity.

Number of countries in which the plant was identified as being medicinal	Number of plants (based on scientific name)
1	639
2	186
3	87
4	78
5	43
6	26
7	15
8	15
9	13
10	6
11	11
12	2
13	1
14	3

Table 2.
 Number of countries in which plant species were identified as being medicinal.

In temperate countries, single crops cover vast hectares. In the tropics, especially on small islands, this is not possible. In the Caribbean, the number of plants identified as being useful for one purpose or another continues to grow exponentially, for food, agriculture, horticulture and for medicinal uses [7, 11–13, 54–76]. It is no wonder then that there is a strong emphasis on the plant in the Caribbean [77, 78]. Many of the plants mentioned above have laboratory and clinical results indicating their antioxidant, anti-microbial and anti-cancer bioactivity. Indeed, to even attempt to summarize the research done on Caribbean plants would take a whole book. It is likely, that for whatever disease, there is probably a plant, or combination of plants in the Caribbean that can prevent or cure it! This includes very old diseases and new infectious diseases. To have such a rich heritage and not use it is like hanging a cheque on the wall because it looks pretty. We should find ways to conserve and use our rich heritage sustainably for health and wealth. The Caribbean has several Intellectual Property offices that can help with the transition from R&D to business (<https://www.ict-pulse.com/2012/08/protecting-intellectual-property-caribbean/>) and the Nagoya Protocol to ensure benefit returns to the region. Associated with the protocol is the access and benefit-sharing clearing-house (ABSCH), which is a key tool for enhancing legal certainty and transparency, and to monitor utilization of genetic resources along the value chain. The following medicinal plants have been suggested for further development, see **Table 3** [12, 70].

4.4 Case studies

4.4.1 Case study: Jamaica and Trinidad medicinal plants

Jamaica has many publications describing local plants with ethnobotanical uses. A 1787 publication listed 89 medicinal plants and associated recipes [71]. A 1929 publication listed 41 medicinal plants [72]. Asprey and Thorton in 1953–1955 listed 250 medicinal plants [73–76]. A TRAMIL study carried out in 2008 and reported in

Ackee (<i>Blighia sapida</i>)	Fever grass (<i>Cymbopogon citratus</i>)
Bamboo (<i>Bambusa vulgaris</i>)	Guava (<i>Psidium guajava</i>)
Bay tree (<i>Pimenta racemosa</i>)	Guinea hen weed (<i>Petiveria alliacea</i>)
Bitterwood (<i>Picrasma excelsa</i>)	Lemon grass (<i>C. flexuosus</i>)
Black jointer (<i>Piper amalago</i> spp. <i>amalago</i>)	Mauby (<i>Colubrina arborescens</i>)
Bottlebrush (<i>Callistemon viminalis</i>)	Neem (<i>Azadirachta indica</i>)
Cannabis (<i>Cannabis sativa</i>)	Nutmeg (<i>Myristica fragrans</i>)
Carapa (<i>Carapa guianensis</i>)	Pimento (<i>Pimenta dioica</i>)
Cerasee (<i>Momordica charantia</i>)	Sarsaparilla, Chaney root (<i>Smilax</i> spp.)
Colic mint (<i>Lippia alba</i>)	Sorrel (<i>Hibiscus sabdariffa</i>)
Cocoa (<i>Theobroma cacao</i>)	Turmeric (<i>Curcuma longa</i>)
Fitweed (<i>Eryngium foetidum</i>)	Yam (<i>Dioscorea</i> spp.)

Table 3.
Caribbean medicinal plants with commercial potential.

2015 listed 116 plants of which 107 had herbarium vouchers and 8 were endemic [63]. A University of the West Indies review in 2006 identified 334 medicinal plants [62]. None of these publications are illustrated, neither is the Flora of Jamaica [79]. There is still no comprehensive illustrated document/database of plants used medicinally in Jamaica. The Manual of Dendrology describes 150 trees of Jamaica and is illustrated [80]. An article describing 30 medicinal plants of Jamaica is illustrated [69] while the Jamaica's Third National Report to the CBD has illustrations of 36 endemic plants and animals of Jamaica [81]. It would be sad to lose this biodiversity before even pictures are taken for prosperity. The Virtual Herbarium of Jamaica has 1638 specimens and is searchable (<http://www.jamaicavirtualherbarium.com/>). There are about 130,000 botanical specimens in the Institute of Jamaica's herbarium (representing over 3000 higher plant species and 600 fern species) and over 80,000 zoological specimens. There are also 30,000 botanical specimens at the University of the West Indies herbarium. There is no indication of how many of these are medicinal. These herbarium vouchers are useful but need to be supplemented with illustrations of the full plant, leaves, stems, flowers, fruit, under-ground parts and internal morphology.

