BIODIVERSITY ASSESSMENT OF THE EASTERN CARIBBEAN

Biodiversity Programme Publication #5

Prepared By

island resources
FOUNDATION

Eastern Caribbean Biodiversity Programme
PO Box 2103
St. John's, ANTIGUA
Email: *<irf@irf.org>*

May 1998

Revised June 1999

Organization of the Report

Biodiversity Assessment of the Eastern Caribbean

INTRODUCTION

This base of this report was initially prepared in 1998 by Island Resources Foundation to assist a potential donor in evaluating the global significance of the biodiversity of the Eastern Caribbean, specifically the eight GEF-eligible states: Antigua-Barbuda, Barbados, Dominica, Grenada, St. Kitts-Nevis, St. Lucia, St. Vincent and the Grenadines, and Trinidad-Tobago. The report's primary focus was to collate and interpret data on the terrestrial and marine biodiversity of the region.

In the ensuing year, Island Resources Foundation had an opportunity to carry out a more comprehensive biodiversity assessment of the country of St. Kitts and Nevis, as the Foundation had earlier undertaken for Antigua and Barbuda, providing a level of detail for these countries that does not yet exist for other Eastern Caribbean states included in this report. It is our hope that this document can serve as a working tool for biodiversity conservation efforts in the region and that it will be continually refined and updated as additional data become available.

Most modern conservation assessments employ a three-part framework: biological status; threat; and response. This report predominantly focuses on the region's biological status. It is *not* a conservation assessment, although on occasion, we offer brief comment on conservation status. To produce a proper conservation assessment would require additional information about biodiversity threat and response factors. However, even without elaborating on the specifics, it is worth noting the concern within the international community that the small size, insularity, and economic dependence of the Eastern Caribbean states make them especially vulnerable to exploitation of their natural resources, including their biodiversity.

TERRESTRIAL BIODIVERSITY: ECOSYSTEMS

We began our analysis of terrestrial ecosystems of the Eastern Caribbean by reviewing *A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean Status* (WWF/WB, 1995). This document represents the most comprehensive attempt to date to identify for the Americas the terrestrial geographic priorities for biodiversity conservation based on the integration of biological distinctiveness and conservation status. Our analysis explores the implications and suitability of this report and concludes that its scale is too large to be effective in assessing the biodiversity of the Eastern Caribbean. We conclude this section by suggesting alternative, scale-appropriate classifications and approaches.

WWF/WB Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean

The WWF/WB study identifies 11 ***Major Habitat Types***, which are divided into 178 terrestrial non-mangrove and 13 terrestrial mangrove ***ecoregions***[1]. Within this exercise, an ecoregion is intended to be the fundamental unit of conservation planning, "the minimum level of resolution required for achieving regional representation and effective conservation planning... [It] should identify an area over which a single conservation strategy could be effectively applied" (p. 4). The report provides profiles of each ecoregion, identifying its 'final conservation status' and 'biological distinctiveness', which are integrated to determine its 'biodiversity conservation priority'.

Of the 11 Major Habitat Types identified for the Americas, seven occur in the Caribbean; only four of these are identified within the Lesser Antilles. The four Major Habitat Types contain seven ecoregions in the Lesser Antilles:

Major Habitat Types ***Ecoregion***	**"country" of occurrence**
Tropical Moist Broadleaf Forest *Windward Islands moist forest*	Windward Islands
Tropical Moist Broadleaf Forest *Leeward Islands moist forest*	Leeward Islands
Tropical Dry Broadleaf Forest *Windward Islands dry forest*	Windward Islands
Tropical Dry Broadleaf Forest *Leeward Islands dry forest*	Leeward Islands
Deserts and Xeric Shrublands *Windward Islands xeric scrub*	Windward Islands
Deserts and Xeric Shrublands *Leeward Islands xeric scrub*	Leeward Islands
Mangroves[2] *Lesser Antilles*	Lesser Antilles

[1] For the most part, the exercise treats ecoregions simply as "geographically discrete units of Major Habitat Types". However, the fuller definition of ecoregions refers to "geographically distinct assemblages of natural communities that share a large majority of their species, ecological dynamics, and similar environmental conditions, and whose ecological interactions are critical for their long-term persistence" (p. 14); and "on the basis of this definition, some ecoregions ... contain a mosaic of distinct habitat types" (e.g., the Cerrado of Brazil is an ecoregion listed under the "Grasslands/Savanna/Shrublands" Major Habitat Type, even though it also contains areas of other Major Habitat Types).

[2] Mangroves: The WWF/WB report states that its evaluation of mangroves is less comprehensive than its evaluation of other terrestrial systems, and much of its discussion is limited to the "non-mangrove ecoregions". However, it does identify 13 major bio-

Table 1. WWF/WB (1995) Matrix for Integrating Biological Distinctiveness and Conservation Status to Assign Priorities for Biodiversity Conservation.

Biological Distinctiveness	*Final Conservation Status*				
	Critical	*Endangered*	*Vulnerable*	*Relatively Stable*	*Relatively Intact*
Globally Outstanding	I	I	I	I	II
Regionally Outstanding	I	I	I	II	III
Bioregionally Outstanding	II	II	III	III	IV
Locally Important	III	III	IV	IV	IV

Note: The roman numerals indicate biodiversity conservation priority classes:

Level I = Highest Priority at Regional Scale (shaded area)

Level II = High Priority at Regional Scale

Level III = Moderate Priority at Regional Scale

Level IV = Important at National Scale

The application of the matrix in Table 1 to the seven ecoregions within the Eastern Caribbean results in the ecoregion profiles shown below (WWF/WB, 1995):

Windward Islands moist forest-Windward Islands: Vulnerable; Bioregionally Outstanding; Moderate Priority at Regional Scale.

The moist forests of both the Windward and Leeward Islands are comprised of many disjunct forests on different islands. Because many species are endemic to forests on a single island, conservation strategies should emphasize adequate representation of each island. Urban development pressures, pollution, grazing, roadbuilding, and exotic invasions threaten the ecoregion. The types and intensity of threats vary among different islands.

geographic *"complexes"* (used more or less interchangeably with "ecoregions"). Subsequent to the publication of this report, WWF convened a workshop of the leading mangrove specialists of the Western Hemisphere to try to apply the methodology of the first assessment to prioritize mangrove conservation issues. They identified the mangroves of the Lesser Antilles, from among all of those of Latin America and the Caribbean, as being the most impacted by development and the ones at the greatest conservation risk (WWF, 1996).

Leeward Islands moist forest-Leeward Islands: Relatively Stable; Bioregionally Outstanding; Moderate Priority at Regional Scale.

> Biodiversity considerations are discussed under Windward Islands moist forests. Urban development pressures, pollution, grazing, road-building, and exotic invasions threaten the ecoregion. The types and intensity of threats vary among different islands.

Windward Islands dry forest-Windward Islands: Endangered; Locally Important; Moderate Priority at Regional Scale.

> Agricultural expansion, grazing, firewood gathering, and development are threats to the ecoregion.

Leeward Islands dry forest-Leeward Islands: Critical; Locally Important; Moderate Priority at Regional Scale.

> The ecoregion faces threats from clearing for development, seasonal burning, firewood gathering, and heavy recreational use.

Windward Islands xeric scrub-Windward Islands: Endangered; Locally Important; Moderate Priority at Regional Scale.

> Grazing, woodcutting, and the conversion and resource exploitation associated with increased urbanization pose threats to the ecoregion for the foreseeable future.

Leeward Islands xeric scrub-Leeward Islands: Critical; Locally Important; Moderate Priority at Regional Scale.

> Grazing, woodcutting, and the conversion and resource exploitation associated with increased urbanization pose threats to the ecoregion for the foreseeable future.

Lesser Antilles mangroves-Lesser Antilles: The mangroves were not ranked in a manner comparable to the non-mangrove terrestrial ecoregions, but see footnote 2.

We believe that the WWF/WB report fails in several important respects when applied to the Eastern Caribbean:

- The scale adjustments are still too coarse for assessing the Eastern Caribbean.
- The seven ecoregions listed do not adequately portray the biodiversity within this region in a manner that allows them to be useful as conservation tools.
- It is not an adequate portrayal of the Eastern Caribbean's contribution to global biodiversity.

Scale Issues

The WWF/WB study divided all of Latin America and the Caribbean into nine bioregions—Northern Mexico, Central America, Northern Andes, Central Andes, Southern South America, Eastern South America, Amazonia, Orinoco and Caribbean. Seven of the eight countries targeted in the IRF assessment of Eastern Caribbean biodiversity are located in the Caribbean bioregion; while the eighth country—Trinidad and Tobago—is in the Orinoco bioregion.

The WWF/WB assessment tries to ensure that there is bioregional representation, and the discussion in the report of this topic is especially valuable when considering the application of the integration matrix to the Eastern Caribbean.

> *The matrix ... provides, by Major Habitat Type, a set of Highest Priority at Regional Scale ecoregions (level I) for all of Latin America and the Caribbean. However, this list within each Major Habitat Type does not necessarily ensure bioregional representation.*
>
> *Bioregional representation is important because of the dissimilarities in the species and natural communities of ecoregions within the same Major Habitat Type but from different biogeographic zones of Latin America and the Caribbean; geographic replacement of species occurs as range boundaries, environmental gradients, and physical barriers are crossed at large geographical scales. By including bioregional representation as a goal in a regional biodiversity strategy, problems of scale are also dealt with in a more objective fashion. For example, many Caribbean ecoregions that share the same Major Habitat Type with continental ecoregions come out poorly in priority rankings. Typically, small island faunas and floras are depauperate compared to continental biotas because of size and isolation. Ideally however, at least one example of each Major Habitat Type in the Caribbean should be considered as Highest Priority at Regional Scale to reflect the importance, at the Latin America and the Caribbean scale, of the biodiversity of that bioregion.*
>
> *We propose that within each bioregion each constituent Major Habitat Type be represented—subject to certain conditions—by at least one ecoregion classed as Highest Priority at Regional Scale. We attain this goal by "upgrading", when necessary, a single level II or level III ecoregion (but never a level IV) to "level I[a]." We choose a level II over a level III ecoregion and a worse conservation status over a better conservation status. Only level III ecoregions that are Critical, Endangered, or Vulnerable are considered eligible. If there is a tie between two or more ecoregions, we choose the ecoregion with the highest biological distinctiveness ...* (WWF/WB, 1995, p. 11).

Despite this attempt to ensure geographic representation, the approach used by WWF/WB fails in regard to the Eastern Caribbean. It simply does not go far enough to be useful in assessing landscape biodiversity of, or within, the Eastern Caribbean. The nine bioregions used in the report may be a manageable number for dealing with an area greater than a continent, but it is so coarse that the Eastern Caribbean becomes lost. The result is one 'upgrade': the Leeward Islands xeric scrub is moved from level II to level I[a]. We feel strongly that this is not the only habitat within the Eastern Caribbean warranting the attention of the global conservation community. Furthermore, the fact

that the Eastern Caribbean includes two bioregions—Trinidad and Tobago, which is classified within the Orinoco bioregion, as well as the Lesser Antilles, which is classified within the Caribbean bioregion—complicates the application of the WWF/WB exercise to an assessment of the biodiversity significance of the Eastern Caribbean.

The WWF/WB report does include a discussion of the "Application of the Methodology to Finer Geographic Scales", recognizing that "regional priority-setting exercises—by virtue of their coarse scale—can seldom identify where the most important investments should be made within ecoregions nor what to do at those sites to best conserve biodiversity" (pp. 46-47). The discussion raises important points and offers excellent suggestions at the intra-ecoregional level. We note, however, that this discussion does not contribute to addressing the concern that we raise above, namely, that ecoregions, as defined in WWF/WB's report, are not the appropriate units to use in evaluating biodiversity conservation of the Eastern Caribbean.

