AN ECOREGIONAL PLAN FOR THE BAHAMIAN ARCHIPELAGO

By

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ISBN 0-9726543-9-9

Published by the Taras Oceanographic Foundation, Jupiter, Florida.
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Cover design by Barbara Brunnick. Layout and design by Stefan Harzen

Edited by Stefan Harzen and Kathleen Sullivan-Sealey

Except for the following, all photographs by the authors.
J. Bendon, p64; A. Burns, pp40, 44; P. Ebling, p56; E. Freid, pp13, 17, 22 bottom, 132 bottom, 135, 136 bottom, 137, 139, 140, 143, 145 bottom, 146, 154 bottom, 155 top; G. Gerber, p67; W. Hayes, p75, 79; C. Knapp, pp71, 73; L. Manfredi, p59; NASA, p158 left; Shedd Aquarium, p105; D. Sottolano, pp78, 153 bottom, 154 top, 155 bottom; Wild Dolphin Project, pp32, 159 right, 160 left, 161 left, 162 right, 165; and Unknown Source, p52.

FOREWORD

The Nature Conservancy (TNC) has been engaged in biodiversity conservation projects in the Bahamian archipelago since 1993. A review of marine conservation priorities for the entire western hemisphere, considered The Bahamas, the Turks and Caicos Islands, along with the Silver and Navidad Banks, as one ecoregion with unique biodiversity value and conservation status. In an effort to build partnerships with local and regional stakeholders and research institutions, and to establish long-term conservation goals throughout the Bahamian archipelago, TNC launched The Bahamas Country Program in 2000.

Through the University of Miami, the Nature Conservancy has been investing in research projects focusing on marine park management, threatened species and coastal conservation in The Bahamas. To better understand the distribution and threats to biological diversity within the entire Bahamian Archipelago, TNC, in partnership with the University of Miami, initiated an ecoregional planning process in 2001. Planning at a landscape scale is a critical part of the Nature Conservancy "conservation action through science" philosophy.

The here presented "Ecoregional Conservation Plan of the Bahama Archipelago" is not a final product, but represents a work in progress. The compendium of data and analysis is contained in text, tables, graphs and maps, available on Compact Disk (CD) and, continuously updated, on the web site at http://islands.bio.miami.edu.

Funding for this project came from The Nature Conservancy, with important contributions from members of the West Virginia and Florida chapters. The University provided additional support for Dr. Sealey's time and research facilities. The United States Geological Survey (USGS) provided funding and technical assistance through their Caribbean Vegetation Mapping Initiative. We are especially thankful to Dr. Kathleen Sullivan Sealey, Dr. Barbara J. Brunnick, Dr. Stefan E. Harzen, Vanessa Nero, Corene Luton and Steve Davidson for the time and effort that went into this project, to which many scientists; researcher and experts contributed invaluable information. A special thanks to Dr. Sealey and Mr. Lester Flowers for forging a partnership through this project that will lead to a Center for Environmental Studies at the College of the Bahamas.

Many Nature Conservancy staff contributed valuable technical and management support, including Gina Green, Dan Campbell, Leslie Hatton, Christopher Kernan, Judy Lembke, Christa Mehard, Alejandro Quintero, Roger Sayre, Aleksandra Stankovic, John Tschirky and Lynn Wilson.

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ACKNOWLEDGEMENTS

The wish to thank our three contributing authors Mark Chiappone, Steve Davidson and Neil Sealey for their invaluable contributions to this report. We would also like to express our appreciation to the United States Geological Survey EROS Data Center (USGS) for providing us with satellite imagery through the Caribbean Vegetation Mapping Initiative, and especially Mike Coan for his generous support in working with the habitat classification models. We are thankful of Ethan Freid, Melissa Greco and Emile Milgrim who helped in various stages of this project, and the advice and expertise of David Lee.

Both the University of Miami and The Nature Conservancy provided funding for this project, and we thank the Nature Conservancy Project Manager, Dr. Georgina Bustamante, for her contributions. Finally, we would like to recognize the academic and administrative support staff at the Department of Biology at UM for their support.

PROJECT OVERVIEW

This Ecoregional Plan for the Bahamian archipelago was prepared under the auspices of the Nature Conservancy by an interdisciplinary team of specialists representing the University of Miami, Wild Dolphin Project, Blue Dolphin Research, National GIS Center in Nassau, the Bahamas Department of Fisheries, and the College of the Bahamas. The scope of the 13 months project included planning, data research and review, and regular meetings with additional experts.

This Ecoregional Plan provides a landscape-scale approach to natural resource management and conservation. The chain of islands and shallow-water banks of the archipelago falls under the jurisdiction of three countries: the Commonwealth of The Bahamas, the Turks and Caicos Islands and the Dominican Republic.

The central tasks of this project comprised (i) the identification of conservation targets that included both natural communities and species, (ii) the compilation of existing data on these targets, including the mapping of species' and communities' occurrence, abundance and population viability, (iii) the identification of conservation goals based on data review and interviews with professionals and experts with specific and local knowledge, and (iv) the development of conservation strategies, sites and priorities, and (v) the organization of a core planning team and regional experts to review available information and develop the ecoregional plan for future implementation. It must be understood, that this Plan can only be effective if it is supported and properly executed by all stakeholders in the region.

We compiled and catalogued existing information on individual species, natural communities and unique features of the archipelago, such as Blue Holes. Ultimately, we chose 15 targets as focal points for future conservation efforts that promote, and if protected, will preserve large parts of the natural processes that shape the marine and/or terrestrial environment in the archipelago. For each target we developed conservation goals and strategies based on the review of available information and consultation with local and foreign experts. We also produced an atlas of maps and spatial data sets that present the distribution of each target, based on historical and current research efforts. Critical conservation strategies, including geographical preferences, were identified for each target as well.

A major challenge to landscape-scale conservation is the classification of natural communities, and identifying key physical and environmental processes determining patterns of biological diversity. Priority sites were chosen based on a classification system of the banks throughout the archipelago. Twenty-three bank systems were divided into 5 types based on energy exposure and island geography. In addition there is a significant latitudinal gradient to the banks, covering 6 degrees of latitude. Northern islands tend to be larger and wetter than their southern counterparts.

Conservation planning needs to encompass areas no smaller that individual bank systems. The priority-setting analysis combined all target viability scores to rank the bank systems within the five types. Obvious gaps in information exist for the Island-Occupied Banks and Fully-Exposed Banks. The ranking process can be updated as more information about these areas becomes available. Currently, there are only a limited number of conservation programs in place, and they are mostly directly toward a few of the island systems and bank types.

A total of seven bank systems are listed as high priority sites for conservation. These include the Western Great Bahama Banks (Andros and the Biminis), Caicos Bank, Exuma Cays, San Salvador, Cay Sal, Southern Greet Bahama Banks (Ragged Islands), Turks Islands and the Western Little Bahama Banks (Grant Bahama). A comprehensive conservation program would need to address a broad spectrum of conservation strategies from low-impact development with advanced wastewater treatments to national parks and protected areas. At this time there are limited conservation actions on only a few of the bank systems and bank types. Island-occupied banks and fully exposed banks are largely unprotected. The strategies for conservation for all of the targets move beyond protected areas to the challenge of changing attitudes about tourism, island development and use of natural resources. The biological diversity of the Bahamian archipelago today suffers from the ‘tragedy of the commons’; species and natural community types are widely distributed in a fragile ecology. An integrated Site Conservation Plan for bank systems will need to include community participation, outreach programs, long-term development goals and restrictions, as well as a network of reserves and protected areas.

A comprehensive ecoregional plan helps to address three problems identified by Bahamians in past forums and interviews as obstacles to abatement of the threats to natural resources.

Many people believe that there is a lack of information or a lack of accessible information on the status and occurrence of resources. The data compilation needs to be done with user groups, including both government and non-government audiences.

In addition, there has not been an organized network of government and non-government organizations that have jurisdiction or authority for terrestrial and coastal resources. The planning process could establish a resource management network within countries to be used for future data dissemination and coordination of programs.

Last but not least, there are not individuals and organizations supported within the Bahamas to maintain and disseminate resource management information. Although some groups like the Bahamas National Trust have a private library, this information is not available to a wide audience of people for management and education purposes. More importantly, an archipelago-wide compilation of natural resource information has never been attempted; this type of data atlas would be invaluable for current discussions of protected areas and environmental policy legislation.

The final product, the Bahamian Archipelago Ecoregional Plan, includes not only the final written documents presented herein, but also dynamic electronic data sets that can be used as tools for future conservation site planning and implementation. In addition, much of the information can be viewed on a website (www.islands.bio.miami.edu), maintained at the University of Miami as part of an ongoing collaboration with the College of the Bahamas. Comments, input, and updates, can be communicated via the website.

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I. INTRODUCTION

Over the past decade, scientists and resource managers have realized that the maintenance of biodiversity and the conservation of natural resources must go beyond the protection of species or unique environmental features. Consequently, 'landscape conservation initiatives' have been developed to emphasize the conservation at multiple levels of biological organization and recognizes that conservation should not be constrained by geo-political boundaries.

The Nature Conservancy (TNC) has met this challenge by adopting a landscape planning initiative, called 'ecoregional planning', which is based on a classification of landscapes (and seascapes) into 'Ecoregions'. The ecoregional planning process, described in 'The Geography of Hope' (TNC, 2000), proceeds in five steps: mapping, defining conservation targets, establishing status and extend of targets, defining conservation goals, and setting priorities. Ecoregions have been identified as reasonably cohesive ecological units for conservation and management planning (Dinerstein et al., 1995; Bailey 1998). They can be broadly defined as relatively large areas of land and water that contain geographically distinct assemblages of natural communities (Dinerstein et al., 1995).

The required diligent and vigorous process for defining Ecoregion includes the identification and compilation of data on the ecology and distribution of conservation targets, on both the species and habitat level (Groves et al., 2000). Other conservation criteria include the biological importance, and threats and stresses that can be identified, measured and mitigated. The overall objective is to develop and implement a conservation plan, which identifies species, patterns and processes that need to be preserved, managed, and restored, in order to represent the entire diversity of the Ecoregion with viable populations, communities and ecosystems. The ecoregional plan should also provide background information and the justification for initiating conservation action at specific sites within the Ecoregion.

The islands of the Bahamas, and Turks and Caicos, represent such an Ecoregion. The archipelago, with its unique geological features and pristine conditions of shallow banks and island, represents a single interconnected system of land and water and is exceptionally well suited for biodiversity conservation planning. Consisting of 1,700 islands and cays, the archipelago stretches over 2,000 km from Little Bahamas Bank in the northwest, to Silver Bank in the southeast. The primary significance is in the extent and quality of the carbonate island system as a whole, including communities such as the dry evergreen forests, pine rock land, mangrove wetlands, blue holes, and coral reefs. The region is home to thriving populations of marine species and communities that are threatened, or have been overexploited in the wider Caribbean. The archipelago also supports important terrestrial species and communities, including the endemic Bahama parrot, the rare migrating Kirtland's warbler, and populations of rock iguanas that are highly threatened in the Caribbean.

Biological diversity in the archipelago spans both the terrestrial and marine environments. While the destruction of coastal vegetation and wetlands associated with unmanaged development is obvious, the physical loss of ecological function in marine habitats due to damaged seabed is keenly connected to inappropriate development as well. The decline in environmental health is apparent with the occurrence of benthic algal blooms in near shore marine habitats related to sewage either dumped directly into waterways or leeched from septic systems built improperly or too close to the coast. This continuous process, along with over fishing, reduces the abundance of important marine organisms, particularly corals, queen conch, spiny lobster, and fishes.

The main challenge to conservation of marine biodiversity in the Caribbean is not just limited to the deep basins and shallow bank systems of the wider Caribbean, which encompasses a vast marine area (4.31 million km^2), but also the fact that the area is bordered by 36 nations (Ottenwalder, 1996). Many of the smaller island nations of the insular Caribbean depend upon the health and beauty of the combined terrestrial and marine environments to sustain their local economies and cultural identities.

The extent and status of Bahamian natural resources offers a unique opportunity to develop cost-effective conservation programs aimed at preserving a large functioning ecological system, before excessive human development has had an impact. Only a handful of the small islands are occupied, with the larger population centred in Nassau on New Providence, and Freeport on Grand Bahama Island. Increasingly however, portions of the Bahamian archipelago are experiencing threats similar to those faced by coastal areas throughout the world, with development promoting economic prosperity, while an unfortunately weak legislation fails to protect resources. And although the Bahamian Government has granted protected status to several critical areas, there is insufficient infrastructure or technical capacity to minimize environmental threats in the Bahamas as well as the Turks and Caicos. Without addressing these concerns, the entire archipelago will experience negative changes in water quality, destruction of critical habitats, and the extinction of species.

Within the Bahamian archipelago, there are two national jurisdictions and several non-governmental and/or regional initiatives involved in resource protection and management. Therefore, the abatement of conservation threats in the Bahamas and the Turks and Caicos will require a combination of efforts initiated within the archipelago by government and non-government organizations, including resource management, education, and strong coastal stewardship programs which will monitor the data required to set environmental standards. The Bahama Ecoregion Plan (BEP) provides a much-needed comprehensive overview and a common database for the coordination of these various protection efforts.

A team of specialists from various disciplines, generally following the guidelines and standards established by TNC, prepared the Bahama Ecoregion Plan, which summarizes and synthesizes the best information available. It provides comprehensive maps and database tools that will be useful to wide audiences interested in the implementation of conservation, education, outreach, and management programs. In the process, team members participated in conferences, workshops, and meetings designed to compile hard-to-access information from ongoing efforts carried out by 133 foreign research permit holders and many non-governmental organizations in the Bahama archipelago.

A total of four community targets, and eleven target species were selected to effectively represent (and protect) all important species and communities. For each of these targets we generally provide a description and information on distribution, population status, ecology and natural history, habitat and associated species. In addition, we identified existing threats, information gaps, research needs, and conservation goals. Last but not least, we provide contact information and a selected bibliography.

Furthermore, we reviewed specific habitat types that are relevant to the archipelago. From a long list of very distinct and elaborate potential habitat descriptions, both marine and terrestrial, a Bahama specific list was eventually developed to include those environments that were mappable and discernable from the LandSat images. This list was representational of all important communities and species in the Bahamas and Turks and Caicos.

The geology, topography and climate of the Bank and Island Systems, as well as four natural communities (uplands, wetlands, coastal zone and marine) are described in detail. These habitats were mapped using ground truth data, collected by team members and other experts in the field, and remote sensing techniques from a series of LandSat7 images. The entire archipelago was classified to measure percentage of each habitat along with human altered terrain, mapping the habitats each target requires to survive.

The here presented Ecoregion Plan is a tool that not only includes a current assessment of terrestrial and marine resources in the Bahama Archipelago, but also initiates a process of consensus building for clearly articulated goals and strategies for fifteen well-defined conservation targets.

II. CONSERVATION TARGET DESCRIPTIONS AND GOALS

1. Introduction to Landscape-Scale Conservation

To achieve the goal of long-term sustained conservation at important sites throughout the globe, The Nature Conservancy and its partners employ an integrated conservation process comprised of four fundamental components:

- Setting priorities through an Ecoregional Planning exercise;
- Developing strategies to conserve conservation areas through site conservation planning;
- Taking direct conservation action; and
- Measuring conservation success.

Figure 1. Landscape-Scale Conservation Process

Conservation targets are a critical part of this integrated conservation process at both the Ecoregional (entire archipelago) and Site (banks and islands) level. Conservation targets are natural communities, species or elements of biological diversity that can be mapped on an ecoregional scale, with current status and extent information. To establish both goals for targets and strategies for site conservation planning, a conceptual model to develop effective strategies was created using the '5-S approach', which includes the following components:

- Systems
- Stresses
- Sources of Stress
- Strategies
- Success Measures

Systems are the conservation targets and supporting ecological processes that will be the focus for Site Conservation Planning and measuring conservation success. Ecological systems are assemblages of communities that occur together on the landscape, are linked by environmental processes, and form a robust, cohesive, and distinguishable unit on the ground. Systems are chosen to represent the biodiversity at the site, including terrestrial, freshwater, and marine biodiversity.

Stresses, the second "S", are the types of destruction or degradation affecting conservation targets and reducing their viability. The damage may occur directly to a target, or indirectly to an ecological process important to sustaining the target.

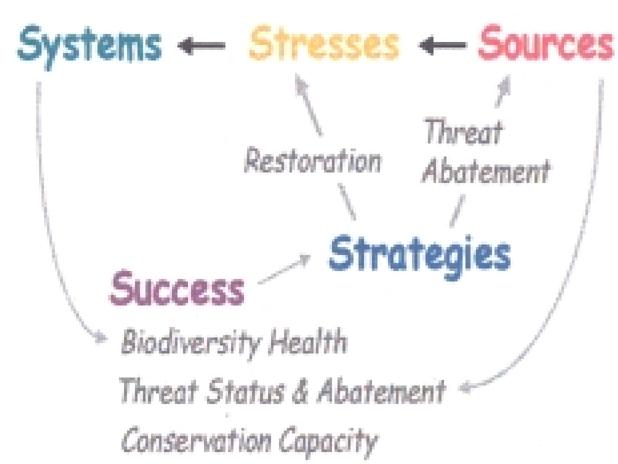

Figure 2. Components of the 5-S Approach

Sources of Stress are the causes or agents of destruction or degradation. These are the human activities, typically uses of land, water or other natural resources, which cause the stresses. Each stress has at least one source, while stresses often have multiple sources. The Conservancy's approach is to focus upon those proximate sources of stress that can be abated with practical strategies. Some sources of stress are ongoing or 'active'; others may be historical. With historical sources, the stresses can persist even in the absence of an active source such as disruptions to a wetland's hydrology that persist long after the drainage of the wetland has ceased.

The assessment of Systems, Stresses, and Sources of stress leads to a listing of critical threats for a conservation area. Based on the identified critical threats, both ecoregional planning and site planning teams develop conservation strategies.

Strategies are the broad action paths necessary to abate critical threats and enhance the viability of conservation targets, and have two broad objectives:

- Threat abatement: eliminate active sources of stress (subsequent reduction in stress and increase in viability);
- Ecological Management and Restoration: directly eliminate stress and enhance viability.

The Nature Conservancy defines conservation success of a conservation area as the long-term abatement of critical threats and the sustained maintenance or enhancement of biodiversity health. The Conservancy has developed Success measures to monitor biodiversity health and threat level. The measure of success is derived from the overall viability of conservation targets at a conservation area. The entire landscape-scale conservation process is long-term and often entails a long-term (decades) commitment to management, monitoring and research.

2. Ecoregional Planning

The initial step in the landscape-scale conservation process is developing an ecoregional plan. Ecoregional planning begins with the selection of conservation targets. It is generally advantageous to select community and ecosystem targets (ecosystem as used here refers to characteristic assemblages of plants and animals), because this approach addresses habitat diversity and ecosystem processes, as opposed to a focus solely on single-species management. The approach assumes that representation of habitats will also protect a representation of the diversity of species (Beck & Odaya, 2001). Conservation targets represented by species can be useful for conservation planning, assuming that there is a relative wealth of information on basic life history parameters, geographic distribution, habitat requirements, and population abundance estimates (Zacharias & Roff, 2001). However, the challenges with using species targets include a paucity of information on distribution, abundance, and population trends, especially for coastal and marine species. Many conservation-planning exercises use habitat types as surrogates, hypothesized to provide a high probability of harbouring species on the target list. For example, the Bahamas Ecoregional Plan includes five terrestrial habitat or community targets, encompassing inland, inland wetland, and coastal wetland habitat types.

The focal point of the ecoregional planning process for the Bahamian archipelago is the identification of conservation targets that is, those species, natural communities, and unique features important to the ecology and conservation, sustainability and economy, and/or culture of the archipelago. A working hypothesis of the ecoregional planning process is that if the conservation targets are 'protected', this will, in effect, preserve large parts of the natural processes shaping the marine and terrestrial environments. The ecoregional plan discusses conservation targets in two ways. First, for each target, the description, taxonomy (if applicable), geographic distribution, current status, ecology/life history, associated species, and supporting literature are provided (summarized below). This information provides the framework for assessing the conservation goals and strategies for each target. In essence, this is an analysis of existing information to determine what it will take in the form of conservation planning to conserve, in perpetuity, the population or habitat structure of conservation targets, whether they be species, subspecies, habitat types, or unique features. Selection of conservation targets for the Bahamas Ecoregional Plan focused on five main criteria:

- There is perceived degradation or a threatened status for the target, whether from habitat destruction or overexploitation, for example;
- Chosen targets can serve as umbrella species for habitat conservation;
- Sufficient information is available to map the status and extent of a target;
- The selection of targets should represent at least

a partial accounting of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) listed species. For example, species listed in CITES Appendices I or II that occur in Bahamian archipelago include flamingos (Phoenicopteridae) and the green turtle (Chelonia mydas); and
- The targets, whether terrestrial or marine, should represent economically or socioculturally important feature.

Conservation goals for each target are developed and provide the focal point for conservation planning. A conservation goal is the number (population size or habitat area) that must be preserved to protect the full range of diversity within an ecoregion. For example, the ecoregional plan for the northern Gulf of Mexico contains both habitat and species targets (Beck & Odaya, 2001). Habitat refers to the area used by a species, with modifiers added to identify the particular habitats used by a plant or animal. Habitat targets include sea grass beds, tidal fresh grass, oyster bars/reefs, octocoral-sponge hard-bottom, tidal flats, beaches and sand bars, and tidal fresh marsh, while species targets for this ecoregional plan were the dwarf seahorse, manatee, fringed pipefish, Gulf sturgeon, and Kemp's Ridley turtle. Unfortunately, the rationale for setting specific conservation goals for targets is not well developed, especially for marine species and habitats. A further challenge is the difficulty in obtaining basic information on population abundance and trends. For the northern Gulf of Mexico plan, for example, it was assumed that the number of collection records for a sub region (bay) was related to the size of the population in a bay (Beck & Odaya, 2001). Another guideline for goal setting for the marine environment is the inclusion of 20% of coastal and marine habitats in no-fishing areas (NRC, 1999). This is only one guideline and does not imply that a list of priority sites cannot be greater.

Conservation target descriptions for the Bahamas Ecoregional Plan were completed with a format similar to CITES documents. Each of the targets is summarized in the following pages. Sections covered for each description in the final ecoregional plan will include:

- Distribution – giving a broad overview of what is known about where this target is found worldwide and in the Bahamian archipelago;
- Status of populations in the wild – with specific data, a worldwide health of the target is outlined;
- Ecology and natural history – the life cycle;
- Current conservation programs – efforts in place that are addressing the threats;
- Information gaps and research needs – areas of concern that warrant additional research and/ or conservation efforts; and
- Conservation goals and strategies – desired outcomes of efforts and methods to achieve specified goals.

Digital imagery of each target is also integrated in the descriptions. Photographs taken in the field that show the target in healthy condition were obtained from various sources.

3. Terrestrial targets

Communities/habitat types:

Dry evergreen forest (coppice): a closed-tree canopy habitat harbouring a diversity of trees and herbaceous plants; few virgin forest areas left in the Bahamian archipelago; important habitat for many threatened species, including the white-crown pigeon, Bahama parrot, and West Indian iguana; threatened by agriculture, development, timber harvesting, soil erosion, and invasion of exotic plants.

Pineland (pine rocklands): pine woodlands restricted to four northern Bahamian islands and the Turks and Caicos; important fire climax community, restricted to areas with open or low shrub/scrub that are periodically burned; important habitat for migratory and resident birds, including Kirtland's warbler and the Bahama parrot, as well as the West Indian rock iguana; threatened by timber production and invasion of exotic plants.

Blue holes/inland wetlands: Unique cave systems that support endemic fauna and microbial communities.

Beach strand: type of shrubland or herbaceous vegetation that occurs along the shoreline with a sand substrate; used by various marine turtle species for nesting; important for preservation of dune systems; relatively small habitat area; threatened by development, sand mining, and invasion of exotic species.