Trinidad also has a history of medicinal plants. An ethnobotanical survey carried out in 1966 and reported in 1976 with 70 informants described 900 recipes and 186 common medicinal plants [82]. No earlier publication could be found. A 1994 study of the Cocoa Panyols listed 148 plants and 198 recipes [83]. All the plants were native to Trinidad but six species had African varieties and perhaps ten were native to Africa including *Aframomum melegueta* which may have been brought to the Caribbean by the Portuguese [83]. A 1995 study of plants for ethnoveterinary use reported on 12 plant species used for four categories of poultry health problems [84]. A more extensive TRAMIL survey covering 50 towns in 2007 and reported in 2015 listed 917 single plant remedies from 96 plant species. The number of multiple-plant remedies was not reported [58]. The herbarium of Trinidad and Tobago holds 50,000 specimens dating back to 1842. This collection also includes samples from Belize, Guyana, Suriname and the Eastern Caribbean (<https://sta.uwi.edu/herbarium/>). An online database of this herbarium is hosted by the University of Oxford (<https://herbaria.plants.ox.ac.uk/bol/trin>).

4.4.2 Case study: Montserrat

Two studies will be highlighted—one on land and one at sea. On an 18-day trip, 13 scientists from Jamaica, Venezuela, Portugal, the United States Virgin Island and

6 Montserrat divers visited 516 sites and completed 475 dives in Montserrat waters. This team counted 40,000 fish from 227 different species; 43 of the 65 species of Caribbean corals were seen including the rare Elkhorn and Staghorn corals. This represents a large investment towards biodiversity monitoring and revealed a sizeable resource that needs to be protected while it is enjoyed [85].

Montserrat is about 16 by 11 km with 40 km of shoreline. In 1989, Hugo as a Category 4 hurricane damaged more than 90% of the structures on the island. Then in 1995, the previously dormant Soufrière Hills volcano became active destroying 60% of the forest. Eruptions buried the capital city of Plymouth with more than 12 m of mud. From the 13,000 residents in 1994, most of the remaining population left (leaving less than 1200 people); this increased to 5200 by 2016. The eruptions rendered the entire southern half of the island uninhabitable; it is now a designated Exclusion Zone with restricted access. Montserrat has several endemic species that are having to be rescued. The national bird is the endemic Montserrat oriole (*Icterus oberi*). Captive populations are held in several UK zoos. An ethnobotanical study in Montserrat reported in 2004 but carried out prior to the eruption identified 272 plant species (169 had folk medicinal uses); herbarium specimens of these were donated to several overseas herbariums [86]. Another publication in 1997 listed 256 medicinal and 24 poisonous plants [57]. Several criteria were suggested for prioritizing biodiversity in Montserrat: globally threatened species, areas of highest species richness, endemic species, optimal habitats, plants that are used by humans, conservation objectives, irreplaceability, and viability [87].

4.4.3 Case study: Identification of Jamaican medicinal endemics

In 2016, Jamaica measured itself against the Social Development Goals (SDG). Two of them are directly relevant: Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development and Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. For Goal 14, none of the indicators were being calculated although data is available for 20%. For Goal 15, some (16.7%) of the indicators were being calculated, 8.3% had available data but the indicators were not being produced while 75% were not being calculated and data was not available to produce them [88]. This by any indication is a poor report card.

While available literature indicates that the folk use of plants for health in Jamaica began a long time ago, even obtaining comprehensive botanical knowledge of this resource is elusive. In 1929, 41 medicinal plants were listed [72] and most are still being used. However, some problems were encountered: (1) the early literature was not illustrated, (2) scientific names were misspelt, (3) some common names did not match the scientific name known today, and (4) others were identified only to genus. Reconciliation of this early publication to existing knowledge is made more difficult as the only document on Jamaican flora is also not illustrated [79]. With the availability of cameras, we have no excuse. The only other reference to these plants is the herbarium voucher, but this includes only above ground plant parts, has no color, and is one dimensional, so is not useful in all cases. Without illustrations, how are we sure what plant they were referring to? This is important for while the author of this 1929 paper [72] thought 'such use of plants represents a rapidly passing phase of human healing', a 2008 ethnobotanical survey [63, 89] indicates that this practice is still being used.

