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Conservation Assessment of the Insular Caribbean Using The Caribbean Decision Support System

Summary Report

A Full Technical Report is Also Available

Principal Author: **Annette Huggins**

Co - Authors: **Anthony Chatwin**
Richard Jeo
Shirley Keel
Phillip Kramer
Francisco Núñez
Steve Schill

Contributors: **Matthew McPearson**
Kim Thurlow
Michelle Libby
Rick Tingey
Michael Palmer
Raquel Seybert

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EXECUTIVE SUMMARY

Stretching across three million square kilometers of shimmering turquoise seas, and including more than five thousand islands and cays, the Caribbean is home to some of the world's biologically richest freshwater, land and marine environments, which are home to thousands of plants and animals, hundreds of which are unique endemics found nowhere else on Earth. These ecosystems are closely interlinked with the communities of twenty three culturally diverse nations and territories. It is also, however, one of the World's most imperiled regions. Human activities in the region are often intense, which can have disastrous effects on the region's species and habitats. Conservation is consequentially challenging in this threatened, diverse, and globally important area. The Nature Conservancy is addressing this challenge through a strong on-the-ground presence lead by country programs that employ science-based conservation strategies with local partners.

To facilitate this approach, a regional biodiversity assessment was initiated that built a framework of data and tools to aid systematic conservation planning and decision making and to guide conservation strategy development. This framework has been developed into the Caribbean Decision Support System (CDSS). The CDSS encompasses two primary components: the first is a detailed database housing vast geospatial information layers about a) habitats (e.g. turtle breeding grounds, mangroves, and coral reefs); b) threats to habitats (e.g. tourism, pollution and road construction); and c) protected areas; and the second component is a suite of tools designed to a) create "environmental risk surfaces" that indicate the level of threat to a particular habitat or species and are used to identify and assess protected area networks and conservation measures; b) identify critical areas of rare habitats across a landscape, and; c) facilitate the use of the site selection software MARXAN (Ball & Possingham, 2000; www.ecology.uq.edu.au/marxan) to create optimal protected area scenarios based on quantitative conservation goals while minimizing impending threats to habitats.

Using the CDSS and working with local experts, the Caribbean biodiversity conservation assessment identified a portfolio of priority areas that represent the region's biodiversity to achieve regional goals and objectives. The process involved steps to; identify and map biodiversity elements known as targets; identify quantitative goals for the amount of each target to be represented; identify and map factors, such as threats, that may affect the suitability of candidate sites for inclusion in the portfolio of conservation areas; and analyze these data to identify a portfolio of priority conservation areas.

Ecosystem, landscape and species level biodiversity elements, known as targets, that represent a full spectrum of terrestrial, freshwater and marine biodiversity were identified and mapped using combinations of biophysical factors such as climate, geology, land elevation and ocean depth. Satellite imagery was used to create and validate habitat maps that were reviewed by local experts. Human activities were mapped and validated to provide a set of environmental risk surfaces that were used as conservation area suitability maps. Appropriate models were used for the three sets of biodiversity in the freshwater, terrestrial and marine environments. The CDSS was used to facilitate the use of the software MARXAN to identify a portfolio of priority conservation areas using the mapped targets and suitability or threat factors. The results were reviewed and developed into a portfolio of conservation areas that met the conservation objectives.

Optimal conservation portfolios identified for the marine environment consisted of 141 areas covering 7,758,894 hectares that encompassed 20.2% of the region. The terrestrial portfolio consisted of 64 conservation areas covering 7,493,888 hectares or 3,533,786 hectares of target, and the freshwater of 15 groups of areas covering 6,679,131 hectares. These conservation portfolios, however, are not intended to be prescriptive. Users are encouraged to utilize the CDSS to facilitate strategic conservation planning that is directly linked to decision making and natural resource management at a more local level. It is hoped that collaborative partnerships and further research and monitoring efforts will be encouraged by this framework that, in time, will facilitate new and strengthen existing conservation efforts in the region.

INTRODUCTION

In the face of limited conservation resources, the need for biodiversity conservation approaches that are linked to systematic and strategic planning has long been recognized (Margules *et al.,* 1988; Margules & Pressey, 2000; Possingham *et al.,* 2000; Beck, & Odaya, 2001; Leslie *et al.,* 2003; Ferdaña, 2005; Jeo *et al.,* 2005 etc). Human well-being in the Caribbean is strongly connected to ecological health and ecosystem services, so decisions concerning the location and size of protected areas and other conservation strategies must consider both biological and socio–economic factors and be supported by systematic decision support tools.

A lack of easily accessible spatial data and tools to map ecological processes and human activities at this broad scale has previously made strategic, data-driven conservation decisions difficult, time-consuming and expensive (Jeo *et al.,* 2005). It has also contributed to difficulties in establishing a basis for cooperative, cross-border actions. Recognizing this, there is increasing interest amongst governments, environmental organizations and funding agencies to move towards technical methods that better manage the region's complex ecosystems and human societies (Jeo *et al.,* 2005). The Caribbean Decision Support System (CDSS) was created with the aim of meeting these needs. It provides the latest and most comprehensive biodiversity and socio-economic data and analytical tools to natural resource managers and decision makers striving to implement national or local conservation strategies across the region.

THE CARIBBEAN DECISION SUPPORT SYSTEM

The CDSS encompasses three components designed to meet the needs of natural resource managers across the region and support the complex decisions they make to protect the region's natural resources. The first component is a detailed geospatial database housing vast information layers about habitats (e.g. turtle breeding grounds, mangroves, and coral reefs), threats (e.g. tourism, pollution and road construction), and protected areas; the second component is a suite of tools designed to create 'environmental risk surfaces' that indicate the level of threat to a particular habitat or species; and the third component is a suite of tools to assess habitat uniqueness across a landscape and facilitate the use of the software MARXAN to create optimal conservation plans based on threat factors and sustainable development scenarios. The CDSS was used to aid the large-scale biodiversity assessment of the region carried out by The Nature Conservancy that identified a portfolio of conservation areas to concentrate detailed planning and conservation strategies and so sustain the biological diversity of the region. The portfolio represents target biodiversity to quantitative goals in areas least threatened by human impacts that can support populations, ecosystems and ecological processes into the future.