Table 1. Conservation targets for the Bahamas Ecoregional Planning Exercise

Common name	Scientific name	Comments
Terrestrial targets		
Dry evergreen formation		Forests, shrublands and thickets of evergreen broadleaf trees and woody herbs, this is a complex 'shifting mosaic of over 600 plant species'.
Pineland (pine rocklands)		Caribbean pines dominate both forests and woodlands in rocky, often soggy areas of the northern islands, and a few isolated islands on Caicos banks.
Blue holes/inland wetlands		Blue holes are unique cave systems that support endemic fauna and microbial communities; Wetlands include seasonal, ephemeral vegetated and deepwater communities, including anchialine ponds. Wetlands are critical wildlife habitats, often small in size, and sensitive to changes in freshwater lenses and hydrology of islands.
Beach strand		Also known as bush or coppice, comprised of a mosaic of > 600 plant species and critical habitats for birds and reptiles.
Coastal wetlands		Mangrove communities that occur along the coastal zone of the archipelago.
Rock iguanas	*Cyclura spp.*	Comprised of three subspecies of C. cychlura, two subspecies of C. carinata, and three subspecies of C. rileyi.
Flamingos	*Phoenicopterus ruber*	Once widespread, these year-round inhabitants of the Bahamas have been threatened by over-hunting.
Shearwaters	*Puffinus lherminieri*	A tropical pelagic species represented in the western Atlantic by an endemic subspecies consisting of only about 5,000 pairs, a significant percentage of which breed in the Bahamas.
White-crowned pigeon	*Columba leucocephala*	The principal game bird of the Bahamas, with recognized declining population trends throughout much of its distribution.
Marine targets		
Acroporid corals	*Acropora spp.*	Elkhorn and staghorn corals.
Queen conch	*Strombus gigas*	Important cultural symbol and fishery species, large-scale population declines.
Spiny lobster	*Panulirus argus*	Most important fishery in the archipelago.
Nassau grouper	*Epinephelus striatus*	Important finfish fishery, large-scale declines from over fishing of spawning aggregations.
Green turtle	*Chelonia mydas*	Important herbivore in sea grass meadows drastically reduced in abundance throughout the Caribbean. Tidal embayments are nursery areas in the Bahamas.
Hawksbill turtle	*Eretomochelys imbricata*	Important sea grass herbivores as juveniles, feed on sponges as adults. Extremely reduced in abundance from fishing for its prized shell.
Spotted dolphin	*Stenella frontalis*	Top predator and critical player in ecosystem processes, long-term studies on Little Bahama Banks.

Coastal wetlands: Mangrove communities that occur along the coastal zone of the archipelago.

Vertebrates:

West Indian rock iguana (*Cyclura spp*.): composed of eight species that inhabit tropical dry forests and Pine Barrens; all three species, including eight subspecies, occur in the Bahamian archipelago. Many subspecies exhibit high endemism with narrow geographic ranges for many subspecies, including distributions restricted to particular islands. Estimated population sizes of some subspecies range in the hundreds of individuals or fewer. Rock iguanas are important seed dispersers for many plants. Principal threats include predation by exotic species, loss of habitat, and illegal hunting and smuggling. All extant species are considered by IUCN to be endangered or vulnerable to human disturbance, and all species are listed as CITES Appendix 1. In the Bahamas, rock iguanas are protected under the 1968 Wild Animals Protection Act.

Flamingos (*Phoenicopterus ruber*): year-round resident of the Bahamas, particularly at Lake Rosa on Great Inagua; thrives in saline lagoons and coastal estuaries, where they filter-feed upon organically rich detritus, as well as unicellular algae, small insect larvae, crustaceans, molluscs, and certain seeds.

Shearwaters (*Puffinus lherminieri*): total population of only 5,000 pairs in the Western Atlantic. Audubon's shearwaters are found in tropical and sub-tropical climates. A large majority of shearwaters breed in the Bahamas, the largest breeding colonies occur on Long Cay and the Allen's Cay group.

White-crowned pigeon (*Columba leucocephala*): common, year-round resident of the Bahamas, dependent upon mangrove forests, pinelands, and woodlands; highly gregarious arboreal bird, occur in large flocks in the western Bahamas during the winter. These birds are frugivores and important seed disperser in seasonal deciduous forests. Populations have declined dramatically, principally from hunting, habitat loss, and introduction of predators. Considered threatened or endangered throughout much of its range, with declining population trends documented in the Bahamas.

4. Marine targets

Invertebrates:

Staghorn coral (*Acropora cervicornis*): one of three species in the genus in the wider Caribbean Atlantic widely distributed in the Bahamian archipelago. Formerly a ubiquitous element of coral reefs, decimated throughout much of its range beginning in the 1970s principally from white band disease, storm damage, and local human disturbances.

Elkhorn coral (*Acropora palmata*): one of three branching coral species in the genus in the wider Caribbean, widely distributed, including the Bahamas and Turks and Caicos. Once a ubiquitous component of many wider Caribbean reefs, but have suffered large-scale population declines since the 1970s. Elkhorn coral is the principal frame builder of reef flat and reef crest environments in most coral reef ecosystems, providing high topographic complexity for a diversity of other fauna. Although the causes of population declines are not fully understood, the loss of this important constructional component has resulted in a phase shift of many wider Caribbean reefs from coral dominance to algal dominance.

Queen conch (*Strombus gigas*): distributed throughout the tropical northwestern Atlantic. Severe stock depletion in many localities, added to Appendix II of CITES, the implementation of a temporary Caribbean-wide moratorium on conch fishing until stocks can recover has been advocated. As an important herbivore and detritivore in shallow-water communities, the queen conch has a complex life history involving multiple habitat types.

Spiny lobster (*Panulirus argus*): distributed throughout the tropical northwestern Atlantic, high exploitation in many localities, most economically important fishery in the Bahamian archipelago. It is an important detritivore and invertebrate predator, uses a variety of benthic habitats during its demersal life stages.

Vertebrates:

Nassau grouper (*Epinephelus striatus*): most important finfish fishery in the Bahamas; historically abundant throughout the tropical western Atlantic; severe stock depletion in most localities; now mostly considered commercially extinct, principally from overexploitation of spawning aggregations; considered vulnerable to exploitation because of life history characteristics such as slow growth, large adult size, delayed reproduction, generally small home range size, and aggregated spawning behaviour; utilizes a variety of benthic habitats during demersal life stages; important top-level predator in subtropical and tropical marine ecosystems.

Hawksbill turtle (*Eretmochelys imbricata*): pan tropical distribution; preference for tropical beaches for nesting; use open-water, demersal, and coastal habitats during the life cycle; important sea grass foragers as juveniles and spongivores as adults; threatened by commercial fisheries, debris ingestion, and habitat degradation.

Green turtle (*Chelonia mydas*): distributed throughout the tropical oceans; prefers tropical beaches for nesting; uses both open-ocean and demersal habitats during the life cycle; uses tidal embayments in the Bahamas as nursery habitats; important herbivore in sea grass beds; threatened by commercial fisheries, debris ingestion, and habitat degradation.

Spotted dolphin (*Stenella frontalis*): endemic to the Atlantic ocean, where it inhabits the tropical, sub-tropical and warm temperate areas of the western North Atlantic, Caribbean, Gulf of Mexico, South America, West Africa, and the Azores; principal threats to this species are pollution and habitat degradation, recreational fishing, and human interaction

In addition to providing conservation target information following the above-described format, supplementary relevant information has also been included throughout this document. Tables showing the occurrences of marine mammals, sea turtles, and seabirds have been placed at the end of the Atlantic spotted dolphin, Hawksbill turtle, and Audubon's Shearwater target descriptions, respectively. These tables elucidate the distributional patterns of each animal group, based upon the habitat or bank type. Additionally, CITES lists and explanations can be found at the end of this document (see Appendix). The lists have been revised from original CITES Annex II and CITES Annex III species lists so that they contain only those species that occur in the Bahamian Archipelago.

5. Target Descriptions

5.1. Community Targets

5.1.1. Beach strand

Description

Community classification based upon Areces et al. (1999):

Class: Shrub land
Class: Herbaceous
Subclass: Evergreen shrub land
Subclass: Perennial graminoid vegetation
Group: Subtropical broad-leaved evergreen shrub land
Group 1: Subtropical grassland
Group 2: Subtropical perennial forb vegetation
Subgroup: Natural/semi-natural
Subgroup: Natural/semi-natural
Formation: Subtropical broad-leaved evergreen shrub land
Formation 1: Medium-tall sod subtropical grassland
Formation 2: Low subtropical perennial forb vegetation

Beach strand is, in part, a vegetation community inclusive of a series of formations (shrub, herb/vine, and herb/shrub alliances) that all occur along the shoreline with a sand substrate. Beach strand formations begin above the high tide mark where plants have begun to colonize the sand. Typically a herb/vine alliance occurs nearest the ocean where loose, shifting sand and occasional flooding does not support larger, shrubby plants. Shrub and herb/shrub alliances commonly occur farther back from the shoreline in "fixed dune" areas (Bahamas National Trust, 2000), where plants have stabilized the substrate with their roots. Variation in species composition takes place within and between these formations. Additional variation is seen due to differences in the physical structure of the landscape, which are caused by differences in the level of energy applied to the coastal zone by local oceanographic conditions, wind, and storm events. These environmental effects produce the common low relief (< 3-5 m) dunes that occur throughout the Bahamian archipelago, as well as the less common high-relief (>5 m) dunes that are known to occur in portions of the Exuma Cays, San Salvador, and East Caicos.

Distribution

Beach strand is found on all major islands in the Bahamian archipelago, especially on east-facing shores and where offshore reef or small islands, or rocky headlands, protect the shoreline from wave action and allow sand to accumulate. Sand can also accumulate on low-relief coastlines exposed to high-energy oceanographic conditions where an 'upstream' source of sand is present. Beach strand vegetation formations occur both at the shoreline and inland on beach-associated dune systems.

Status of beach strand

Beach strand is a widespread habitat throughout the Bahama archipelago, though it is often compromised by direct or indirect human activity. For example, beach strand on New Providence has been severely eroded as a result of development close to the shoreline as well as heavy beach use. Beach strand areas throughout the archipelago have been degraded through the invasion of non-native Casuarina trees. Many beach strand areas on inhabited and uninhabited islands also suffer from the build-up of marine debris along the shoreline.

Ecology and natural history

Dune systems are most common on eastern shores of the islands, as the prevailing winds are from the east (Sealey, 2001). Dunes originate from beach sand, and are formed as wind carries dry sand inland (Sealey, 1994).

The primary accumulation of sand that is colonized by plants is known as the fore dune (Barbour, 1992). The main dune, which supports a greater variety of plants, accumulates as sand is carried by the wind past the fore dune. Dune areas provide plants with protection from salt spray, wind, and wash over, as well as with a source of moisture (large dunes are known to hold significant amounts of fresh water (Sealey, 1994)). Because of stabilization of the substrate, protection afforded by dunes, and overall decline in stresses to plants, species abundance changes and species richness often increases from the fore dune inland (Barbour, 1992; Doing, 1985).

There are additional distinctions between beach strand locations in terms of the class of dominant vegetation. The two main recognized classes of vegetation are shrub land and herbaceous. Primarily herb/vine alliances are found at the leading edge of all beach strands in the Bahamas. Plants in this pioneer zone are halophytic (salt tolerant) and grow low to the ground. Common plants to this area are the vines *Canavalia obtusifolia* and *Ipomea pes-caprae* and the succulents *Batis maritime* and *Sesuvium portulacastrum* (Correll & Correll, 1982, Bahamas National Trust, 2000). A variety of vegetation alliances can occur beyond the fore dune, depending, among other things, on the level of exposure to wind and other elements. Perennial graminoid vegetation commonly occurs in this area and is often dominated by Sea Oat (*Uniola paniculata*). Dense stands of just Uniola paniculata can form, but will typically occur together with shrubs and other graminoids. These grassy zones are usually crisscrossed with vines, such as Ipomea violacea, and low growing forbs including *Ambrosia hispida* and *Canavalia rosea* (Smith, 1982). Many grassy zones are inter-dispersed with clumps of shrubs, with shrubs occasionally becoming the dominant vegetation type. Some areas beyond the fore dune support chiefly shrubby vegetation with an underlying herbaceous component. With the introduction of Casuarina to the Bahamas, an additional non-natural forest class can be recognized. This non-native and detrimental species (Hammerton, 2001) is now common in numerous coastal areas of the Bahamas.

Habitat

Beach strand habitat is always composed of a sand substrate, which, as mentioned earlier, is loose and shifting near the shoreline and stabilized in inland areas covered by plants. Physical elements of the beach strand are harsh; plants that grow near the shore must tolerate bright sun, wind, salt spray and a lack of moisture. Salt spray, and perhaps fire rarely, maintains coastal strand and prevents it from succeeding to coastal coppice, which is a vegetation type dominated by shrubs or short trees. In southeast Florida and possibly on some of the northern Bahamas islands, rare frosts also maintain strand from succeeding to coppice.

Associated species

Hawksbill turtles (*Eretmochelys imbricata*) nest in beach strand areas on islands and mainland throughout the Caribbean and subtropical Pacific and Indian Oceans (NMFS, 2001). Loggerhead turtles (*Caretta caretta*) and Green turtles (*Chelonia mydas*) also use grassy, sparse beach strand areas for nesting grounds during the summer months, and are known to nest in the Bahama and Turks and Caicos Islands. The endangered piping plover (*Charadrius melodus*) winters on islands in the Bahama archipelago, and uses beach strand areas to feed and find shelter.

Threats

Major threats to beach strand communities include physical impacts from development, invasion of exotic/ invasive species, damage to vegetative cover, and sand mining. In the Bahamas, many of the larger islands have undergone substantial development along stretches of the shoreline. Direct development completely destroys the beach strand and dune system, and often leads to problems with erosion of the beach itself. For example, if a structure of any sort is built directly upon the shoreline, the long-shore or lateral drift of sand will be obstructed, causing a lack of sand and consequent erosion by wave action on the leeward side of the structure.

Additionally, as development takes place there is typically an associated invasion of exotic plant species such as Casuarina and Scaevola. These exotic species quickly colonize disturbed areas, and out-compete the natural vegetation. These non-natives do not stabilize sand on beach strand or dune systems as well as native plants, especially during storms and high tides. Areas that have been invaded by Casuarina are known to have their plant species diversity reduced from an average of 25 - 35 species to less than 5 species (Austin, 1978). Casuarina is particularly damaging to the dune because dune plants are intolerant of shade. In addition, Casuarina reduces salt spray, which then can lead to succession to coppice by plants that would not normally grow within the spray zone.

Another major threat to the dune system is damage to the vegetation that holds the dune sand in place. Often, dunes of popular beaches suffer heavy pedestrian and automobile traffic, resulting in destruction of the dune vegetation. Without vegetation to hold the sand in place, dunes will quickly erode in the wind. Many examples of this dune erosion can be seen on New Providence and Paradise Island (Sealey, 1994).

Sand mining, or the practice of taking sand from dunes, beaches and bays causes loss of natural beach strand areas and the protection that they provide to inland areas. Sand is widely used in construction, and the least expensive way to get sand is to take it from beaches and dunes. This has been a problem particularly in Freeport, North Andros and the Exumas (Sealey, 2001). Sand mining destroys both the primary body of the dune, or beach, and its vegetation, leading to further erosion after the initial damage. Loss of dunes that protect developed inland areas can lead to property damage during severe weather. In addition, a common practice to replace onshore mining of sand is offshore dredging. If dredging of sand occurs in areas that naturally replenish beaches, the beaches may eventually diminish. This is exactly what happened in Montagu Bay, where dredging for construction sand, along with placement of a seawall along the beach, has resulted in the loss of the beach itself (Sealey, 2001).

Current conservation programs

Several national parks protect coastlines in the Bahamas, including beach strand areas. Pelican Cays Land and Sea Park, on the west side of Abaco, encompasses a 2100-acre area, some of which is beach strand. Conception Island National Park protects an island (also of 2,100 acres) that contains many miles of beach strand. Additional protected beach strand can be found within Tilloo Cay National Reserve, LuCayan National Park, Peterson Cay National Park, and Exuma Cays Land and Sea Park. Existing legislation protects beach strand from mining in some areas, such as near Freeport, Grand Bahama, where mining of sand can result in prosecution.

Information gaps and research needs

Species distributions among beach strands, and especially among islands, differ in their composition. As species lists do not exist for most beach strand areas, species compositions are usually inferred from a general list. Documentation is needed on the effects of near shore development and sand mining. Also, information is needed about the effects of offshore dredging of areas that might supply sand to beaches. No studies to date have described the successional stages of beach strand that have been invaded by species of Scavoela or Casuarina.

All of this information is necessary for the development of both sound management practices and protective legislation for beach strand.

Blowing Rocks Preserve: A Model Approach to Beach Strand Restoration

In dealing with coastal degradation and/or erosion in the Bahamas, lessons can be learned from similar issues experienced along the coastline of South Florida. The geology and topography of Florida is very similar to that of the Bahamas, as land in both places is made up of exposed, low-lying carbonate deposits. Degradation of coastlines in South Florida has taken place in much the same way as it is currently occurring in the Bahamas. Coastal development and invasions by Casuarina trees have been (and in many cases still are) prevalent issues along much of the Florida coastline. To prevent further degradation and erosion of compromised shorelines, some measure of restoration is essential. Successful restoration is achieved when function is returned to the natural shoreline ecosystem. One success story in beach strand/shoreline restoration can be found at The Nature Conservancy's Blowing Rocks Preserve, on Jupiter Island, Florida.

When The Nature Conservancy (TNC) acquired the 73 acres on Jupiter Island in 1969, the majority of the area was covered with non-native plants, especially Casuarina trees. Plans to begin a large-scale restoration of the area began with looking at historical aerial images to determine what vegetation types occurred and where they occurred within current Preserve boundaries. The images were also used to examine changes in vegetation over time, and to assess causes of change. With this information, staff at TNC created a map of the preserve showing coverage of the different types of vegetation that could be achieved through restoration. This map, which reflected historical vegetation coverage as well as permanent changes to the landscape that had occurred since, became a basis for restoration goals.

Concurrently, stewards of the preserve began a rigorous program to remove invasive plants. The help of the community was enlisted in this program. Volunteers were sought by passing out flyers advertising the need for weekend help in removing invasive species. The initial volunteer response was tremendous, however, too much time was allotted to overseeing volunteers that Preserve staff opted to target individual volunteers rather than to continue supervising large groups. Current individual volunteers in the non-native plant removal program have a higher level of safety training, allowing the use of more advanced and effective removal equipment, including herbicides.

A large effort was put forth to determine what to do with the bulky remains of cut Casuarina trees. Several different approaches to this problem were tried. Letting the felled trees decay naturally was not an option as the wood is dense and decays only very slowly. The wood of Casuarina burns very hot, and on-the-spot incineration proved to sterilize the soil and remove the seed bank of native vegetation, causing a temporary barren area. The felled trees were also processed and used as mulch in areas that were being re-planted. Current experiments at the preserve are assessing the effects of different thickness of this mulch on germination and survival of seeds of native plants. It was suggested, although there is not a market in South Florida for the product, that either the resulting mulch or cut stacks of firewood be sold or given away to alleviate the problem of disposal. Finally, re-sprouting from cut stumps was the cause of large amounts of re-growth. It was determined that herbicide treatment, grinding the stump down to the roots, or removing the stump entirely was necessary to stop re-sprouting.

It was found that upon removal of Casuarina and other plants that caused unnatural shading or blocking of salt spray in beach strand areas, native vegetation returned without further effort. However, to create diversity within the vegetation, and to move toward restoration goals, TNC staff started a native plant nursery on the premises. Again using volunteers, native plant seeds were collected from the surrounding area. Seeds were prepared for germination (which sometimes included seed scarification) and planted in containers in a mixture of potting soil and sand or soil from local areas. Volunteers propagate and raise all plants in this nursery according to a set restoration schedule. For example, if it is known that a number of Sea Grape (Coccoloba uvifera) trees are to be out planted in a certain area, the growing process is started far in advance to ensure that trees are mature enough to survive on their own when out planted.

Restoration biologists working at the Preserve stressed the need to complete removal and restoration in phases so that habitat of some sort will always be available for wildlife. The restriction of foot and/or auto traffic to designated pathways is also necessary, as this type of disturbance destroys vegetation. Restoration of functioning strand/dune ecosystems at Blowing Rocks Preserve has been highly successful. Not only has this helped to preserve the shoreline, it has also become an attraction for tourists and local residents.

Goals

- To preserve and protect all intact, undamaged coastal strands in the Bahamas; and
- To enact a restoration plan for all altered/ damaged coastal strands in the Bahamas.

Justification

Coastal strands are dynamic areas whose ecology is dominated by energy from the ocean and from weather. Anthropogenic disturbances are magnified in coastal areas due to this dynamic nature. Coastal strands are also easily fragmented because of their narrow, linear distribution. Intact coastal strands provide habitat and nesting areas for many threatened and endemic species. The integrity of a coastal strand's ecological function is essential to the survival of these species. The sensitivity to disturbance of coastal stands as well as their narrow distribution around the fringes of islands makes protection of all coastal strands throughout the Bahamas necessary. Coastal strands play a key role in the geology of and coastal stabilization in the Bahamas. They are also a vital aspect of the tourism industry. Many coastal strands in the Bahamas have been damaged or entirely destroyed. Restoration plans that focus on rebuilding the ecological function of a coastal strand have been successful in the past, and would benefit threatened wildlife, natural coastal strand communities and the tourism industry in the Bahamas. Restoration would also help to curb the expansion of damaged/eroding areas. However, restoration of inland dunes may be difficult because palmettos, one of the primary types of dune vegetation, grow slowly. Dune areas are also very susceptible to exotic plant invasion.

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Figure 3. Beach strand pioneer zone on Abaco

Figure 4. Beach strand dune vegetation on Abaco

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5.1.2. Dry Evergreen Formation (Coppice)

Description

Community classification based upon Areces et al. (1999)

Class: Closed tree canopy

Class: Open tree canopy

Subclass: Evergreen forest

Subclass: Evergreen woodland

Subclass: Evergreen shrub land

Group: Subtropical seasonal evergreen forest

Group: Subtropical broad-leaved woodland

Group: Subtropical broad-leaved shrub land

Subgroup: Natural/semi-natural

Formation: Many formation types exist (see Vegetation Classification document)

Dry evergreen formation or coppice harbours a diversity of trees, shrubs and herbaceous plants that, depending on the location and history of disturbance, differs in its composition. The dry evergreen formation communities are found in several different habitat types throughout the Bahamian archipelago. They consist mostly of hardwood trees and shrubs, with the dominant vegetation type differing in each locality. The herbaceous component of these formations is often small, as coppice vegetation characteristically grows close together, creating a heavily shaded under story. Relative canopy heights of dry evergreen formation in the Bahamas are greater in inland areas of the larger northern and central islands. The vegetation toward the drier, southern extent of the archipelago tends to be scrubbier (Smith & Vankat, 1992), both due to limited access to fresh water and proximity to the ocean.

Distribution

Dry evergreen formations occur on all major islands in the Bahamian archipelago. These coppice formations occur both in sandy and organic soils underlain by oolitic limestone, which is often protruding from the soil surface. They range from just beyond the shoreline throughout the interior of all islands, especially in elevated areas. The location and type of coppice depends on the physical landscape and the hydraulic regime as well as the land use history. Dry evergreen formations growing on elevated islands in pine woodlands are affected by the fire history of those areas.

Status of populations in the wild

The different types of dry evergreen formations are common throughout the Bahama archipelago. Much of the existing inland coppice is thought to be secondary or even tertiary growth (Bahamas National Trust, 2000) due to historic clearing and/or utilization of many of the coppice trees. Consequently, the canopy heights of most coppice areas in the Bahamas are probably lower than they have been in the past. Virgin forest can only be found on Little Inagua (Bahamas National Trust, 2000), where the tallest trees reach up to 25 m in height (Correll & Correll, 1982). On inhabited islands, coppice is often fragmented due to either agricultural clearing or development.

Ecology and natural history

Depending on locality, dry evergreen formation can be divided into two separate types. Dry evergreen formations that grow inland from beach dune or coastal rock areas usually occur on sand or rock substrate that affords relatively little moisture or nutrients. Plants that grow in this coastal broadleaf evergreen woodland community, or coastal coppice, are hardier and are sometimes interspersed less densely, leaving a slightly open canopy. Coastal coppice is also shrubbier in terms of species composition and canopy height than other coppice areas. Many of the same species that occupy the beach strand (see target description) can be found in the coastal coppice (Ford, 1997). Trees that are common to coastal coppice include the sea grape (*Coccoloba uvifera*), Acacia (*Acacia choriophylla*), wild dilly (*Manilkara bahamensis*), poisonwood (*Metopium toxiferum*), silver thatch palm (*Coccothrinax argentata*), beefwood (*Guapira discolor*), and less commonly, mahogany (*Swietenia mahagonia*) (Correll & Correll, 1982; Smith, 1982). Also found in coastal coppices are many endemic epiphytes, mainly species of Encyclia, Epidendrum, and Tillandsia (Correll & Correll, 1982).

Coppice in the interior of the islands with substantial fresh water lenses is generally taller, denser, and has a closed canopy. This type of coppice is often referred to as 'blackland' coppice or high coppice (Northrop, 1902; Correll & Correll, 1982; Smith, 1982; Ford, 1997), the latter because it is found on ridges or elevated inland areas. Depending on the elevation in which this type of dry evergreen formation is found, the canopy height can be shorter or taller, with taller canopies occurring in more elevated areas (Sauleda & Adams, 1979; Eshbaugh & Wilson, 1990; Smith & Vankat, 1992). Blackland coppice has an oolitic limestone substrate with organic soil development in many areas. Weathering of the limestone creates a pitted terrain. Sinkholes, some up to 7 m diameter and depth, are common in the black land coppice. Species of Coccoloba as well as Metopium toxiferum are among the most common in black land coppice. Butter bough (*Exothea paniculata*), gumbo-limbo (*Bursera simaruba*), and ficus (*Ficus spp.*) are also among the many species of dominant trees (Smith, 1982; Correll & Correll, 1982; Smith & Vankat, 1992). Trees that are valued for their wood, such as mahogany and horseflesh (*Lysiloma sabicu*), are less common than in previous times due to over harvesting. Important under story plants include wild coffee (*Psychotria ligustrifolia*), box briar (*Randia aculeata*), and Cat's claw (*Pithecellobium bahamense*).