Another issue arises when one tries to identify a plant species by what is referred to as a type species. In the annals of time, wisdom dictated that a herbarium voucher be

54	<i>Acanthospermum camphoratum</i>		197	<i>Alvaradoa jamaicensis</i>	
183	<i>Amyris plumieri</i>	Candlewood	314	<i>Boerhavia scandens</i>	Rat ears
245	<i>Cassia italica</i>	Jamaica senna	36	<i>Cassia jamaicensis</i>	Jamaican broom
45	<i>Cinnamodendron corticosum</i>	Mountain cinnamon			
174	<i>Coccoloba krugi</i>		257	<i>Conyza karvinskyanus</i>	Rockside daisy
22	<i>Cordia brownei</i>	Black sage	241	<i>Cordia jamaicensis</i>	Black sage
274	<i>Croton wilsoni</i>	Pepper rod	299	<i>Dendropemon pauciflorus</i>	Mistletoe
285	<i>Dryopteris</i> sp.	White stick	188	<i>Fagara elephantiasis</i>	Yellow sanders
187	<i>Fagara martinicensis</i>	Prickly yellow	266	<i>Ipomea jamaicensis</i>	Wild potato slip
43	<i>Lobelia accuminata</i>		44	<i>Lobelia viridiflora</i>	
262	<i>Pectis</i> spp.	Stink weed	40	<i>Peltophorum linnaei</i>	Brazilletto
161	<i>Peperomia clusiifolia</i>		163	<i>Peperomia proctorii</i>	
120	<i>Phoradendron wattii</i>		312	<i>Pimenta jamaicensis</i>	Wild pimento
168	<i>Piper fadyenii</i>		170	<i>Piper murrayanum</i>	
171	<i>Piper verrucosum</i>		286	<i>Polypodium exiguum</i>	Hug-me-tight
99	<i>Rhytidophyllum tomentosum</i>	Search-mi-heart			
144	<i>Sauvagesia brownei</i>	Iron shrub			
201	<i>Smilax balbisiana</i>	Chaney root	104	<i>Clusia portlandiana</i>	
190	<i>Spathelia glabrescens</i>		191	<i>Spathelia sorbifolia</i>	Mountain Pride
343	<i>Triumfetta sloanei</i>	Bur weed	71	<i>Vernonia acumata</i>	Bitter bush
72	<i>Vernonia pluvialis</i>		74	<i>Wedelia gracilis</i>	Consumption weed

The numbers in front of the scientific names is the reference number in the source document [62] which gives more information about these plants.

Table 4.
Endemic plant species of Jamaica, common names are in blue [62].

designated the type species to which putative species would then be compared. This is problematic for plants such as *Smilax* species that cannot always be morphologically distinguished only by above-ground characteristics. Many *Smilax* species are in the islands and mainland countries; while transporting them to Europe, the origin of the different species has become muddled, and the type species are insufficient as a reference.

A total of 334 plants growing in Jamaica were identified as having medicinal properties [62]. Of these 37.2% could also be found in Africa or Asia, 31% species only in the Americas but genus elsewhere, 19% species and genus only in the Americas, and 13% species found only in Jamaica. By comparison of these 334 medicinal plants of Jamaica with available flora databases, a list of 31 putative endemic medicinal species was assembled (**Table 4**).

4.4.4 Case study: Cockpit country, Jamaica

The Cockpit Country is a biodiversity hotspot within the Caribbean Island biodiversity hotspot (CIBH). It has karst geomorphology, which is an array of conical hills produced as the limestone erodes. Over 1500 different plant species grow naturally here [90]. Varied soil types on the different sections of the conical hills have resulted in a high rate of endemism. It has been estimated that 71 of Jamaica's endemic plants can

Taxon	# of species resident on Jamaica	# endemic to Jamaica	# Jamaican endemics in Cockpit Country	# endemic to Cockpit Country
Ferns	~600	82 (14%)	15 (18%)	2
Vascular plants	3304	923 (28%)	281 (30%)	71

Source: <https://www.cockpitcountry.com/plantsEndemicChecklist.html>

Table 5.
Jamaica endemics in the Cockpit Country.