Users are encouraged to utilize the CDSS across the region, taking advantage of the flexibility designed into the system to customize the decision-making process by incorporating local knowledge and accommodating local concerns towards natural resource management. It is hoped that collaborative partnerships and further research and monitoring efforts will also be encouraged by the CDSS framework that, in time, will facilitate new and strengthen existing conservation efforts in the region. The CDSS is available on the accompanying DVD. Full details of the tools and database and how they can be can be freely accessed are available in the technical report and on the accompanying DVD, or online at http://www.conserveonline.org/workspaces/Caribbean.conservation.

THE CARIBBEAN REGION

The Caribbean basin comprises over 20 nations and territories, each characterized by unique and wide ranging biodiversity and culture. It is one of the world's greatest centers of biodiversity and endemism, arising from the region's geography and climate: an archipelago of habitat-rich tropical and semi-tropical islands tenuously connected to surrounding continents. Plants and animals arrived from the neighboring continents and islands, and as their descendants spread into new environments they evolved as a result of new ecological opportunities. The region harbors a staggering 12,000 plant species, 1,518 terrestrial vertebrate species and 3,000 shallow marine species. Of this diverse flora and fauna, many are endemics found nowhere else on Earth, some unique to individual islands, or to isolated places within specific islands.

Marine

The Caribbean forms the heart of Atlantic marine diversity. Roughly 8 to 35% of species within the major marine taxa are endemic to this area. The shallow marine environment contains 25 coral genera (62 species scleractinian coral), 4 mangroves, 7 seagrasses, 117 sponges, 633 mulluscs, 378 bivalves, 77 stomatopods, 148 echinoderms, over 1400 fishes, 76 sharks, 45 shrimp, 30 cetaceans, 1 sirenia, and 23 seabirds. The Caribbean contains approximately 10,000 square kilometers of reef (Spalding, *et al.,* 2001; Andrefouet *et al.,* 2005); 22,000 square kilometers of mangrove (amended from Spalding *et al.,* 1997); and as much as 33,000 square kilometers of seagrass beds (Spalding *et al.,* 2003). Other unique and interesting carbonate structures found in the insular Caribbean include stromatolites, algal ridges, ooid shoals and blue holes.

The strong and predictable Caribbean Current meanders through the basin year round transporting larvae between islands and regions. Large ranging and highly migratory species such as turtles, whales, sea birds and pelagic fishes inhabit different portions of the Caribbean basin during different stages of life. Despite this high degree of mixing, there are significant differences in geology, climate, productivity, and island size, all of which influence the relative abundance, extent, intactness, and vulnerability of marine biodiversity in the Caribbean. Three distinct ecosystems were identified: The Bahamian, The Greater Antilles and The Lesser Antilles.

Terrestrial

The Caribbean is one of the world's centers of terrestrial biodiversity and endemism. It harbors about 12,000 plant species and 1,518 vertebrate species, of which 668 are birds, 164 mammal, 497 reptile, and 189 amphibian species. Of this diverse flora and fauna, 7,000 vascular plant species and 779 vertebrate species (148 bird, 49 mammal, 418 reptile, and 164 amphibian species) are endemic to the Caribbean, found nowhere else on Earth. Many are endemic to individual islands, or to isolated places within specific islands (Myers, *et al*., 2000; Davis *et al.*, 1997; Woods & Sergile, 2001; Global Amphibian Assessment, 2004; Raffaele *et al.*, 1998; Nowak, 1994; Nature Serve)..

Caribbean species richness is supported by diverse habitats. There are 4 major habitat types, 16 WWF ecoregions**,** and 14 Holdridge life zones. The major habitat types include tropical/subtropical dry broadleaf forest, tropical/subtropical moist broadleaf forest, tropical/subtropical coniferous forest, shrubland and xeric scrub. Natural disturbances, such as earthquakes, volcanic eruptions and hurricanes, in combination with human interference such as mining/quarrying, air/water pollution, forest fires, agriculture development, urban sprawl, tourism, introduced animals, and invasive exotics have modified vegetation and the landscape of the Caribbean.

Freshwater

The Caribbean's freshwater biodiversity is found in a variety of habitats including large lowland rivers, montane rivers and streams, lakes, wetlands and underground karst networks. In addition to being habitats for many important, unique and migratory animals and plants, these freshwater habitats provide clean water, food and many services to local communities. These services are especially important as the small islands of the insular Caribbean are completely surrounded by salt water, and rely greatly on limited, land-based freshwater from functional ecosystems.

Information on the distribution of many Caribbean freshwater species is scarce, distribution is not known for most freshwater taxa, even for fish that are otherwise well studied. 167 freshwater fish species have been identified (Neodat, 2007; Lee *et al*., 1983; Reis *et al*., 2003), although there have been a large number of introduced species from aquaculture and aquarium collections. Fifty of these species are endemic to the Caribbean. There are several species of reptile, whilst amphibians are primarily terrestrial although some truly aquatic species exist here. Macroinvertebrates are important to Caribbean freshwater biodiversity due to their great influence on ecosystem functioning. Six freshwater ecoregions were identified (Figure 3): The Bahamas Archipelago Ecoregion: The Cuba Archipelago Ecoregion: The Jamaican Ecoregion: The Hispaniola Island Ecoregion: The Puerto Rico Island Ecoregion: Lesser Antilles Complex Ecoregion.

Detailed descriptions of the marine, terrestrial and freshwater ecoregions can be found in the technical report: http://www.conserveonline.org/ workspaces/ Caribbean.conservation

The diverse marine, terrestrial and freshwater habitats and species of the region are closely linked to the local human communities. Human well being relies upon diverse ecosystem services, such as buffering coastal communities from the effects of storms, freshwater, growing and harvesting food, providing a basis for recreational and tourism industries in addition to providing habitat for commercial species.