Habitat

Coastal flats with sandy or rocky soil are usually covered by broadleaf evergreen woodland or shrub land. In dune systems, coastal coppice often occurs on the inland side of the main dune or in the troughs between dunes. Headlands and rocky shorelines may support thin, shrubby coppice beginning a few meters beyond the high tide line. Inland coppice grows in a variety of habitats, often upon elevated tracts of land. It is often referred to as black land coppice due to the dark soil that is a product of the breakdown of organic matter in the forest. Inland coppice often surrounds mangrove communities and blue holes, or is found as elevated islands in pine forests. Sinkholes are common throughout the inland coppice habitat.

Associated Species

Dry evergreen formations harbour plant alliances that are important to many threatened species. The white crown pigeon (*Columba leucocephala*), also known as the blue pigeon, bald pate, and white head, and the Bahama parrot (*Amazonia leucocephala*) are known to nest in the treetops of the black land coppice, and also feed on the fruits of many tree species. The Bahama parrot, or Bahama Amazon (*Amazonia leucocephala var. bahamensis*), is restricted to the pine woodlands and the evergreen broadleaf coppice on the southern end of Abaco Island and on Great Inagua (Keith & Gnam, 2000). The population of Bahama parrots that inhabit Abaco nests in the sinkholes within dry evergreen formations. The Bahama boa constrictor, as well as some species of West Indian iguana (*Cyclura spp*.), occur in coppice areas. A few rare species of orchids can be found only in the high coppice on particular islands in the Bahamas. The Turk's cap (*Melocactus intortus*), a species of cactus, grows in dry, rocky areas of sparse coppice, as well as in open rock flats and rocky slopes (Correll & Correll, 1982). This cactus occurs in the lower islands of the Bahamian archipelago, including the Samana Cays, Crooked Island, Acklin's Island, Mayaguana, Little Inagua, Great Inagua, and throughout the Turk's and Caicos Islands (Correll & Correll, 1982). Dry evergreen formation also provides habitat for the many species of migratory birds that winter in the Bahamas.

Threats

The principal threats to coppice habitats in the Bahamian archipelago are agriculture, development, timber harvesting and browsing ungulates. Agriculture has been the main threat to coppice since the time of the Arawak Indians (1000-1500 AD) in the Bahamas (Byrne, 1980). Because soil accumulates in coppice, especially black land coppice, it is a suitable place for agriculture and has long been cleared through both cutting and fire. It has been noted by Byrnes (1980) that because of the unstable island habitat (due to hurricanes, fires, etc.), many coppice species have evolved a 'pioneer species' nature, and thus disturbed coppice is able to regenerate quickly. However, repeated disturbance, as well as current agricultural practices in which the limestone is ground into a rocky soil or 'ripped' to expose soil beneath a crust (Sealey, 1994), can significantly alter the composition of coppice plant species. In addition, as more invasive, non-native plants become established in the Bahamas they will likely successfully compete with native plants in disturbed sites.

Commercial and residential development is also a major threat to coppice areas. During the 1950s and 1960s, the population growth rate of the Bahamas increased dramatically (Sealey, 1990), and the ensuing development affected many of the major islands in the Bahamian archipelago. Development practices have completely destroyed coppice. Furthermore, they are often associated with erosion of surrounding areas and introduction of invasive, non-native species, both of which can add to the degradation of natural coppice. Development also leads to fragmentation of coppice, which causes loss of continuous habitat for animal inhabitants and a reduction in both dispersal and gene flow among plant and animal species.

The cutting of valuable trees in dry evergreen formations has been practiced on a large scale since the 1600s (Byrne, 1980), when mahogany and horseflesh were used in boat building by Spanish explorers. Such trees were later logged for export to England, and large specimens of these and other species of commercial quality are now rare on most islands. Other coppice plants that have been widely harvested for non-timber purposes and are now rare in many areas include cascarilla bush (*Croton eluteria*), whose bark is still exported, wild cinnamon (*Canella alba*), brasiletto (*Caespalpinia spp.*) and logwood (*Haematoxylum campechianum*), which both produce dye, and hog cabbage palm (*Psuedophoenix vinifera*) which is used for pig feed (Byrne, 1980; Little et al., 1977; Sealey, 1990).

Finally, free ranging domesticated, or feral, ungulates pose a threat to coppice areas through grazing and browsing activities. Heavily grazed/browsed areas are devoid of an herbaceous under story, and the lower portion of most trees or shrubs will often be stripped of leaves. Goats have historically had large impacts on the composition of vegetation in the coppice on Cat Island, Long Island, New Providence, Exuma and Eluthera (Byrne, 1980; Little et al., 1977; Sealey, 1990), and undoubtedly feral populations occupy many other islands in the archipelago. Browsing and grazing by ungulates increases erosion, changes the plant species composition of coppice areas, and creates competition for food in threatened native species such as the West Indian Iguana (Gerber & Iverson, 1998).

Current conservation programs

Unknown acreage of dry evergreen formations is protected in several national parks, including coastal and inland coppice in Inagua National Park, Lucayan National Park, and Rand Nature Center. Coastal coppice is protected in Union Creek Reserve, Pelican Cays and Exuma Cays Land and Sea Park, Tilloo Cay and Black Sound Cay National Reserves, and Peterson Cay and Conception Island National Parks. No existing legislation protects dry evergreen formation outside of reserves or parks.

Information needs and research gaps

Although the general flora of dry evergreen forest, woodland and shrub land is documented (e.g. Correll & Correll 1982; Northrop, 1902), coppice differs greatly in species composition and abundance between areas. Species lists for each area do not exist. Also needed is information on the effects of fragmentation, clearing, fire and feral ungulates on the abundance and distribution of plant and animal species associated with coppice. No studies to date have described the successional stages of coppice after these types of disturbances. Such information is needed in the development of sound management practices.

Goals

- Protect and maintain large intact tracts of dry broadleaf evergreen formation, representative of the variety of habitat types encompassed by this target, on each major island in the Bahamas; and
- Establish protected area status, active management, and a source of funding for the identified tracts of dry broadleaf evergreen formation.

Justification

Dry evergreen formations provide habitat to many endemic and rare Bahamian plant and animal species. Protection and management of large forest, woodland and/or scrubland areas that contain a variety of habitat types would ensure that the maximum number and diversity of dependent plant and animal species could be sustained. Agricultural clearing, development and invasive non-native species, including feral animals, also threaten dry evergreen formations. Some islands in the Bahamas, such as New Providence, have highly fragmented or few remaining areas of dry evergreen formation in a natural state. Preserving and protecting these areas would be the first step towards restoration. In contrast, areas such as south Andros have large, intact dry evergreen formations requiring little restoration work. Protection, active management, and funding are required for the perpetuation of dry evergreen formation throughout the Bahamas, in a natural state and harbouring a diversity of habitats.

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Figure 5. Closed canopy coppice growing in the interior of New Providence

Figure 6. Shrubby coastal coppice on Abaco

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5.1.3. Pineland (Pine yard)

Description

Classification following Areces et al. (1999):

Class: Woodland
Subclass: Evergreen woodland
Group: Subtropical needle leaved
Subgroup: Natural/Semi-natural
Formation: Pinus caribea var. bahamensis

The Pinus *caribea var. bahamensis* woodland alliance occurs on four northern Bahamian Islands (Abaco, Andros, Grand Bahamas, New Providence) and in the Turks and Caicos Islands. Also called pine rock land or pine barren, the substrate upon which the woodland is found is heavily pitted oolitic limestone, usually with little soil present. An open primary canopy that is formed by stands of *Pinus caribea var. bahamensis*, which is a subspecies of Caribbean pine endemic to the Bahamas, characterizes pine woodlands. Trees typically occur 3 m to 7 m apart (Northrop, 1902; Emlen, 1977) and give approximately 50% to 60 % canopy cover. Mature pines can reach between 20 m and 30 m in height and have a maximum trunk diameter of 1.5 m (Northrop, 1902; Correll & Correll, 1982). Low branches are rare; branches are found high on the trunk due to both the growth form of these pines and the pruning action of fire. The upper canopy consists of opposite, spreading branches that can be seen bearing 9 cm to 14 cm cones year round.

Because periodic fires clear the under story of pine woodland, there is no significant sub canopy above the shrub layer. The shrub layer is 1-2 meters high and consists of broad leaf evergreens with an underlying herbaceous layer. Shrubby plants in the pine woodland can be patchy, with open areas or can form a dense, impassable layer. Substantial diversity is found within the shrub and herbaceous layers, with 189 plant species having been cited as to occurring in this alliance (Northrop, 1902; Correll & Correll, 1982; Eshbaugh & Wilson, 1990; Frazer, 1993). Diversity is also seen in the types of woodland that occur. According to the dominant shrub layer and the basic hydrology of the area, three different associations of pine woodland have been described (Areces et al., 1999; Freid, 2001; Correll & Correll, 1982).

Distribution

There are three varieties of Pinus caribea that occur in the greater Caribbean region: Honduran, Caribbean, and Bahamian. *Pinus caribea var. bahamensis* is endemic to the Bahamian Islands. Large stands occur on Grand Bahama, Abaco, Andros and New Providence, as well as the Caicos Islands, where it forms expansive woodlands on North Caicos, Grand Caicos, and Pine Cay (Correll & Correll, 1982), and scattered populations on other islands of the Turks and Caicos (Northrop, 1902; Correll & Correll, 1982). Pinelands also historically occurred on the Berry Islands (Sealey, 1990).

Status of populations in the wild

Much of the pine woodland in the Bahamas occurs on Crown Lands. As of 1974, a total of 373,677 acres of pineland exist on Crown Lands (Henry, 1974) on Abaco, New Providence, Grand Bahama and Andros. A current census would probably show less acreage. While the tracts of pineland reported are somewhat intact they encompass many separate woodlands on different parts of the islands. No degree of fragmentation of these woodlands has been reported. Clear cutting between 1957 and 1975 (Henry, 1974) has resulted in pinelands with little variance in age class structure. There is also additional, usually fragmented acreage of pineland not encompassed by Crown Lands.

Ecology and natural history

Pine woodlands of the Bahamas, similar to those in South Florida and elsewhere in the Caribbean, are recognized as 'fire climax' communities. The bark of Pinus caribea is multi-layered and thick, and acts to keep the tree's cambium from reaching a lethal temperature threshold. Pinus caribea is a light demanding species. Without periodic (3-7 years on average) fires to clear out undergrowth, pine seedlings would not receive sufficient light or nutrients to survive (Sealey, 1990). In areas of the pineland that have not been subjected to recent fires (> 15 years) there is a transition to dry broadleaf evergreen forest, woodland, and shrub land with a remnant over story of pine trees (Eshbaugh & Wilson, 1990). Annual fires are known to keep the diversity of the under story at a minimum.

In low lying areas that accumulate ephemeral fresh water ponds, as well as areas in which the subterranean fresh water lens is near to the surface, the under story shrub layer is dominated by Sabal palmetto. Other common species that are found in the shrub layer in low pine woodlands are *Metopium toxiferum*, *Byrsonima lucida*, *Lantana involucratea*, *Bourreria ovata* and *Thrinax morrisii* (Eshbaugh & Wilson, 1990). Among the numerous vines and herbs that occur in the under story herbaceous layer are *Rajania hastate*, *Smilax ariculata*, *S. havanensis*, *S. laurifolia*, *Ipomoea microdactyla*, *Centrosema virginiana*, *Rhabdadenia biflora*, *Dichromena colorata*, *Eustachys petraea*, and *Andropogon spp*. (Correll & Correll, 1982; Eshbaugh & Wilson, 1990). Additional variation in low pine woodland occurs in areas of Northern Andros. There the relative nearness of the fresh water lens to the surface stunts the growth of Pinus caribea var. bahamensis, creating pygmy woodland with a broadleaf and herbaceous under story that is both reduced in diversity and density (Freid, 2001 personal observation).

Wet and dry pinelands are often inter-dispersed and share many of the same species, although the dominant species change depending on the proximity of water. In upland areas that are better drained the under story is usually dominated either by the palms *Coccothrinax argentata* and *Thrinax morrissii*, or by poisonwood (*Metopium toxiferum*) (Correll & Correll, 1982; Areces et al., 1999; Eshbaugh & Wilson, 1990). Other species that occur more commonly in dry pinelands are *Petitia domingensis*, *Acacia choriophylla*, *Cordia bahamensis*, *Turnera ulmifolia*, *Veronia bahamensis*, *Dichromena colorata*, *Hypericum hypericoides*, *Duranta repens*, *Tetrazygia bicolor*, *Chiococca parvifolia*, *Linum bahamesis*, and *Cassia lineata* (Correll & Correll, 1982; Eshbaugh & Wilson, 1990). Two species of note are *Bletia purpurea* (purple orchid) and *Pteridium aquilinum* (bracken fern), both of which are common in the dry pineland. Also found in the dry pineland is the cycad *Zamia integrifolia*, which is the exclusive host plant of the small and rare Atala hairstreak butterfly.

An additional association can be recognized as occurring on Abaco in areas of the pine forests in which the fire regime has been unnaturally altered to occur on a yearly basis. In these areas shrubby broadleaf evergreen species are not able to re-establish, and the weedy fern Pteridium aquilinum has become the dominant under story species, forming an impenetrable thicket (Freid, 2001 personal observation).

Habitat

In general, pine woodlands occur in well-drained or freshwater-saturated limestone rock lands of oolitic origin. The limestone is usually heavily pitted, with sinkholes often present. Pine woodlands can occur on a thin layer of soil or no soil at all. Because of the need for high light intensity, they are only able to establish in areas with low or open shrub/scrub that are periodically burned. Pine woodlands can be re-established in thinly coppiced areas and thatch palm, poisonwood, and palmetto woodlands growing on limestone that have recently been burned. Large tracts of pine woodland habitat have been destroyed through agricultural development, which includes clearing and grinding the limestone into a rocky soil.

Associated Species

The pinelands are an important alliance for both migratory and resident bird species with migrant birds essentially doubling the biomass of the bird community. In a 1977 study, Emlen found that during the winter, 21 migratory species joined the 24 species of birds that were permanent residents of the pine woodlands of Grand Bahama Island. The endangered Kirtland's Warbler, whose wintering grounds are restricted to islands of the Bahamian archipelago, is among the visiting migrant species. The Bahama parrot, or Bahama Amazon (*Amazonia leucocephala var. bahamensis*), is also associated with pinelands. This endangered subspecies is restricted to the pine woodlands on the southern end of Abaco Island (Keith & Gnam, 2000) and the evergreen broadleaf coppice on Great Inagua. The pineland alliance is also home to many species of frogs, insects, and rodents, as well as the threatened Bahamian Boa and rock iguana. Pineland habitats also support dozens of orchid species (Orchidaceae), some of which are rare.

Threats

Pine woodlands have long been recognized for their commercial value. Caribbean pine is an excellent timber tree, and is also useful in pulp production. Large-scale harvest of this resource began in the early 1900's when sawmills were constructed for commercial harvest and export of the lumber. Logging practices in the Bahamas have not been intentionally managed for the long-term sustainability of pine woodlands. The other principal threats to the pineland community are habitat destruction, fragmentation, inappropriate fire regime, and invasion of exotic species. Direct development destroys pine woodlands. Altering the limestone substrate for agriculture changes the habitat unfavourably for Caribbean pine trees and other plant species associated with pine woodlands. In addition, the changing of the natural fire regime on Abaco is clearly changing the structure of the pine forest. Typically, pineland fires occur every 3 to 7 years allowing time for pine seedlings to reach a height at which some will survive fires and other species to re-establish and then reproduce. The introduction of almost yearly burnings in some areas does not allow enough time for shrubby species to regenerate, and weedy species such as *Pteridium aquilinum* have become the dominant under story vegetation (E. Freid personal communication). Such loss of diversity in the under story of pine woodlands will not support the natural diversity in fauna that usually occurs in this alliance, and also may impoverish the resources of threatened species such as the Andros rock iguana, Bahamian Boa and Bahama parrot. In addition, immature pines usually perish in fires, as they have not yet developed the thick, insulating bark needed for fire resistance and their meristems have not attained a sufficient height to avoid lethal temperatures. A practice of annual or near annual burning will not allow juvenile pines to replace older trees that die, thus preventing regeneration of the pine woodland.

Introduction of invasive *Casuarina spp*. and *Schinus terebinthefolius* has occurred along the roadways of the northern Bahamas. These non-native trees reproduce at a rapid rate and compete successfully with native plant species for resources. Fragmented pine woodlands are especially vulnerable to invasion by these species. Casuarina is known to reduce the diversity of plants growing beneath or nearby through an allelopathy. In addition Casuarina forms a dense, shallow root system that is thought to prevent rooting by other species and to increase erosion (Hammerton, 2001). *S. terebinthefolius* is an especially troublesome species. Also known as Brazilian pepper, this species has been named by the Florida Exotic Pest Plant Council as one of Florida's most invasive and threatening alien plant species (Brazilian Pepper Task Force, 1997). It's copious seed production and attractive red fruit afford this species a wide dispersal by birds, raccoons and other animals. *S. terebinthefolius* forms dense, monotypic stands and severely reduces floral diversity in areas where it becomes established. Once established, it is difficult to remove. Establishment of both *S. terebinthefolius* and Casuarina poses a threat both to the diversity and the long-term survival of pine woodlands in the Bahamas.

Current conservation programs

Abaco National Park, which was established in 1994, covers 20,500 acres of pine woodland at the southern end of Abaco Island (Bahamas Environment, Science and Technology (BEST) Commission, 2002). The Rand Nature Center protects 100 acres, some of which are pine woodland, in Freeport, Grand Bahama. No existing legislation protects pine woodlands outside of the national parks except for particular sections of penal code, which allow for punishment of those harming trees or harvesting without a license (Henry, 1974).

Information gaps and research needs

While the general flora that can be found in pine woodland has been often described (e.g. Correll & Correll, 1982; Henry, 1974; Northrop, 1902), species lists for each woodland or island do not exist. Also needed is information on the effects of fragmentation, clearing, and fire on the abundance and distribution of plant and animal species associated with pine woodlands. No studies to date have described the successional stages of pine woodland after these types of disturbances. On Andros, the freshwater lens has been tapped and a significant amount is pumped out each day to supply fresh water to other areas of the Bahamas. This extraction could change the vegetation communities on Andros; hence long-term studies are needed to determine changes in hydrology and in vegetation cover and to develop sound management practices.

Goals

- Protect and maintain large intact tracts of pineland, particularly on Grand Bahama, Abaco, Andros, and North Caicos, with smaller preserves in New Providence (Bahamas) and Pine Cay (Turks and Caicos Islands), in many successional states such that the matrix of heterogeneous habitat and functional ecology are maintained; and
- Establish protected area status, active management, and a source of funding for the identified tracts of pineland.

Justification

The variety of Caribbean pine that is endemic to the Bahamas forms extensive formations that serve as habitat for many other organisms. Preserving large intact tracts is necessary for the survival of many endemic Bahamian plant and animal species. Fragmentation of these large pine woodlands could change dispersal dynamics of such species. Many migratory bird species also utilize pinelands. It is difficult to maintain the heterogeneous habitat needed to sustain species diversity within small or fragmented tracts of pineland. Large tracts are also easier to maintain with controlled burns than are small sections. While relatively small tracts of pineland remain on New Providence and Pine Cay, large tracts can be found on Grand Bahama, Abaco, Andros, and North Caicos. Protection, active management and funding are required for the perpetuation of pineland in multiple successional states that harbours a diversity of habitats.

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Figure 7. Pine rock land on saturated limestone on Andros

Figure 8. Pine rock land on well-drained limestone on Abaco

5.1.4. Freshwater and Coastal Wetlands
Mangrove swamps, anchialine ponds, marshes, ephemeral ponds

Description

Wetlands are, in general terms, lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Over the years, numerous classifications of wetlands and deepwater habitats have been developed (Stewart & Kantrud, 1971; Golet & Larson, 1974; Jeglum et al., 1974; Odum et al., 1974; Zoltai et al., 1975; Millar, 1976). In the most commonly used classification system (Cowardin et al. 1979), wetlands must have one or more of the following three attributes:

- At least periodically, the land supports predominantly hydrophytes;
- The substrate is predominantly undrained hydric soil, and
- The substrate is non-soil and is saturated with water or covered by shallow water at some time during the year.

Wetlands of the Bahamian archipelago include in three systems:

Estuarine Systems, characterized by coastal wetlands, mangroves, mangrove creeks and ponds influenced by tidal regimes, and elevated salinities (brackish to marine to hyper saline conditions).
Lacustrine Systems, consisting of large lakes and ponds that have minimal tidal influence, and are mostly freshwater. This includes large blue holes and anchialine ponds. In the Bahamas, most of these systems have underlying saltwater beneath the freshwater lens. These wetlands are characterized by open (deepwater) habitats.
Palustrine Systems, comprising small ponds, marshes and swamps with emergent wetland vegetation. This includes sable palm wetlands, buttonwood swamps or low-lying seasonal or ephemeral wetlands.

Coastal wetlands are characterized as estuarine systems, and are the largest group of wetlands by area and extent of occurrence in the Bahamian archipelago. Like all wetlands, coastal wetlands are sometimes easy to recognize, but can also be very difficult to distinguish from uplands. Coastal wetlands can occur in areas with standing water, tidal water, or only periodic or seasonal flooding. The carbonate rock geology of the Bahamian archipelago is porous and permeable. There is salt water underneath islands with a layer of less dense fresh water “floating” on top. This creates unusual inland brackish ponds, tidally-influences blue holes and extensive seasonal wetland environments. There is a critical need for a comprehensive wetlands inventory of the entire archipelago to identify and characterize the range of wetlands throughout the islands.

The most important coastal wetlands in the archipelago are the mangrove communities. Mangroves are among the most common coastal wetlands and very productive natural systems. The mixing of nutrients from land and sea produces huge amounts of organic matter, of which only fish and invertebrates directly consume a small fraction. In fact, bacteria decompose most of this organic matter, producing an organic soup that feeds organisms such as amphipods, shrimp, crabs, snails, shellfish and finfish.

The term ‘mangrove’ is ambiguous in its meaning. On one hand, it refers to a type of halophilic (salt-loving) plant. The mangroves, as plant species, are a large, diverse group that have hit upon a common solution for inhabiting saline soils. Mangrove forests and shrub lands dominate tropical and subtropical coastlines around the world. The term ‘Mangrove’ is also used to refer to a community of plants and animals living in tidal swamp forests. Their distribution is influenced by: climate (i.e. temperature and rainfall), salinity and tidal range, substrate and underlying geology, and wave energy. Mangrove communities were defined as having one of four vegetation structures: shrub lands, scrub thickets, woodlands or true forests (see vegetation classification for a detailed description of mangrove vegetation classification). Vegetation structure is determined by the dominant strata of the community, which includes an assessment of both the height of the plants and the area of ground covered by the canopy.

Abiotic factors such as tidal range, coastal morphology, wave energy and rainfall determine the extent of mangrove communities, as well as distinctive zonation from deep water to upland communities. Mangroves, even red mangroves can grow well in fresh water, but may not be found there because of seed dispersal mechanisms or because of competition with other plants. Mangrove communities also take a variety of topographic forms, based on the geology, hydrology, and biology of the area. The major types of mangrove communities found in the Bahamas are described:

Over wash Mangrove forests

These are often isolated islands or mud banks that are frequently over washed by tidal currents. All species of mangroves may be present, but the red mangroves will dominate around the perimeter of the island (most seaward). Eventually these over wash forests may trap enough sediment for other coastal plants to become established.

Fringe Mangrove forests

Mangroves can form a relatively thin fringe along waterways. A steeply sloping shoreline can cause zonation to be compressed into a relatively narrow area.

Table 2: Description of the tree and leaf morphology of the common mangroves of the Bahamian archipelago

Tree species	Leaves, Flowers and Propagules	Tree Shape, Bark and Roots
RED *Rhizophora mangle*	Broad, long, blunt tipped leaves. Deep Green, shiny leaves; 'Cigar' shaped propagule.	Reddish bark with prop roots.
BLACK *Avicennia germinans*	Elliptic or oblong shiny leaves, often salt covered, pubescent underside to leaves. 'Lima-bean' shaped propagules.	Dark grey-black back; long horizontal cable roots with pneumatophores.
WHITE *Laguncula-ria racemosa*	Long rounded leaves with salt glades at apex of petiole. Small 'pear-shaped' propagules.	Lighter grey bark, tall, often-emergent trees. No visible roots.
BUTTON-WOOD *Conocarpus erectus*	Silver grey or green leaf colour varieties. Long pointed with salt glands at petiole. 'Button' shaped flower and seed.	Silvery-greyish bark, gnarled wood and bark.