A secondary concern in the application of these ecoregions to the eight GEF-eligible countries in the Eastern Caribbean has to do with the great variability among these islands. Table 2 illustrates the conservation status and biodiversity condition for nine ecoregions for the eight GEF-eligible countries in the Eastern Caribbean. For terrestrial ecoregions, these assessments of biological significance reflect some of the actual discussions which resulted in the World Bank/WWF hemispheric assessments. For the Mangrove and two illustrative marine habitats, the IUCN standards for conservation status and the World Bank/WWF criteria for biological distinctiveness were applied by experts who had participated in the terrestrial ordering exercise in Miami in October of 1995. To simplify the biological distinctiveness ratings for this illustration, the ratings are "outstanding, important, and significant," based on a regional estimate of relative numbers of endemic or threatened migratory species which would be affected by changes in the major habitats characterizing each ecoregion.

These status estimates are provided to illustrate the wide variety of conditions encountered in the eight GEF-eligible countries in the Eastern Caribbean. They are *not* intended to define those conditions, although such an assessment would be a desirable *product* of a potential GEF biodiversity project for these eight countries, and one which might lead to regional cooperation and coordination of biodiversity conservation at an operational level which has been heretofore unattainable.

Finer-scale Classifications of Terrestrial Ecosystems of the Eastern Caribbean

Unlike the analysis of biodiversity at the species level—where a consensus exists on definitions—analysis of biodiversity at the landscape level is greatly affected by the criteria used to define the landscape unit and by the scale on which the assessment is applied. Not just the definitions, but "the relationships between ecological patterns and processes change with the scale of observation" (Biodiversity Support Group, 1995; Jones, *et al.*, 1998).

The most influential work on classifying the vegetation of the Caribbean remains that of Beard (1949; 1955). He recognized 28 categories within 6 major forest types (some of the categories did not apply to the Lesser Antilles, and in some cases there may no longer be viable samples). Most of the researchers that followed based their approach to vegetation classification on Beard's work. Howard (1974), the editor of the definitive flora of the region, used ecological factors to modify Beard's vegetation classification, and he identified 14 categories within 3 major groupings (Table 3).[3]

[3] Another valuable contribution to the understanding of the flora of the Caribbean is the Centres of Plant Diversity project. Although the data in *Centres of Plant Diversity: A Guide and Strategy for Their Conservation* (Davis, *et al.*, 1997) are not presented in a format that is directly applicable to an assessment of the biodiversity of the Eastern Caribbean, this project and its collaborators represent an important resource for any conservation effort in the region.

Table 2. Conservation Status and Biological Distinctiveness for Nine Eco-regions in Eight GEF-eligible Countries in the Eastern Caribbean.

	Windward Moist Forest	Leeward Moist Forest	Windward Dry Forest	Leeward Dry Forest	Windward Xeric Scrub	Leeward Xeric Scrub	Lesser Antilles Mangroves	Coastal Coral Reefs	Offshore Grass & Reef Complexes
Antigua-Barbuda[4]	na	na	na	Critical Important	na	Critical Outstanding	Critical Significant	Critical Important	Endangered Outstanding
St. Kitts-Nevis[4]	na	Critical Important	na	Vulnerable Important	na	Vulnerable Important	Critical Significant	Critical Important	Vulnerable Important
Dominica[5]	Stable Outstanding	na	Critical Significant	na	na	na	Endangered Significant	Critical Significant	na
St. Lucia[5]	Endangered Significant	na	Endangered Important	na	Critical Important	na	Critical Important	Critical Significant	Endangered Significant
St. Vincent[5]	Vulnerable Important	na	Critical Important	na	Vulnerable Important	na	Endangered Significant	Endangered Important	Vulnerable Outstanding
Barbados[6]	na	na	Critical Important	na	Critical Significant	na	Critical Significant	Critical Important	Critical Significant
Grenada[5]	Endangered Important	na	Endangered Important	na	Vulnerable Significant	na	Endangered Important	Critical Important	Vulnerable Important
Trinidad-Tobago[7]	Endangered Outstanding	na	Endangered Important	na	Vulnerable Significant	na	Endangered Outstanding	Critical Important	Endangered Important

[4] Leeward Islands

[5] Windward Islands

[6] Barbados is counted as a Windward Island by the World Bank Assessment.

[7] Trinidad-Tobago are counted as Windward Islands for this example, although the World Bank Assessment assigns them to the South American coastal ecoregion.

Table 3. Ecologically-distinct Categories of the Lesser Antilles (as identified by Howard, 1974).

COASTAL FORMATIONS	LOWLAND FORMATIONS	MONTANE FORMATIONS
Beach	Thorn scrub	Wet or dry forest on limestone
Strand	Savanna-grassland	Montane sclerophyll
Rock pavement	Marsh or swamp	Palm brakes
Mangrove		Tree fern communities
		Volcanic-soufriere communities
		Crater lakes
		Elfin thickets

Our experience from Antigua-Barbuda and St. Kitts-Nevis, where we have recently completed an intensive and relatively comprehensive biological inventory, offers an additional perspective. The system that we used was based on the National Vegetation Classification System being prepared by the U.S. Federal Geographic Data Committee (FGDC, 1996); and, in particular, we referenced the Vegetation of the West Indies, an application of this system to the Caribbean by the Southeast Regional Office of The Nature Conservancy (Weakley, 1996). The U.S. national effort is part of a global initiative to characterize land cover and land use in a standardized manner.

In Antigua-Barbuda, we identified 54 Alliances and Associations—the basic units of conservation planning within this system—within the country of Antigua-Barbuda. Each of these was sufficiently different from one another to be distinguishable in the field. We then identified the conservation status of each of the 54 Alliance/Associations, using a two-tier labeling system modified from the Red Data Book Categories of the International Union for Conservation of Nature and Natural Resources: 16 Alliances/Associations were classified as Rare (very restricted in distribution and/or size); and 5 of these were also considered Endangered (in danger of extirpation).

In St. Kitts-Nevis, the flora could be differentiated into 36 vegetation communities. Eleven are Common, 9 are considered Rare and 16 are Uncommon. The Common communities, with the exception of one coastal community, can be considered Stable, and, fortunately, many of the Rare and Uncommon communities can also be considered Stable because of their isolation and difficult access. However, nearly half (16 of 36) of the vegetation communities are at risk; three of these are Endangered.

An obvious conservation priority for each of these countries is ensuring that at least a few sites of each of these natural communities are protected. Not only would this pro-

tect the country's biodiversity at the ecosystem level, but at the species level it should provide substantial protection of much of the flora and fauna.

Thus, we have at least three different levels at which to consider the issue of ecosystem biodiversity in the Eastern Caribbean. Clearly, the WWF/WB exercise, whose objective was to identify geographic biodiversity conservation concerns for all of the Americas, could not be expected to operate at the fine level of detail that we used in Antigua-Barbuda and St. Kitts-Nevis. Equally clear, the finer-scale level represents a valuable tool in efforts to ensure that each country protects its ecosystem biodiversity. Furthermore, it seems reasonable that something on the order of the 14 ecological categories[8] identified by Howard—rather than just the 4 used in the WWF/WB report for all of the Lesser Antilles—could serve as an appropriate compromise for a careful consideration of landscape-level biodiversity of the Eastern Caribbean.

Unfortunately, while Howard used ecological categories in the descriptions of plant species, the *Flora* does not provide any text or maps showing the distribution of these vegetation types in the Eastern Caribbean. Such an analysis should be a priority in any effort to protect regional biodiversity.

TERRESTRIAL BIODIVERSITY: SPECIES RICHNESS AND ENDEMISM

The number of species that occur in the West Indies is influenced by its small size and insularity, factors that contribute to the relatively high endemism and vulnerability of its biota.

In Appendix 1, we summarize much of the available data on the number of plant and animal species found on each island, with notes on endemism. The data on mammals, reptiles, birds and plants are fairly complete, although it is important to note that, in general, these islands have not been adequately scientifically investigated. We are not suggesting that they contain large numbers of species new to science, but rather that the information on presence/absence of species and their distribution is very incomplete.

Data on other taxa are much less comprehensive and reliable. For example, the freshwater fish fauna of the Antilles is believed to consist of 71 "mostly endemic" species, primarily in Cuba and Hispaniola (Lee *et al.*, 1983). According to this source, only one of these (*Rivulus cryptocallus*, from Martinique) is endemic to the Lesser Antilles, but we were not able to find accounts of any comprehensive surveys of the islands of the Lesser Antilles (Burgess and Franz, 1989).

The state of knowledge of the invertebrate fauna is even more limited. We include a more detailed discussion of invertebrate biodiversity below, because we feel that it of-

[8] Some of the category labels may misleadingly suggest abiotic communities, but each refers to a distinct biological community of plants and associated animals.

fers a biodiversity perspective not possible from analyses of the more traditional foci such as mammals and birds.

Invertebrates

One of the few invertebrate groups that has received substantial attention in the Caribbean is the Coleoptera. The notes below, paraphrased from discussions with Dr. Michael Ivie, an entomologist who has worked extensively in the Virgin Islands, offer an interesting and valuable perspective:

> *Beetles (Order Coleoptera) are the single largest group of organisms on earth. For the West Indies, it is even more dominant than elsewhere because so many other groups are relatively underrepresented or already extinct. Beetles occupy the largest number of trophic levels, have the largest size range, and the greatest ecological diversity of any group of West Indian organisms. Yet, we know very little about them. Further, our knowledge is very uneven geographically, with the best data existing for the Virgin Islands and Guadeloupe.*
>
> *Based on data from the better-studied islands [Table 4], we know that the area and elevation of an island seem to be the best predictors of its species diversity. Thus, St. Kitts, which is larger and higher than St. Thomas should have more beetle species, yet less than 10% of the number known for St. Thomas have been recorded for St. Kitts. Redonda, with 1 known species, would be expected to have more species than Guana, BVI, which has 250 catalogued species.*
>
> *In the Virgin Islands, we have identified some 1400 species; 50% or more of the species on each island are endemic to that island, or at least to that island bank (the land mass that would have been exposed above sea level during the low-water maximum of the Pleistocene period; i.e., ~-200m contour). The Northern Leewards area (from Sombrero, Anguilla to Montserrat) probably contains well over 1,000 undescribed, undiscovered species (and many genera) of beetles alone on the 8 separate Pleistocene banks.*

Ivie goes on to argue that a critical step in trying to identify biodiversity conservation priorities requires that we have a relatively good inventory of at least some groups; and that the best candidates are the vascular plants and at least one of the insect orders. Given the well-established evolutionary and ecological relationship between plants and insects, the inventories would target as many different plant communities as could be identified. Our most effective measure to safeguard the biodiversity of plant species and terrestrial invertebrate biodiversity would be to protect, to the fullest extent possible, representatives of all the different vegetation communities that occur in the Eastern Caribbean.

Table 4. Data from Beetle Studies in the West Indies (M. Ivie, University of Montana, unpublished data).