VULNERABILITY AND THREATS

Heightening human pressures in the region are thought to be putting the biodiversity of the region under unprecedented stress. Activities include cruise ship tourism, terrestrial and marine tourism and their associated infrastructures, hydropower dams and reservoirs, canalization, freshwater withdrawals, road building, agriculture, over-fishing, introduction of alien species, sand and bedrock mining, discharge of untreated sewage and industrial waters, intensive agrochemicals use, aquaculture, overharvesting, population growth, urban sprawl and resource extraction. These activities can lead to changes in ecological systems such as habitat fragmentation, degradation and loss, invasive species, hydrological regime change, degraded water quality, pollutant release, sedimentation, ecosystem service degradation and the resulting effects on local human communities. The cumulative impacts of all these influences on biodiversity are largely unknown.

The complex mix of political and social factors exacerbates these problems and results in the Caribbean being one of the world's most threatened places. The strategies necessary to balance sustaining the livelihoods of people and the growth of economies with the need to reduce threats and protect remaining biodiversity are complex and interrelated. Deciding how and where to act in the face of multiple, imminent threats is an increasing challenge. It is hoped the data on the distribution of many of these threats, in addition to conservation targets and tools, contained within the Caribbean decision support system will greatly facilitate actions to meet these challenges.

CONSERVATION TARGETS and DATA SOURCES

One of the principle goals of the assessment was to identify important areas of biodiversity; those areas that contain multiple and viable, or feasibly restorable examples of native plants, animals, and ecological communities and systems across key environmental gradients. These biodiversity features are often termed conservation targets and serve to focus The Nature Conservancy's conservation planning and action.

A suite of conservation targets were selected and mapped to represent as full a range of biodiversity as possible across the region. Inevitably, a range of surrogates were used, as the representation of all biodiversity elements of the region is not possible. These surrogates are often in the form of habitats or geoclimatic types thought to influence and reflect the communities of species and ecological systems inhabiting them. Emphasis was placed on habitat targets as they offer several advantages including increasing the feasibility of the assessment because their delineation is less time intensive and resources and can be incorporated from remote sensing data (Jeo *et al.,* 2005; Huggins, 2002). They can also encompass major ecological processes that do not operate at the scale of species and small natural communities.

A key component of the selection of targets and the target mapping process was contributions from experts who are familiar with the different species, ecological communities, habitat types and ecological systems present in the region. The three environments of freshwater, terrestrial and marine implemented different appropriate methodologies for spatial representation of targets according the availability of data across the region. All data are available in the CDSS on the accompanying DVD and fully described in the technical report, also available on the DVD and from
http://www.conserveonline.org/workspaces/Caribbean.conservation.

The Caribbean marine region has long been known as a center of biodiversity for shallow coastal communities, notably coral reefs, seagrasses and mangroves. New models for marine distributions were developed using depth and remote sensing in addition to existing maps, with the help of experts from many parts of the region. The targets identified were beaches, wetlands and mangroves forests, estuaries, lagoons, rocky shores, seagrass beds, seabird nesting and roosting areas, sea turtle nesting areas, channels, coral reefs, coral walls, marine mammals and reef fish spawning aggregations.

In the terrestrial environment, climate and geology and the soils they support are the dominant environmental variables controlling the distribution of vegetation and its associated biodiversity, so terrestrial targets were created by combining maps of ecoregions (WWF Dinersttein *et al*., 1995) and geology (USGS French & Schenk, 2004) with a map of natural areas (Landcover Tucker *et al*., 2004), resulting in a distribution map of 55 target vegetation communities.

The freshwater biodiversity of the Caribbean is characterized by the existence of steely sloped rivers in highlands over 10,000 feet tall, small floodplain rivers, ground water rivers, wetlands, coastal lagoons, lakes, natural ponds and geothermal springs. Other water features such as artificial reservoirs, channels for agricultural irrigation and cattle ponds are present but were not considered conservation targets as they do not represent natural systems. Where local maps were not available, the elevation dependant targets such as streams and rivers were modeled from terrain data and the other targets were mapped from the land cover map (Tucker *et al*., 2004) with the help of experts from across the region.

Full target and mapping details are available in the technical report available on the accompanying DVD or online at http://www.conserveonline.org/workspaces/Caribbean.conservation

CONSERVATION GOALS

Quantitative representation goals were defined for each target in order that a robust set of priority conservation areas could be selected to represent the full spectrum of biodiversity and ecosystem processes within the region. The goals are proportions of the distributions or of each biodiversity target sufficient to allow the possibility of sustaining viable populations and ecosystem processes over time. Accepted methods to determine conservation goals focus on measures of abundance and distribution (Groves *et al.*, 2000; Groves, 2003), although there are no rules to determine exact quantities necessary to capture enough biodiversity to maintain ecosystem processes and habitats into the future. For some Caribbean biodiversity there are uncertainties as many gaps exist in the knowledge of species and populations, due to the very low numbers of research carried out within some areas, especially within the freshwater environment. Ecological and evolutionary processes are also poorly understood.

Marine target goals were calculated using similar criteria, including; landscape context, degree of endemism and rarity, current status compared to historic, vulnerability and whether the habitat was a source area. These criteria were used previously by local biodiversity assessments such as Puerto Rico (Chatwin, 2004), Jamaica (Zenny, 2005) and Andros Island, Bahamas (Thurlow *et al*., 2005). The goals ranged from 5% of the distribution of wide ranging species up to 40% for other targets.

The goal for terrestrial targets was to represent an area of vegetation equivalent to ten percent of the original extent of each target. This is the theoretical or potential area obtained from the ecoregion and geology maps. This is based on inferences from species-area relationship studies and represents a realistic and practical goal.

The goals for freshwater targets were assigned after evaluating several criteria including the number of occurrences or abundance; the degree of endemism and rarity in the ecoregion; the vulnerability; and whether there was a potential for extinction. The goals ranged from 25 – 99% of targets' current extent.

CANDIDATE AREAS FOR COMPARISON

Through evolutionary history, as a result of differing environmental conditions, there are now areas in the Caribbean that are distinct from each other in the ecosystems, communities, populations and occurrences of biodiversity and associated ecological processes that they contain. These areas, known as ecoregions (see Figure 3 for an example), were treated separately so that goals for representing biodiversity targets were met in each. The whole region was divided into smaller hexagonal 'planning units' (Figure 1) to be able to assess different candidate areas with regard to their contribution to conservation goals and their suitability for inclusion in a conservation area. The planning unit size (1039 Ha) and shape was designed to best reflect the conservation targets and facilitate future conservation efforts. The analysis selected planning units in clusters to form conservation areas.