Basin Mangrove Forests

These forests occur inland in depressions channelling run-off towards the ocean. A basin forest could develop along dredge waterways that allow saltwater intrusion up rivers and waterways. Further inland white and black mangroves would dominate. Bring a mangrove seedling home, and it will sprout in a bucket of freshwater with a small amount of sand or soil on the bottom. These seedlings grow rapidly and are commonly cultivated for coastal restoration projects.

Hammock forests

Hammock mangrove communities are similar to basin-type communities except they occur on slightly higher ground (5 to 10 cm elevation above mean tide). This allows the establishment of white and grey mangroves. Trees generally do not grow very tall.

Scrub or dwarf forests

This community type is unique to the Florida Keys, and the Bahamas. All species are present, but trees are very small (less than 1.5 meters), sparsely populating the flat coastal fringe areas. These trees may be quite old (tens of years), but are dwarfed due to low nutrient input and poor substrate (limestone marl).

Distribution

There are wetlands and mangrove communities on all islands in the archipelago. Coastal wetlands are found along the leeward margins of islands along low-energy shorelines. The accumulation of fine sediments and mud by advancing mangroves can create an extensive system of over wash banks and creeks as seen along the western coast of Andros island. The western margins of many islands are mangrove-dominated when sheltered from over water and wave energy.

Blue holes systems are poorly defined throughout the archipelago, but systems are documented on Andros, Great Exuma, Long and Crooked Island. Inland blue holes or ‘cenotes’ are identified from aerial photography. Many islands have low-lying areas that accumulate water during the rainy season.

Ecology and natural history

Wetlands are essential breeding, rearing, and feeding grounds for many species of fish and wildlife. They also play a significant role in flood protection and pollution control.

Coastal wetlands are among the most productive ecosystems in the world, comparable to tropical rain forests and coral reefs. Because of their abundance of nutrients, and a high primary productivity they serve as biological nurseries for many other species, including aquatic plants, fish, shellfish, insects, amphibians, birds, and mammals, providing food as well as shelter and protection from predators. Furthermore, coastal wetlands filter sediment and chemicals, thus reducing the amount of pollution that washes into bays and the ocean.

Mangroves are important to both transient and permanent inhabitants. Rising and falling tides move both the organic soup and small feeding organisms between the salt marsh and adjacent coastal waters. The abundance of small habitats within a salt marsh allows for numerous organisms to hide from predators, feed without expending much energy, grow faster, and raise young. In addition to the transient organisms, mangroves shelter species that may spend their entire life in the salt marsh; killifish take refuge in small salt marsh ponds, fiddler crabs hide in burrows, and mussels close their shells and await the next flood tide.

Over 75 percent of the fish caught commercially, and 80-90 percent of fish caught recreationally inhabit mangroves and mangrove creeks at one time or another. Mangroves were once considered a trash tree, and removed to make room for marinas, and other coastal developments. In mangrove communities, much of the primary production is exported to other coastal communities that are related in function and energy flow in the coastal ecosystem. Many animals do not feed directly on the mangrove leaves. Microbial action is important in transforming the leaf energy from hard-to-digest cellulose to more usable organic molecules (proteins, simple sugars or fatty acids).

In locations where mangroves have been present for some time and low wave energy and depositional conditions persist, high amounts of peat soil formation and deposition will occur. Peat soils are formed through an accumulation of partially decomposed woody or fibrous plant matter under reducing conditions. This peat soil formation is driven by the productivity and subsequent decomposition of large amounts of plant matter (litter fall: i.e. leaves, wood, propagules, and flowers).

Although there is a large quantity of leaves produced by mangroves, much of the organic matter produced may be moved out of the coastal plant community. In the description of community types, it is obvious that some communities will have a greater loss or export of nutrients. The dwarf or scrub communities do not store large amounts of nutrients because of a sparse settling of trees and high flushing rates (daily tidal flooding with strong currents). The larger and more developed the mangrove forest, the greater its ability to accumulate and store important nutrients in order to fuel production. Your observations should comment on the storage, biomass and productivity of the community.

Habitat

Wetland habitat is described based on a classification system developed by the Fish and Wildlife Service (Cowardin et al., 1979). The Bahamian archipelago includes estuarine, lacustrine systems and palustrine systems. Blue Holes present a unique component of lacustrine systems. The boundary between ‘wetland’ and ‘deepwater’ habitat in the lacustrine system is about 2 meters; ‘deepwater’ habitats refers to the lack of emergent vegetation, which can be both a function of water depth and tidal currents (Welch, 1952; Zhadin & Gerd, 1963; Sculthorpe, 1967).

The estuarine system (see Figure 9, Ref. Cowardin et al., 1979) consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. In the Bahamas, the connection to open ocean may be maintained through a subterranean connection to the ocean, or storm wash-over of adjacent dunes. One or more of the following forces affects estuarine water regimes and water chemistry: oceanic tides, precipitation, and freshwater runoff from land areas, evaporation, and wind. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines there is appreciable dilution of seawater with rainfall and storms.

In terms of wave action, estuaries are generally considered to be low-energy systems (Chapman 1977:2). For an extended discussion of estuaries and lagoons, see Lauff (1967).

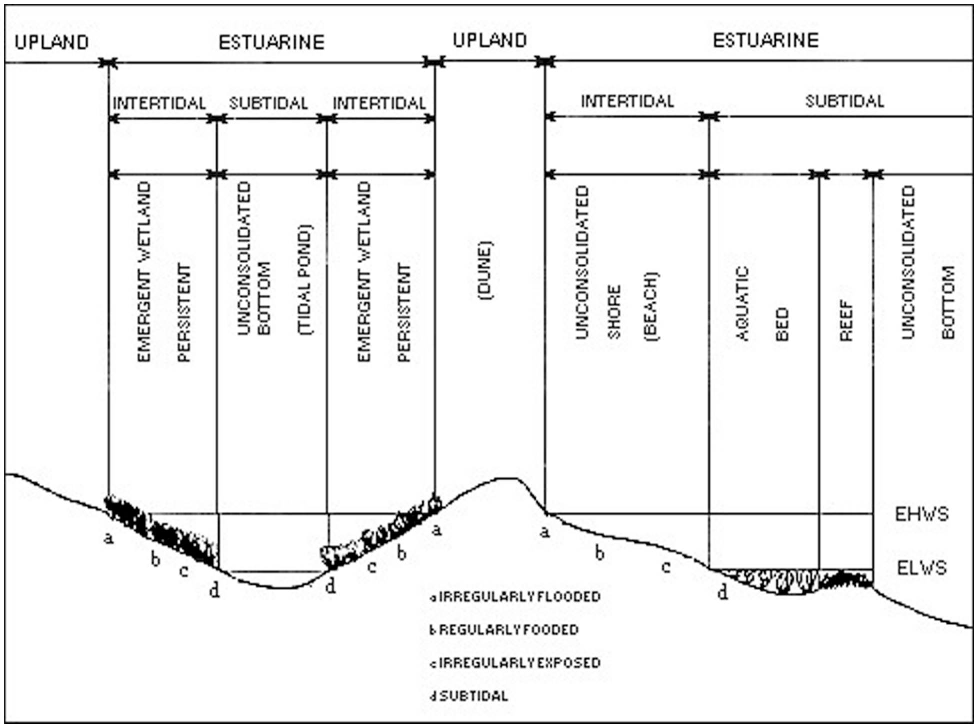

Figure 9. Distinguishing features and examples of habitats in the Estuarine System
[EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides]

The lacustrine system (see Figure 1; Ref. Cowardin et al., 1979) includes wetlands and deepwater habitats with all of the following characteristics:

- A lack of trees, shrubs, or persistent emergent; and
- A total area exceeding 8 hectares (20 acres).

Similar wetland and deepwater habitats totalling less than 8 ha are also included in the lacustrine system if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. This includes all inland blue holes. Lacustrine waters may be tidal or non-tidal, but ocean derived salinity is always less than 0.5 ‰. In the archipelago, this freshwater is often layered over a deeper, saline water mass. Typically, there are extensive areas of deep water and there is considerable wave action. Islands of palustrine wetlands may lie within the boundaries of the lacustrine system.

The palustrine system (see Figure 11; Cowardin et al., 1979) includes all non-tidal wetlands (marsh, swamp, bog and ponds) dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ‰. It also includes wetlands lacking such vegetation, but with all of the following four characteristics:

- An area less than 8 ha (20 acres);
- A lack of active wave-formed or bedrock shoreline features; and
- Water depth in the deepest part of the basin that measures less than 2 m at low water, and salinity due to ocean-derived salts that measures less than 0.5 ‰.

Palustrine wetlands may be situated shoreward of lakes, or estuaries. The emergent vegetation adjacent to lakes is often referred to as “the shore zone” or the “zone of emergent vegetation” (Reid and Wood 1976), and is generally considered separately from the lake.

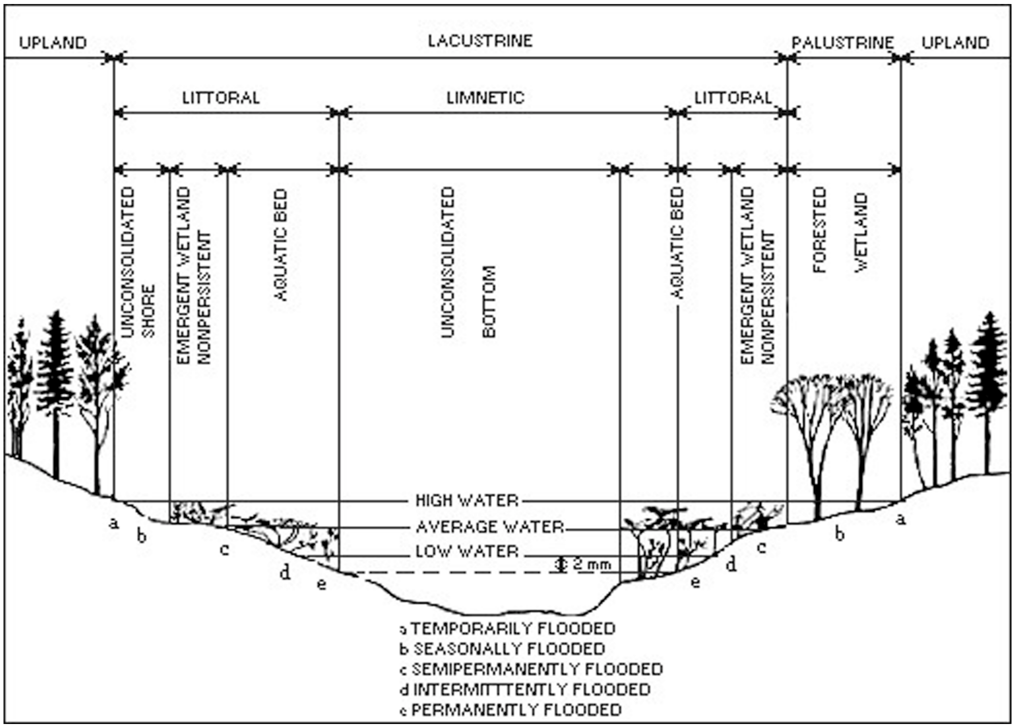

Figure 10. Distinguishing features and examples of habitats in the Lacustrine System

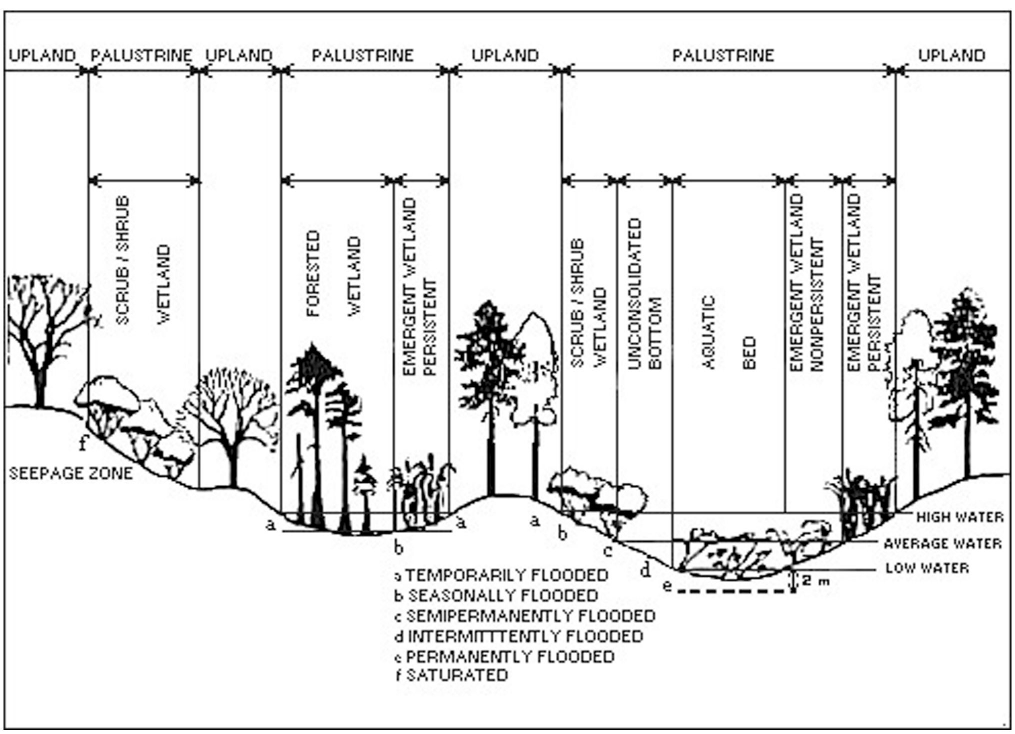

Figure 11. Distinguishing features and examples of habitats in the Palustrine System

Associated Species (see other target descriptions for details)
White-crowned Pigeons
West Indian Flamingos
West Indian Whistling Duck
There are likely a large number of endemic species in the Blue holes and anchialine pond systems. These environments represent the greatest concentration of species endemism in the archipelago.

Threats

Many factors are responsible for coastal wetland loss. Historically, coastal wetlands were drained and used for development and marina access. More recently, coastal wetlands have been filled or dredged for roads, houses, golf courses, marinas, and tourism development. Even wetlands that are not actually filled or dredged are becoming degraded due to pollution, changes in water flows, and invasion by weeds or other non-native plants and animals. Coastal wetland losses can be directly traced to population pressures and other human changes occurring along the coast. Coastal wetlands can and do move inland with rising sea level, but in developed areas, roads, houses, parking lots, and other human structures interfere with this natural migration of coastal habitats. In many places, artificial seawalls keep rising water levels back for a time and coastal wetlands become submerged, eventually dying and eroding away.

Current conservation programs

There is a growing concern for the protection of coastal wetlands, particularly tidal creek and pond systems. Restoration efforts to restore flow to tidal creeks have been critical to protected coastal wetlands, especially on New Providence island.

Information Gaps and Research Needs

Increasing national and international recognition of these functions has intensified the need for reliable information on the status and extent of wetland resources. A national wetland inventory for the archipelago is desperately needed both to capture the biological diversity of these habitats, and better understand the ecology of wetlands related to island hydrology and water resources.

Conservation Goals

Based on report by Garcia (1998):

- Better resolve of conflicts among competitive uses and users of wetland habitats;
- Increase the collaboration between conservationists, developers and communities; and
- Account for the economic, cultural and environmental value of wetlands.

Based on a report by Higgins and Lammert (Nature Conservancy Background):

- Compilation and analysis of wetland-related data to direct conservation and development planning;
- Development of tools and data management and analysis tools;
- Development of a standard hierarchical framework for classifying wetlands; and
- Providing a standardized conservation ranking system and preliminary ranks for wetlands (aquatic communities) to guide identification and planning for high-priority wetlands (freshwater communities).

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5.2. Target Species

5.2.1. Atlantic Spotted Dolphin (*Stenella frontalis*)

Description

Phylum Vertebrata
Class Mammalia
Order Odontoceti
Family Delphinidae

The Atlantic spotted dolphin (*Stenella frontalis*) belongs to the Family Delphinidae, or true dolphins, which comprises 32 species (Leatherwood and Reeves 1983; Klinowska 1991). The spotted dolphin shares that family with other more familiar species, including the common dolphin (*Delphinus delphis*), the bottlenose dolphin (*Tursiops truncatus*), the spinner dolphin (*Stenella longirostris*), and the killer whale (*Orcinus orca*). The Atlantic spotted dolphin is one of five species in the Genus Stenella: the spinner dolphin (*S. longirostris*), the pantropical spotted dolphin (*S. attenuata*), the clymene dolphin (*S. clymene*), and the striped dolphin (*S. coeruleoalba*).

Generally, spotted dolphins have a moderately long beak, a tall, falcate dorsal fin, and a slightly noticeable keel, especially in large adult males (May, 1990; Klinowska, 1991). The coloration of the Atlantic spotted dolphin is complex. Individuals have a distinct cape, from dark to brownish grey in colour, which is narrow on the forehead and dips low below the dorsal fin into a saddle-like formation. The pigmentation of the spotted dolphin develops with maturation, with newborn calves having no spots. The intensity and onset of spotting varies geographically, but typically spots appear before the onset of puberty. Patterns are unique to each individual and are suitable as markers for photo-identification (Perrin, 1969; Klinowska, 1991; Herzing, 1997).

Distribution

The Atlantic spotted dolphin is endemic to the Atlantic Ocean. It is known to inhabit the tropical, sub-tropical and warm temperate areas of the western North Atlantic, Caribbean, Gulf of Mexico, South America, West Africa, and the Azores (Klinowska, 1991; Steiner et al., 1998). Spotted dolphins are believed to occur in both coastal and pelagic communities (Klinowska, 1991).

Status of populations in the wild

Opportunistic sightings have been reported for the tropical and sub-tropical waters of the Atlantic, but the wider population status of this species is unknown. The vast majority of what is known has been discovered from long-term studies in the northern Bahamas. The singular nature of the Bahamian marine environment provides the only opportunity to study and gain insight into the natural history, population dynamics and habitat utilization of this unique species. Although highly represented in marine mammal surveys of the Gulf of Mexico, the species is under-represented in stranding records, suggesting the existence of a significant offshore population, which awaits further studies. This species remains the target of small harpoon fisheries in the Caribbean and western Atlantic.

Ecology and natural history

Atlantic spotted dolphins (of both sexes) reach approximately 2.2 m in length and are born at approximately 80 cm to 90 cm (Leatherwood & Reeves, 1983). In the Bahamas, the onset of sexual maturity ranges from 8 to 15 years for females, but no figures available for males. Females may have offspring in subsequent years if the calf is lost, but generally have a calf every three years. Gestation is estimated to last from 11 to 13 months for the pantropical species and is considered to be similar for the Atlantic spotted dolphins (Perrin et al., 1976; Herzing, 1997). The life span extends beyond 35 years (Herzing, 1997; Herzing & Brunnick, 1997).

Atlantic spotted dolphins are known to have a variable diet (Klinowska, 1991). Specimens stranded on the U.S. East Coast were found to have fish, squid, or a combination of both in their stomachs. The stomach contents included otoliths from two varieties of sea trout (*Cynoscion spp*. and *Stentomuschrysops spp*.), a herring species (Anchoa spp.), conger eels (Family Congridae), cod (Family Gadidae), and sea robins (Family Triglidae). Stomach contents from animals captured off the northern Florida coast contained cephalopod beaks (Klinowska, 1991). In the Bahamas, spotted dolphins have been observed using echolocation while foraging on burrowing species living on the sandy banks. Known prey includes flounder (Family Bothidae), lizardfish (Family Synodontidae), wrasses (Family Labridae), blennies (Family Tripterygiidae), clinids (Family Clinidae), and conger eels (Herzing, 1996; Herzing & Johnson, 1997). Nocturnal observations indicate that spotted dolphins also forage on flying fishes (Family Exocetidae) and squid (Family Loliginidae) in deeper water (Matlack & Herzing, 1995; Herzing & Johnson, 1997).

Habitat

Atlantic spotted and bottlenose dolphins are among the top predators in the ecosystem of the Bahamas, and play a significant role in maintaining a balanced ecosystem within the archipelago. Together with other cetaceans, they can serve as biological indicators of the health of the entire ecosystem and the processes that connect it with the adjacent larger bodies comprising the Gulf of Mexico and the Atlantic Ocean. The Bahamian archipelago consists of a series of shallow banks nestled in the warm waters of the Sargasso Sea, between the Gulf Stream and Atlantic Ocean, where water can reach depths over 500 m. In shallow areas, water depths vary from 1 m to 20 m, and increase northward.

The banks are thick, submerged platforms of calcareous rocks, and represent the remains of ancient reefs covered by centuries of sedimentation. The bottom topography is variable depending primarily upon exposure to wave and wind energy. The bottom is mostly bare sand with patches of turtle grass (Thalassia testudinum), but also includes platform reefs and rocky areas (Rossbach 1997). While in appearance the banks may seem deserted, they are actually inhabited by an abundance and variety of life forms including crustaceans, shellfish, sea turtles, sharks and, of course, bottlenose and spotted dolphins. The sandy bottom is home to a variety of burrowing species. An extensive variety of tropical fish can be found swimming around patch reef and sea grass-dominated areas. Of the shark species observed on the banks, the nurse shark is a filter feeder that poses no threat, but the hammerhead, bull, and tiger sharks are known predators of the dolphins in the Bahamas (Brunnick, 2000).

Dolphins are known to prey upon several species on the banks, as well as in adjacent deeper water. The banks provide protected areas ideal for reproduction and child-care, while also serving as a specific foraging platform suitable for pregnant females, cow/calf pairs, and juveniles. The clear waters and narrow water column also allow for increased protection from sharks during periods of time.

Associated Species

Bottlenose dolphin (*Tursiops truncatus*)

Threats

Atlantic spotted dolphins are killed in small harpoon fisheries in the Caribbean and off St. Vincent and the Azores. All efforts to successfully keep this species in captivity have failed. The principal threats to this species are pollution and habitat degradation, recreational fishing, and human interaction. Both water quality and boat traffic have a significant impact on habitat utilization by dolphins as well (Leatherwood & Reeves, 1982; Odell, 1975).

The mass dolphin die-off in 1987-88, where several hundred bottlenose dolphins died on the eastern coast of the U.S., was related to an algae toxin by one group (Geraci, 1989) and to high levels of organochlorines and other pollutants found in the carcasses by another (Kuehl et al., 1991). High levels of contamination of CHC's, PCB's, and DDT have been found in different tissues of a variety of marine mammals species worldwide, including the bottlenose dolphin (Holden, 1978; Risebrough, 1978; O'Shea et al., 1980; Gaskin, 1982; Wagemann & Muir, 1984; Cockcroft et al., 1989). The toxic effects of these compounds are difficult to assess, but because marine mammals lack many of the enzymes necessary to metabolise these compounds, the effects on these long-lived animals are increasingly recognized. High concentrations of PCBs and DDT are implicated in reproductive abnormalities, as well as reduced blood testosterone levels and survival rates (Duinker et al., 1979; Reijnders, 1986; Subramanian et al., 1987). The concentration of residues is closely correlated with age until the animal reaches sexual maturity. While males continue to accumulate residues throughout their lives, females show a decline in residues, attributed to offloading during pregnancy (Gaskin et al., 1983; Tanabe et al., 1988). Evidence suggests that upwards of 80% or 90% of the residue load of a female bottlenose dolphin may be passed to a first-born calf, which is expected to have a significant impact of its survival (Cockcroft et al., 1989).

More recently, diseases of the autoimmune system, such as the Moribilli virus, are also considered a potential threat to dolphins (Lipscomb & Kennedy, 1994). Rawson et al. (1991) reported anthracosis or the deposit of carbon in mediastinal lymph nodes, in bottlenose dolphins from the Florida west coast. Their results indicate that the impact of air pollution on marine mammals inhabiting coastal waters may be more severe than commonly expected.

Most cetaceans, including the spotted and bottlenose dolphins, use acoustic means to detect prey (Ljungblad et al., 1977; Würsig & Würsig, 1979). Therefore, excessive noise levels can potentially have a serious impact on the well-being of the animals, both physically and socially (Myrberg, 1978).

Sport fishing appears to have a fatal attraction to the dolphins. Often attracted by bait and debris, dolphins have been fatally entangled in microfilament, ingested hooks and lures, and severely injured in propellers. Human interaction in the form of organized 'swim with the dolphins' programs also presents a potential hazard and risk to both humans and dolphins in the wild. More and more people are seeking out close encounters with wild dolphins by closely approaching, petting, feeding, and/or swimming with the animals. Although dolphins appear 'friendly', wild animals always present a danger and can cause bodily harm to swimmers if harassed. The National Marine Fisheries Service (1994) also reports that repeated exposure to humans and human activities places the animals at greater risk of injury and death due to vandalism, increased interactions with vessels and fishing activities, and ingestion of inappropriate or contaminated foods. They have concluded that feeding wild dolphins is proximately and ultimately harmful and intrusion from well-meaning, but misguided tourists can impede or alter foraging strategies, reproductive success, and/or other natural dolphin behaviour (NMFS, 1994).