Island Group	Area (km^2)	Max. Elev. (m)	Known spp Beetles	Estimate of Completeness
Puerto Rico	8897	1333	ca. 1300	< 30%
Virgin Islands	500	527	ca. 1450	ca. 70%
N. Leeward Is.	1045	1307	< 250	ca. 10%
Guadeloupe	1434	898	ca. 1400	ca. 70%
Sombrero	5	12	0	
Anguilla	91	65	7	
St. Martin	91	424	23	
St. Barths	18	281	54	
Barbuda	161	62	9	
Antigua	280	403	87	
Saba	13	864	4	
Statia	21	599	7	
St. Kitts	166	1307	37	
Nevis	93	979	10	
Redonda	5	295	1	
Montserrat	101	909	74	
St. Croix	230	353	>450	
St. Thomas	77	470	>400	
St. John	52	387	>400	
Guana (BVI)	3	245	>250	

Birds

The islands of the Lesser Antilles have a particularly distinct avifauna[9], including seven endemic genera—*Catharopeza, Cichlitherminia, Cinclocerthia, Cyanophaia, Leucopeza,*

[9] There is an ongoing effort to identify similarities and reconcile differences if they exist between Partners in Flight and Birdlife International regarding regional avian conservation concerns. Both these initiatives treat Trinidad and Tobago separately from the rest of the Eastern Caribbean, as does IRF in this report. Contacts for these organizations:

David Wege; Americas Programme Manager; Birdlife International; Wellbrook Court; Girton Road; Cambridge, CB3 0NA, UK; e-mail: <*david.wege@birdlife.org.uk*>.

Chuck Hunter; U.S. Fish and Wildlife Service; Division of Refuges and Wildlife; 1875 Century Boulevard, Suite 420; Atlanta, GA 30345; e-mail: <*chuck_hunter@mail.fws.gov*>.

Melanospiza and *Ramphocinclus* (Birdlife International, 1998). Collectively, they support 25 endemic bird species and an additional 11 subspecies, some of which are expected to be elevated to species status; at least 23 of these taxa are likely vulnerable or known to be highly endangered (C. Hunter, U.S. Fish and Wildlife Service, pers. comm.). Using slightly different criteria, Birdlife International has prepared an account of 'restricted-range species'. Restricted-range species are inherently vulnerable by virtue of their limited distribution, regardless of other factors—they account for 75% of all threatened bird species. Birdlife International identifies 2,600 restricted-range species globally, 130 of which are in the Caribbean; 24 of these are in the Lesser Antilles Endemic Bird Area. Details on endemism—single-island, multi-island, and regional—are provided for each country in Appendix 1.

The Eastern Caribbean is known to serve as an important link in the seasonal migrations of numerous birds. For at least one species, Blackpoll Warbler, most of its total world population is believed to use this area for stop-over sites during autumn. Several species of thrushes, vireos, cuckoos and warblers also migrate through the Eastern Caribbean in large numbers at this time of year. This period overlaps the late summer-autumn tropical storm season, and migrants forced to land are completely dependent upon habitat provided by these Lesser Antillean islands. Some of these species, including Bicknell's Thrush, which is considered a high priority migrant by the U.S. Fish and Wildlife Service, may overwinter in the Lesser Antilles—often in the same habitats supporting highly vulnerable endemic species. The Eastern Caribbean also provides critical stop-over sites for numerous shorebirds that migrate along the Trans-Atlantic route to South America after breeding further north in the temperate zone (C. Hunter, U.S. Fish and Wildlife Service, pers. comm.).

The numerous islands of the West Indies, some little more than rocky outcrops, contain globally significant breeding sites for approximately 25 species of seabirds, many of which are endemic species, sub-species or races. The most recent annual meeting of the Society for Caribbean Ornithology convened a workshop on this topic, and will soon release a report identifying all the known sites, with estimates of the numbers of individuals they support. The preliminary findings highlight: 7 'high priority' species with 4,000 or fewer breeding pairs; 6 'priority' species with between 4,000-8,000 breeding pairs. In at least two cases, Roseate Tern and Magnificent Frigatebird, these small breeding populations represent a substantial percentage of their global populations. The final report is expected to convey the concern shared by the specialists participating at the workshop, who noted that

1) global populations of most seabirds are on the decline;

2) generally, the populations of nesting seabirds tend to be fairly isolated from one another; so that

3) the deterioration or demise of nesting sites may significantly diminish the genetic pool of any given species (D. Lee, North Carolina State University, pers. comm.; Shreiber, Ornithological Society, pers. comm.).

The islands of the Eastern Caribbean share many of the same bird species, face similar conservation issues and threats. We include a profile of one of the islands, Antigua-Barbuda-Redonda, as Appendix 2, in order to look at these avian issues in greater detail.

PROTECTING TERRESTRIAL BIODIVERSITY

To protect the terrestrial biodiversity of the eight GEF-eligible countries of the Eastern Caribbean, biodiversity conservation efforts must operate at the island-specific ecosystem level. Certainly, there are selected narrower targets—endemic and endangered species, for example—that warrant conservation attention, but the most effective protection that will provide coverage for the greatest number of species will require an ecosystem approach.

This is especially relevant for the islands of the Eastern Caribbean, which have:

- a large number of geographically small ecoregions;
- a relatively small number of locally and regionally threatened and endangered, unique or regionally endemic species, especially sparse in relation to the number of potential habitats or ecosystems; and
- extremely high costs of land (average costs of over US$10,000 per acre for undeveloped land are common), implying politically sensitive decision-making in the selection and management of protected areas.

As has been noted elsewhere in this report, neither the ecosystems or the vegetative systems of the islands of the Eastern Caribbean have yet been classified in a manner that could guide development of a parks and protected areas (PPA) system whose objective is the protection of terrestrial biodiversity. Development of appropriate classification systems is certainly feasible, and it is strongly recommended that these efforts be given the highest priority, within a general program to improve management of biodiversity resources.

The existing protected areas identified in Appendix 1 provide a valuable foundation for future efforts. Some include critical habitat needed to preserve the fauna and flora of the region's islands. But, it must be noted that biodiversity conservation *per se* was rarely, if ever, the major criterion in the selection of these sites. In conjunction with implementation of the classification systems proposed above, it should be possible to review the existing PPAs in the eight GEF-eligible islands of the Eastern Caribbean and identify gaps that need to be filled to ensure long-term protection of biological diversity.

Because a detailed vegetation classification and a biodiversity profile[10] have been prepared for Antigua-Barbuda, it is possible to preliminarily identify significant sites for biodiversity conservation in that country. These should include the following:

- The northeastern coastal wetlands of Antigua, adjoining nearshore marine habitats and the adjacent offshore islands
- Codrington Lagoon on the island of Barbuda
- The high elevation areas of Antigua, including and between Wallings and Boggy Peak
- The remaining dry forests of Antigua and Barbuda
- The island of Redonda.

These sites are large relative to the size of the country, and we are not suggesting that they be "fenced off". Instead, we consider them good candidates for protection, using a variety of techniques that feature multiple-purpose sustainable usage of an area while protecting its core biological resources.

MARINE BIODIVERSITY

We believe that the marine biodiversity of the Eastern Caribbean is a valuable global resource whose conservation warrants the concern and assistance of the international community. Virtually all aspects of marine biodiversity are much more poorly understood than for terrestrial biodiversity (de Fontaubert *et al.*, 1996), including the central issue of conservation priorities. We know that while the marine environment is home to only 250,000 of the 1.7 million species catalogued to date, it has been much less explored. Although there probably are fewer species in the marine environment than on land, marine animals show more diversity at the evolutionary and taxonomic level. Of the 33 animal phyla (i.e., the major branches on the tree of life), all but one have some species members in the sea (in contrast, only about half of the phyla have any representative species on the land; de Fontaubert, 1996; WR Report, 1996).

The most recent publication of the annual stock-taking of natural resources, *World Resources: A Guide to the Global Environment*, has this to say about marine biodiversity:

> *Because only about 7% of the oceans have been sampled, the current state of knowledge regarding species distribution and hot spots is poor...Patterns of marine endemism are generally not well known. Most marine species appear to have much larger ranges than terrestrial species because of their life cycles. Many species, including sedimentary organisms such as mussels and coral, produce free-floating planktonic larvae. Their young may drift for as little as a few hours or up to 6 months or more—depending on the species—before changing into their adult forms. This free-floating stage permits these species to disperse well beyond spawning areas.*

[10] Lindsay, K, and B. Horwith, 1997a; and Horwith, B. and K. Lindsay, 1997a.

> *Beyond simply looking at areas with high levels of species richness and endemism, several other criteria can be applied to define conservation priorities. These include protecting ecosystem diversity (preserving representative samples of all habitats and unique ecosystems) and conserving areas noted for their high levels of biological productivity (because they are rich fishing areas) as well as areas that serve as breeding grounds and nurseries (such as estuaries and mangroves) for marine species.* (WR Report, 1996).

Marine Ecosystem Biodiversity

The task of protecting marine ecosystem diversity begins with the same challenges as on land—defining ecological criteria that allow one to define marine 'ecosystems' and identifying their locations. An ongoing initiative led by The Nature Conservancy (TNC) represents the state-of-the-knowledge on marine ecosystem biodiversity in the Caribbean. TNC identified approximately 10 marine 'provinces', analogous to the Major Habitat Types employed in the WWF/WB terrestrial assessment. The Central Caribbean was selected as the pilot area to which TNC applied a finer-scale analysis and identified 51 'coastal systems' based on differences in biota (e.g., coral, sea grass and mangrove) and physical factors (such as water circulation patterns, proximity to land, etc.). These coastal systems represent ecological—not just geographic—differences, so in this respect they are considerably more detailed than the terrestrial assessment. This marine assessment resulted in a two-volume report that is currently under review by a small group of marine specialists that includes the workshop participants that generated the data (J. Tschirky, TNC, pers. comm.).

Coral reefs are considered the mega-diversity areas of the oceans, often compared to tropical rainforests in terms of their biodiversity. They contain an estimated 25% of all marine species and 20% of catalogued marine fish species; yet, they comprise only about 0.1% of the earth's surface. The tropical Atlantic is believed to contain approximately 15% of global coral coverage, the majority of which (9% of global coral coverage) occurs in the Caribbean (de Fontaubert, 1996; WR Report, 1996).

By some estimates, 10% of the world's coral reefs has already been destroyed, and another 60% is in danger of being lost within the next 20 to 40 years (de Fontaubert, 1996). These grave projections may be even worse for the Eastern Caribbean, which faces unprecedented development pressures (Island Resources Foundation, 1991).

The World Resources Institute is working on a global assessment of threats to reefs, which should be published in late June, 1998. WRI staff has agreed to share preliminary products of that study with Island Resources Foundation. In spite of the fact that this paper generally does *not* discuss issues of threat or response to biodiversity loss, we discuss these results here because little information on *threats to reefs* is otherwise available.

For purposes of its *Reefs at Risk* initiative, World Resources Institute identifies four major threats to reefs:

- Sediment and land-based pollution
- Exploitation
- Marine sources of pollution
- Coastal development.

These data on 'threat condition' were translated into a 'reefs at risk' assessment, with disturbing findings: the coastal and near shore waters of the eight countries of interest in the Eastern Caribbean all received *high* or *very high* risk assessments (WRI):

- Antigua-Barbuda,
- St. Kitts,
- the leeward (west) side of Dominica
- the leeward (west) side of St. Lucia,
- south and west coasts of Barbados,
- St. Vincent and Bequia,
- Grenada and Carriacou, and
- portions of Tobago.

Table 5. Summary Threat Characterization for Eastern Caribbean States.