SUITABILITY MAPS

To enhance the decision support system, suitability maps were used to identify and spatially represent factors that may favorably or adversely influence an area's suitability as a candidate for a conservation area. An area that has extensive development and sources of pollution may be less suitable as a conservation site, both because the ecological integrity of the biodiversity may be impacted and because the cost of conservation strategies may be higher, and the likelihood of their success lower. An area that has previously received a protective designation may provide a higher probability of conservation effectiveness and success.

Maps of these factors or environmental risk were used to indicate the likely suitability of candidate areas. They were created using available models and also using the tools within the CDSS. A marine suitability map was made from human impact models created by the World Resource Institute Reefs at Risk Program (WRI, 2004). A freshwater suitability map was calculated using a flow accumulation model that measured downstream influence of human activities, and a terrestrial suitability map (Figure 2) was created using a human impact methodology that combined proximal distance and intensity (Huggins, 2004) using the CDSS. All suitability maps incorporated an increased suitability in areas already designated under a protected designation.

The protected area component of the suitability map was mapped by gathering and improving available marine and terrestrial protected area attribute and boundary data, primarily from the WDPA Consortium 2003 World Database on Protected Areas, with additional local information. All maps are available in the CDSS.

SELECTING CONSERVATION AREAS

The biodiversity conservation assessment of the Insular Caribbean aimed to develop the Caribbean Decision Support System to provide a decision support framework for biodiversity conservation and to promote sound natural resource management. The wider framework includes systems to determine and justify conservation goals, targets and suitability factors. It has a flexible approach that allows assessment of how changes in these factors might alter decisions, and can offer alternatives for conservation practitioners. These systems can be implemented across regions and repeated in the future should it become necessary as situations change or other data become available and are incorporated into the CDSS.

Part of the CDSS provides a system to facilitate the use of software to select a comprehensive network of conservation areas to concentrate detailed planning and conservation strategies and so sustain the biological diversity of the region. The network of conservation areas or 'portfolio' should be the most suitable suite of areas that meet the conservation goals for representation of all biodiversity targets in an efficient way that minimizes total area and a measure of risk from threats. Users are encouraged to critically evaluate the CDSS framework and data, and to utilize them to facilitate strategic conservation planning that is directly linked to decision-making and natural resource management at appropriate scales.

The CDSS facilitates the use of the conservation area selection software MARXAN (Ball & Possingham, 2000) to evaluate biodiversity targets, goals and suitability factors in a spatial context under different alternative scenarios to identify portfolios of conservation areas for consideration by the planning team. MARXAN can be used to implement a 'simulated annealing' optimization algorithm. Many potential portfolios are assessed according to how efficiently they meet representation, suitability and spatial goals such as connectivity and management practicality. This flexibility allows expert knowledge to be utilized in a planning exercise where a suite of efficient portfolios that attain all goals are possible. Full details of the software are available in **Error! Reference source not found.**. Tutorials and guidelines on running MARXAN are available for GIS beginners and for those with GIS experience (Huggins, 2005), on the accompanying DVD and online at http://www.conserveonline.org/workspaces/Caribbean.conservation, to enable users to explore its use and capabilities.

Inputs to MARXAN are created from GIS data by the CDSS and are in the form of the area or number of occurrences of biodiversity targets within each planning unit, the quantitative conservation goal (area, length or number of occurrences) for each target, the suitability of each planning unit and the planning unit boundary lengths. The boundary lengths are used to allow the selection of planning units clustered into conservation areas. Planning units with a higher suitability would be favored for selection when biodiversity target values and clustering implications are similar.

Other user inputs to the analysis include the number of portfolio configurations automatically assessed during each run of the algorithm, the number of independent runs of the algorithm, penalties when a target does not meet its goal and a factor to control the amount of clustering of planning units into potential conservation areas to improve spatial cohesion of the portfolio.

A high penalty for meeting representation goals was levied to ensure so that all carefully considered and agreed biodiversity representation goals were met. This also allowed conservation scenarios to be compared by the planning team. The analyses were based on many independent runs of the algorithm, each of one million iterations. Many levels of clustering were evaluated by the planning teams and the final value that offered an appropriate balance between ecological coherence and efficiency was carried forward to further analysis. The value varied across the marine, terrestrial and freshwater analyses.

DELINIATION OF CONSERVATION AREAS

The site selection program MARXAN provides a 'best' or most efficient portfolio of conservation areas and information about how many times each area was selected to be part of the portfolio in the many independent runs of the program. There are often many portfolios that are very efficient, the best may be only marginally more efficient that the next best. Areas that are chosen most often may be seen as highest priority to include in a conservation area. They may contain biologically rich areas or areas that contain a large proportion of one or several biodiversity targets or may have reasonable amounts of targets and a high suitability score. Those that are chosen less often may still be very important to include in conservation areas to meet goals, but there is a choice about which areas can be chosen. This may be because the targets in those areas are more widespread or the suitability of the site is lower.

Several scenarios for the portfolio of conservation areas were analyzed. These scenarios included constraining the portfolio to include the current protected areas, using the environmental risk map as a measure of suitability, and analyzing without these constraints. These conservation portfolios were reviewed by the planning teams with experts to determine the most appropriate scenario and create a final optimal portfolio.

Marine Portfolio Selection

The team considered that the scenario that included the suitability surface, but did not lock protected areas into the portfolio, to be the most appropriate. The team did lock special areas into the portfolio. Some slight alterations were made by the planning team to improve spatial cohesion and to remove some isolated and highly flexible units to improve the realistic acceptance of the portfolio. This caused a reduction in efficiency and the number of targets represented to their goal, but increased the practical use of the analysis. The optimal portfolio was over 1039,000 hectares smaller than the portfolios identified when protected areas were locked into the portfolio. The final optimal portfolio consisted of 141 areas covering 7,758,894 hectares (20.2% of the region) and representing 53 (75%) of ecosystem targets to their goals and is illustrated in Figure 4.