Current conservation programs

Although the Atlantic spotted dolphin in the Bahamas is a top predator and critical player of the eco-system, provides unique research opportunities and is the primary target of swim-with-the-dolphin expeditions, they are not the focus of any conservation program at this time.

Information gaps and research needs

Current population size and dynamics, including genetics and distribution in the Bahamas are still unknown, as is the longevity and much of the natural history. Feeding, foraging habits and habitat utilization are just beginning to emerge and require further quantitative analysis.

Conservation Goals

- Preservation and protection of the natural habitat of the Atlantic spotted dolphins, which includes the shallow banks as well as the adjacent deep waters east and west of the Bahamas;
- Limitation of human-dolphin interaction to research-based activities. The waters of the Bahamian archipelago provide a singular opportunity to examine this species (and other whales and dolphins) from an underwater perspective. Certain control measures are required to secure this unique access;
- Studies of the natural history, population dynamics, social structure, habitat utilization, and communication of Atlantic spotted dolphins, and create a comprehensive database to monitor the health of the population; and
- Securing funding for the necessary long-term, multidisciplinary studies and the implementation of the resulting management and educational tools.

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Figure 12. Atlantic Spotted Dolphin on Little Bahama Banks

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5.2.2. **Green turtle** (*Chelonia mydas*)

Description

Phylum Vertebrata
Class Reptilia
Order Chelonia
Family Cheloniidae

The green turtle is a member of the Family Cheloniidae (Lutz & Musick, 1997). Anatomical features include an extensively roofed skull with well-developed rhamphothecae, extremeties in form of nonretractile flippers, forelimbs equipped with highly elongated digits firmly bound together by connective tissue and a shell covered with horny scutes, variable in number but generally including five vertebras (Lutz & Musick, 1997). Adults can reach 350 lbs and 100 cm in carapace length.

Distribution

Green turtles occur in tropical oceans around the world and prefer tropical beaches for nesting. Juveniles may be resident in tropical or subtropical developmental habitats for years, as long as the seasonal temperature remains stable. Green turtles may utilize continental foraging areas in temperate latitudes (to about 48º N) during the summer, but must return to subtropical latitudes in winter to avoid cold stunning (Lutz & Musick, 1997).

Table 3. Marine mammals of the Bahama Ecoregion

Cetacea			**Geomorphic habitat type**						
Common Names	Scientific Name	Citation	IT	HB	SS	PM	PR	DR	OO
Right whale	*Eubalaena glacialis*	Müller, 1776							h,b*
Fin whale	*Balaenoptera physalus*	Linnaeus, 1758							b**
Brydes' whale	*Balaenoptera edeni*	Anderson, 1879						?	?
Minke whale	*Balaenoptera acutorostrata*	Lacépède, 1804						x	x
Humpback whale	*Megaptera novaeangliae*	Borowski, 1781				b	b	b	b
Sperm whale	*Physeter macrocephalus*	Linnaeus, 1758							C/c***
Dwarf sperm whale	*Kogia simus*	Owen, 1866						x	x
Pygmy sperm whale	*Kogia breviceps*	Blainville, 1838						x	x
Cuvier's beaked whale	*Ziphius cavirostris*	Cuvier, 1823						x	x
True's beaked whale	*Mesoplodon mirus*	True, 1913						x	x
Gervais' beaked whale	*Mesoplodon europaeus*	Gervais, 1855						x	x
Blainville's beaked whale	*Mesoplodon densirostris*	Blainville, 1817						x	x
Killer whale	*Orcinus orca*	True, 1913		?	?	x	x	x	x
False killer whale	*Pseudorca crassidens*	Owen, 1846				?	x	x	x
Pygmy killer whale	*Feresa attenuata*	Gray, 1874				?	?	?	?
Melon head whale	*Peponocephala electra*	Gray, 1846						?	?
Short-finned pilot whale	*Globicephala macrorhynchus*	Gray, 1846				?	?	?	?
Rough toothed dolphin	*Steno bredanensis*	Cuvier, 1828						?	?
Bottlenose dolphin	*Tursiops truncatus*	Montagu, 1821		x	x	x	x	x	x
Pantropical spotted dolphin	*Stenella attenuata*	Gray, 1846				?	x	x	x
Clymene dolphin	*Stenella clymene*	Gray, 1850							x
Striped dolphin	*Stenella coeruleoalba*	Mayen, 1833							?
Atlantic spotted dolphin	*Stenella frontalis*	Cuvier, 1829		x	x	x	x	x	x
Spinner dolphin	*Stenella longirostris*	Gray, 1828							?
Common dolphin	*Delphinus delphis*	Linnaeus, 1758							x
Fraser's dolphin	*Lagenodelphis hosei*	Fraser, 1956							?
Rissos dolphin	*Grampus griseus*	Cuvier, 1812		?	?	x	x	x	x
Manatee	*Trichechus manatus*	Linnaeus, 1758	x	x	x	x	x	x	x
Monk seal	*Monachus tropicalis*	Gray 1850	e	e	e	e	e		

Status of populations in the wild

Assessment of marine turtle populations is very difficult. Attention is focused on nests and nesting females. Because females rarely nest every year, but usually at two, three, or four year intervals, and because it is not possible to determine what proportion of the total mature female population is at the nest beach in any given year, population estimates are typically not precise. This is further complicated by the fact that nesting numbers on individual beaches can show extreme variation from one year to another. In a good year over 10,000 females may nest on Europa, and up to 80,000 at Raine Island (Australia); these appear to be the only stable populations not heavily exploited (Groombridge & Luxmoore, 1989; Groombridge, 1982).

Ecology and natural history

Upon entering the sea, green turtle hatchlings actively swim offshore for at least 24 hours (Frick, 1976; Ireland et al., 1978; Wyneken & Salmon, 1992). Thereafter, hatchlings rest at night, but continue to swim actively during the day (Wyneken & Salmon, 1992; Lohmann et al., 1996; Wyneken, 1996). Young turtles are believed to be passively transported from the Gulf Stream across the North Atlantic to the East Atlantic, where they drift south past the Azores to the Canary Islands and eventually return to the western Atlantic via the north equatorial current (Witham, 1980). The studies of Carr (1987) and Walker (1994) suggest that young green turtles inhabit open ocean biotopes and, according to Bjorndal (1985), are omnivorous even though they appear to have a strong tendency to carnivory.

Several studies have shown that juveniles recruit to demersal developmental habitats at about 30 cm to 40 cm in size (Balazs, 1982; Keinath & Musick, 1991; Bjorndal & Bolton, 1995). The summer developmental habitat in the western Atlantic includes estuarine waters as far north as Long Island Sound, and south throughout the tropics (Henwood & Ogren, 1987; Keinath & Musick, 1991; Morreale & Standora, 1992; Epperly et al., 1994). Off the Florida east coast, juveniles occur on polyachaete reefs and, as they become larger, on sea grass beds in the Indian River Lagoon (Gusemann and Ehrhart 1990). In the Bahamas, tidal embayments appear to serve as important developmental habitats for juveniles (Bjorndal & Bolton, 1996). Immigration to the Bahamas, Columbia, Cuba, Dominican Republic, Nicaragua, Panama and Venezuela is also documented (Bjorndal & Bolton, 1996).

At the time green turtles enter the benthic foraging areas they shift to herbivorous diet, which consists primarily of sea grass and algae. In the Caribbean, the sea grass Thalassia testudinum is the primary diet species for the green turtle (Bjorndal, 1980; 1982). Mortimer (1976) found that T. testudinum comprised 87% of the dry mass of stomach contents from turtles captured on foraging grounds off the Caribbean coast of Nicaragua. The diet of green turtles studied in Florida consisted of sea grasses (Syringodium filiforme and Halodule wrightii) and red and green algae (Mendonça, 1983). However, individuals are also known to feed upon jellyfish, salps, and sponges (Mortimer, 1981; 1982). An herbivorous diet has important consequences for the life history parameters and survival outlook of green turtles. Green turtles have a significant effect on the nutrient cycling and community structure of their sea grass foraging habitats.

Habitat

Green turtles use oceanic habitats as nursery areas and coral reefs and sea grass beds during older juvenile and adult life stages. Oceanic convergence zones and major gyre systems represent important habitat for sea turtles. They are attracted to floating seaweed where they may hide and feed for long periods of time. Due to the low primary production of these areas (productive up welling areas are the exception), they provide protection from predatory fishes and sea birds. Loggerheads utilize the ocean nurseries much longer and to a greater size, and seem well adapted to long periods of opportunistic feeding on a great variety of prey items (Bjorndal, 1990). Older juvenile and adult green turtles recruit to more productive demersal developmental habitats at a relatively small size.

Because of their relatively specialized diet, green turtles may be attracted to structured habitats, such as reefs, which also provide protection from sharks and large teleosts predators. Green turtles in the Caribbean establish grazing plots in pastures of the sea grass *Thalassia testudinum* that can vary from 10 m to 100 m and may be maintained for up to two years. Through this process of continuous re-cropping, the green turtle diet increases in protein content while becoming lower in lignin (short leafs contain less lignin). Grazing on algae on coral reefs is expected to significantly impact the percent cover by algae in these ecosystems (Bjorndal, 1980).

Associated Species

Loggerhead turtle (*Caretta caretta*)
Leatherback turtle (*Dermochelys coriacea*)
Kemp's ridley (*Lepidochelys kempi*)

Threats

The principal threats to sea turtles are commercial fisheries, debris ingestion, and habitat degradation. Commercial fisheries have a serious impact on sea turtle mortality through incidental capture (NRC, 1990) and direct competition between humans and sea turtles for the same food source (Pauly & Christensen, 1995). Destructive human practices include the use of dynamite or bleach in coral reef areas, and the use of bottom trawls in benthic communities. The often sub-lethal effects of food limitation resulting from such competition may reduce productivity of populations by lowering growth rates, delaying the onset of sexual maturity and reducing reproductive output. In addition, sea turtles, especially the green and hawksbill turtles, have come under immense pressure from the trade of meat and shells.

Debris ingestion is another serious problem, especially for the young pelagic stage turtles inhabiting the convergence zones in which floating debris, such as plastics, synthetic fibres, tar and many other become concentrated. Small amounts of debris can kill a sea turtle. Effects on gut function as a result of plastic or latex ingestion include a decline in blood glucose levels, interference in gut lipid metabolism and gas accumulation in the large intestine, resulting in a loss of buoyancy control (reviewed in Balazs, 1985).

The third major threat to sea turtles is habitat degradation caused by human activities. For example, scarring of sea grass beds from anchoring or propellers can seriously reduce the standing crop and productivity of sea grasses for long periods of time (Williams, 1988). Inappropriate land management practices often lead to the deposition of silt on coral reefs, rocky bottom habitats, and sea grass beds and decrease the amount of foraging habitat available to sea turtles (Lutz & Musick, 1997).

Current conservation programs

The green turtle is listed as endangered by the International Union for the Conservation of Nature. Under the U.S. Endangered Species Act of 1973, the green turtle was listed as threatened except for the breeding populations in Florida and on the Pacific coast of Mexico, where it is listed as Endangered. *Chelonia mydas* is listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Appendix I listing requires that trade in the taxon and its products is subject to strict regulation by ratifying states and international trade for primarily commercial purposes is forbidden. Although green turtles are nominally protected by legislation in much of the range, in many areas the legislation is inadequately enforced. Some nesting beaches fall within National Parks or Nature Reserves and are accorded varying degrees of protection. The species breed in captivity, but large-scale closed-cycle captive breeding has not yet been demonstrated to be possible.

Information gaps and research needs

Total population estimates for the green turtle are unavailable, and trends are particularly difficult to assess because of wide year-to-year fluctuations in numbers of nesting females, difficulties of conducting research on early life stages and the long generation time. Present estimates range from 200 to 1,100 females nesting on U.S. beaches. The number of nests has increased on Hutchinson Island, Florida, over the period 1971 - 1989, although nesting levels have been low on other nesting beaches. Populations in Surinam, and Tortuguero, Costa Rica, may be stable, but there is insufficient data for other areas to confirm a trend. The recovery team for the green turtle concluded that the species status has not improved appreciably since it was listed endangered 1979 (Groombridge & Luxmoore, 1989; Groombridge, 1982).

Conservation Goals

- Preservation and protection of the natural habitats of the green turtle, especially the nesting beaches and developmental habitats, including estuarine waters and tidal embayments;
- Minimization of the hunting of turtles and trade of products until scientific data provides reliable assessment of sustainable harvest;
- Studies of the natural history and migration, and creation of a comprehensive database to monitor the health of the turtle populations as well as their impact on demersal developmental and benthic foraging habitats; and
- Securing funding for the necessary long-term, multidisciplinary studies and the resulting management and educational tools. The slow maturation period for marine turtles can mask the effects of exploitation and conservation efforts; therefore long-term research programs are essential.

Justification

Active management strategies to protect vital marine turtle habitats could include the creation of marine sanctuaries or coastal and near-shore ocean park reserves in the Bahamas. Since sea turtles are migratory and pass through the jurisdictions of many countries, international cooperation and regional agreements on conservation are highly desirable. Research and education programs could be combined in turtle rehab/ rescue centres that are open to the public. Similar facilities in the US are both popular and profitable. Participation in international turtle research and rescue programs is important. The favourable public image and charisma of sea turtles can be used to infuse the importance of conservation of the species and it's vast habitats, into the culture through education and media exposure.

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Figure 13. Green sea turtle off South Florida

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5.2.3. Hawksbill turtle (*Eretmochelys imbricata*)

Description

Phylum Vertebrata
Class Reptilia
Order Chelonia
Family Cheloniidae

The Hawksbill turtle belongs to the family Cheloniidae (Lutz & Musick, 1997). Anatomical features include an extensively roofed skull with well-developed rhamphothecae, extremeties in form of nonretractile flippers, forelimbs equipped with highly elongated digits firmly bound together by connective tissue and a shell covered with horny scutes, variable in number but generally including five vertebras (Lutz & Musick, 1997). Adults can reach 150 lbs and 80 cm in carapace length.

Hawksbills nest solitarily, mostly on islands (Witzell, 1983). The fledglings move immediately into the sea and juveniles are found in great numbers in open ocean, pelagic habitat, in close association with Sargassum (Carr, 1987). It is not fully understood whether they have the shortest pelagic state of all sea turtles, or recruit directly to demersal developmental habitats on coral reefs or mangrove flats. In the Virgin Islands, juveniles are reported to recruit to the demersal coral reef habitat at a length of 20 cm to 25 cm (Boulon, 1994). It is presumed that they recruit to the neritic developmental habitat at a smaller size than either loggerhead or green turtle, probably at the age of 1 year to 3 years. Their developmental habitats include shallow coral reefs with water depth of less than 20 m, and mangrove estuaries rich in sponges, their principal food (Witzell, 1983; Meylan, 1988).

Distribution

The Hawksbill turtle has a pantropical distribution and exhibits a preference for tropical beaches for nesting. Juveniles and adults can be found in the same foraging areas, suggesting that developmental habitat does not differ from that of adults (Lutz and Musick, 1997). According to Hillis (1994), hawksbills of the Virgin Islands frequently migrate to other areas indicating that at least in some regions, individuals are migratory rather than resident.

Figure 14. Hawksbill turtle off South Florida

Status of populations in the wild

The hawksbill turtle's status has not changed since it was listed as endangered in 1970. It is a solitary nester, and thus, population trends and estimates are difficult to determine. Most researchers accept the decline of nesting populations. As of 1983, the only known apparently stable populations were reported from Yemen, northeastern Australia, the Red Sea, and Oman. Commercial exploitation is the major cause of the continued decline of the hawksbill sea turtle. There is a continuing demand for the hawksbill's shell as well as other products including leather, oil, perfume, and cosmetics. Prior to being certified under the Pelly Amendment, Japan had been importing about 20 metric tons of hawksbill shell per year, representing approximately 19,000 turtles. A negotiated settlement was reached regarding this trade on June 19, 1992. The hawksbill shell commands high prices (currently $225/kilogram), a major factor preventing effective protection.

Ecology and natural history

Post hatchlings are often encountered in close association with floating rafts of Sargassum such as *S. fluitans* and *S. natans*. Their diet also includes the sea grass *Syringodium filiforme*, the green alga *Microdictyon marinum*, shell fragments of goose barnacles, eggs of pelagic fish, tunicates, and crabs (Meylan, 1984, 1988; Carr, 1987; Walker, 1994). In the Caribbean, they are known to begin foraging in benthic habitats at 20 cm to 25 cm in length (Meylan, 1984, 1988) and are mostly encountered over coral reefs and rock outcroppings, but also feed on sea grasses in mangrove-fringed bays (NMFS 1993). Larger juveniles and adults specialize on sponges (Meylan, 1984) with > 98% of the dry mass of all identified sponges belonging to three of the 13 orders of demo sponges (Astrophorida, Hadromerida, Spirophorida). In descending order, the ten most important prey sponges are *Chondrilla nucula, Ancorina sp., Geodia sp., Placospongia sp., Suberites sp., Myriastra sp., Ecionemia sp., Chondrosia sp., Aaptros sp.*, and *Tethya cf. actinia* (Meylan, 1988). Several authors recorded marine plants in the digestive system of Caribbean Hawksbills and identified tunicates as another major diet component of 20 individuals captured off Puerto Rico (Acevedo et al., 1984; Meylan, 1984; Alvarez and Uchida, 1994). Meylan (1984) and Alvarez and Uchida (1994) suggested that gravid females ingest coralline substrate and substantial quantities of the calcareous algae *Halimeda incrassata* as a source of calcium for eggshell production.

Habitat

The principal habitats of the Hawksbill turtle are oceanic nurseries and demersal habitats such as reefs and sea grass beds. Oceanic convergence zones and major gyre systems represent important habitat for sea turtles that are attracted to floating seaweed where they may hide and feed for long periods of time. Due to the low primary production of these areas (productive up welling areas are the exception), these systems provide protection from predatory fishes and sea birds. Loggerheads utilize the ocean nurseries much longer and to a greater size, and seem well adapted to long periods of opportunistic feeding on a great variety of prey items (Bjorndal, 1990). Loggerheads, as major predators of invertebrates, may affect community structure in benthic habitats. Such predation may be the major mortality factor for adult queen conch (Strombus gigas) in the Bahamas. Older juvenile and adult green turtles, hawksbill and Kemp's ridleys on the other hand, recruit to more productive demersal developmental habitats at smaller size.

Because hawksbill turtles have a relatively specialized diet, they tend to be associated with structured habitats such as reefs, which provide protection from sharks and large teleost predators. By feeding on sponges, which compete with other reef organisms for space, hawksbills may actually affect this competition and exert a significant influence on complex reef communities. Because they bite through the outer (tough) covering of sponges, thus exposing the soft inner tissues, they make sponges available to other predators (Meylan, 1988).

Associated Species

Loggerhead turtle (*Caretta caretta*)
Leatherback turtle (*Dermochelys coriacea*)
Kemp's ridley turtle (*Lepidochelys kempi*)

Threats

The principal threats to sea turtles are commercial fisheries, debris ingestion, and habitat degradation. Commercial fisheries have a serious impact on sea turtle mortality through incidental capture (NRC, 1990) and direct competition between humans and sea turtles for the same food source (Pauly & Christensen, 1995). Destructive human practices include the use of dynamite or bleach in coral reef areas, and the use of bottom trawls in benthic communities. The often sub-lethal effects of food limitation resulting from such competition may reduce productivity of populations by lowering growth rates, delaying the onset of sexual maturity and reducing reproductive output. In addition, sea turtles, especially the green and hawksbill turtles, have come under immense pressure from the trade of meat and shells.

Debris ingestion is another serious problem, especially for the young pelagic stage turtles inhabiting the convergence zones in which floating debris, such as plastics, synthetic fibres, tar and many other become concentrated. Small amounts of debris can kill a sea turtle. Effects on gut function as a result of plastic or latex ingestion include a decline in blood glucose levels, interference in gut lipid metabolism and gas accumulation in the large intestine, resulting in a loss of buoyancy control (Balazs, 1985).

Another major threat to sea turtles is habitat degradation caused by human activities. For example, scarring of sea grass beds from anchoring or propellers can seriously reduce the standing crop and productivity of sea grasses for long periods of time (Williams, 1988). Inappropriate land management practices often lead to the deposition of silt on coral reefs, rocky bottom habitats, and sea grass beds and decrease the amount of foraging habitat available to sea turtles (Lutz & Musick, 1997). The Kemp's Ridley turtle, for example, is particularly vulnerable because two major feeding areas of adults are in areas of intense development for offshore oil production in the Gulf of Mexico (USFWS, 1992).

Current conservation programs

The hawksbill turtle is listed as an endangered species by the International Union for the Conservation of Nature and Natural Resources. The species is also included in the Endangered Species Act of 1973 and considered endangered throughout its range. An exhaustive review of the worldwide conservation status concluded that the hawksbill is suspected, or known, to be declining in 38 of 65 geopolitical units where information is available. Severe declines were noted in the western Atlantic Ocean and the Caribbean region. It is sobering to consider that current nesting levels may be far lower than previously estimated. Despite protective legislation, international trade of hawksbill shells and subsistence use of meat and eggs continue unabated in many countries and pose a significant threat to the survival of the species in the region. The most recent status review of the hawksbill in the United States recognized that numerous threats still exist despite a decade of protection. The hawksbill population in the Atlantic was listed on Appendix I of CITES in 1975. The population in the Pacific was listed on Appendix I of CITES in 1977.

Information gaps and research needs

Nesting numbers for hawksbills are difficult to monitor due to the wide area over which nesting is scattered; population estimates for this species are considered to be even less reliable than for other sea turtles. Most populations are known, or believed, to be severely depleted. People have been slow to recognize the extreme plight of hawksbill populations in the Caribbean and elsewhere. One critical problem in studying this species is the lack of reliable historical data, against which to assess population declines. For centuries, hawksbills have been extensively exploited for the keratinised scutes covering their shells, which are the source of tortoiseshell or bekko (Parsons, 1972; Groombridge and Luxmoore, 1989; Meylan, 1999). Thus, populations were already greatly reduced or extirpated before they were recorded and/or quantified. This is compounded by the fact that they are long-lived and data is difficult to collect in short term studies. The time required to reach 35 cm in length is unknown. As a result, actual age at sexual maturity is not known, and the true status of a population is often miscalculated (Bjorndal, 1985). Any species with delayed sexual maturity has, of necessity, many year-classes of sub adults. In hawksbills, for which the best estimate of sexual maturity is about 20 to 40 years (Chaloupka & Limpus, 1997; Crouse, 1999), even a small population of adult hawksbills will have a relatively large number of juveniles in the 20 to 40 age classes of sub adults. These are not 'excess' turtles that can be removed from the population without affecting population status; they are the minimum number required to sustain a small breeding population. Thus, the number of turtles in a region often belies the true status of the population and can give a perception of population stability that does not reflect reality (Bjorndal, 1999).

Justification

- Preservation and protection of the natural habitats of the hawksbill turtle, especially the nesting beaches and developmental habitats on coral reefs and mangrove flats;
- Minimization of the hunting of turtles and trade of products until scientific data provides reliable assessment of sustainable harvest;
- Studies of the natural history and migration, and creation of a comprehensive database to monitor the health of the turtle populations as well as their impact reefs (sponge beds) and mangrove flats; and
- Securing funding for the necessary long-term, multidisciplinary studies and the resulting management and educational tools. The slow maturation period for marine turtles can mask the effects of exploitation and conservation efforts; therefore long-term research programs are essential.

Strategies

Active management strategies to protect vital marine turtle habitats could include the creation of marine sanctuaries or coastal and near-shore ocean park reserves in the Bahamas. Since sea turtles a migratory and pass through the jurisdictions of many countries, international cooperation and regional agreements on conservation are highly desirable.

Research and education programs could be combined in turtle rehab/rescue centres that are open to the public. Similar facilities in the US are both popular and profitable. Participation in international turtle research and rescue programs is important. The favourable public image and charisma of sea turtles can be used to infuse the importance of conservation of the species and it's vast habitats into the culture through education and media exposure.