	Sediments	Exploitation	Marine Pollution	Coastal Development	Composite Threat
Antigua-Barbuda		High		Medium	High
St. Kitts-Nevis		High		Medium	Medium
Dominica		High			High
St. Lucia	Medium	High	High	Medium	High
Barbados	Medium	High		Medium	High
St. Vincent & Grenadines	High	High		Medium	Medium
Grenada	Medium	High			High
Trinidad-Tobago	Medium	High	Medium	Medium	High

In other words, the World Resources Institute assessment finds virtually all of the reef systems of the eight proposed biodiversity programs to be highly threatened from the direct and indirect effect of human actions (see Appendix 3 for more details on this initiative).

As we did elsewhere in this report in regard to other natural resource topics, we include a profile to allow for a more detailed examination of a selected country. The data on the marine environment of Antigua-Barbuda are the most recent and most relevant for biodiversity considerations among the target countries; and most of the issues that apply to that country pertain more broadly to the Eastern Caribbean (Appendix 4).

Global significance of reef risk in the Eastern Caribbean: The high risk ranking given to the reefs of the Eastern Caribbean has special global significance given that its reefs are upwind and upstream of all other reef systems in the Wider Caribbean. The dynamics of large marine ecosystems in general, and the Caribbean specifically, are not well known. (IOCARIBE has been coordinating a research proposal on this subject.) In the absence of such knowledge, prudence dictates that the biodiversity of the Eastern Caribbean reefs should be especially cared for because of the reasonable assumption that reefs in the Eastern Caribbean are the sources of both "seed stock" and potential water-born pathogens which might affect all reef systems in the path of the wider Caribbean circulatory systems, including coastal U.S. areas, all of the Bahamas Bank, Bermuda, and the Azores (Ogden, 1997).

Marine Mammals

Within the waters of the Caribbean, 26 of the global total of 78 species of cetaceans have been recorded (Gricks, 1994).

Conservation implications: While there are no country-specific conservation issues regarding cetaceans, many species are endangered throughout their range by hunting and/or over-fishing of their prey. Perhaps the greatest threat, however, is chemical pollution of the world's oceans. Bio-accumulation of PCBs and other toxins in the animals' fat reserves are suspected to contribute to breeding difficulties and illnesses associated with pollution-suppressed immune systems.

PROTECTING MARINE BIODIVERSITY

A 1995 initiative by the Great Barrier Reef Marine Park Authority, World Bank and World Conservation Union identified priority areas for the establishment and management of a global representative system of marine parks and protected areas to conserve marine biodiversity and achieve sustainable use of the marine environment (Kelleher, *et al.*, 1995). This report identified priorities primarily on the basis of ecological and biogeographic criteria, but it also included an assessment of the feasibility of establishing and managing the selected sites as marine protected areas. Two sites were identified within the Lesser Antilles:

- *Barbuda* (a part of the two-island country of Antigua and Barbuda). Barbuda is a low-lying limestone-based island with relatively uniform topography (approximately 62 square miles in size). Coral reefs (extensive development on the eastern coast), mangroves and sandy beaches characterize its coastline. A lagoon averaging about one and a half miles wide runs along most of the western side of the island which, along with satellite ponds, provides a variety of feeding habitats for native and migratory species. The island consists of a group of well-conserved biotypes (coral reefs, sandy beaches and lagoons) of particularly high species richness.

- *Soufriere Marine Management Area* (island of St. Lucia). The Soufriere region is located on the southwestern coast of St. Lucia and is important for its reef resources and the quality of its coastal landscapes, as well as the economic activities these resources support. Coral veneers in the vicinity of Soufriere provide spectacular attractions for divers. The area has been established as a marine management area that includes marine reserves, fishing priority areas and multiple-use areas, with a zoning system that seeks to respond to various resource users in order to achieve compatible conservation and development objectives.

Although this global assessment represents a valuable contribution to marine conservation efforts in the Caribbean, that effort will undoubtedly be further enhanced by the ongoing TNC-led initiative referred to previously in this report.

FACTORS COMPLICATING AN ASSESSMENT OF EASTERN CARIBBEAN BIODIVERSITY

The small size and insularity of the land areas of the Eastern Caribbean correspond to lower numbers of terrestrial species within this region relative to larger, continental areas. But the isolation of the islands also leads to higher levels of endemism than for comparably-sized continental areas. The absence of reasonably comprehensive and current biological data, illustrated dramatically for the Coleoptera, is an obstacle affecting the assessment of almost all of the taxa, to varying degrees. For example, in regard to the herpetofauna, a group that is relatively well-studied, there are about as many subspecies and races identified as there are species; and scientists suspect that there are several cases of taxonomic misidentification and that several 'species' now thought to be distributed throughout multiple islands will turn out to be single-island endemics of new taxonomic revisions (Johnson, 1988; Schwartz and Henderson, 1991; Woods *et al.*, 1989; Horwith and Lindsay, 1997).

For small islands, a critical question is not how many species occur on a hectare of land, but how many of those species would be lost if that hectare was lost. Whereas most continental species have huge ranges, the species occurring on small islands often do not, and therefore the protection of each hectare is far more critical. The majority of the snake species found in the Lesser Antilles are endangered—two species of snake, one

restricted to a tiny islet off the shore of Antigua and the other restricted to tiny islet off the coast of St. Lucia—are among the world's rarest animals. A preserve in Antigua would do nothing to safeguard the St. Lucian endemic snake species, which lives only a few hundred km away. Looked at from another perspective, using Coleoptera to illustrate the point, the Virgin Islands supports an endemic species on every 0.6 hectare, while Brazil takes 5.87 hectares to do the same (M. Ivie, University of Montana, pers. comm.).

This report also argues for the need to recognize the importance of the Eastern Caribbean for marine and terrestrial migratory species, while acknowledging the difficulty in quantifying this contribution. Many of these species are not restricted to the region, but they require access to critically threatened habitat—even if this habitat may not otherwise be considered biologically distinctive within a global context. It would be prudent for the international community to act under the assumption that the Eastern Caribbean is serving as a critical link in the continued existence of this large group of migratory species.

Even though there are situations where it is justified to set conservation priorities, the task should be approached cautiously and conservatively:

> *This should not be a counting game among locations... Comparing a large place with 20 vulnerable endemics with a small place with 5 vulnerable endemics is perhaps not the best way to go in establishing conservation priorities. Instead, should not the point be to emphasize that there are 25 vulnerable species that need attention?* (C. Hunter, U.S. Fish and Wildlife Service).

Bibliography

American Ornithologists' Union Check-list of North American Birds. 1983 (6th edition).

Alston, AHG. 1935. Pteridophyta of Antigua. *J of Botany* V73(366):33-40.

Auffenberg, WA. 1958. A small fossil herpetofauna from Barbuda, Leeward Islands. *Quarterly Journal of the Florida Academy of Sciences*, V21:248-54.

Bacon, PR., 1991. The Status of Mangrove Conservation in the CARICOM Islands of the Eastern Caribbean. Report to the Commission of the European Communities as part of the Tropical Forestry Action Plan for the Caribbean Region; 211 pp.

Bacon, PR. 1993. Mangroves in the Lesser Antilles, Jamaica, and Trinidada and Tobago. pages 155-210 in, LD Lacerda (ed), Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions. Part I-Latin America. International Society for Mangrove Ecosystems. 272 pp.

Barnes, MJC. 1996. A Provisional Guide to Some Common Moths of the Eastern Caribbean. Unpublished in files of Island Resources Foundation. 101 pp.

Barton, M and C Wilmhoff. 1996. Inland fishes of the Bahamas - new distribution record for New Providence. *Bahamas Journal of Science*, V3(2):7-11.

Bass, David. 1996. Unpublished data on freshwater invertebrates, in files of Island Resources Foundation.

Bauchot, M. 1959. La faune ichtyologique des eaux douces antillaises. *Compte Rendu Summaire des Seances de la Societe du Biogeographie*, V36(311):1-26.

Beard, JS. 1949. The natural vegetation of the Windward and Leeward Islands. Oxford For. Mem. 21. Oxford, UK: Oxford University. 192 pp.

Beard, JS. 1955. The classification of tropical American vegetation-types. *Ecology*, V36: 89-100.

Belkin, JN and SJ Heinemann. 1976. Collection records of the project Mosquitoes of Middle America, part 4, Leeward Islands: Anguilla, Antigua, Barbuda, Montserrat, Nevis, St. Kitts. *Mosquito Systematics* V8(2):123-62.

Biodiversity Support Program, Conservation International, The Nature Conservancy, Wildlife Conservation Society, World Resources Institute, and World Wildlife Fund. 1995. A Regional Analysis of Geographic Priorities for Biodiversity Conservation in Latin America and the Caribbean. Biodiversity Support Program, Washington, DC, USA, 140 pp.

Birdlife International. 1998. Endemic Bird Areas of the World - Priorities for Biodiversity Conservation. Birdlife Conservation Series No. 7.

Bond, J. 1980. Birds of the West Indies. Fourth edition. Houghton Mifflin Company. 256 pp.

Breuil, M and D Masson. 1991. Quelques remarques sur la biogeographie des chauves-souris des Petites Antilles. C.R. Biogeogr, V67:25-39.

Breure, ASH. 1974. Caribbean land molluscs: Bulimidae, I. *Bulimulus. Studies on the Fauna of Curacao and other Caribbean Islands.* V45(145):1-80.

Brusca, RC and GJ Brusca. 1990. Invertebrates. Sinauer Associates. 922 pp.

Bunce, L. 1993. Coral Reef Monitoring and Baseline Data of Antigua's Coral Reefs. Unpublished in files of Island Resources Foundation.

Bunce, L. 1996. Post Hurricane Luis assessment of coral reefs in the North Sound. Prepared for the Organization of American States. Unpublished in files of Island Resources Foundation.

Burgess, GH, and R Franz. 1989. Zoogeography of the Antillean Freshwater Fish Fauna. in Woods, CA (ed). 1989. Biogeography of the West Indies. Sandhill Crane Press. U of Florida. pp 263-304.

Cater, J. 1944. Forestry in the Leeward Islands. Development and welfare in the West Indies, bulletins, no. 7. Advocate Co., Ltd., Bridgetown, Barbados.

Censky, E and K Lindsay. 1997. Note on Gymnothalmus underwoodi (Antillean Lizard). Submitted to Herpetological Review.

Collins, M. 1994. Unpublished in files of Island Resources Foundation [The Caribbean Termite Survey collected in Antigua as part of a 58 island Caribbean effort that raised Snyder's 1956 list of 66 species to the new total of 94 species; Collins; Smithsonian Institution].

Coomans. HE. 1958. A survey of the littoral gastropoda of the Netherlands Antilles and other Caribbean islands. Studies on the Fauna of Curacao and other Caribbean Islands V8(31):42-111.

Cory, CB. 1891. A collection of birds taken by Cyrus S. Winch in the islands of Anguilla, Antigua, and St. Eustatius. *The Auk,* V8(1):46-7.

Cory, CB. 1891. Notes on West Indian birds. *The Auk,* V8(1):41-6.

Danforth, ST. 1934. The birds of Antigua. *The Auk,* V51(3):350-364.

Davis, SD, VH Heywood, O Herrera-MacBryde, J Villa-Lobos and AC Hamilton. 1997. Centres of Plant Diversity: A Guide and Strategy for Their Conservation. Volume 3: The Americas. WWF/IUCN.

De Fontaubert, AC, DR Downes and TS Agardy. 1996. Biodiversity in the Seas: Implementing the Convention on Biological Diversity in Marine and Coastal Habitats. IUCN Gland and Cambridge (vii+82 pp).

Deichmann, E. 1963. Shallow water holothurians known from Caribbean waters. Studies on the Fauna of Curacao and other Caribbean islands, V14(63):100-18.