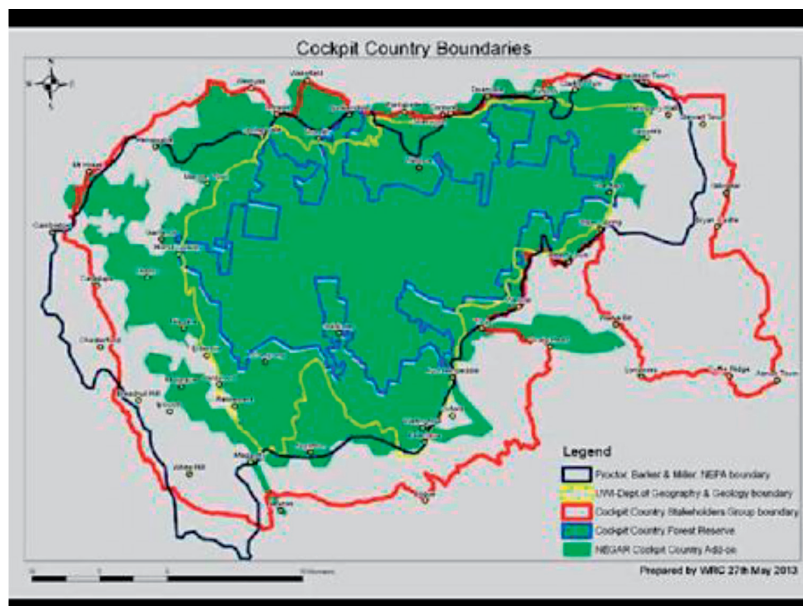
only be found in the Cockpit Country (**Table 5**). The area is also a refuge for birds and butterflies. An interesting feature is that it has over 300 caves and 21 bat species. One of these bats can eat up to 1000 mosquitoes per hour [90]. The other hotspot within the CIBH in Jamaica, the Blue and John Crow Mountain, was designated a UNESCO World Heritage Site in 2015 for its natural and cultural heritage and is protected. However, the Cockpit Country unfortunately is still in turmoil as the borders of the Cockpit Country are still in dispute. The Cockpit Country Protected Area (CCPA) comprised of 74,726 ha that was established on November 2nd 2017, prevents mining within its borders (**Figure 9B**). However, it only covers 67% of the area proposed by the Cockpit Country Stakeholders Group (CCSG) (bordered by the outermost red line) (**Figure 9A**). The red line border was determined by those who live in the area and other stakeholders which includes the Maroons as being best to protect them, the natural biodiversity and Jamaica at large [90, 91]. A proposed bauxite mining area, SML 173, is outside the CCPA but inside the CCSG boundary (**Figure 9A, B**). Mining bauxite in the Cockpit Country (as determined by the CCSG) could cause long-term loss of topsoil, disruption of social fabric, loss of water/climate regulation, loss of unique biodiversity and diminished use of the area as a biodiversity refuge.

4.4.5 Case study: DCBD

The Dutch Caribbean Biodiversity Database (DCBD, <https://www.dcbd.nl/>) is a central repository for biodiversity related research and monitoring data from the Dutch Caribbean. Research and monitoring data can be submitted to the Dutch Caribbean Nature Alliance (DCNA) secretariat for the DCBD. Material stored includes books, scientific articles, maps, charts, reports, biodiversity projects as well as portals to other global databases. Monitoring is continuous (www.dcnanature.org/resources/research-monitoring). The historical and ongoing taxonomic collections from the Dutch Caribbean are held at Naturalis in Leiden, the Netherlands.

Understanding biodiversity changes requires comparison with historical collections. Fortunately, Naturalis houses 10,000 specimens from Saba, St Eustatius and St Maarten including those collected in 1908. However, by 2013, only 10% of this herbarium collection had been digitized. In the Netherlands, all Caribbean collections are housed in a single institute where about 100 scientists work on biodiversity [92]. The flora on Aruba, Bonaire and Curacao comprise 569 indigenous and naturalized species composed of South American, Central American and Caribbean species and 86 foreign species (imported accidentally or purposefully). Nine endemic species have been identified (**Table 6**). The flora is continually being updated. Local naturalists can email pictures taken by digital cameras to online photo-libraries to get plants identified or new ones added to the collection.

Coral reefs are an area of focus. Elkhorn (*Acropora palmata*) numbers have decreased by 97% since the 1980s [93]. This is due to a multitude of issues such as disease, coral bleaching, hurricanes, human activity and collapse of the long-spined sea urchins (*Diadema antillarum*) populations that grazed the reefs keeping it clear



A)



B)

Figure 9. Cockpit Country: (A) proposed boundaries [78] and (B) CCPA and proposed bauxite mining area SML173 (Observer newspaper, p. 12, August 04, 2019).

of algae. Research includes outplanting of *Acropora* spp., identification of coral diseases, and growing coral on artificial structures.