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Table 4. Synopsis of Sea Turtle Occurrences by Habitat Type

Common Name	Scientific Name	Citation	IT	SS	PM	PR	DR	OO
Green turtle	Chelonia mydas	1	N	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	H, EJ, A
Hawksbill turtle	Eretmochelys imbricata	2	N	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	H, EJ
Loggerhead turtle	Caretta caretta	3	N	EJ, LJ, A	EJ, LJ, A	?	?	H, EJ, A
Kemp's ridley	Lepidochelys kempi	4	N	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	EJ, LJ, A	H
Leatherback turtle	Dermochelys coriacea	5	N	?	?	?	?	H, EJ, LJ, A

Habitat type key

N	Nesting
H	Hatchling
EJ	Early Juvenile
LJ	Late Juvenile
A	Adult

Citation Key

1	Carr, 1987; Bjorndal & Bolton, 1995; Keinath and Musick, 1991; Epperly et al., 1994.
2	Lutz & Musick, 1997; Meylan, 1984, 1988; Carr, 1987; Walker, 1994; Bjorndal, 1990.
3	Bjorndal, 1990;Carr et al., 1966; Bolton et al., 1990, 1992; Eckert & martins, 1989; Mellgren & Mann, 1996.
4	Collard, 1990a, 1990b; Shaver, 1991; Lutz & Musick, 1997; Collard & Ogren, 1990; Bolton& Martins, 1990.
5	Wyneken & Salmon, 1992; Lutz & Musick, 1997; Lee & Palmer, 1981; Grant & Ferrell, 1993; Lazell, 1980a.

5.2.4. Audubon's shearwater (*Puffinus lherminieri*)

Description

Phylum Vertebrata
Class Aves
Order Ciconiiformes
Family Procellariidae

The Audubon's shearwater (*Puffinus lherminieri*) is a medium sized sea bird of approximately 11 inches in length and with a wingspan of 26 inches. They have white bellies with dark brown wings and back, and a dark brown head with a white throat. Sexes are similar in appearance. It is a small and active bird that flies with rapid, butterfly-wing beats and short glides, often using its tail as a rudder. Typically, they skim close to the water, with intermittent periods of flapping and gliding, and they always seem to be on the move.

Distribution

Nesting populations of the Audubon's shearwater have a widespread distribution in the tropical seas and into sub-tropical regions. In the Atlantic they breed on islands throughout the Caribbean, including the Bahamian archipelago. Other populations are known from the Galapagos, the western and central Pacific, the Philippine Sea and the Indian Ocean.

Status of populations in the wild

The shearwater is a tropical pelagic species represented in the western Atlantic by an endemic subspecies consisting of a total of only about 5,000 pairs, a significant percentage of which breed in the Bahamas (Carey et al., 2001). Currently, the largest colony of shearwaters can be found on Long Cay (Carey et al., 2001). The

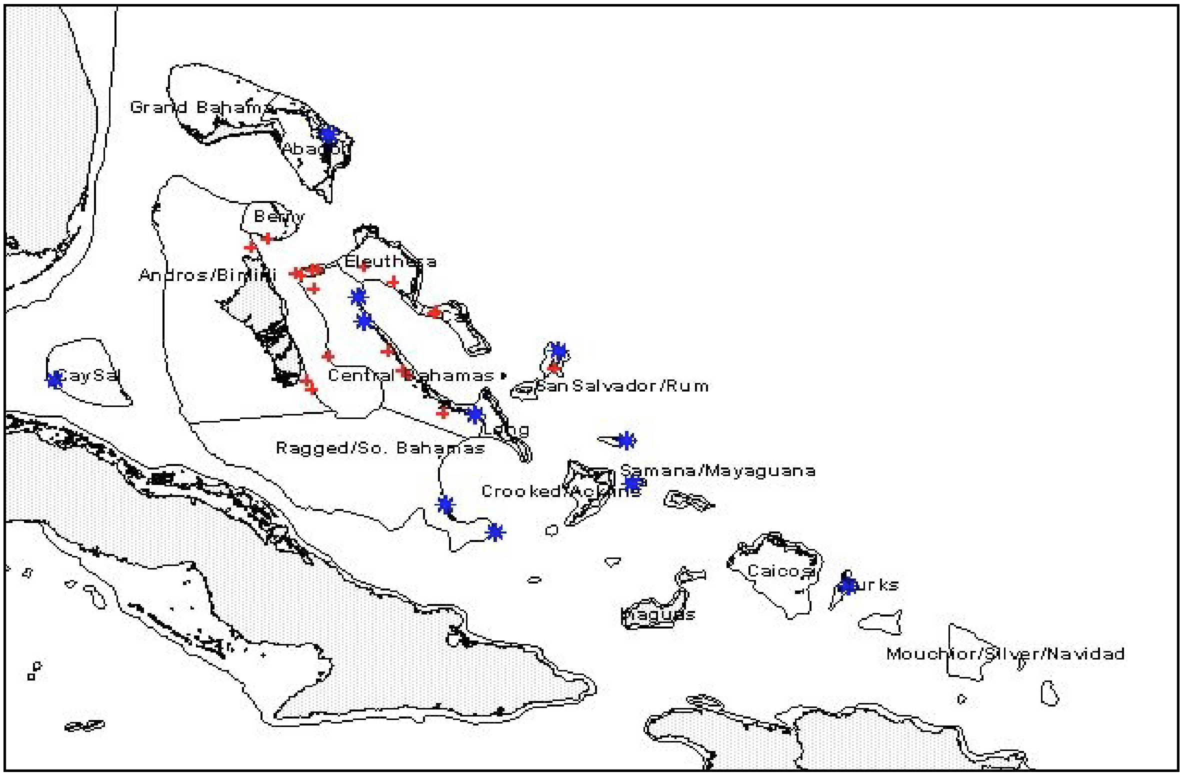

Figure 15. Map depicting locations of high-density shearwater populations (indicated by blue asterisks) and locations of established bird sanctuaries (indicated by red crosses)

second largest known colony in the world occurs in the Allen's Cay group (Allen's, SW Allen's and Leaf Cays) (Carey et al., 2001). Other smaller breeding colonies can be found on Mira Por Vos (southwest of the Acklins Bight), the northern cays off Abaco, Plana Cays, and cays of Graham Harbour (Green (25 pairs), Cato (2 pairs), Little Gaulin (30 pairs), Manhead (35 pairs), and Cut Cays (2 pairs).

Ecology and natural history

The Audubon's shearwater is a pelagic bird that comes ashore only to breed. They breed in a variety of habitats whose common denominator is the absence of terrestrial predators. They lay a single egg in natural cavities in sea cliffs, but will also nest in open spaces beneath rocks and coral rubble, under agavi leaves, or in burrows that they have dug themselves. Accordingly, nest sites may be just above high tide lines or on higher elevations in the interior of islands. The average hatching time is 51 days, during which both parents incubate the egg with incubation shifts lasting from 8-10 days. Both parents also feed the chick until fledging, about two and a half months later. They breed throughout the year and a successful pair can produce a chick about every 9-10 months.

Audubon's shearwaters feed on small planktonic crustaceans and fish larvae, which they take from the surface, and on small fish, and squid, which they catch by plunge diving to depths of about six feet. It is not uncommon to see them fishing in large flocks, or in mixed flocks with pelicans and brown noddies.

Habitat

Audubon's shearwaters are usually found well out at sea, usually over deep-water channels. They are primarily found on or near land while attending their nests. Nests are commonly in cliff crevices, caves or vegetation, under rocks, or within a 60 cm to 90 cm burrow. Birds will only enter and leave the nests during night time. Not much else is known about the habitat of these birds because they are difficult to study.

Associated Species
White-tailed tropicbird (*Phaethon lepturus*)

Figure 16. Audubon's Shearwater

Threats

There are both naturally occurring as well as introduced threats contributing to the decline in the numbers of Audubon's shearwaters in the West Indies. Domestic cats, introduced rats, human predation and interference, and even barn owl (*Tyto alba*) predation are all possible causes for diminishing bird populations. Population declines are difficult to assess in the West Indies because there is not much historical information for comparison. Some fossil and sub-fossil material indicates that these birds have disappeared as a breeding species in parts of the West Indies. This may be due to species vulnerability to predation by feral cats, because pre-fledglings are easy prey when they emerge from their burrows at night to exercise their wings.

Current conservation programs

Currently, Audubon's shearwaters are protected under the Wild Bird Protection Act of 1987, which prohibits the shooting, killing, or catching of the birds (Eco-Bahamas, 1997). This act also insures that no hunting, killing, or capturing occurs in established wild bird reserves (Eco-Bahamas, 1997).

Information gaps and research needs

- Determination of population sizes at all cays known to be used as breeding sites flats; and
- Determination of specific habitat needs of these birds.

Conservation goals

Increase, or at least maintain, the current estimated population of 5,000 breeding pairs in the Western Atlantic. Establishment of Important Bird Areas (IBA's) which will prevent or limit human use of the land, thereby reducing the chances that visitors will trample vegetation and nests or frighten adult birds off nests, leaving the eggs exposed to lethal levels of heat (Carey et al., 2001). Especially important is the education of tourists about sites inhabited by shearwaters to minimize the negative impacts of humans on their habitat. Reduction in the extent of development in shearwater habitat so as to maximize available nesting grounds.

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Table 5. Seabirds of the Bahama Ecoregion

				Nesting Sights						
Family	**Common Name**	**Scientific Name**	Subregions sighted	1	2	3	4	5	6	7
Procellariidae	Audubon's Shearwater	*Puffinus lherminieri*	LBA, CBA, SEBA	*	*	*	*		*	
Phaethontidae	White-tailed Tropicbird	*Phaethon lepturus*	LBA, CBA, SEBA						*	*
Pelicanidae	Brown Pelican	*Pelicanus occidentalis*	CBA, SEBA					*	*	
Sulidae	Red-footed Booby	*Sula sula*	CBA			*				*
Sulidae	Masked Booby	*Sula dactylatra*	CBA			*				*
Sulidae	Brown Booby	*Sula leugocaster*	SEBA		*		*		*	*
Gregatidae	Magnificent Frigatebird	*Fregata magnificens*	LBA, SEBA	*		*	*		*	*
Laridae	Laughing Gull	*Larus atricilla*	CBA, SEBA							*
Laridae	Gull-Billed Tern	*Sterna nilotica aranea*	CBA, SEBA					*		*
Laridae	Common Tern	*Sterna hirundo*	CBA, SEBA							*
Laridae	Roseate Tern	*Sterna dougllii*	CBA, SEBA							*
Laridae	Bridled Tern	*Sterna anaethetus*	CBA							*
Laridae	Sooty Tern	*Sterna fuscata*	CBA						*	*
Laridae	Least Tern	*Sterna antillarum*	LBA, CBA, SEBA		*	*	*	*	*	
Laridae	Royal Tern	*Sterna maxima*	CBA, SEBA		*	*		*		*
Laridae	Sandwich Tern	*Sterna sandvicensis*	CBA, SEBA		*		*	*	*	*
Laridae	Caspian Tern	*Sterna caspia*	CBA							*
Laridae	Brown Noddy	*Anous stolidus*	LBA, CBA, SEBA							*

Key

LBA	Little Bahamas Bank
CBA	Central Bahamas
SEBA	South-Eastern Bahamas and Turks and Caicos
1	Abaco, Little Bahamas Bank, Grand Bahama
2	Andros, The Biminis, Cay Sal Bank, Great Bahama Bank, Exumas, Green Key, Eleuthera, Santo Domingo Cay, Ragged Island, Long Isl., New Providence, Salt Cay, North Rock, Cat Island, Hawksbill Cay
3	San Salvador, Conception Island, Rum Cay
4	Mira Por Vos, Propeller Cay, East Plana Cay, Mayaguana, Atwood Key, Bird Rock, Cay Verde
5	Inagua
6	Turks and Caicos
7	Non-specific Bahamas

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5.2.5. West Indian Flamingo (*Phoenicopterus ruber ruber*)

Description

Phylum Chordata

Class Aves

Order Ciconiiformes

Family Phoenicopteridae

Members of the genus Phoenicopterus are large, brilliantly coloured aquatic birds of approximately 107-122 cm (42-48") in height. Long legs, a curved neck, webbed feet; a round body and a short tail are general characteristics. These birds have the longest neck and legs compared to body size. Although the body is rather rounded, the very long, slender neck and long, thin legs give flamingos a very stretched appearance, especially as they fly rapidly on strong wing beats (Sykes, 1983). They are generally a pink or maroon colour, with the colour of their feathers mostly determined by carotenoids from their diet, which consists of small crustaceans, molluscs, tiny water invertebrates, algae, seeds, and other plant matter. Birds will forage in shallow water with their heads upside-down, filtering these small organisms through their bills, which are lined with rows of bristles called lamellae. Flamingos are the only birds that utilize a method of filter feeding.

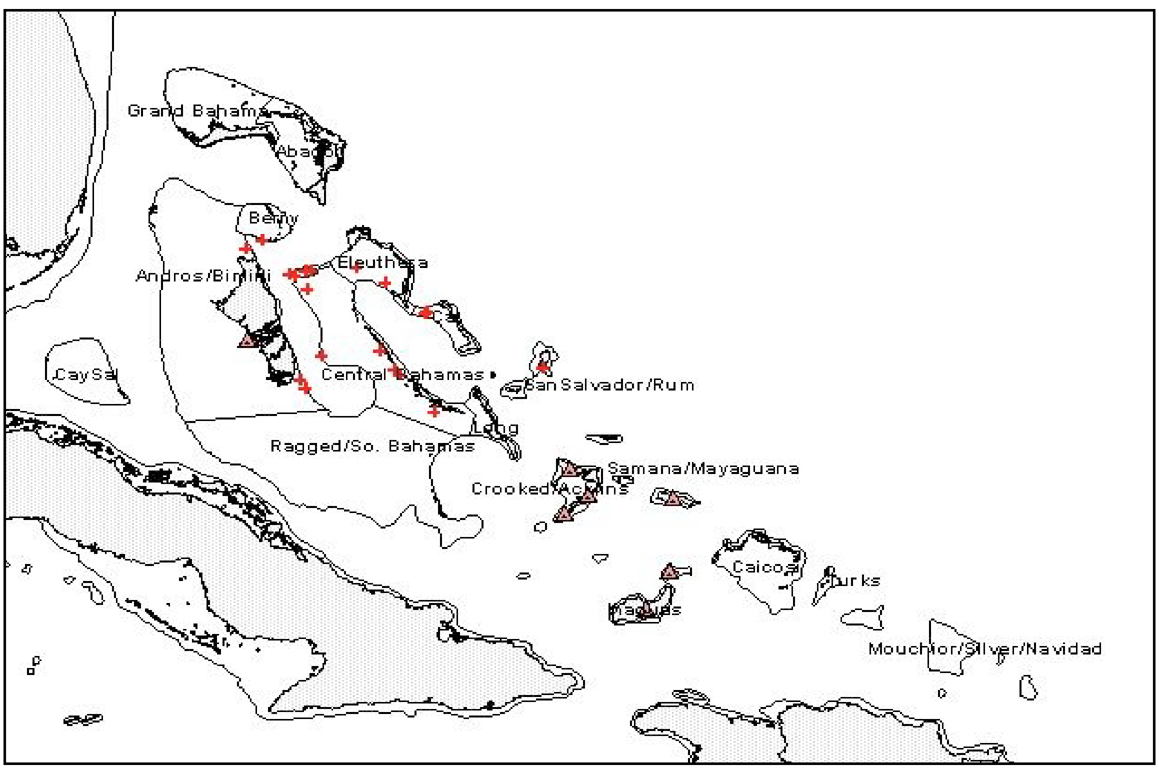

Figure 17. Map depicting locations of high-density flamingo populations (indicated by pink triangles) and locations of established bird sanctuaries (indicated by red crosses)

Distribution

Originally West Indian flamingos occurred widely around the shores and on the islands of the Caribbean (Sprunt, 1975), primarily within the Yucatan, Cayman Islands, Virgin Islands, The Bahamas, Galapagos Islands, the northernmost tip of South America, and in south Florida. A group of flamingos is present along the north coast of the Yucatan Peninsula (Sprunt, 1975). Birds nest in a relatively limited area, the Rio Lagartos, in the north-eastern part of the peninsula and spend the off-season on both coasts: on the Gulf of Mexico side south almost to Campeche and on the Caribbean side to the Bahia de la Ascencion (Sprunt, 1975). A population of West Indian flamingos is established in the Galapagos, isolated by extensive expanses of open ocean (Sprunt, 1975). This location is probably the reason why this population of birds is the smallest component of the overall population. Proper flamingo habitat is limited and it is doubtful that a large number of individuals could be supported (Sprunt, 1975). The group is unique in its apparent ability to breed successfully in small colonies, sometimes as few as five to ten nests (Sprunt 1975). The southern Caribbean population ranges along the northern coast of South America and breeds primarily on Bonaire (Sprunt, 1975). The largest and in some ways the most complex segment of the West Indian flamingo population is located along the northern rim of the Caribbean in the Bahamas, Cuba, Hispaniola, the Turks and Caicos Islands, and historically in South Florida (Sprunt, 1975).

Status of Populations in the Wild

West Indian flamingos are abundant year-round residents on Great Inagua in the Bahamas where a colony of approximately 60,000 birds frequents Lake Rosa (Rafaelle et al., 1998). Smaller colonies occur on nearby Acklins, Crooked and Caicos Islands (Rafaelle et al., 1998). Birds are very common on North and Middle Caicos, North Caicos being home to about a thousand flamingos. Flamingos have recently been reported from Turner Sound in the southwest corner of North Andros, but it is not known if they are breeding there (White, 1998). On Mayaguana there is a resident flock of about 200 flamingos (White, 1998).

Ecology and Natural History

Flamingos are known as wading filter feeders, consuming organically rich detritus, as well as unicellular algae, small insect larvae, crustaceans, molluscs, and certain seeds (Fox, 1975). Thus the birds obtain an assortment of carotenoid pigments, particularly from fresh water, salt water, or marine algae (Fox, 1795). These unicellular plants represent the world's richest source of primary organic matter, and of carotenoids (Fox, 1975). The major keto-carotenoids contributing to leg and feather pigments are only five in number (Fox, 1975). Three red compounds and one orange compound derive from beta-carotene, and one yellow-orange compound derives from alpha-carotene (Fox, 1975), including Echinenone, Canthaxanthin, Phoenicopterone, Phoenicoxanthin, and Astaxanthin.

Flamingos are slow breeders and usually do not reach sexual maturity until they are about six years old, when they will lay one egg a year. They begin an elaborate courtship display in January, and commonly breed from March to July. Nesting is colonial, where mud is compacted into an elevated mound about ten inches high with a concave top about a foot wide, which is used to hold a single egg. Eggs are incubated by both parents for about a month. Parents feed the grey chick 'flamingo milk', which is a secretion of their crops rich in blood and other nutrients (Campbell, 1978). The chick stays on the home mound for only a few days and then joins large mobile flocks of other babies. By June most of the adult flamingos disperse to distant feeding grounds and the juveniles move across the mud flats, feeding on the rich brine beneath their feet (Campbell, 1978). It takes 75 days for flamingo chicks to fledge sufficiently to fly (Campbell, 1978).

Habitat

Flamingos typically live in shallow lagoons and coastal estuaries with high salinities (Rafaelle et al., 1998). Flamingos sometimes use other habitats such as mangrove swamps, tidal flats, and sandy islands in intertidal zones as well. Since these habitats are rather inaccessible and inhospitable, they deter most land-based predators. The presence of absence of fish in a lake may determine the presence or absence of flamingos because fish also feed on the same tiny invertebrates that flamingos consume.

Threats

A major historical threat to the West Indian flamingo is hunting. In the early 1800's, the bird was hunted for its large pink feathers, which were used as decoration for clothing and other items. Also, during World War II, flamingo populations on Andros were disturbed and driven away by noisy, low-flying planes. Presently, flamingos are hunted in some Caribbean countries where people eat flamingo meat. However, it is illegal to capture, harm, or kill any flamingos in the Bahamas.

Figure 18. West Indian Flamingo

Current Conservation Programs

No species of flamingo is listed as endangered under the U.S. Endangered Species Act, but some are listed as near threatened. The West Indian Flamingo is listed in Appendix II of the Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES). The Appendix lists species that are in need of protection and are considered to be threatened or likely to become endangered if trade is not regulated. The West Indian Flamingo is also protected under the U.S. Migratory Bird Treaty Act of 1918, which implements various treaties and conventions between the U.S., Canada, Mexico, Japan, and the former Soviet Union. The act inhibits taking, killing or possessing migratory birds. In 1905 the National Audubon Society asked the Bahamas government to provide legal protection for the flamingos, and the government responded by passing the Wild Birds Protection Act (White, 1998). An initial effort to save the flamingo breeding colonies on Andros failed in the 1950's, despite the courageous efforts of the wardens who stayed at their posts through several hurricanes (White, 1998). In 1951 the National Audubon Society began a research program on flamingos in the West Indies. The largest breeding population was found on Great Inagua, at which time a group of Bahamians and others, including the Audubon Society, founded the Society for the Protection of the Flamingo (White, 1998). In 1959 the government and the society agreed to the terms for a 99-year lease on much of the land on Great Inagua, and the Bahamas National Trust Act was passed (White, 1998). Soon thereafter the Society for the Protection of the Flamingo joined the trust, and in 1964 boundaries and other details for Inagua National Park were finalized (White, 1998). The dedication of the rangers on Great Inagua and the support of the Bahamian government and the Bahamas National Trust are the principal factors that have enabled the flamingo flocks to grow from fewer than 10,000 birds to over 60,000 birds (White, 1998).

Information Gaps and Research Needs

Determination of the status of flamingos on Andros; determine if the birds are breeding there.

Goals

Increase, or at least maintain, the current population of these once abundant birds. Total population estimates should not drop below 60,000 individuals, although numbers greater than this are preferred. Establishment of Important Bird Areas (IBA's) which will prevent or limit human use of the land, thereby reducing the chances that visitors will interfere with flamingo feeding and nesting grounds. Especially important is the education of tourists about sites inhabited by flamingos so as to minimize negative impacts of humans on the habitat. Strengthening of the enforcement of the laws that prohibit hunting of flamingos.

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5.2.6. White-crowned pigeon (*Columba leucocephala*)

Description

Phylum Chordata

Class Aves

Order Columbiformes

Family Columbidae

The white-crowned pigeon, a common year-round resident of the Bahamas, is conspicuous because of the white crown upon its head (Raffaele et al., 1998). While male and female adults are the same size, the species is considered to be sexually dimorphic. The male has a pure white crown, while the female's crown tends to be more greyish or brownish in colour (Pire, 2001). The rest of the body is entirely dark grey (Raffaele et al., 1998), although the hen's chest and abdomen are typically lighter than the male's (Pire, 2001). Immature individuals lack the conspicuous crown marking and have brownish feathers instead (Patterson, 1972). Adults range in size from 33 cm to 36 cm (Raffaele et al., 1998). Characterized as a highly gregarious arboreal species, white-crowned pigeons typically occur in flocks (Raffaele et al., 1998). White-crowned pigeons are far more abundant in the Bahamas from March through the summer months, during which time they make daily trips between the cays and the main islands to gather food they process to feed their young (Tony White, personal communication).

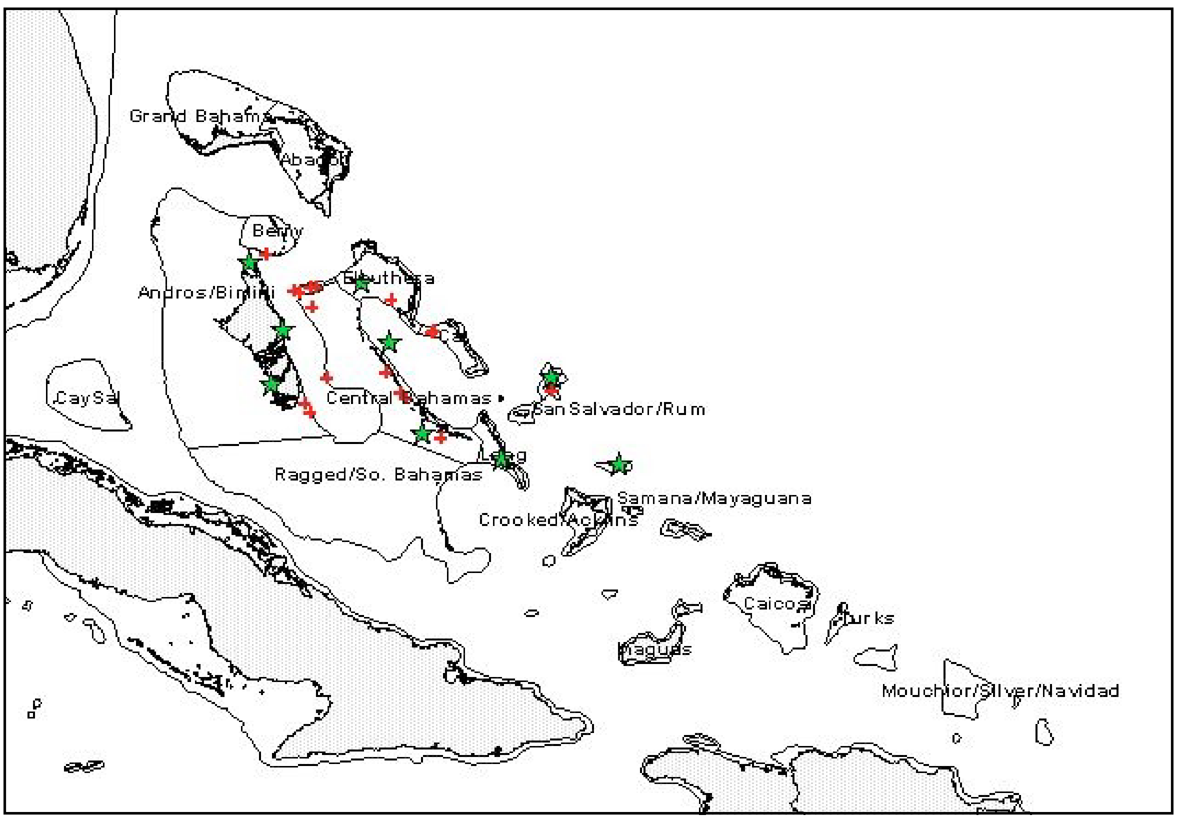

Figure 19. Map depicting locations of high-density white-crowned pigeon sites (indicated by green stars) and locations of established bird sanctuaries (red crosses).