De kort-Gommers, M and N Nieser. 1969. Records of Antillean water-striders (Heteroptera). Studies on the Fauna of Curacao and other Caribbean Islands. V30(112):72-87

Dunkle, SW. 1989. Dragonflies of the Florida Peninsula, Bermuda and the Bahamas. Scientific Publishers. 155 pp. [contact the International Odonata Research Institute; PO Box 1269; Gainesville, FL 32602-1269]

Dunkle, SW. 1990. Damselflies of Florida, Bermuda and the Bahamas. Scientific Publishers. 148 pp. [contact the International Odonata Research Institute; PO Box 1269; Gainesville, FL 32602-1269]

Dunn, ER. 1934. Physiography and herpetology in the Lesser Antilles. *Copeia* V1934?:105-111.

Etheridge, R. 1964. Late Pleistocene Lizards from Barbuda, British West Indies. Bulletin of the Florida State Museum, *Biological Sciences*, V9(2):43-75.

Evans, P. 1990. Birds of the Eastern Caribbean. MacMillan Caribbean. 162 pp.

Federal Geographic Data Committee. 1996. FGDC Vegetation Classification and Information Standards. Draft, available in files of Island Resources Foundation. 35 pp.

Francis, J, C Rivera and J Figueroa. 1994. Toward a woody plant list for Antigua and Barbuda: past and present. Gen. Tech. Rep. SO-102. New Orleans, LA: US Dept of Agriculture, Forest Service, Southern Forest Experiment Station. 28 pp.

Gibbs, PE. 1974. Notes on Uca burgersi Holthius (Decopoda, Ocypodidae) from Barbuda, Leeward Islands. *Crustaceana* V27(1):84-91.

Goreau, M and TJ Goreau. 1996. Ecological Assessment of Antigua and Barbuda Reefs. Report to the Environmental Awareness Group. Unpublished, avaialble in files of Island Resources Foundation.

Gricks, N. 1994. Whale-watching in the West Indies: A Guide to Cetaceans and Sites of the Region. Island Resources Foundation. 40 pp.

Gricks, N, B Horwith and K Lindsay. 1997. Birds of Antigua-Barbuda-Redonda. Unpublished in files of Island Resources Foundation.

Haas, F. 1962. Caribbean land molluscs: Subulinidae and Oleacinidae. Studies on the Fauna of Curacao and other Caribbean Islands. V13(58):49-60.

Harris, DR. 1965. Plants, Animals, and Man in the Outer Leeward Islands, West Indies: An Ecological Study of Antigua, Barbuda and Anguilla. University of California Press. Berkeley and Los Angeles. 184 pp.

Henderson, A, G Galeano and R Bernal. 1995. Field Guide to the Palms of the Americas. Princeton University Press. 352 pp.

Hoedemann, JJ. 1958. Rivulid fishes of the Antilles. Studies on the Fauna of Curacao and other Caribbean Islands, V8(32):112-26.

Holland, CS and JM Williams. 1978. Observations on the birds of Antigua. *American Birds*, V32(6):1095-1105.

Horwith, B and K Lindsay. 1997a. Antigua-Barbuda-Redonda: Biodiversity Profile. Unpublished in files of Island Resources Foundation.

Horwith, B and K Lindsay. 1997b. Mangrove Report. Submitted to Ivor Jackson and Associates. Unpublished in files of Island Resources Foundation.

Horwith, B and K Lindsay. 1997c. Wildlife Report. Submitted to Ivor Jackson and Associates. Unpublished in files of Island Resources Foundation..

Howard, R. 1973. The Vegetation of the Antilles. *In* A. Graham (ed.), Vegetation and Vegetational History of Northern Latin America, pp 1-38. Elsevier Scientific Publishing Company. New York.

Howard, R. 1974. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 1. Orchidaceae by L Garay and H Sweet. Arnold Arboretum, Harvard University.

Howard, R. 1977. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 2. Pteridophyta by G Proctor. Arnold Arboretum, Harvard University.

Howard, R. 1979. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 3. Monocotyledoneae. Arnold Arboretum, Harvard University.

Howard, R. 1988. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 4. Dicotyledoneae—Part 1. Arnold Arboretum, Harvard University.

Howard, R. 1989. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 5. Dicotyledoneae—Part 2. Arnold Arboretum, Harvard University.

Howard, R. 1989. Flora of the Lesser Antilles: Leeward and Windward Islands. Volume 6. Dicotyledoneae—Part 3. Arnold Arboretum, Harvard University.

Humann, P. 1993. Reef Coral Identification: Florida, Caribbean, Bahamas. Vaughan Press. Florida. 239 pp.

Humann, P. 1993. Reef Creature Identification: Florida, Caribbean, Bahamas. Vaughan Press. Florida. 320 pp.

Humann, P. 1993. Reef Fish Identification: Florida, Caribbean, Bahamas. Vaughan Press. Florida. 267 pp.

Island Resources Foundation. 1991. Synthesis of Country Environmental Profiles for the Eastern Caribbean.

Island Resources Foundation. 1996. Characterization of Marine Resources. Prepared for the Organization of American States.

Island Resources Foundation. 1997. Bird Island Marine Reserve Management Plan. Prepared for the Organization of American States.

Jones, KB, KH Ritters, JD Wickham, RD Tankersley, Jr., RV O'Neill, DJ Chaloud, ER Smith and AC Neale. 1998. An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas. US EPA.

Jones, KJ, Jr. 1989. Distribution and Systematics of Bats in the Lesser Antilles (in Woods, CA, ed, Biogeography of the West Indies. Sandhill Crane Press. U of Florida.

Jones, KJ, Jr & DC Carter. 1976. Annotated checklist with Keys to Subfamilies (in Biology of Bats the New World – Family Phyllostomidae, Part 1. Special publications Museum Texas Tech University).

Kaiser, H and JD Hardy, Jr. 1994. Catalogue of American Amphibians and Reptiles. *Eleuthrodactylus martinicensis*. Society for the Study of Amphibians and Reptiles.

Kaiser, H.. 1992. The trad-mediated introduction of *Eleuthrodactylus martinicensis (Anura:Leptodactylidae)* on St. Barthelemy, French Antilles, and its implications for Lesser Antillean biogeography. J. Herpetol. 26:264-273.

Kelleher, G, B Bleakley, and S Wells. 1995. A Global Representative System of Marine Protected Areas. Vol. II: Wider Caribbean, West Africa and South Atlantic. The Great Barrier Reef Marine Park Authority, The World Bank, The World Conservation Union (IUCN).

Kohls, GM. 1969. New records of Ticks from the Lesser Antilles. Studies on the Fauna of Curacao and other Caribbean Islands. V28(106):126-134.

Koopman, KF. 1989. A Review and Analysis of Bats of the West Indies (in Woods, CA, ed, Biogeography of the West Indies. Sandhill Crane Press. U of Florida.

Lanagan, FT. 1844. Antigua and the Antiguans. Vol. II. Saunders and Otley. London. 355 pp.

Lawrence, GN. 1878. Catalogue of the birds of Antigua and Barbuda, from collections made for the Smithsonian Institution, by Mr. Fred A. Ober, with his observations. Proceedings of the United States National Museum, V1:232-42.

Lawrence, GN. 1879. A general catalogue of birds noted from the Lesser Antilles visited by Mr. Fred A. Ober; with a table showing their distribution, and those found in the United States. Procedings of the United States National Museum, V1:486-8.

Lazell, JD and EE Williams. 1962. The Anoles of the Eastern Caribbean (Sauria, Iguanidae). Parts IV-VI. *Bulletin of the Museum of Comparative Zoology*. Harvard University 127(9):451-478.

Lee, DS, SP Platania and GH Burgess. 1983. Supplement. Atlas of North American Freshwater Fishes. North Carolina Biological Survey Contribution No. 1983-6. 67 pp.

Lindsay, K and B Horwith. 1997a. Antigua-Barbuda Vegetation Classification: Implications for Conservation. Prepared as part of Island Resources Foundation Eastern Caribbean Biodiversity Program [manuscript submitted to *Caribbean Journal of Science*].

Lindsay, K and B Horwith. 1997b. Plants Species of Antigua-Barbuda-Redonda. Unpublished in file of Island Resources Foundation.

Lindsay, K and L Blackman. 1997. Freshwater Fish of Antigua-Barbuda. Unpublished in files of Island Resources Foundation.

Little, EL and FH Wadsworth. 1974. Common Trees of Puerto Rico and the Virgin Islands. Second Volume. Washington, DC.

Little, EL and FH Wadsworth. 1989. Common Trees of Puerto Rico and the Virgin Islands. Revision of First Volume (1964). Washington, DC.

Loveless, AR. 1960. The vegetation of Antigua, West Indies. *J of Ecology*, V48(3):495-527.

Lynch, JD. 1960. The status of the tree frog, Hyla babudensis Affunberg, from Barbuda, British West Indies. *Coepia*, V3:524-30.

Lynne, WG. 1957. Notes on a collection of reptiles and amphibians from Antigua. BWI *Herpetologica*, V13:53-56.

MacLean, WP, R Kellner, and H Dennis. 1977. Island Lists of West Indian Amphibians and Reptiles. *Smithsonian Herpetological Information Service*, no. 40 (1977). 48p.

Marcuzzi, G. 1962. Tenebrionid beetles of the West Indies. Studies on the Fauna of Curacao and other Caribbean Islands V13(57):21-48.

Martin-Kaye, P. 1959. Reports on the geology of the Leeward and British Virgin Islands. Voice Publishing Company, St. Lucia. 117pp.

Martin-Kaye, P. 1969. A summary of the geology of the Lesser Antilles. *Overseas Geology and Mineral Resources*, V10:263-286.

Miller, LD and JY Miller. 1989. The Biogeography of West Indian Butterflies (*Lepidopter:Papilionoidea, Hesperoidea*):, Burgess, GH, and R Franz. 1989. Zoogeography of the Antillean Freshwater Fish Fauna. in Woods, CA (ed). 1989. Biogeography of the West Indies. Sandhill Crane Press. U of Florida. pp 263-304.

Morello, J. 1983. Ecological diagnosis of Antigua and Barbuda. Organization of American States, Dept. Reg. Dev., Washington, DC.

Morton, M. 1994. A Short Survey of the Bats of Antigua & Barbuda. Unpublished in files of Island Resources Foundation.

Multer, G. 1996. Antigua reef assessment. Unpublished in file of Island Resources Foundation.

Nutting, CC. 1919. Barbados-Antigua Expedition. Vol VII (3):1-270. Studies in Natural History. University of Iowa Studies.

Ogden, JC. 1997. Marine managers look upstream for connections. *Science*, 278(21 November 1997):1414-1454.

Parker, HW. 1933. Some amphibians and reptiles from the Lesser Antilles. Annals and *Magazine of Natural History*, V11(10):151-158.

Pregill, GKD, W Steadman, SL Olson, and FV Grady. 1988. Late Holocene fossil vertebrates from Burma Quarry, Antigua, Lesser Antilles. *Smithsonian Contr. Zool* V463:1-17.

Pregill, GKD, DW Steadman and DR Watters. 1994. Late Quaternary Vertebrate Faunsa of the Lesser Antilles: Historical Components of Caribbean Biogeography. Bulletin of Carnegie Museum of Natural History. Number 30. 51pp.

Ricklefs, RE and GW Cox. 1977. Morphological similarity and ecological overlap among passerine birds on St. Kitts, British West Indies. *Oikos*, V28.