The Bonaire Deep Reef Expedition I was carried out from May 30th to June 1st, 2013 when the deep reef of Bonaire was explored by researchers from IMARES Wageningen UR. The Dutch Ministry of Economic Affairs commissioned the research institute IMARES to study the deeper reef as part of the EEZ management plan for the Dutch Caribbean—they went down to 200–250 m. An interesting find was that lionfish were found as deep as 165 m. More interesting information can be found on the DCBD website.

4.4.6 Case study: TRAMIL

TRAMIL is the ‘program of applied research to popular medicine’ which brings together Caribbean institutions interested in the traditional medicine of the islands. Ethnobotanical studies are followed by lab research on efficacy and toxicity of the

Aruba	Bonaire	Curaçao
• <i>Agave arubensis</i>	• <i>Agave boldinghiana</i>	• <i>Agave boldinghiana</i>
• <i>Agave rutteniae</i>	• <i>Cynanchum boldinghii</i>	• <i>Cynanchum boldinghii</i>
• <i>Cynanchum boldinghii</i>	• <i>Melocactus macracanthus</i>	• <i>Melocactus macracanthus</i>
• <i>Melocactus macracanthus</i>	• <i>Maytenus versluisii</i>	• <i>Maytenus versluisii</i>
• <i>Melocactus stramineus</i>	• <i>Myrcia curassavica</i>	• <i>Myrcia curassavica</i>
• <i>Melocactus x bozsingianus</i>		

Source: <https://www.dcnanature.org/flora-of-aruba-bonaire-and-curaçao/>

Table 6.
 Endemic plant species of the Leeward Dutch Caribbean Islands.

reported folk recipes. This information is then returned to the people. TRAMIL has the most comprehensive database on Caribbean medicinal plants (<http://www.tramil.net/en>—in three languages—French, English and Spanish, Accessed: July 05, 2019). Importantly the information in the TRAMIL library includes scientific and common names, several pictures, herbarium sample, scan, botanical description, thin section, territories with significant TRAMIL use, preparation, posology, chemistry, biological activities and recommendation. The database is online, available and searchable. The site also has links to publications, workshops, and a map of activities. It is important that this database, especially the illustrations, continues to serve Caribbean interests and remains accessible.

4.5 Interregional and intraregional collections and databases

Several herbariums are available in the Caribbean (Table 7). Also, there are many interregional and intraregional biodiversity institutions with Caribbean

Number/Name of herbarium(s)	Number of specimens	Official acronym	Country
Nassau Botanical Gardens	7215	BNH	Bahamas
University of the West Indies	5000	BAR	Barbados
Ministry of Agriculture, Fisheries, etc.	10,000	BRH	Belize
Natural Trust of the Cayman Islands	1369	CAYM	Cayman Islands
22 herbaria	807,527	AJBC, BSC, CSC, HABA, HABE, HAC, HACC, HAJB, HAJU, HANC, HFA, HMC, HPC, HPPR, HPVC, IH, IM, LS, MNHN, ROIJ, SV, ULV	Cuba
Three herbaria	175,000	JBSD, UCMM, USD	Dominican Republic
Institut de Recherche pour le Developpement, IRD	170,000	CAY	French Guiana
Institut National de la Recherche Agronomique and Parc National de Guadeloupe	10,000	GUAD	Guadeloupe
Three herbaria	57,850	BRG, FDG, HJBG	Guyana
Université d'Etat d'Haiti	7216	EHH	Haiti

Number/Name of herbarium(s)	Number of specimens	Official acronym	Country
Institute of Jamaica (IJ) and UWI (UCWI)	161,600	IJ, UCWI	Jamaica
Seven herbaria	167,430	FPDB, MAPR, MSM, RPPR, SJ, UPR, UPRRP	Puerto Rico
University of Suriname	37,000	BBS	Suriname
The National Herbarium of Trinidad and Tobago	70,000	TRIN	Trinidad
None recorded	?	?	US Virgin Island
External			
The New York Botanical Gardens	7,800,000	NY	USA
Royal Botanic Gardens at Kew	7,000,000	K	UK
Naturalis—from 1829	6,900,000	L, Wag, U	Netherlands
Missouri Botanical Garden	6,600,000	MO	USA

Table 7.
Herbaria of the CIBH [94].

collections (<http://sweetgum.nybg.org>). Some of these collections are accessible to the Caribbean, but some are not. The 2007 Dominica ethnobotanical survey voucher specimens are deposited at the University of Missouri Dunn-Palmer herbarium [64]. The same situation happens to databases, so some of this information resides outside of the Caribbean and is not easily available (**Table 8**).