Distribution

The white-crowned pigeon occurs throughout the tropical northwestern Atlantic, including the Florida Keys and on islands offshore of Mexico and Belize (Raffaele et al., 1998). The species is considered a year-round resident in the Bahamian archipelago (Patterson, 1972), although there are far fewer white-crowned pigeons in the Bahamas in winter than in summer (Tony White, personal communication). Within the Bahamas, the pigeon can be found on New Providence, North and South Bimini, the Berry Islands, Eleuthera, the Exumas, Cat Island, San Salvador, Long Island, the Ragged Islands, Acklins, Mayaguana, and Cay Sal (White, 1998). Some of the biggest colonies of white-crowned pigeons from the Bahamas have been observed off Eleuthera (Tony White, personal communication). Specific locales of large colonies include Big Green Cay, Finley Cay, Joulters Cay, Schooner Cays, Deadman's Cay, Goat Cay, Duck Cay, Samana Cay, and Red Shank Cay (White, 1998). Within the Turks and Caicos, the white-crowned pigeon is commonly seen on the island of Providenciales (White, 1998). The bird is also common in Cuba, Jamaica, and Antigua. White-crowned pigeons are locally common on Hispaniola, Puerto Rico, the Virgin Islands, San Andres, and Providencia, but are uncommon in the Cayman Islands, Anguilla, and St. Bartholemy. This species is rare on St. Martin, Guadeloupe, and the Lesser Antilles south to the Grenadines (Raffaele et al., 1998).

Status of populations in the wild

Although the white-crowned pigeon was historically abundant throughout most of its range, the species has declined dramatically, and is now threatened due to a variety of factors, namely habitat loss, severe over-hunting, harvesting of nestlings for food, and introduction of predators (Raffaele et al., 1998). The white-crowned pigeon is currently listed as threatened by the State of Florida, and is considered threatened or endangered throughout much of its range (Bancroft et al. 2000). Declining population trends are recognized for the Bahamas, Cuba, Haiti, Dominican Republic, Puerto Rico, U.S. and British Virgin Islands, Anguilla, St. Martin, and Nicaragua (Strong et al., 1991). In 1976, the Bahamian population was estimated at 80,000 breeding birds, although it is possible that this number has risen since then (White, 1998). Once hunting season begins, the number of white-crowned pigeons drops rapidly, as surviving birds leave the area (Tony White, personal communication).

Ecology and natural history

White-crowned pigeons breed primarily from March to August, but nesting seasons can differ among areas depending upon the extent of local food supply (Raffaele et al., 1998). After the breeding season, the birds may migrate from cooler locations (e.g. Florida Keys) eastward to the Caribbean and especially the Bahamian archipelago (Strong & Bancroft, 1994). White-crowned pigeons are typically colonial nesters (Raffaele et al., 1998), but they do not nest with or near other colonial species (USGS, 1998). White-crowned pigeons build flimsy twig nests in mangroves, dry scrub, or in large trees in residential or commercial developments (Raffaele et al., 1998). Both males and females participate in nest building, but males perform the majority of the gathering and delivering of material to the nest site (Wiley & Wiley, 1979). The nest-building material is usually gathered from trees (not from the ground) that are close to the nest site (Wiley & Wiley, 1979). Nests are created on top of cacti, bushes, or mangroves and are rarely found low to the ground or over water (USGS, 1998). The pigeons are monogamous, with males attending the nest from mid-morning though early evening and females staying with the nest throughout the night (Wiley & Wiley, 1979).

White-crowned pigeons lay a clutch of two glossy white eggs (Raffaele et al., 1998), with the second egg being laid approximately 24 hours to 36 hours after the first (Pire, 2001). Each egg hatches two weeks after it has been laid (Pire, 2001). Incidences of nest predation tend to increase as the nesting season progresses, and predator success increases as the extent of parental attendance at the nest decreases (Wiley & Wiley 1979). White-crowned nestlings demonstrate threat displays, including violent head thrusts, bill clicking, and hissing, but it is the defence mechanisms of the supervising adult that are more effective in minimizing juvenile mortality (Wiley & Wiley, 1979). Common predators of the white-crowned pigeon nestlings include the pearly-eyed thrasher, red-tailed hawk, and brown rats. Other suspected predators include red-winged blackbirds, laughing gulls, American crows, Virginia opossum, and bobcats (Strong et al., 1991). Recently, the raccoon (Procyon lotor) was observed to be a nest predator (Strong et al., 1991). Raccoons are the only predators observed to have a significant influence on nesting distribution of the white-crowned pigeon (Strong et al., 1991).

The newly hatched young do not leave the nest for another two weeks after hatching (Pire, 2001). Young birds may travel more than 20 km from the nest during the first ten days of dispersal (Strong & Bancroft, 1994). Post-fledgling dispersal may be a form of facultative migration, in which the young continue to move away from the natal site until they encounter a site with adequate food supplies. This process allow for the completion of the post-juvenile molt or to add fat reserves prior to migration (Strong & Bancroft, 1994). The exact mechanisms of habitat selection during post-fledgling dispersal are unknown, but it is suspected that continued parental contact may be maintained, allowing previous experience of the parents to influence post-fledgling habitat selection (Strong & Bancroft, 1994).

The white-crowned pigeon is an obligate frugivore and thus an important seed disperser in seasonal deciduous forests (Strong & Bancroft, 1994). Characterized as a powerful flyer, this species may commute 45 km in each direction between its roosting and feeding grounds (Raffaele et al., 1998), and possibly even farther during periods of relative fruit scarcity (Bancroft et al. 2000). These birds feed on at least 37 species of trees (Bancroft et al., 1994), including poisonwood fruit, strangler fig, mastic, pigeon plum, sea grape, and other tropical fruits (Everglades National Park, 1997). By including a wide variety of plant species in their diet, the white-crowned pigeon disperses the seeds of many plants, thus playing an important role in maintaining plant species diversity in seasonal deciduous forests (Strong & Bancroft, 1994). Seed dispersal among isolated forest fragments may be critical to preserving long-term plant biodiversity (Bancroft et al., 2000). Fruit from only four trees dominates the nestling diet: poisonwood, blolly, short-leaf fig, and strangler fig (Bancroft et al., 1994). The white-crowned pigeon is arboreal in its feeding, usually choosing to feed on the upper parts of the most highly situated fruit clusters (Wiley & Wiley, 1979). Because adults do not supplement the nestling diet with arthropods, it is hypothesized that breeding activity may be correlated with peak fruit abundance. Bancroft et al. (2000) determined that the availability of poisonwood fruit, which is the preferred food item of white-crowned pigeons, was, in fact, correlated with clutch initiations by pigeons. In addition, the overall availability of fruits from the four dominant components of nestling diet may influence the nesting phenology of white-crowned pigeons. Strong and Johnson (2001) determined that the migration patterns of non-breeding white-crowned pigeons are a response to fruit availability. Peak abundance of white-crowned pigeons in Portland Ridge, Jamaica, for example, coincided with the peak of ripe fruit abundance. The white-crowned pigeon is a species that is well adapted to utilizing resources while they are plentiful and then moving on once resources are depleted (Raffaele et al., 1998).

Habitat

Mangrove forests, pinelands, woodlands, and scrublands are essential or critical habitats of the white-crowned pigeon. Characterized as a Caribbean arboreal species, the white-crowned pigeon inhabits West Indian hardwood hammocks and pine and mangrove forests of south Florida (Farrand, 1983). This species primarily inhabits coastal woodlands and mangroves when breeding, but can follow available food sources inland into upland areas during the non-breeding season (Raffaele et al., 1998). They are known to breed and roost in large concentrations on brushy, small, low islands and keys, among coastal mangroves and pines (USGS, 1998). White-crowned pigeons are known to nest on offshore mangrove islands, but there is little information available on nesting distribution (Strong et al., 1991). These birds prefer deciduous seasonal forests and avoid suburban and urban habitats (Strong & Bancroft, 1994). The white-crowned pigeon utilizes open forest, woodland, and scrub habitats during its foraging for fruits, seeds, and berries (USGS, 1998).

Figure 20. White-crowned pigeon

Associated Species

Other bird species of conservation interest that are associated with the white-crowned include the plain or blue pigeon (*Columba inorcata*), zenaida dove (*Zenaida aurita*) and mourning dove (*Zenaida macroura*).

Threats

The principal threats to the white-crowned pigeon are habitat clearing and fragmentation, hurricanes, introduction or colonization of nest predators, and over-harvesting. Seasonal deciduous forests of the Florida Keys are increasingly fragmented by human development (Bancroft et al., 2000), which leads to the removal of trees that are commonly utilized for feeding and nesting sites. Ficus trees are frequently removed because their extensive root systems often interfere with septic systems, while poisonwood trees are removed because their sap causes contact dermatitis in humans (Bancroft et al., 2000). Continued loss of such critical foraging habitat and important food sources can have serious long-term implications for the persistence of white-crowned pigeons. Current protection has allowed the population to increase in southern Florida, but rapid clearing and development of tropical hardwood forests is still a concern (Strong et al., 1991).

The White-crowned pigeon is the principal game bird of the Bahamas. By the early 1970s, there was concern about the large numbers of pigeons hunted, and protective measures were taken with regard to the protection of the breeding cays (Patterson, 1972). Reductions in population numbers are directly attributable to severe hunting pressure on Bahamian and other Caribbean nesting grounds (Everglades National Park, 1997). Tighter controls on hunting activities has stopped the shooting during the breeding season and reversed the decline in the pigeon's population, which is now slowly recovering from the adverse effects of over hunting (White, 1998).

The introduction or colonization of predators affects the breeding distribution of white-crowned pigeons. Studies as early as 1942 reported that raccoon colonization of a mangrove island in Florida Bay caused abandonment of the white-crowned pigeon nesting sites (Strong et al., 1991). Studies in the Florida Keys illustrate that the nesting sites were not detected in areas where opossums or bobcats were observed, and nests were rare on sites where raccoons were observed (Strong et al., 1991). Raccoon-inhabited sites only had a maximum of seven nests per key, suggesting that raccoons at least limit the distribution of high-density nesting areas (Strong et al., 1991). The sympatric occurrences of raccoons and white-crowned pigeons are indicative of recent raccoon invasion, and the expansion of raccoons to more locations could make additional sites unsuitable for nesting (Strong et al., 1991).

Destructive storm events, such as hurricanes, are additional threats to the white-crowned pigeon and their essential habitats (Fleming, 2001).

Current conservation programs

The Bahamas National Trust, established in 1959, manages the country's National Parks, historic preservation, conservation education, policy planning, and research protecting the indigenous species of The Bahamas, including the white-crowned pigeon (Eco-Bahamas, 1999). The Wild Bird Protection Act of 1987 established a closed season for white crowned pigeons, which lasts from March 1 to September 28, during which it is illegal to kill, capture, or have in one's possession a protected bird unless it can be proven that it was taken in season (Eco-Bahamas, 1997). This act ensures that only Bahamian citizens, permanent residents, licensed foreigners, and those who have resided in The Bahamas for a continuous 90-day period may hunt in the Bahamas, while setting a bag limit of 50 wild birds within one day and a total of 200 birds at any one time (Eco-Bahamas, 1997). Additionally, several wild bird reserves have been established on various islands throughout the country, in which it is illegal to hunt, kill or capture wild birds (Eco-Bahamas, 1997). Penalties for those who commit an offence include fines, imprisonment, and forfeit of equipment and vehicles used in committing the illegal act. To help enforce the law, a reward is provided to those who provide information leading to the conviction of the offender (Eco-Bahamas, 1997).

Information gaps and research needs

The development of effective management plans for this species may depend upon a thorough understanding of the relationship between resource availability and breeding patterns (Bancroft et al. 2000). Continued monitoring to determine the annual variation in use of various sites by white-crowned pigeons is necessary (Strong and Johnson 2001). Estimates of the populations on several islands do not exist, and population size determination should be a priority. Also, studies investigating the exact mechanisms of habitat selection during post fledging dispersal are unknown.

Goals

Maintain a wild population with a minimum size of 100,000 individuals.

Justification

It is known that the white-crowned pigeon is suffering from many anthropogenic effects and that the population continues to decline. Based on past censuses, this goal is reasonable and realistic. It is necessary to take measures to protect the critical habitat of the white-crowned pigeon because increased development continues to fragment the habitat and degrade the conditions of the habitat. The white-crowned pigeon may be particularly prone to extinction because of the difficulty in protecting refuges of adequate size for these large, mobile frugivores.

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5.2.7. Rock Iguanas

Description – Cyclura

General Information about the genus

The Genus Cyclura is composed of eight species of West Indian rock iguanas that inhabit tropical dry forests and pine barrens throughout the Greater Antilles and the Bahamas (Alberts et al., 1997). Cyclura is a distinct lineage that is not closely related to any other iguanine

(Malone et al., 2000). Endemism in this genus is extreme; each distinct lineage is restricted to only one island or one small island group (Malone et al., 2000). The general pattern of Cyclura radiation reflects a southeast to northwest directionality (Malone et al., 2000). Of the eight existing rock iguana species, three species are found on the islands of the Bahamas and the Turks and Caicos: *C. carinata*, *C. cychlura*, and *C. rileyi* (Malone et al., 2000; Buckner & Blair, 2000b; Gerber & Iverson, 2000). Rock iguanas are the largest and most conspicuous lizards in the western hemisphere, inhabiting islands throughout the Greater and Lesser Antilles and the Bahamas (IUCN Specialist Group Reports, 1998; Shedd Aquarium, 2001).

Cyclura lizards are large herbivorous lizards and are the largest native herbivores on many West Indian islands (Hartley et al., 2000; Shedd Aquarium, 2001). Different populations of the same species of rock iguana may use remarkably different food resource plants, even if the vegetation of the habitats may be similar; such observations suggest that learning by the lizards and local variation in plant palatability may be important factors in determining diet (Auffenberg, 1975). In addition to plants, rock iguanas may also consume other foods to obtain protein.

Through observation, it has been determined that most adult rock iguanas restrict their activity to rather small territories within the vegetation, using crevices in the coralline rock and burrows in the sand for shelter (Gicca, 1980; Schwartz & Henderson, 1991). However, territory size has not yet been determined for the Andros Island rock iguana, which is not restricted to small cays (S. Buckner, personal communication). Most species of Cyclura exhibit some form of territorial defence, which is often displayed in encounters as the lateral compression of the body and enlargement of the gular pouches (Knapp, 2000b).

Breeding typically begins in early spring (when males are most brightly coloured), and females lay their eggs by the middle of June (Auffenberg, 1976). Eggs are laid in shallow burrows in the sand. After hatching, the young dig their way to the surface, where they begin eating small plants and insects. The juvenile diet will become primarily herbivorous with increased growth (Auffenberg, 1976). An Alberts et al. (1997) study of captive individuals illustrated that those hatchlings that emerged from eggs incubated at warmer temperatures displayed faster growth in mass, snout-vent length, head width, and head length, even though all hatchlings from all incubation temperatures were initially equal in size. Larger body size may benefit hatchling reptiles by allowing them to utilize a greater variety of food resources, dominate conspecifics, and evade predators. Larger body size may also enhance the social status and mating ability of males while decreasing the age at first reproduction (Alberts et al., 1997).

Rock iguanas are important seed dispersers for many plants; consequently, the loss of West Indian iguanas has had serious consequences on the ecosystems the lizards inhabit (IUCN Specialist Group Reports, 1998). A Hartley et al. (2000) study done outside of the Bahamas documented that seeds of *Ziziphus rignoni* (not found in the Bahamas) that were ingested and subsequently defecated by Cyclura iguanas germinated much more rapidly than seeds that were not ingested by the lizards. Although there was no difference in the final percentage of ingested versus non-ingested seeds that germinated, the rapid germination facilitated by the iguanas could provide considerable advantages to seeds in xeric habitats, such as increased moisture, prevention from desiccation, and the ability to better utilize available rainfall (Hartley et al., 2000). Furthermore, Cyclura lizards can play an important role in seed dispersal by dispersing seeds to microhabitats where seedling competition is lessened or where conditions are more favourable for germination (Hartley et al., 2000). Because rock iguanas inhabit relatively small islands, their potential for long distance dispersal of seeds is limited (Hartley et al., 2000).

The principal threats to rock iguanas are predation by exotic species, habitat loss due to residential and commercial developments, and illegal hunting and smuggling. Lizards of the genus Cyclura are among the most endangered lizards because much of their fragile island habitat has been either destroyed by human development or degraded by exotic species (IUCN Specialist Group Reports, 1998). All extant species of Cyclura are considered by IUCN to be endangered or vulnerable to human disturbance, and all species are listed as CITES Appendix 1 (Malone et al., 2000). Throughout the Bahamas, all Cyclura iguanas are protected under the Wild Animals Protection Act of 1968, but rock iguanas are still illegally hunted and/or smuggled for the pet trade (Shedd Aquarium, 2001). Because rock iguana populations are naturally small and the lizards are limited to the shrinking habitats of their islands, any combination of even seemingly minor threats can cause populations to decrease or even be eradicated in only a few years (Shedd Aquarium, 2001). Feral dogs, cats, pigs, rats, and mongooses (not in the Bahamas) prey upon eggs and juveniles (Shedd Aquarium, 2001; Alberts et al., 1997). Predation on rock iguana juveniles and eggs by exotic species can result in scant to nonexistent recruitment in severely impacted populations (Alberts et al., 1997). Humans may pose as one of the biggest threats; in a small survey, Knapp et al. (1999) found that almost every Bahamian resident of Andros Island that they interviewed had eaten iguana. Other than man, the only likely natural predators of Cyclura are sea gulls, ospreys, Alsophus sp.snakes, and herons (Gicca, 1980 and Knapp, personal communication).

A serious problem facing the success of rock iguana conservation attempts stems from the fact that individuals that have been removed from the Bahamas cannot be reintroduced back into the Bahamas. The potential to introduce exotic pathogens into native natural populations thorough release of captive individuals is widely recognized, thereby making repatriation highly unfeasible (Hudson, 2002). Reptiles can harbour an array of pathogens, but the ability to screen for those pathogens that are dangerous is crude at best; for this reason, many researchers have stressed the importance of developing pre-release health screening protocols and methods (Hudson, 2002). Because of the complications involving disease transmission from reintroduced individuals to native populations, conservation strategies must address steps to prevent illegal poaching and smuggling out of the Bahamas.

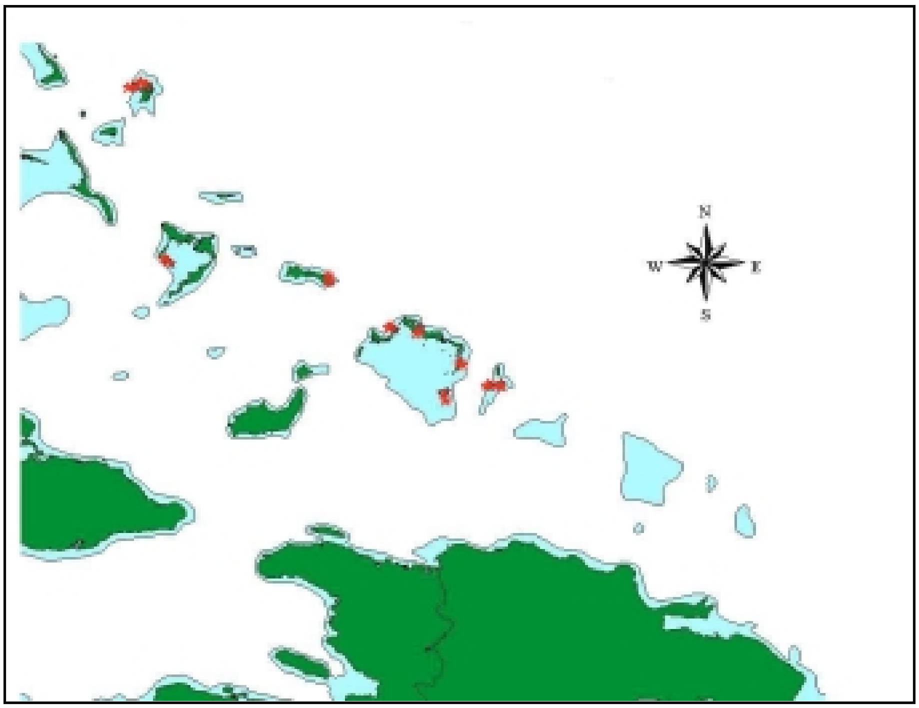

Figure 21. Map depicting locations of rock iguana location (indicated by red crosses) in the southern Bahamas

5.2.7.1. Bartsch's rock iguana (*Cyclura carinata bartschi*)

Description

Phylum Chordata
  Class Reptilia
    Order Squamata
      Suborder Sauria
        Family Iguanidae
          Subfamily Iguninae

Bartsch's iguana is greenish to brownish-grey, with a yellow dorsal crest, although the body colour is somewhat paler than other carinata species (Buckner & Blair, 2000b). The paler body colour may be a response to temporal or climatic cues. Large specimens of C. cychlura bartschi can attain lengths of approximately 2.5 feet (Auffenberg, 1976). Maximum observed lengths in the field are 335 mm SVL in males and 285 mm SVL in females (Buckner & Blair, 2000b).

Distribution

Bartsch's iguana is restricted to Booby Cay, which is located 0.5 km off the eastern end of Mayaguana Island (Buckner & Blair, 2000b). The island is 2 km long and 750 m wide at its widest point. Two ponds occupy 30% of the island (Buckner & Blair, 2000b). The iguanas may likely be concentrated on the eastern half of the island because of dense vegetation (Buckner & Blair, 2000b), however, very little is known concerning the distribution and density of this inhabitant of such a remote cay (Auffenberg, 1976).

Status of populations in the wild

Bartsch's rock iguana is restricted in distribution to the south-eastern Bahamas, specifically on Booby Cay east of Mayaguana Island. A census of the population has never been completed, but it is unlikely that the population exceeds 500 individuals. The best estimates of the remaining population range from 200 to 300 individuals (Buckner & Blair, 2000b).

Ecology and natural history

Bartsch's rock iguana is primarily herbivorous throughout its life, although it will also eat insects, molluscs, crustaceans, arachnids, lizards, and carrion (Buckner & Blair, 2000b).

Bartsch's rock iguana individuals reach sexual maturity at about 220 mm SVL (about 7 years of age) and females reach sexual maturity at 185 mm to 200 mm SVL (about 6-7 years of age). C. carinata individuals synchronize reproductive cycles with climatic cycles: courtship begins in May and a clutch of two to nine eggs is laid in early June (Schwartz & Henderson, 1991). Serial polygyny is expected, but there may be cases of monogyny among some males (Schwartz & Henderson, 1991). Females defend the nest burrow for several weeks after nesting, but the females are not territorial during the rest of the year (Gerber & Iverson, 2000). Hatchlings emerge after 90 days of incubation, with an average size of 80 mm SVL (Gerber & Iverson, 2000).

Two C.c.inornata rock iguanas involved in a territorial encounter will briefly circle each other with legs extended directly below their bodies; such encounters have been observed to last only 15 to 20 seconds until one of the participants fled (Knapp, 2000b). The mean home range area for *C.cychlura* inornata males (3,019 m^2) is much larger than female home range (235 m^2) (Knapp, 2000b). A common result of the rock iguana's territoriality is an increase in the number of tail breaks, since tails are exposed during antagonistic confrontations. The incidence of tail breaks is higher in the more territorial populations of Cyclura (Knapp, 2000b). Specific information about the behaviour of C. cychlura bartschi is not available.

Figure 22. Bartsch's rock iguana

Habitat

Critical habitats for the Bartsch's iguana are tropical dry forests, rocky coppice, and sandy strands. Like the Turks and Caicos iguana, Bartsch's iguana probably also inhabits rocky coppice and sandy strand vegetation habitats (Buckner & Blair, 2000b). Little research, however, has been conducted on the habitat requirements of this subspecies.