Terrestrial Portfolio Selection

The planning team identified the most practical portfolio to be the scenario that locked in the official current protected area system and included the environmental risk map as a suitability map. This optimal portfolio consists of 64 conservation areas, totaling 7,493,888 hectares which comprises 3,533,786 hectares of targets. 5,450,594 hectares of this portfolio were selected as part of a portfolio in more than 82% of the runs.

Freshwater Portfolio Selection

The four scenarios were run for the freshwater analysis with two targets (natural lakes and freshwater coastal lagoons) locked into the portfolio as they were considered in need of full 100% representation. Analysis of the portfolios showed that they did not fully represent known important freshwater sites in the region. In each scenario some important areas were present but others were missing. This may be due to the data describing the targets, as those parts of target in areas known to be important were not distinguished from other parts of the same target. The portfolio sites represented either an unrealistic target bias by locking in the protected areas or were disseminated across the landscape in a diffuse pattern. The analysis does not consider the linear nature of freshwater targets and the necessity of connectivity through each individual system. Modifications could be made to encourage clustering of PU's through each freshwater system, but it would be necessary to accomplish this target by target rather than PU by PU.

Considering the high number of occurrences of some targets in the portfolio, an evaluation of target aggregation and regional importance was conducted in order to reduce the number of sites and prioritize areas to focus on conservation strategies. Those sites that were removed were isolated occurrences or areas with a size and potential threat that would affect their viability in the long term. Modifications were therefore made to the portfolio selected using the suitability map but not locking the protected areas, by the planning team, to represent a more realistic and acceptable portfolio. After modifications were made, a regional portfolio of sites was obtained that contained the relevant important freshwater conservation areas in the region, although some targets no longer met their goals.

Marine

While coral reefs have declined over the past three decades, there are encouraging signs that recovery is occurring at local scales for sea turtles, whales, and sea birds. In comparison to many other tropical regions, the Caribbean region has a high literacy rate, rising per capita income, and decreasing birth rates. Over the last decade, rising environmental awareness and a stewardship ethic has been spreading throughout the region. The capacity in marine sciences and coastal management is moderate and there are already well established networks of marine scientists and international agreements. The Caribbean marine ecoregions therefore represent places where conservation actions are likely to have a lasting impact on protecting tropical Atlantic biodiversity.

The portfolio of sites established during the insular Caribbean biodiversity conservation assessment provides a starting point to help guide conservation efforts at both national and regional scales. Representing at least 20% of the known marine biodiversity, this portfolio can help set conservation priorities at different scales and link sites together into larger regional networks. Many of the portfolio sites are already designated managed areas, but lacking management plans and effective enforcement, while others represent areas to look towards for expanding or redesigning marine managed areas to make them more resilient to human and natural impacts. The marine strategies presented below are preliminary large-scale cross cutting strategies developed for all three marine ecoregions of the insular Caribbean. They focus on the need to combat unsustainable and destructive fishing, coastal habitat loss, changes in coastal water quality and freshwater inflows, climate change and other emerging threats in the insular Caribbean. Implementation of these strategies within each geography varies considerably and will be refined in future editions of this plan.

Marine Conservation Strategies

Establish and strengthen networks of marine protected areas that provide tangible economic, social and environmental benefits to coastal communities by improving management effectiveness of current sites and creating new ones;

Improve the leadership, technical and financial capacity of local organizations to deliver benefits to civil society through the conservation and sustainable use of marine and coastal resources;

Foster political will to enforce environmental laws, reduce perverse fishing subsidies and generate sustainable funding from multi-lateral and government agencies for marine and coastal conservation across 19 coastal and island political units;.

Engage the private sector, including tourism, fishing, real-estate and energy industries, to adopt sustainable patterns of production, certify products and promote social entrepreneurship;

Establish a comprehensive monitoring and evaluation protocol for triple bottom line approaches to marine and coastal conservation through the development of a score card system and other evaluation tools to establish base line data, improve adaptive management, share best practices, replicate projects and develop exit strategies;

Develop comprehensive regional strategies and policy alternatives that address current and emerging threats to island and coastal resources and communities including: climate change; over-fishing;

unsustainable tourism; coastal development; oil and gas development; uncertified aquaculture and invasive species;

*Significantly decrease the pollution and damage to downstream coastal area***s** caused by upstream development, habitation, agricultural and industrial activities.

Use and share the best available technology to plan for future development by creating comprehensive geospatial databases, developing innovative science tools, and providing training that helps facilitate cooperation among communities and key stakeholders.

Terrestrial

The selection of a portfolio of conservation areas relies on the quality and scale of input data. The terrestrial portfolios represent a first approximation under a given set of constraints. There may still be areas important to biodiversity that are not included in any of the portfolios. This is likely to have been a result of the target data. The data could be refined to include measures that differentiate known quality indicators such as patch size. We therefore encourage the participation of experts and stakeholders to review the data and portfolios in order to achieve the goal of protecting all Caribbean biodiversity.

Terrestrial conservation strategies

These strategies are based on the preliminary region-wide threat analysis and protected areas gap analysis with an emphasis on preventing habitat loss and reducing the impact of invasive species and climate change on biodiversity:

Establish new conservation areas via public or private land acquisition and strengthen the current national protected areas system. The terrestrial portfolios presented in this report can serve as reference points for site selection.

Facilitate The Nature Conservancy's field programs and partners *build local capacities for ecosystem management* to maintain or restore the ecological integrity of landscape-scale conservation areas.
Create an information system that allows sharing best management practices and monitoring conservation results.

Develop land conservation strategies that produce benefits to freshwater and marine ecosystems, such as forest certification programs or carbon sequestration projects that protect watersheds.

Demonstrate the economic benefits of environmental services (e.g. watershed protection and drinking water) as a vehicle to encourage the participation of the general public and government agencies in protecting the environment.

Engage regional stakeholders in addressing large-scale threats to islands: invasive species and sea-level rise.

Influence policy changes at the regional level by enhancing laws and regulatory systems to strengthen biodiversity conservation and maintain a clean environment.

Freshwater

The selection of regional conservation areas was conducted using the criteria of coarse-scale focus, representativeness, efficiency, integration, functionality and completeness outlined in *Geography of Hope* (The Nature Conservancy, 2000) and guided by TNC's Freshwater Classification Approach for Biodiversity Conservation Planning (Higgings *et al.,* 2005).