4.6 SWOT analysis

Valuation requires a SWOT analysis.

4.6.1 Strength

The strength of the Caribbean is its diversity—plants, animals, microbes, and people. All Caribbean countries have National Biodiversity Strategy and Action Plans (<https://www.cbd.int/nbsap>), FAO reports on PGRFA (<http://www.fao.org/plant-treaty/en/>) and national environmental protection agencies. There are also many terrestrial (<https://www.cepf.net/>; <https://www.thegef.org/>) and marine initiatives for the Caribbean (<http://caribbean.cepal.org/t/marine-resources>). These reports carry a lot of information which are being under-utilized. The diversity of people has resulted in many innovations the rest of the world could benefit from. The databases on Caribbean medicinal plants are growing as is the research, development and innovation to develop useful products.

4.6.2 Weaknesses

Lack of appreciation of biodiversity for health and wealth; low level of development that hampers conservation, research and data gathering; and overdependence on imported fuel that uses foreign exchange that could otherwise be used for conservation projects. The status of Caribbean biodiversity is difficult to assess due to the wide extent of the bioresource, varied allegiances and languages, destruction

Database	Link to database
Inter-Regional	
TRAMIL	http://www.tramil.net/en
Dutch Caribbean Biodiversity Database	www.DCNAnature.org
Digital Library of the Caribbean	https://dloc.com/dloc1/collect
Caribbean Database of Documentary Heritage	http://nlj.govjm/caribbeanregister/docs/collections.htm
West Indian Drug Herb Interaction Database [95]	Not available online
International Union for Conservation of Nature (IUCN)	https://www.iucn.org/tags/regions/caribbean Standardized methodology for creation of Caribbean national registers of their marine and terrestrial biological resources; Database is being populated [96].
Intra-Regional	
Fairchild Tropical Botanic Garden	http://www.virtualherbarium.org/Latham/Caribbean.htm
New York Botanical Garden	https://www.nybg.org/plant-research-and-conservation/explore/caribbean/ , Said to have over 300,000 Caribbean plant and fungi specimens.
Naturalis in Leiden, the Netherlands	https://www.naturalis.nl/ , Historical taxonomic collections from the Dutch Caribbean
The British Library	https://www.bl.uk/collection-guides/caribbean-collections
World Museum, Liverpool, UK	https://www.liverpoolmuseums.org.uk/wml/collections/botany/seed-plants/trinidad-and-tobago/index.aspx , Trinidad and Tobago plant collection
Kew Gardens, UK	https://www.kew.org/kew-gardens/plants/islands-flora-collection—Island flora collection—447 taxa, 790 accessions, includes UK Overseas Territories (UKOTs) [97] and Caribbean samples
Tropicos	https://www.tropicos.org/ was originally created for internal research but is now freely available. Includes nomenclatural, bibliographic, and specimen data accumulated in MBG's electronic databases during past 30 years. This system has nearly 1.3 million scientific names and over 4.4 million specimen records. Specimen counts per country are available.
Smithsonian, National Museum of Natural History, Flora of the West Indies	https://naturalhistory2.si.edu/botany/WestIndies/ Checklist of scientific names of seed plants from West Indies, synonyms, common names, distribution by island, images
Ocean Biogeographic Information System	https://obis.org/

Table 8.
Databases that include Caribbean biodiversity knowledge.

of local biodiversity, imports of new plant varieties, insufficient genotyping more so for terrestrial ecosystems and microbes than for marine; flora without illustrations; insufficient botanical data gathering due to insufficient taxonomists, researchers and custodians of local biodiversity. On one hand is insufficient information, on the other hand is volumes of raw data. Both issues need to be addressed using dedicated and trained personnel. The historical database is insufficient. Another weakness is that much information about the Caribbean resides outside of the region and needs

to be repatriated or made more readily available. Although the biodiversity data gathered appears extensive, it is not robust enough. While every island has at least one herbarium or access to one, the floras of the region are inadequate. The Flora of Jamaica [79], which is the most comprehensive description of Jamaican flora is not illustrated and there is no other document that comes close to it in terms of the number of plants covered. Unfortunately it is out-of-print and unavailable. A similar situation can be found for flora of other Caribbean countries.