Riley, JH. 1905. Catalogue of a collection of birds from Barbuda and Antigua, British West Indies. Smithsonian Miscellaneous Collections, V47:277-91.

Riley, ND. 1975. A Field Guide to the Butterflies of the West Indies. Collins. London. 224 pp.

Schmitt, WL. 1959. Narrative of the 1958 Smithsonian-Bredin Caribbean expedition. in An Annual Report of the Smithsonian Institution for 1958. Washington, DC: US Government Printing Office. p 419-30.

Schwartz, A and RF Klinikoski. 1963. Observations on West Indian birds. Proceedings of the Academy of Natural Sciences of Philadelphia, V155(3):53-77.

Schwartz, A and RW Henderson. 1990. The Butterflies of Barbuda, West Indies. Caribbean Journal of Science. Vol 26(3-4):98-100.

Schwartz, A and RW Henderson. 1991. Amphibians and Reptiles of the West Indies: Descriptions, Distributions and Natural History. University of Florida Press. Gaineville. 720 pp.

Schwartz, A. 1967. Frogs of the genus Eleutherodactylus in the Lesser Antilles. Stud. Fauna Curacao and Carib. Is. V23(91):1-62.

Shoemaker, CR. 1959. Three new cave amphipods from the West Indies. J of the Washington Academy of Sciences V49(8):273-283.

Spencer, W. 1981. A Guide to the Birds of Antigua. 16 pp. Unpublished in files of Island Resources Foundation.

Steadman, DW, DR Watters, GK Pregill and SL Olson. 1984. Fossil vertebrates from Antigua, Lesser Antilles: Evidence for late Holocene hman-caused extinctions in the West Indies. Proceedings of the National Academy of Sciences USA, V81:4448-4451.

Stehle, H. 1945. Forest types of the Caribbean Islands. *Caribb. For.* 7(supplement):273-408.

Stiling, PD. 1986. Butterflies and other insects of the Eastern Caribbean. Macmillan Caribbean. 85 pp.

Stock, JH. 1977. The taxonomy and zoogeography of the hadziid amphipoda. Studies on the Fauna of Curacao and other Caribbean Islands V55(177):1-130.

Stoddart, DR, GW Bryan and PE Gibbs. 1973. Inland mangroves and water chemistry, Barbuda, West Indies. *J of Natural History* V7(1):33-46.

Stokes, FJ. 1984. Divers and Snorkelers Guide to the Fishes and Sea Life of the Caribbean, Florida, Bahamas and Bermuda. The Academy of Natural Sciences. Philadelphia. 160 pp.

Terborgh, JW, J Faaborg and HJ Brockmann. 1978. Island colonization by Lesser Antillean birds. *The Auk*, V95:59-72.

Terborgh, JW and J Faaborg. 1980. Saturation of bird communities in the West Indies. *American Naturalist*, V116(2):178-95.

Trinidad and Tobago: Interim First National Report (Revised) to the Convention on Biological Diversity Secretariat. 1997?

Underwood, G. 1962. Reptiles of the Eastern Caribbean. Caribbean Affairs (new series) No. 1. Dept of Extramural Studies, University of the West Indies, Trinidad.

Van Doesburg, PHV, Sr. 1970. Records of Syrphidae (Diptera) from the Lesser Antilles. Studies on the Fauna of Curacao and other Caribbean Islands. V34(126):90-101.

Velez, I. 1957. Herbaceous angiosperms of the Lesser Antilles. San Juan, Puerto Rico: Biology Department. InterAmerican University of Puerto Rico. 121 p. bibliog.

Watkins, FH. 1924. Handbook of the Leeward Islands. 308 pages.

Watters, DR, EJ Reitz, DW Steadman, and GK Pregill. 1984. Vertebrates from archaeological sites on Barbuda, West Indies. Annals of Carnegie Museum, V53:383-412.

Weakley, A.S. 1996. Vegetation of the West Indies (Cuba, the Greater Antilles, the Lesser Antilles, and the Bahamas. Draft. Available in the files of Island Resources Foundation.

Weiss, MP and HG Multer. 1988. Map of Modern Reefs and Sediments of Antigua, West Indies. Department of Geology, Northern Illinois University.

Wheeler, LR. 1916. The botany of Antigua. *J of Botany*, V54:41-52.

Widecast. 1992. Sea Turtle Recovery Action Plan for Antigua and Barbuda. authored by J Fuller, K Eckert and JI Richardson for CEP Technical Report No. 16. 88 pages.

Woods, CA (ed). 1989. Biogeography of the West Indies. Sandhill Crane Press. U of Florida.

World Wildlife Fund. 1996. A Conservation Assessment of Mangrove Ecosystems of Latin America and the Caribbean. eds. DM Olson, E Dinerstein, G Cintron and P Iolster. 44 pp.

Appendix 1: Biogeographical Overview of Selected Eastern Caribbean Countries

	General	Antigua-Barbuda	St. Kitts-Nevis	Dominica	St. Lucia	St. Vincent and the Grenadines	Grenada	Trinidad-Tobago	Barbados
Ecological Features		Antigua: Mainly coral-based and low-lying with undulating hills of volcanic origin in the south; coastline deeply indented with many natural harbors; white sand beaches, sea grass beds, fringing reefs Barbuda: Low limestone island; to the north and west is an area of lagoons and ponds separated by beach ridges and mangrove swamps; extensive reefs on eastern coast	St. Kitts: High volcanic island with a central mountain range; golden sandy beaches surround the southeast peninsula, although most island beaches are of gray to brown volcanic sand; narrow coastal shelf Nevis: Volcanic origin, dominated by a central peak; no bays, inlets or cays of significance but long stretches of sandy beaches; many wetlands along leeward coast	High volcanic mountains rising in the south to 1,424 m and in the north to 1,730 m; rain forests, lakes, waterfalls and numerous rivers; little flat land apart from the Portsmouth area which has two swamps	High volcanic island with rugged interior displaying fertile valleys indented by rain-forest-covered mountains; white sand beaches, sea grass beds, coral reefs	St. Vincent: rugged volcanic mountains in the interior with deeply dissected ridges and valleys; rain forests, numerous rivers, and black sand beaches Grenadines: 32 small islands and cays that are lower and drier than St. Vincent, with extensive reefs, numerous protected bays and white coral sand beaches	Volcanic island with some limestone in the north; mountainous and thickly wooded with numerous streams and rivers; beaches, sea grass beds, mangroves	Tropical forests, swamps, reefs, beaches	Low flat volcanic island, narrow submarine shelves, sand beaches, mangroves, sea grass beds, coral reefs
Forest Cover In Hectares and (% of Total Land Area)		9,000 (20.5)	5,000 (19.2)	41,000 (54.6)	8,000 (13)	12,000 (30.8)	5,000 (14.5)	208,000 (43)	negligible
Area of Coral Reefs		25 km^2 of reef, mostly fringing (WCMC data)	Bank barrier reefs occur along much of the coast of both islands	Limited reef development, mainly on west coast	Widespread reefs that are generally small and not well developed	Scattered fringing reefs with most extensive, well-developed coverage around Tobago Cays in the Grenadines	Grenada: patchy reefs around all but west coast Carriacou: large barrier reef on windward side	Trinidad: only small patches of coral Tobago: important but not extensive reefs	Fringing reefs, generally poorly developed, around west side of island
Species Lists: Mammals	44 mammals (excluding cetaceans) are known from the LA (4 are believed to be extinct); 24 are bat spp., 7 of which are endemic to the LA (29%); within the LA, only Grenada has native terrestrial mammals (Jones, 1989; Woods, 1989). 26 cetacean spp (Gricks, 1994)	2 LA endemic bat species: *Monophyllus plethodon*, *Brachyphylla cavernarum*, and 1 Caribbean? regional *Artibeus jamaicensis* (Horwith & Lindsay, 1997; CEP) Introduced terrestrial mammals include a sub-species, *Dama dama dama* (Horwith & Lindsay, 1997; CEP)	5 regional endemic bat species: *Monophyllus plethodon*, *Ardops nichollsi*, *Brachyphylla cavernarum*, *Myotis dominicensis*, *Artibeus jamaicensis* (CEP) Introduced mammals include *Cercopithecus aethiops*, *Odocoileus virginianus* (CEP)	4 of 12 bat spp are regional endemics: *Monophyllus plethodon*, *Ardops nichollsi*, *Brachyphylla cavernarum*, *Myotis dominicensis* (Johnson, 1988)	3 regional endemic bat spp: *Monophyllus plethodon*, *Ardops nichollsi*, *Brachyphylla cavernarum* (Johnson, 1988)	3 regional endemic bat spp: *Monophyllus plethodon*, *Ardops nichollsi*, *Brachyphylla cavernarum* (Johnson, 1988)	None of the 11 bat species are single or regional endemics (Johnson, 1988) 4 native terrestrial species: *Dasypus novemcinctus*, *Marmosa fuscata carri*, *M. robinsoni chapmani*, *Dasyprocta albida* (CEP)	1 of the 100 spp is endemic (WRI, 1996)	

Appendix 1 (continued): Biogeographical Overview of Selected Eastern Caribbean Countries