Regional freshwater selected sites were the results of an iteration of MARXAN analysis after a critical analysis that collected expert opinion on the portfolio sites. This analysis, however, has resulted in portfolios which were assembled with little consideration of the need for linkages, connections or juxtapositions among sites with respect to the ecology of the conservation targets. This is a limitation in the methodology that should be clearly stated for those using the results achieved in this regional assessment. We encourage review of the data and portfolios to strive to meet biodiversity goals for the Caribbean region.

Freshwater conservation strategies

Work with governments to identify rivers that still have relatively intact surface and groundwater hydrologic regimes, freshwater biodiversity and ecosystem functions in order to timely prevent alterations and use them as models for ecosystem restoration.

Promote policies and regulations that financially support ecosystem functioning and freshwater biodiversity conservation thru payment for environmental services.

Increase effective management of protected areas associated to freshwater conservation targets.

Work with infrastructure development agencies to reduce impacts of housing projects, highways, secondary roads and rural roads constructions and maintenance.

Produce incentives for clean energy production through small hydropower plants managed by indigenous / local community organizations.

Promote regulations of water withdrawals in order to maintain ecologically sustainable river flow.

Promote efficiency of crop and animal production through best practices that reduce water and agrochemical uses to lower the impact of agriculture and husbandry on water quality.

Develop educational programs in agricultural communities to link human health with aquatic ecosystem health originated by preservation of good water quality in streams.

Establish platform projects that showcase results and serves as training centers of applied best management practices to improve water quality and biodiversity conservation.

Influence multilateral and bilateral agencies to request countries planning to build new dams to have infrastructure design considering sustainable river flow and conservation of river biodiversity.

Influence government offices to set dam standard operation procedures that sustain ecologically needed river flows.

Encourage mapping of principal contributing subwatersheds to identify major contamination sources to focus watershed management on priority sites.

Work with governments to create institutional mechanisms for an *integrated watershed-coastal management* committee.

Identify freshwater systems with no presence of invasive species and work with GO Offices, NGOs and communities to prevent introductions, as well as establish early warning surveillance systems and rapid response plans to eradicate or control incipient invasions.

Users are encouraged to utilize the CDSS to facilitate strategic conservation planning that is directly linked to decision making and natural resource management at a more local level. It is hoped that collaborative partnerships and further research and monitoring efforts will be encouraged by this framework that, in time, will facilitate new and strengthen existing conservation efforts in the region.

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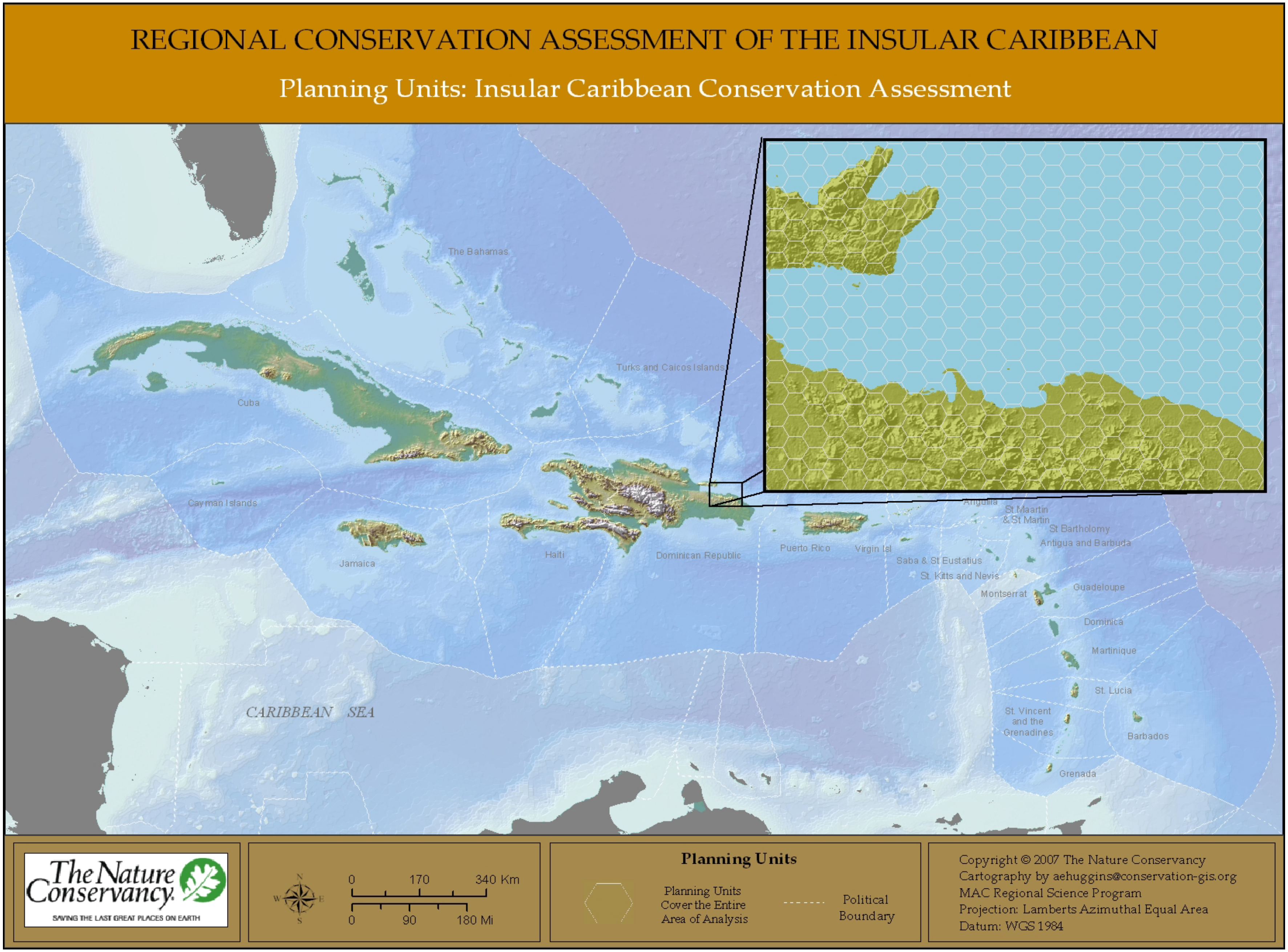