4.6.3 Opportunities

Since about the turn of the century, interest in medicinal plants has increased. Most islands now have annotated books on their medicinal plants. Many ethnobotanical surveys have been carried out with several databases being developed. TRAMIL, TROPICOS, and OBIS are important repositories of biodiversity information. Caribbean medicinal plants are reported to have multiple bioactivities. Island research can help to assess how communities are affected by different threats. Making use of these opportunities could bring health and wealth to the region that is sustainable. With more and more countries of the Caribbean signing onto the Nagoya Protocol, these benefits will be shared more equitably with the region.

4.6.4 Threats

Climate change, hurricanes, drought, volcanic eruptions, unsustainable agricultural practices, high population densities in rural areas, roads, urbanization, pollution overfishing and invasive species. The greatest threat is if insufficient action is taken to identify, catalog, rationalize, conserve assess and manage our biodiversity.

4.7 Global problems

Some of the problems the Caribbean has in terms of mass extinctions and biodiversity are the same as elsewhere. These include population pressure on biodiversity and climate change. On the other hand, there are fundamental problems that remain in the Caribbean that are not a priority elsewhere such as plant identification and conservation; for example, 20 of 94 root tonic forest plant species are still unknown to science [12]. Global funds have reached the Caribbean, but they are insufficient and not tailored to the needs on the ground. If the Caribbean hotspot is to be maintained for future generations, it is going to take researchers inside and outside of the region working together to determine the best way forward.

The Caribbean is affected by what happens elsewhere in the world. For example, the largest extent of *Sargassum* algae mats occurred in June 2018, when at least 20 million metric tons of the algae covered 8840 km of ocean from Africa to the Gulf of Mexico. Satellite tracking the algae mats over the last 19 years recorded a sudden and dramatic increase in summer 2011 when the algae changed from isolated groups to an extensive mat. The main cause for the dramatic increase has been linked to increased fertilizer use and deforestation of the Amazon resulting in increasing nutrients pouring into the ocean. Although the floating sargassum shelters turtles, fish and other marine species, too much is smothering corals, seagrass and wreaking havoc on the coasts across the Caribbean and the Gulf of Mexico as meter-thick seaweed covers the beaches and rots [98].

A big concern of the Caribbean is what will happen if we cannot keep global warming from passing 1.5°C above pre-industrial levels [99]. Hurricanes and droughts have caused billions of dollars in damage across the Caribbean especially in the last 20 years. Climate resilience is needed even now. However, the Caribbean

needs '1.5 to stay alive' (<https://www.ipcc.ch/sr15/>). Capping global temperature rise at 2°C—as some developed countries have suggested—would have catastrophic impacts on the Caribbean. This would cause extreme temperatures, increases in frequency, intensity and/or amount of heavy precipitation, increase intensity or frequency of droughts and incursion of sea water due to sea level rise. Climate smart agriculture is being recommended while climate and crop modeling is being developed. Identification, storage, sharing and utilization of climate-smart germplasm of important food crops is recommended for building climate resilience that safeguards food and nutrition security, and throughout the region institutions are developing biotechnology solutions for conservation and multiplication of germplasm. But even these efforts will be futile if global warming was to increase above 1.5°C.

5. Valuing our biodiversity knowledge

A big threat to biodiversity is lack of respect for its value. We do not protect what we do not value. We need to spend more time in the garden and away from our computers. We need to ensure our children learn about our natural biodiversity; one way is by ethnobotanical school assignments [100]. Other activities recommended to help us value our biodiversity knowledge and ensure its perpetuity for future generations include:

- Identification of terrestrial, freshwater and marine biodiversity and production of illustrated flora, fauna and microbe monographs
- Ethnobotanical surveys
- Economic valuation of ethnobotanical knowledge to finished product
- Evaluation and conservation of rare, endemic and indigenous germplasm
- Interaction of scientists with rural communities to increase resilient choices
- Development of alternative and sustainable rural livelihoods
- Development of propagation protocols and provision of clean planting material
- Training farmers to conserve and use new (bio)technology
- Production and use of soil ameliorants and innovative machines that run on renewable energy—solar pumps, bamboo charcoal, water harvesters
- Development of local agroprocessing solutions including essential oils, lotions, creams, soaps
- Development of educational material about useful and threatened biodiversity
- Increasing awareness of rural groups to intellectual property and the Nagoya Protocol and what it means for them

Given their conservation risks, small size, and high levels of endemism, islands offer particularly high returns for species conservation efforts and therefore

warrant a high priority in global biodiversity conservation activities. The scientists who are working to conserve and sustainably use biodiversity in the islands need to be supported so that their efforts are not wasted.