	General	Antigua-Barbuda	St. Kitts-Nevis	Dominica	St. Lucia	St. Vincent and the Grenadines	Grenada	Trinidad-Tobago	Barbados
Birds	Of the approximately 200 species that occur in the LA, about 100 are resident; estimates of endemism range from 24 species (Birdlife International, 1998) to 35 species and subspecies (Hunter, pers comm., U.S. Fish & Wildlife Service; other key references are Evans, 1990; Bond, 1980)	8 LA endemics: *Dendroica adelaidae* subspecies (Barbuda, St. Lucia), *Eulampis jugularis*, *Myiarchus oberi*, *Margarops fuscus*, *Loxigilla noctis*, *Dendroica petechia bartholemica*, *Cinclocerthia ruficauda*, *Buteo platypterus* sub-sp (Hunter, pers comm., U.S. Fish & Wildlife Service)	1 single-island endemic, *Loxigilla portoricensis grandis*, maybe extinct; 6 LA endemics: *Eulampis jugularis*, *Myiarchus oberi*, *Margarops fuscus*, *Loxigilla noctis*, *Dendroica petechia bartholemica*, *Cinclocerthia ruficauda* (Hunter, pers comm., U.S. Fish & Wildlife Service)	2 single-island endemics: *Amazona arausiaca*, *A. imperialis*; 13 LA endemics: *Chaetura martinica*, *Eulampis jugularis*, *Cyanophaia bicolor* (Dom, Mart), *Myiarchus oberi*, *Cichlherminia lherminieri*, *Cinclocerthia ruficauda*, *Margarops fuscus*, *Loxigilla noctis*, *Dendroica plumbea* (Dom, Guad), *Dendroica petechia amelanoptera* (Dom, Guad), *Saltator albicollis* sub-sp, *Buteo platypterus* sub-sp, *Troglodytes* aedon *matinicensis* (Johnson, 1988; Hunter, pers comm., U.S. Fish & Wildlife Service)	6 single-island endemics: *Amazona versicolor*, *Melanospiza richardsoni*, *Leucopeza semperi* (maybe extinct), *Icterus laudabilis*, *Caprimulgus otiosus* sub-sp, *Dendroica petechia babad*; 12 LA endemics: *Dendroica adelaidae* subspecies (endemic to Barbuda and St. Lucia), *Chaetura martinica*, *Eulampis jugularis*, *Myiarchus oberi*, *Cichlherminia lherminieri*, *Cinclocerthia ruficauda*, *Ramphocinclus brachyurus*, *Margarops fuscus*, *Loxigilla noctis*, *Saltator albicollis* sub-sp, *Buteo platypterus* sub-sp, *Troglodytes aedon matinicensis* (Johnson, 1988; Hunter, pers comm., U.S. Fish & Wildlife Service)	3 single-island endemics: *Amazona guildingii*, *Catharopeza bishopi*, *Dendroica petechia alsiosa*; 9 LA endemics: *Chaetura martinica*, *Eulampis jugularis*, *Myiarchus nugator*, *Cinclocerthia ruficauda*, *Margarops fuscus*, *Loxigilla noctis*, *Tangara cucullata* (SVG, Gre), *Buteo platypterus* sub-sp, *Troglodytes aedon matinicensis* (Johnson, 1988; Hunter, pers comm., U.S. Fish & Wildlife Service)	1 single-island endemic: *Leptotila wellsi*; 6 LA endemics: *Myiarchus nugator*, *Margarops fuscus*, *Loxigilla noctis*, *Tangara cucullata* (SVG, Gre), *Troglodytes aedon matinicensis*, *Buteo platypterus* sub-sp (Johnson, 1988; Hunter, pers comm., U.S. Fish & Wildlife Service)	1 of 420 species is endemic (T&T:IFNR, 1997?)	1 single-island subspecies endemic: *Dendroica petechia petechia*; 2 LA endemics: *Margarops fuscus*, *Loxagilla noctis* (Hunter, pers comm., U.S. Fish & Wildlife Service)
Reptiles	36 of the 45 lizard spp. in the LA are endemic (80%); 16 of the 20 snake spp. in the LA are endemic (80%) (Schwartz & Henderson, 1991) Marine turtles: Caretta caretta, *Chelonia mydas*, *Dermochelys coriacea* and *Eretmochelys imbricata* nest throughout (Widecast, 1992)	1 single-island endemic: *Alsophis antiguae* (Horwith and Lindsay, 1998)	No endemics	2 single-island endemics: *Ameiva fuscata*, *Anolis oculatus*; 6 regional endemics: *Sphaerodactylus fantasticus*, *S. vincenti*, *Iguana delicatissima*, *Alsophis antillensis*, *Liophis* (*Dromiscus*) *juliae*, *Typhlops dominicana* (Johnson, 1988)	5 of 18 species are single-island endemics: *Anolis luciae*, *Sphaerodactylus microlepis*, *Cnemidophorus vanzoi*, *Liophis* (*Dromicus*) *ornatus*, *Bothrops caribbaeus*; 4 are regional endemics: *Sphaerodactylus vincenti*, *Anolis wattsi*, *Gymnophthalmus pleei*, *Leptotyphlops bilneata* (Johnson, 1988)	3 single-island endemics: *Anolis griseus*, *A. trinitatus*, *Chironius vincenti*; 3 regional endemics: *Gymnophthalmus underwoodi*, *Sphaerodactylus vincenti*, *Mastigodryas bruesi* (Johnson, 1988)	Single-island species (2): *Typhlops tasymicris*, *Clelia clelia groomei* (subspecies); regional endemics (3): *Anolis aeneus*, *A. richardi*, *Mastigodryas bruesi* Marine turtles: *Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea* and *Eretmochelys imbricata* nest throughout (Johnson, 1988)	2 of the 70 species are endemic (WRI, 1996)	

Appendix 1 (continued): Biogeographical Overview of Selected Eastern Caribbean Countries

	General	Antigua-Barbuda	St. Kitts-Nevis	Dominica	St. Lucia	St. Vincent and the Grenadines	Grenada	Trinidad-Tobago	Barbados
Amphibians	8 of the 14 spp. in the LA are endemic (57%)	1 of the 2 species is an LA endemic: *Eleutherodactylus johnstonei*	1 LA endemic: *Eleutherodactylus johnstonei* (CEP)	2 regional endemics: *Eleutherodactylus martincensis, Leptodactylus fallax* (Johnson, 1988)		1 single-island endemic sub-species: *Eleutherodactylus urichi shrevei* (Johnson, 1988)	4 species, 1 endemic sub-species: *Eleutherodactylus urichi euphronides* (Johnson, 1988)	2 of the 26 species are endemic (WRI, 1996)	
Freshwater Fishes	Although the freshwater fish fauna of the Antilles consists of 71 "mostly endemic" species (primarily in Cuba and Hispaniola), the Lesser Antilles apparently has only 1 endemic species, *Rivulus cryptocallus*, from Martinique (Burgess and Franz, 1989); Lee *et al.* (1983) list 5 native species, but Burgess and Franz (1989) think that 3 of these—*Poecilia vivipara, P. reticulata* and *Synbranchus marmoratus*—are introduced							76 known species--no data on endemism (WRI, 1996).	
Plants		3 threatened, 1 endemic (WCMC); A-B is one of the few countries with a recorded flora: 4 species of gymnosperms in 3 families; 1109 species of Angiosperms in 141 families (Lindsay and Horwith, 1997)	3 threatened, 0 endemics (WCMC)	59 threatened, 97 endemic (WCMC)	9 threatened, 3 endemic (WCMC)	8 threatened, 4 endemic (WCMC)	5 threatened, 4 endemic (WCMC)	16 threatened, 27 endemic (WCMC) WRI (1996) lists 236 of 1,982 flowering plants as endemic T&T:IFNR (1997? lists 110 of 2160 species as endemic	3 threatened, 2 endemic (WCMC)

Appendix 1 (continued): Biogeographical Overview of Selected Eastern Caribbean Countries

	General	Antigua-Barbuda	St. Kitts-Nevis	Dominica	St. Lucia	St. Vincent and the Grenadines	Grenada	Trinidad-Tobago	Barbados
Pteridophytes	In the LA: 323 species in 68 genera and 11 families; 46 taxa, or 14%, endemic. (Howard)	45 species of ferns and fern-allies in 5 families (Lindsay and Horwith, 1997), an addition of 17 spp (60%) to Howard's total of 28 for these islands	SK:129; N:79 (Howard)	194 (Howard)	116 (Howard)	SV:162; G:3 (Howard)	151 (Howard); 1 single-island endemic: *Danaea* sp (Johnson, 1988)		30 (Howard)
Orchids and Other Monocots	In the LA: 141 species of orchids in 44 genera, 4 endemic (Howard)			1 endemic orchid, *Epidendrum discoidale* (Howard)		2 endemic orchids, *Chloraea ulantha, Cyrtopodium andersonii* (Howard)	1 endemic orchid, *Oreodoxa oleracea* (Johnson, 1988)		
Protected Area Coverage: size in hectares & (number) & [% total land area protected]		6,628 (3) [15.1] Antigua • Nelson's Dockyard National Park, 4,128 ha • Diamond Reef Marine Park, 2,000 ha Barbuda • Palester Reef Marine Park, 500 ha	94 (1) [<1] St. Kitts • Brimstone Hill National Park Nevis None	7,403 (2) [9.86] • Morne Trois Pitons National Park, 6,872 ha • Cabrits National Park, 531 ha	2,026 (4) [3.29] • Central Forest Parrot Sanctuary, 1,494 ha • Maria Islands Marine and Nature Reserve, 12 ha • Pigeon Island Na tl. Park, 20 ha • Savannes Bay Mangrove Area (marine & nature reserve), 500 ha + 22 additional marine reserves, estimated 80 ha (CEP, WCMC data)	8,284 (2) [21.3] • Parrot Reserve, 4,399 ha • Tobago Cays National Park, 3,885 ha	None A system of national parks and protected areas was proposed in 1988, including 27 areas in Grenada and 16 in Carriacou, representing 4,458 ha [13% of land area] + several marine areas (CEP); there may have been recent action on establishment of Levera National Park and Mt. Hartman Bird Sanctuary (pers comm., Vincent, OAS)	15,728 (6) [3.07]	230 (1) [<1] • Barbados Marine Reserve

Note: References to "CEP" in the above table refer to the *"Country Environmental Profiles"* published in 1991 by Caribbean Conservation Association and Island Resources Foundation. Profiles were prepared for the following target countries: Antigua-Barubda, Dominica, Grenada, St. Kitts-Nevis, St. Lucia, and St. Vincent and the Grenadines.

Appendix 2

Avian Conservation in the Lesser Antilles: The Case of Antigua-Barbuda-Redonda

Research during the past decade has substantially increased the number of bird species recorded for Antigua and Barbuda from 106 (Faaborg and Arendt, 1985) to 182 (Gricks *et al.*, 1997). Approximately two-thirds of these species are migratory. Of the other third, some 20 of the species that occur in the country are restricted to the Caribbean basin (primarily West Indian, but some also occurring on adjoining mainland). The country has at least 8 Lesser Antillean endemics, 1 of which, a sub-species or race of the Adelaide's Warbler, is found only in Barbuda and St. Lucia.

Several species are known from the fossil record: 3 of these are extinct; 12 are extirpated from Barbuda and 8 are extirpated from Antigua (Pregill *et al.*, 1994).

Several two-to-three-year periods of severe drought over the past two decades are assumed to have impacted bird populations; as did the hurricanes of 1995. Drastic reductions in the populations of many of the small song bird species were noted, especially for the three hummingbird species. Unregulated and excessive misuse of pesticides also may be affecting bird populations, especially species that frequent farms and residential areas. For example, older people say that there have been reductions in the numbers of Ground Dove and Zeneida Dove, even though hunting of these two species has declined over the past several decades to the point that it is only a minor recreational activity.

Conservation implications: The major threat to local birds is loss of habitat, in particular mangroves and other wetlands. Even mangroves with nesting herons and chicks have been bulldozed. Species that are particularly at risk in Antigua due to deterioration of wetland habitat include: Black-crowned Night Heron, West Indian Whistling Duck, White-cheeked Pintail, Ruddy Duck, Masked Duck, Clapper Rail, Caribbean Coot, and the Magnificent Frigatebird. Despite the conservation importance of mangroves and associated wetlands, and despite the alarming rate at which they are being destroyed and degraded, we do not have accurate, quantitative data on the amount that has been lost in recent years or the amount remaining. Bacon (1991) provides the best information, but it lacks adequate detail at the site level and is in need of updating. The destruction of any particular site is unfortunate, and should only be allowed if justified by a careful cost-benefit analysis; but it is the cumulative impacts of the loss of these sites that is the most serious cause for concern and the reason for requiring a different approach to the evaluation (Horwith and Lindsay, 1997; Bacon, 1993).

Neither economists nor ecologists pretend that they can reasonably quantify all of the direct and indirect benefits that result from healthy functioning wetlands—but most

responsible people in both disciplines acknowledge that these values exist and that there may be a steep price to pay if these ecosystems are destroyed. In areas where mangroves can exist (not all coastline provides the appropriate requirements), they are considered to be the keystone component—essential to the well-being of the nearshore fisheries, seagrass beds and coral reefs (WWF, 1996).

Redonda, and many of the small islands off the Antiguan mainland, especially those in the North Sound, provide valuable nesting habitat for Brown Pelican, Black-crowned Night Heron and several seabird species: Laughing Gull, Roseate Tern, Least Tern, Bridled Tern, Sooty Tern, Brown Noddy, and Red-billed Tropic Bird.

Guiana Island supports a population of between 80-100 West Indian Whistling Ducks. The Society of Caribbean Ornithology considers this species threatened and has established a West Indian Whistling Duck Working Group to collect better regional data on the duck and develop an action plan to safeguard its survival.

Table 1/Appendix 2 below identifies bird species of special conservation concern for the country. This list includes 42 species, or more than 20% of the avian fauna, and is this high because of the extent of threatened habitat in the country.