Figure 1; Planning Units

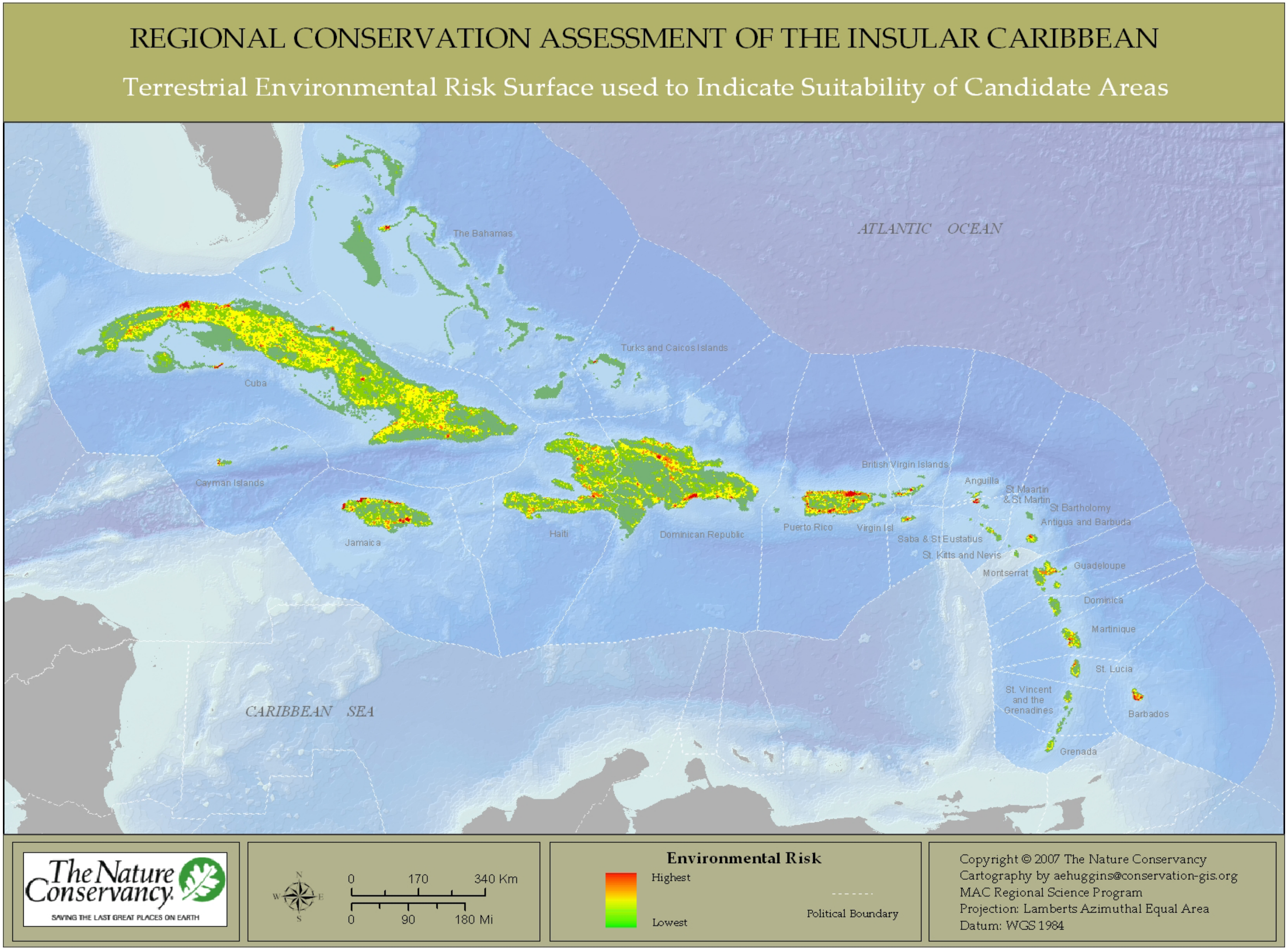

Figure 2; Terrestrial Environmental Risk Surface used as a Suitability Map for the Insular Caribbean
(Maps are available for all terrestrial, marine and freshwater environments in the technical report: http://www.conserveonline.org/ workspaces/ Caribbean.conservation)