6. Way forward

With a global understanding of the need to conserve biodiversity, especially key species, endangered, medicinal and economically important biodiversity, especially in hotspots, a dedicated initiative tailored to the needs of the region would help ease the pressure. The Caribbean has the following to offer:

- World-class universities and research institutions
- Quality publications highlighting the problem and offering solutions.
- Growing knowledge of Caribbean medicinal plants, freshwater and marine systems.
- Sought-after Caribbean traditional knowledge.
- Lots of sunshine and wind allowing for solar and wind energy.
- Climate change aware governments and scientists.
- Strong and flexible financial systems.
- A desire and understanding of what needs to be done.
- What works in one small island developing states (SIDS) can be applied to others.

Considering the wealth of Caribbean biodiversity knowledge, its presently recognized value and a SWOT analysis, the following areas are most in need of support:

- Identification of Caribbean organisms still unknown to science eg root tonic species, endemics, endangered species.
- Standardization of morphological descriptors and DNA fingerprinting of Caribbean biodiversity.
- Assessment of the interplay between terrestrial, freshwater and marine environments and their biodiversity.
- Education solutions that increase value placed on Caribbean biodiversity
- Annotated and illustrated floras and faunas. Online herbariums.
- A workable diffuse seed bank system (true seed and vegetative organs).
- Biofactory for production and conservation of elite planting material.

- Long-term storage facilities for elite germplasm (cryopreservation/biobanking).
- Research into biofarming and biopharming possibilities.
- Field studies to determine sustainable methods for producing high yield, high quality, high drought resistance, permaculture, climate smart crops.
- Permaculture and managed forest studies.
- Support for equipment access, data collection, overseas conferences and workshops, and publishing research outcomes in high impact journals.
- Access to labs, machines, methods, and educational material as needed.
- Repatriation of Caribbean biodiversity data and links to global databases.
- Establishing Caribbean pharmacopeia linked to online biological global databases.
- Plant monographs and Marine information sheets.
- Inclusion of Caribbean plants into Aquacrop, DSSAT and other modeling systems. Inclusion of Caribbean data into Statistica, FAO-stats, Knoema and other global statistical databases systems.
- Inclusion of Caribbean biodiversity custodians and scientists in global decision making endeavors.
- Use of access and benefit sharing systems for genetic resources, associated traditional knowledge holders and derived products.
- Robust Intellectual property systems.
- Robust plant variety protection.
- Biodiversity sensitive trading platforms.

7. Conclusion

All major countries of the world are represented in the Caribbean. In a region with so many forces that divide, plants and animals are a unifying force. This is because all biologists speak one language, an organism in any country will have the same unique scientific name. However, if we do not identify and value our biodiversity, it could be lost and we would not know. Increasing the knowledge base will provide increasingly accurate valuation of Caribbean biodiversity. Before we lose this precious and diverse bioresource to inaction, insufficiency, irresponsibility, rising sea levels and other vagaries of climate change, we have to act now. A big problem requires a big solution and those that perceive and understand have to lead the process. We hereby call on those with a conscience to support us in the region who are acting responsibly, to join forces, as we attempt to protect and sustainably use our biodiversity so the Caribbean can play its part in the welfare of the whole human race.

8. Websites on Caribbean biodiversity

- https://www.telbba-plant-wiz.com/landscapes?fb_ref=Default
- <https://naturalhistory2.si.edu/botany/WestIndies/>
- <http://legacy.cepf.net/resources/hotspots/North-and-Central-America/Pages/Caribbean-Islands.aspx>
- <https://naturalhistory2.si.edu/botany/WestIndies/>
- <http://thecommonwealth.org/media/news/caribbean-nations-prepare-maritime-boundary-talks-commonwealth-support>
- <http://atlas-caraibe.certic.unicaen.fr/en/page-122.html>
- hull fouling: <http://www.harsonic.com/harsonic-boats/hull-fouling-is-highest-for-boats-that-remain-stationary/>
- ballast water: <http://www.imo.org/en/MediaCentre/HotTopics/BWM/Pages/default.aspx>
- invasive species that were brought in as pets: <https://bcinvasives.ca/commitments/dont-let-it-loose>

Acknowledgements

I would like to thank all those who helped with this chapter.

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