Table 1 for Appendix 2
Antigua-Barbuda-Redonda Bird Species of Special Conservation Concern (Rare; and/or Vulnerable, Endangered; and/or Endemic).

Audubon's Shearwater (*Puffinus lherminieri*)	Widespread breeder in Eastern Caribbean, but Redonda is only nesting site in the country
Red-billed Tropic bird (*Phaethon aethereus*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound
Masked Booby (*Sula dactylatra*)	Redonda is 1 of only 12 known nesting sites in the Caribbean
Brown Booby (*Sula leucogaster*)	Redonda is one of the few nesting sites in the Caribbean
Red-footed booby (*Sula sula*)	Redonda is 1 of 3 nesting sites in the Lesser Antilles
Brown Pelican (*Pelecanus occidentalis*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound
Magnificent Frigatebird (*Fregata magnificens*)	Common, Vulnerable due to dependence on Codrington Lagoon mangrove stand for nesting
Black-crowned Night Heron (*Nycticorax nycticorax*)	Rare throughout Lesser Antilles; Vulnerable due to threats to nesting habitat
West Indian Whistling Duck (*Dendrocygna arborea*)	West Indian endemic. Rare, Endangered in Lesser Antilles due to habitat loss and hunting
White-cheeked Pintail (*Anas bahamensis*)	Uncommon, Vulnerable in Lesser Antilles due to habitat loss and hunting
Ruddy Duck (*Oxyura jamaicensis*)	Rare, Vulnerable in Lesser Antilles due to habitat loss
Masked Duck (*Nomonyx dominica*)	Rare, Vulnerable in Lesser Antilles due to habitat loss
Osprey (*Pandion haliaetus*)	Rare winter visitor
Broad-winged Hawk (*Buteo platypterus insulicola*)	LA endemic sub-species
Peregrine Falcon (*Falco peregrinus*)	Rare, Endangered in Antigua and globally
Clapper Rail (*Rallus longirostris*)	Rare, Vulnerable to habitat loss
Caribbean Coot (*Fulica caribaea*)	West Indies and north-western Venezuala
Laughing Gull (*Larus artricilla*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound

Roseate Tern (*Sterna dougallii*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound
Least Tern (*Sterna antillarum*)	Rare, Vulnerable due to threats to nesting habitat in North Sound
Bridled Tern (*Sterna anaethetus*)	Rare, Vulnerable due to threats to nesting habitat in North Sound
Sooty Tern (*Sterna fuscuta*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound
Brown Noddy (*Anous stolidus*)	Uncommon, Vulnerable due to threats to nesting habitat in North Sound
Red-necked pigeon (*Columba squamosa*)	West Indies endemic
White-crowned pigeon (*Columba leucocephala*)	West Indies (and Florida Keys)
Zenaida Dove (*Zenaida aurita*)	West Indies (and Yucatan Peninsula)
Bridled Quail-Dove (*Geotrygon mystacea*)	Lesser Antilles & Puerto Rico
Ruddy Quail-Dove (*Geotrygon montana*)	West Indies (and Central and South America)
Mangrove cuckoo (*Coccyzus minor*)	Lesser Antillean sub-species?
Antillean Nighthawk (*Chordeiles gundlachii*)	West Indies; Uncommon in Barbuda
Purple-throated Carib (*Eulampis jugularis*)	Lesser Antillean endemic
Green-throated Carib (*Sericotes holosericeus*)	Lesser Antilles, Virgin Islands & Puerto Rico
Antillean Crested Hummingbird (*Orthorhyncus cristatus*)	Lesser Antilles, Virgin Islands & Puerto Rico
Lesser Antillean Flycatcher (*Myiarchus oberi*)	Lesser Antillean endemic (Barbuda, not Antigua)
Caribbean Martin (*Progne dominicensis*)	West Indies (Rare in Antigua); winters in South America
Tropical Mocking Bird (*Mimus gilvus*)	Rare, only on Guiana Island; Vulnerable
Scaly-breasted Thrasher (*Margarops fuscus*)	Lesser Antillean endemic

Brown Trembler (*Cinclocertia ruficauda*)	Lesser Antillean endemic. Extirpated from Antigua and Barbuda, where it is known from fossil records and occasional sightings of vagrants from neighboring islands
Adelaide's Warbler (*Dendroica adelaidae*)	Lesser Antillean sub-species endemic to Barbuda and St. Lucia
Yellow Warbler (*Dendroica petechia bartholemica*)	Lesser Antillean endemic sub-species
Blue-headed Euphonia (*Euphonia musica sp?*)	Lesser Antillean endemic sub-species?
Lesser Antillean Bullfinch (*Loxigilla noctis*)	Lesser Antillean endemic

Note: This list follows the order and nomenclature adopted by the American Ornithologists' Union Check-list of North American Birds (1983, 6th edition), which includes the Caribbean. Other key references (Hunter, U.S. Fish & Wildlife Service, pers comm.; Birdlife International, 1998).

Appendix 3

World Resources Institute's Reefs at Risk Project

Reefs at Risk is a global assessment of likely threats to coral reefs, which will be evaluated under four separate threat factors:

- coastal development,
- marine-based pollution,
- over-exploitation of marine resources, and
- land-based pollution, including sedimentation.

The first three threat factors are evaluated based upon threshold distances from "stressors", while the third involves a more complex watershed-based modeling approach. In the case of coastal development, for example, the stressors potentially threatening reefs include cities, settlements, airports, mines, and tourist resorts.

Some of the associated distance threshold rules are simple, such as, any reef within 10 kilometers of an airport (military or civilian) is under medium threat from that stressor. In the case of cities, the distance threshold is based upon city size and whether or not the given country is likely to have reasonable sewage treatment.

The marine-based pollution threat factor includes as stressors: medium and large-size ports, oil rigs and tanks, and shipping hot spots (zones of high ship traffic and narrow passage).

The over-exploitation threat factor makes use of estimates of coastal population density to estimate the threat from Malthusian over fishing and uses an expert-derived mapping of areas at risk from destructive fishing practices (primarily cyanide and blast fishing).

The original distance thresholds were developed based upon data on known impacted reefs from ICLARM's ReefBase, which were used as distance benchmarks where possible. The set of "stressors" and their associated decision rules were the subject of and were revised as a result of two workshops. The first workshop, where our preliminary results for Africa were presented, was held in Washington DC in early August. Our methodology was revised based upon workshop results and was implemented for the world. The revised methodology and draft global results (as depicted on attached maps) were the subject of a workshop held at ICLARM in Manila in late September. The second workshop led to further refinement of the methodology and the development of two "expert derived" data layers reflecting areas at risk to destructive fishing and "shipping hot spots." (For example, preliminary destructive fishing zones were developed

based upon 20 km buffers of known occurrences of destructive fishing as shown in ReefBase. These zones were then modified on hardcopy maps at the workshop.)

The Land-based Pollution threat factor is significantly more complicated to implement as it involves hydrologic modeling. A detailed description of the pilot implementation for Africa is available upon request.

For more information on the Reefs at Risk Project contact:

Lauretta Burke or Dirk Bryant
WRI / Reefs at Risk Project
+1 202 662-2593
+1 202 638-0036 (fax)
e-mail: <*lauretta@wri.org*>
or <*dirk@wri.org*>

Appendix 4

Marine Biodiversity in the Lesser Antilles: The case of Antigua-Barbuda-Redonda

Even though we do not have quantitative data on the deterioration of the Antigua-Barbuda's marine environment, the trend is clear and disturbing. In 1996, Island Resources Foundation examined a total of 110 sites in 7 areas of the North Sound and found:

- *Most hard corals in shallow areas are dead.* Over 95% of the hard corals surveyed in waters of approximately 9.1 meters or shallower are dead. This problem is spread over a wide geographic area (all seven areas) and occurs in both *linear* (including bank barrier and fringing reefs) and *patch* reefs (relatively isolated, with characteristic ring of bare sand from fish and sea urchins that inhabit the reef and graze the vegetation close to it).

- *Deeper reefs tend to be healthier.* Studies confirm this relationship, one recognized by the fishermen and divers. Bunce's October 1995 post-Hurricane Luis study of several reefs at depths of 9.1-13.7 meters labeled them in "good" health (Bunce, 1996). Other studies of reefs in Antigua and elsewhere in the Caribbean often note the better condition of corals at depths of 18.2 meters and more.

- *Changes in the resource base.* There has been significant deterioration of hard and soft corals with replacement (or overgrowth) of macroalgae and seagrass. Much of the reef recorded in 1988 (Weiss and Multer, 1988) now appears as sand/coral/sea grass.

While it is possible to show that some of the areas previously recorded as coral have deteriorated, the 1988 map does not distinguish live coral from dead coral, and therefore it is not possible to quantify the decrease in the percent of live corals over this time period[11]. However, the few studies that do exist present an alarming picture. Multer collected some live coral coverage data from a few transects in the Great Bird Island area in the 1980s. We resurveyed the approximate areas (but we couldn't know if we were looking at the exact same spots) and found 75% and more dead coral with isolated live coral heads, where he had recorded less than 25% dead corals (Multer, 1996).

Multer also surveyed reefs in other parts of Antigua (Nonsuch Bay, Goat Head, and Bishops Reef). He first surveyed these sites in 1983, and then resurveyed them in early

[11] The question of how to measure the health of coral reef systems is controversial among marine specialists. The percentage of live vs dead coral coverage is considered to be one of the more informative measurements, but raises two concerns: (1) it is subject to sampling bias because reef boundaries are not well-defined in nature and there has been a tendency to sample the more species-rich sites; (2) there is disagreement within the scientific community on live:dead coral ratios in 'natural' conditions—some estimates suggest that it may be as low as 50% as an overall average covering a wide range of habitat, and less than 25% in selected areas (pers comm, B. Hatcher, Dalhousie University).

1996. In all three areas, he observed that three-quarters of the corals alive in 1983 were dead 13 years later (Nonsuch Bay declined from 35% live corals to 7%; Goat Head and Bishops Reef went from 20% to 5%; and 15% to 2%, respectively). Soft corals showed a comparable decrease.

Goreau and Goreau (1996) conducted a rapid ecological assessment of coral reefs off the coasts of Antigua and Barbuda. They also reported that most sites were dominated by dead coral rubble and had live coral cover of only between 5% and 20%. These figures were approximately the same as those reached by Bunce (1993; 1996) and the Fisheries Division, who based their findings on detailed transect surveys.

Equally important in this analysis, is the near-universal response of fishermen and dive operators, who report the same pattern of deterioration over the past 20 years or more.

Several factors, possibly interacting synergistically, have been proposed to account for the deterioration of coral reefs in the Caribbean. Although their relative impacts on Antigua's reefs are not known, the following stresses are assumed to be involved:

Natural stresses:

- Predation by other organisms and cannibalism by other corals;
- Crowding and substrate take-over by algae;
- Bleaching;
- Black line disease, white line disease, and related pathogens;
- Physical breakage and high turbidity;
- Long term climate (temperature) changes.

Human-induced stresses:

- Over-fishing;
- Nutrient-enriched runoff and biocides (pesticides, herbicides, and fungicides)
- Hydrocarbons and trace elements from terrestrial waste streams and marine products;
- Anchor, boat grounding and swimmer damage and coral removal (site-specific, and observed as a factor around Great Bird Island);
- Suspended sediment discharge following rainy periods from unstabilized slopes, spoil banks, construction sites, roads, ravines, etc. (world-wide, this is considered the greatest single factor).