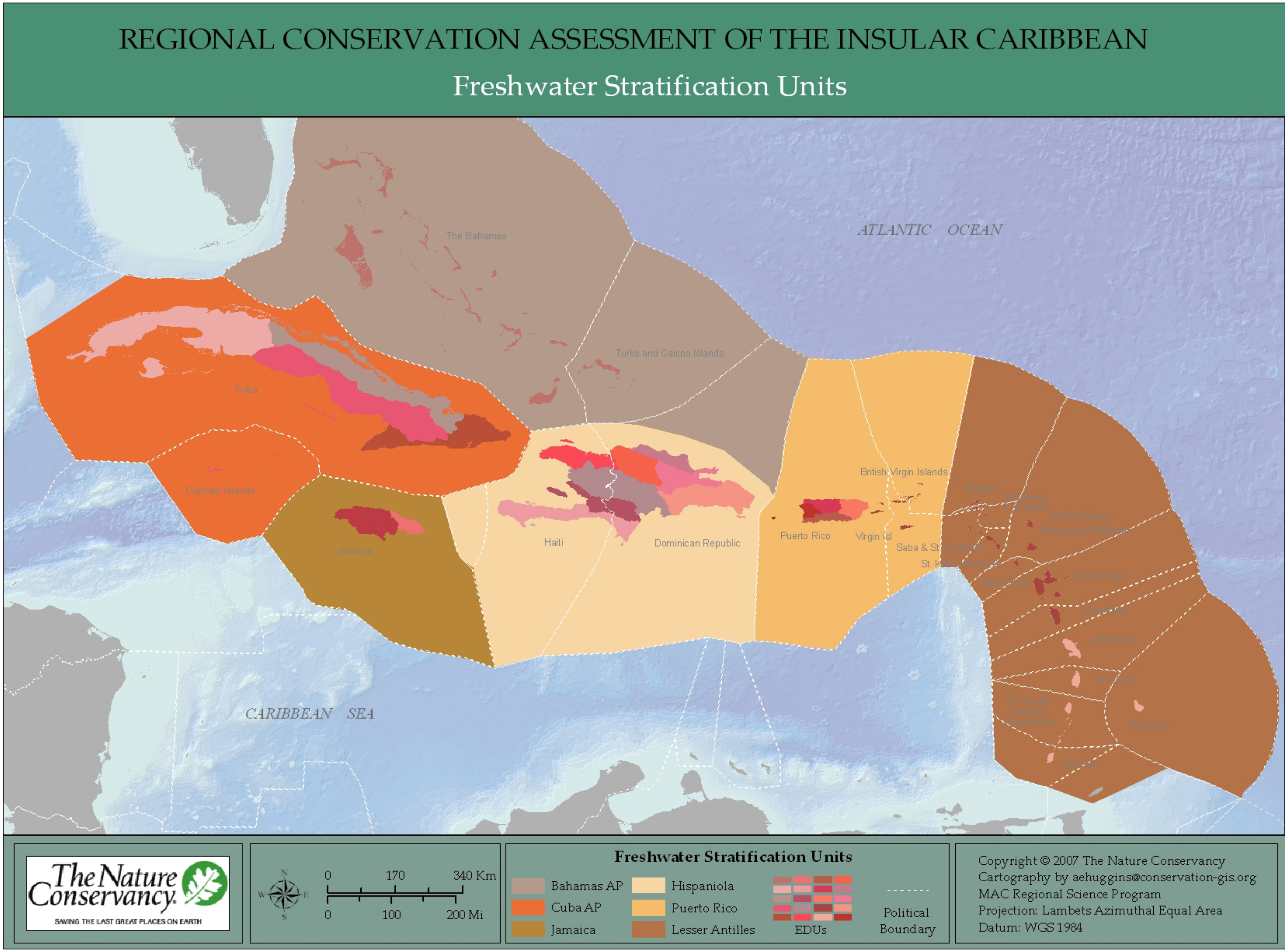

Figure 3; Freshwater Stratification Units

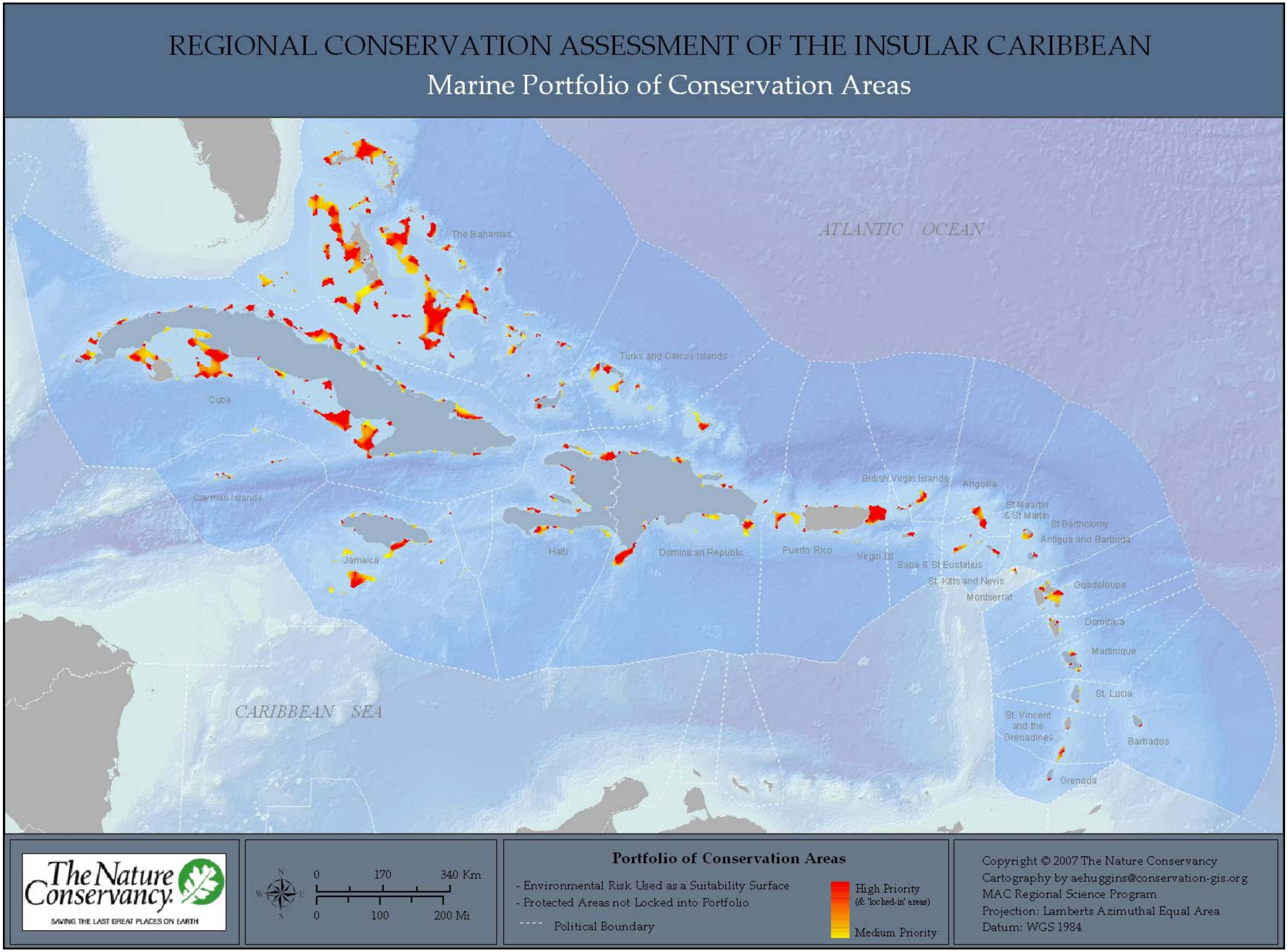

Figure 4; Optimal Marine Portfolio