Associated Species - see other conservation target descriptions for details
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

Introduced goats pose as the most serious threat to the already-small population of *Cyclura cychlura bartschi* on Booby Cay (Buckner & Blair, 2000b). Booby cay is not readily accessible from the settlements of nearby Mayaguana Island, which may have allowed the population to exist thus far; however irregular visits by local conch fishers may be a problem (Buckner &

Blair, 2000b). Cats are on East Mayaguana and may pose a problem if they are able to reach Booby Cay (J.Waselewski, personal communication). Additionally, the potential damage caused by catastrophes, such as hurricanes, or hurricane surges, deserve consideration (Buckner & Blair, 2000b).

Current conservation programs

All Bahamian rock iguanas are protected under the Wild Animals Protection Act of 1968; there have been no reports of poaching of iguanas on Booby Cay and it is not known if any iguanas are taken by local fishermen for consumption (Buckner & Blair, 2000b). The Bahamas National Trust has proposed to the national government that Booby Cay be named a protected area under the National Parks system (Buckner & Blair, 2000b).

Beginning in early 1995, representatives of the Wildlife Committee of the Bahamas National Trust and the Department of Agriculture began to survey the status of the iguanas on Booby Cay and to initiate the removal of feral goats (Buckner & Blair, 2000b). Although no captive programs currently exist, there is now an active research program (led by Bendon and Gerber) underway to study more about this subspecies (S.Buckner, personal communication).

Information Gaps and Research Needs

- Assess the present status of the population on Booby Cay, identify plant species cay wide, and monitor vegetation changes after the removal of goats (Buckner & Blair, 2000b); and
- Determine whether any subpopulations exist at the eastern end of Mayaguana and establish captive breeding programs with the potential goal of restocking on Mayaguana (Buckner & Blair, 2000b).

Goals

A minimum population size of 300 individuals.

Justification

Although this is a crude estimate of a viable population, a population of 300 individuals will help insure the persistence of these sub-species. Since this sub-specie is restricted to a single small cay, it is essential to establish a population level that is high enough to tolerate the current threats as well as prevent genetic complications and inbreeding depression.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex ratios, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes & Carter, 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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5.2.7.2. Turks and Caicos rock iguana
(*Cyclura carinata carinata*)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The body colour of the Turks and Caicos rock iguana varies among island populations, from grey or brown to dull green (Gerber & Iverson, 2000). In some populations, the head and neck have a vermiculated pattern, and the dorsal crest scales and the tail of adult males are pale blue and reddish-brown.

Distribution

The Turks and Caicos iguana is restricted in distribution to the Turks and Caicos Islands, now apparently present on only 56 of the 120 cays examined in a recent survey (Gerber & Iverson, 2001).

Status of populations in the wild

The Turks and Caicos iguana was once widespread among all of the islands of the Turks and Caicos, but the subspecies has been extirpated from many areas, including many of the larger islands (Gerber & Iverson, 2000). A 1995 survey resulted in iguana sightings on 56 of 120 cays examined, with an estimated remaining adult population of 30,000 individuals (Gerber & Iverson, 2000). Five of the 56 cays known to be inhabited by C. cychlura carinata comprise half of the area inhabited by the subspecies, but current densities at these sites are considerably low (Gerber & Iverson, 2000).

Ecology and natural history

The Turks and Caicos iguana eats the fruits, flowers, and leaves of at least 58 plant species, but may also occasionally consume insects, molluscs, arachnids, lizards, and carrion (Gerber & Iverson, 2000). Strumpfia (bay cedar) is the single most important food item in the diet during the first year of life (Iverson, 1979). During the winter months, when cooler, drier conditions cause plants to stop their production of fruits and flowers, the Turks and Caicos iguana becomes an obligate foliovore (Iverson, 1979).

The Turks and Caicos iguana exhibits sexually dimorphic body size, and size also varies among islands (Gerber & Iverson, 2000). Females tend to be shorter in length than males (Norton & Clarke, 1992). The largest recorded male and female are from Pine Cay on the west side of Caicos Bank, measuring 360 mm SVL and 290 mm SVL, respectively (Gerber & Iverson, 2000). Juvenile growth rate averages 19.2 mm SVL per year, while adults grow between 2 and 17 mm SVL per year (Iverson, 1979).

Individuals reach sexual maturity at about 220 mm SVL (about 7 years of age) and females reach sexual maturity at 185-200 mm SVL (about 6-7 years of age). Individuals synchronize reproductive cycles with climatic cycles: courtship begins in May and a clutch of two to nine eggs is laid in early June (Schwartz & Henderson, 1991). Serial polygyny is expected, but there may be cases of monogyny among some males. Females defend the nest burrow for several weeks after nesting, although the females are not territorial during the rest of the year (Gerber & Iverson, 2000). Hatchlings emerge after 90 days of incubation, with an average size of 80 mm SVL (Gerber & Iverson, 2000).

Adult male C.c.carinata iguanas are territorial year-round, apparently to guarantee access to food and females (Gerber & Iverson, 2000). Dominant males have larger home ranges (averaging 1,590 m^2) than do subordinate males, whose home ranges average 1,260 m^2 (Schwartz & Henderson, 1991). Female home ranges average 980 m^2 (Iverson, 1979).

Habitat

Critical habitats for the Turks and Caicos rock iguana are tropical dry forests, rocky coppice, sandy strands, and, less commonly, pine barrens. *Cyclura carinata carinata* is most commonly found in rocky coppice and sandy strand vegetation habitats (Gerber & Iverson, 2000). This subspecies requires a sandy habitat for nesting. It spends the nights in burrows it has dug or in natural retreats under rocks (Gerber & Iverson, 2000). Individuals generally avoid lower areas with thicker soils due to the proximity of the water table to the surface and their inability to dig through root mass (Iverson, 1979). During feeding, the herbivorous Turks and Caicos rock iguana utilizes both arboreal and terrestrial resources to obtain fruits, flowers, and leaves (Gerber & Iverson, 2000).

Associated Species - see other conservation target descriptions for details
Pine forests
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

The principal threats to the Turks and Caicos rock iguana are predation by exotic species, habitat loss from residential and commercial development, and illegal hunting and smuggling.

The introduction of mammals, especially dogs and cats, constitutes the biggest threat to the Turks and Caicos iguana (Gerber & Iverson, 2000). Feral livestock, such as goats, cows, donkeys, and horses, are also a threat because they compete for food plants, alter vegetation composition of habitats, and trample the soft substrates that iguanas use for burrows and nests (Gerber & Iverson, 2000). The effects of feral animals are well documented: a population of approximately 5,000 *C. cychlura carinata* individuals was nearly extirpated in only three years following the introduction of these predators, and, furthermore, iguanas were found on only five of 26 islands with cats or livestock on them (Gerber & Iverson, 2000). Loss of habitat may also be at least partially responsible for the decline in the population of the subspecies (Norton & Clarke, 1992). Humans inhabit eight of the larger islands of the Turks and Caicos, and considerable habitat has been lost to tourism developments (Gerber & Iverson, 2000). Additionally, periodic hunting of iguanas for food does occur (Norton & Clarke, 1992), and international trade, which is illegal, most likely continues (Gerber & Iverson, 2000).

Current conservation programs

Although the Turks and Caicos have a fairly extensive system of national parks, reserves, and sanctuaries, the effects of introduced mammals are still apparent (Gerber & Iverson, 2000). Legislation to protect the iguanas within the Turks and Caicos Islands has recently been drafted, and the government has also granted the National Trust stewardship of Little Water Cay, which supports a large population of iguanas, but needs management due to tourism popularity (Gerber & Iverson, 2000). A preliminary study of genetic variation in the Turks and Caicos iguana using blood samples collected from 29 island populations in 1995 found significant differences among islands and revealed a pattern of strong differentiation (Gerber & Iverson, 2000). No captive programs currently exist for this taxon (Gerber & Iverson, 2000).

Information Gaps and Research Needs

- Eradicate or control introduced mammals on islands uninhabited by humans. Free-ranging domestic livestock should also be captured and relocated to inhabited islands;
- Complete study genetic differentiation among island populations;
- Establish a long-term monitoring program and GIS database of iguana populations' capabilities islands; and
- Conduct field to determine the conditions necessary to re-establish healthy, self-sustaining populations of the Turks and Caicos iguana on islands uninhabited by humans, supporting suitable habitat, and lacking feral mammals. Results could serve as a valuable model for other West Indian rock iguanas, some of which may depend on reintroduction programs for their survival.

Goals

Obtain a population minimum of 30,000 individuals.

Justification

Population counts need to remain high to ensure the persistence of this sub-species. Recent censuses have resulted in a population estimate of 30,000 adults, making this goal realistic and reasonable. A population of this size may be large enough to tolerate the current threats that could otherwise impose irreversible damage to this sub-specie.

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Figure 23. Turks and Caicos rock iguana

5.2.7.3. Allen's Cay rock iguana
(*Cyclura cychlura inornata*)

Description
Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The Allen's Cay Rock Iguana is characterized by a lack of horn-like frontal or pre-frontal scales, rostral scale in contact with nasal scales, slightly enlarged prefrontal scales separated from frontal scale by four scale rows, and a dorsum pigmented grey-black with cream, pink, or orange mottling (Iverson, 2000). Pink or orange pigment is most obvious on the posterior lower labial scales. This subspecies is large, with individuals attaining a maximum total length of 1000 mm (Iverson, 2000).

Distribution

The subspecies inornata occurs on three small islands in the Allen's Cays, Exuma Islands (Iverson & Mamula, 1989). Individuals are known from Allen's Cay, U Cay, and Leaf Cay, although breeding populations only occur on Leaf Cay and U Cay (Iverson, 2000). Breeding does not occur on Allen's Cay because of a lack of nesting substrate (Carey et al., 2001). In 1989, the population of sub-adults and adults on each of the two smaller islands (Leaf Cay and Southwest Allen's Cay) was estimated to be between 200 and 300 lizards. A maximum of seven adult lizards is thought to inhabit Allen Cay, the largest of the three islands that supports *C. cychlura inornata* (Iverson & Mamula, 1989; Iverson, 2000). A population of this subspecies has also been introduced to an undisclosed island in the Exuma Cays Land and Sea Park (ECLSP) by J. Iverson (S.Buckner, personal communication).

Status of populations in the wild

The subspecies *C. cychlura inornata* occurs on three small islands in the Allen's Cays, Exumas (Iverson & Mamula, 1989). In 1989, the population of sub-adults and adults on each of the two smaller islands (Leaf Cay and Southwest Allen's Cay) was estimated to be between 200 and 300 lizards. Only one or two lizards are thought to inhabit Allen Cay, the largest of the three islands that supports *C. cychlura inornata* (Iverson & Mamula, 1989).

Ecology and natural history

Cyclura cychlura inornata feeds upon the fruits, leaves, and flowers of most of the plants present on its small island (Iverson, 2000). The subspecies is also opportunistically carnivorous, as evidenced by crab claws in their faeces (Iverson, 2000). In addition, the lizards are frequently fed a variety of foods (from table scraps to fresh produce) from humans on the island (Iverson, 2000). Although the impact of this food supplementation has not yet been determined, it is speculated that food provisioning by humans may be causing a breakdown in the natural social structure of the iguana population (Knapp, 2000b).

A study of the Allen's Cay rock iguana revealed that male iguanas reach greater maximum sizes than females, but the two sexes are practically identical in external morphology (Iverson & Mamula, 1989). On average, males grew 1.764 cm per year, while females grew only 1.139 cm per year (Iverson & Mamula, 1989). The growth of island iguanas is slower than the growth of mainland species, even though island species are typically larger than mainland species (Iverson & Mamula, 1989).

Little is known about the breeding habits of Cyclura cychlura inornata, although all subspecies of C. cychlura are thought to be similar in their breeding and nesting habits (Iverson, 2000, Buckner & Blair, 2000a).

Adult rock iguanas restrict their activity to rather small territories within the vegetation, using crevices in the coralline rock and burrows in the sand for shelter (Gicca, 1980; Schwartz & Henderson, 1991). Most species of Cyclura exhibit some form of territorial defence, which is often displayed in encounters as the lateral compression of the body and enlargement of the gular pouches (Knapp, 2000b). However, demonstrating behaviour that is quite different from most other rock iguanas, the Allen's Cay iguana (C. cychlura inornata) appears to be non-territorial, and this lack of territoriality has been explained by a combination of food provisioning by tourists, population density, and small island size (Knapp, 2000b). Social tolerance can be beneficial for animals living in small, isolated, densely population habitats for two reasons. First, a reduction in territoriality increases the number of individuals that can inhabit the island, thereby decreasing the probability of negative effects caused by genetic drift and inbreeding. Second, resources such as food, nesting areas, and retreats, which are of limited supply, would be difficult to obtain in a territorial system (Knapp, 2000b).

Habitat

Critical habitats of the Allen's Cay rock iguana are rocky coppice and sandy strands. It occupies all potential habitats on the cays they inhabit; these habitats include sub optimal areas of bare, honeycomb limestone (Iverson, 2000). The subspecies will also climb up into the vegetation to obtain food items.

Associated Species-see other conservation targetdescriptions for details
Dry Evergreen Forests

White-crowned pigeon
Beach Strand

Threats

The principal threats to the Allen's Cay rock iguana illegal hunting and smuggling. The major threat to the persistence of the subspecies inornata is the removal by humans for poaching activities, but not for human consumption (S.Buckner, personal communication), which is exacerbated by the fact that this subspecies inhabits cays that are less than a day's sail from Nassau (Iverson, 2000).

Current conservation programs

Although the subspecies is protected under Bahamian law, enforcement is difficult without a warden present (Iverson, 2000). Signs erected on the island explain the vulnerability of these lizards and most visitors on yachts radio the authorities if anyone is seen harassing the iguanas (Iverson 2000). Unfortunately, visitors enjoy feeding the iguanas unnatural foods (Iverson, 2000). Long-term investigations of growth, survivorship, and population status of these iguanas are ongoing by J.Iverson (Iverson, 2000), as is a study of their reproductive ecology (S.Buckner, personal communication).

Between 1988-1990, eight individuals from Leaf Cay were used to form a protected population on Alligator Cay in the Exuma Land and Sea Park, and that population, which is now thriving, increased ten-fold in a decade (Carey et al., 2001).

Information Gaps and Research Needs

- Continue to collect age-specific reproductive data on the marked population of Allen's Cay iguanas for which long-term growth data already exist
- Explore the feasibility of modifying sinkholes on Allen's Cay to create nesting habitat for iguanas.
- Continued monitoring of the introduced population on Alligator Cay.

Goals

A population with a minimum size of 400 individuals

Justification

Because two of the breeding populations are located on cays, which are heavily visited by tourists, it is necessary to maintain this population minimum. Although this is a crude estimate of a viable population, this is a realistic goal, since the total wild population is estimated to be up to 500 individuals.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes & Carter, 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 24. Allen's Cay rock iguana

5.2.7.4. Andros Island rock iguana
(Cyclura cychlura cychlura)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The Andros Island iguana is a large iguana that is dark-grey to black, with yellowish green or orange tinted scales on the legs, dorsal crest, and particularly the head (Buckner & Blair, 2000a). With maturity, the yellow slowly changes to orange-red, especially in larger males (Auffenberg, 1976). However, it should be noted that coloration patterns might vary widely among individuals (Knapp, personal communication).

Distribution

The *Cyclura cychlura* subspecies occurs on Andros Island.

Status of populations in the wild

Previous estimates put the wild population at 2,500 to 5,000 individuals distributed among three or more subpopulations, but since individuals are only observed on occasion, experts believe that this estimate may be too optimistic (Buckner & Blair, 2000a). However, because much of the habitat is remote and inaccessible, there is a possibility of encountering large subpopulations, especially in the western reaches of south Andros (Buckner & Blair, 2000a).

Ecology and natural history

C. cychlura cychlura is a very large subspecies, attaining a total length of 1500 mm (Buckner & Blair, 2000a), and is unquestionably the largest extant native land animal in all of the Bahamas. Individuals of this subspecies can exceed 8kg in body mass (Knapp, personal communication). However, the largest individuals are confined to small parts of the range in the extreme southwest, and the largest individuals are now much less common (Auffenberg, 1976).

The Andros rock iguana eats guanaberry (*Byrsonima lucida*) (Knapp et al., 1999), as well as a variety of other plants, including black mangrove (*Avicennia germinans*) leaves, coco plums (*Chrysobalanus icaco*), pigeon plums (*Coccoloba diversifolia*), and Joe-wood leaves (*Jacquina keyensis*) (Knapp, personal communication). Individuals also use termite mounds for food sources. Furthermore, an examination of Andros Island iguana scat has also confirmed that some rock iguanas also eat claws of the white land crab, *Cardisoma sp*. (Knapp et al., 1999).

Little is known about the specific breeding habits of the Andros rock iguanas. Female Andros iguanas are the only iguanid known to use termite mounds as incubation chambers for their eggs (Knapp, personal communication). Andros rock iguana breeding begins in the early spring, when males are most brightly coloured. Females lay their eggs by the middle of June (Auffenberg, 1976). Hatchling iguanas appear to remain close to their hatch site for three to five years before dispersing to larger pine, beach strand scrub, and broadleaf woodland areas (Knapp, personal communication).

Habitat

The principal habitats of the Andros rock iguana are tropical dry forests, pine barrens, rocky coppice, and sandy strands. Individuals occupy the interior pine barrens (*Pinus caribbea var. bahamensis*) of Andros Island, where they prefer open canopies (Knapp et al., 1999). The habitat on Andros offers a variety of fruits, flowers, and leaves, and the karst rock found there provides suitable retreats (Buckner & Blair, 2000a). Ongoing research suggests that some iguanas may also use the mangrove systems as dispersal and migration corridors (Knapp, personal communication).

Associated Species - see other conservation target descriptions for details
Pine forests
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

The Andros rock iguana is threatened by predation by exotic species, habitat loss from residential and commercial development, and illegal hunting and smuggling.

Feral pigs, which are able to uproot recently oviposited nests and eat the eggs, are a substantial threat to *C. cychlura cychlura* populations on Andros Island (Knapp et al., 1999). Additionally, Andros Island rock iguanas are endangered by the presence of sponge and crab hunters, who burn large areas of vegetation to expose crab burrows, thereby exposing iguanas and forcing them deeper into the interior of the island (Knapp et al., 1999). Many local residents of Andros are apparently unaware of the protected status of this subspecies (Buckner & Blair, 2000a). Poaching continues to be a serious problem for the Andros population, with northern populations doing less well than those in the south (IUCN Specialist Group Reports, 1998; S. Buckner, personal communication). Historically, most iguana hunting has occurred on North Andros because of the presence of extensive logging roads and larger human settlements there (Knapp, personal communication).

Current conservation programs

The subspecies is protected under the Wild Animals Protection Act of 1968, but no areas have been specifically designated for the protection of iguanas on Andros, and no specific conservation programs are in place (Buckner & Blair, 2000a). There are currently no captive programs for this subspecies (Buckner & Blair, 2000a), and the old individual that was once held at Ardastra Gardens and Zoo has recently died (S. Buckner, personal communication). Attempts to breed a large male held captive by a private resident of South Andros have resulted in the death of at least two other iguanas (Buckner & Blair, 2000a).

Information Gaps and Research Needs

- Determine the status of the population and its range, including the existence of viable subpopulations on South Andros exist;
- Conduct ecological studies and collect natural history data, ideally with the involvement of local residents iguanas;
- Establish captive breeding programs; and
- Institute control measures for introduced species.

Goals

Maintain a population minimum of 4,000 individuals.

Justification

Although this is a crude estimate of a viable population, this is a very reasonable and realistic goal. Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes & Carter, 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 25. Andros Island rock iguana

5.2.7.5. Exuma Island rock iguana
(Cyclura cychlura figginsi)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The subspecies figginsi is conspicuously different from other subspecies in that individuals have supranasals usually separated by a small, azygous scale and two pairs of prefrontals, the posterior pair of which is greatly enlarged (Knapp, 2000a). Coloration is variable between populations on different cays, ranging from dull grey to dull black. The subspecies figginsi is often regarded as the smallest of the three subspecies of cychlura, however, Knapp (2000a) recorded maximum sizes of 470 mm SVL.

Distribution

The subspecies figginsi inhabits small cays in the central and southern Exuma chain (Knapp, 2000b). The seven cays that are occupied by the subspecies are Bitter Guana, Gaulin Cays, White Bay, Noddy, North Adderly, Leaf Cay, and Guana Cay, although the population is concentrated in White Bay, Noddy, North Adderly, and Leaf Cays (Knapp, 2000a).

Status of populations in the wild

The total figginsi population is estimated to be 1,000 to 1,200 lizards (Knapp, 2000a). Although many of the subpopulations appear relatively stable, some are still in need of monitoring (Knapp, 2000a).

Ecology and natural history

Cyclura cychlura figginsi is an arboreal and terrestrial feeder. Preferred food items are the flowers, fruits, young buds, and leaves of *Rachicallis americana*, *Reynosia septentrionalis*, *Strumpfia maritima*, *Jacquinia keyensis*, *Erithalis fruticosa*, *Coccoloba uvifera*, *Coccothrinax argentata*, *Eugenia axillaries*, *Suriana maritima*, and the rotting fruit of *Casasia clisiifolia* (Knapp, 2000a). This subspecies is also coprophagous, actively foraging for the faeces of the zenaida dove and the white-crowned pigeon (Knapp, 2000a).

Individuals of the subspecies figginsi have been observed to nest on Guana Cay; females dig a nest burrow approximately 61 cm long and 8 cm to 13 cm deep (Knapp, 2000a). Gravid females will actively defend an incomplete tunnel from conspecifics, but stops defence behaviours after oviposition (Knapp, 2000a). Limited excavations of nest chambers have revealed clutches of three eggs.

Adult rock iguanas restrict their activity to rather small territories within the vegetation, using crevices in the coralline rock and burrows in the sand for shelter (Gicca, 1980; Schwartz & Henderson, 1991). Most species of Cyclura exhibit some form of territorial defence, which is often displayed in encounters as the lateral compression of the body and enlargement of the gular pouches (Knapp, 2000b). However, the Exuma Island iguana exhibits an unusual social system for the genus, showing neither a territorial or hierarchical behaviour (Knapp, 2000a). Adults have been observed basking in large aggregations without evidence of aggression towards conspecifics, although occasional assertive and/or challenge displays may occur at times, usually only because of space violation or sex recognition (Knapp, 2000a).

Habitat

Critical habitats of the Exuma Island rock iguana are tropical dry forests, rocky coppice, and sandy strands. *Cyclura cychlura figginsi*, found on the central and southern cays of the Exumas, utilizes a variety of habitats, such as sandy beaches, xeric limestone devoid of vegetation, and vegetated areas with or without sand or rock substrate (Knapp, 2000a). This subspecies also utilizes trees, as it is both a terrestrial and arboreal feeder.

Associated Species - see other conservation target descriptions for details
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

The principal threats to the Exuma Cays rock iguana are predation by exotic species, habitat loss through from residential and commercial developments, and illegal hunting and smuggling.

Populations of *Cyclura cychlura figginsi* appear to be healthy, but the populations on Bitter Guana and White Bay Cays are currently threatened by hunting pressure and tourism development (Shedd Aquarium, 2001). Goats are now present on Gaulin Cay (Knapp, personal communication). Predation by dogs may be contributing considerably to the population decline, and the presence of feral rats is also thought to be negatively affecting the population (Knapp, 2000a). Additionally, interviews with Bahamian yachtsmen confirm that iguanas are hunted as a food source (Knapp, 2000a).

Current conservation programs

All Bahamian rock iguanas are protected under the Wild Animals Protection Act of 1968 (Knapp, 2000a). C.Knapp is continuing field studies to assess the current populations and to better define the geographic distribution of the subspecies (Knapp, 2000a). Blood samples are being collected from each study population to establish genetic profiles from each cay (Knapp, 2000a). As part of a mitigation agreement with an island owner wishing to sell the island, Knapp also recently translocated 16 individuals from Leaf Cay to Pasture Cay in the Exuma Cays Land and Sea Park (C.Knapp, personal communication). The translocated individuals are doing fine, and Leaf Cay has now been turned over to the Bahamas National Trust (S.Buckner, personal communication). Potential threats unique to each cay are being documented in order to provide the Bahamian government with information that will aid in setting conservation policies (Knapp, 2000a). The Bahamas National Trust has erected signs on Gaulin Cay notifying the public of the protected status of the iguanas. The Bahamian government currently does not recognize any non-Bahamian captive breeding programs, although unsanctioned breeding of these iguanas is apparently occurring in the United States (Knapp, 2000a).

Information Gaps and Research Needs

- Determine the status of the population throughout its range;
- Examine the possibility of translocation to other suitable cays;
- Carry out genetic studies on all populations;
- Conduct ecological, behavioural, and natural history studies on each population; and
- Establish a captive breeding program.

Goals

Maintain a population whose minimum size is 1,000 individuals

Justification

Although this is a crude estimate of a viable population, this is a realistic goal, since the current population is estimated to be between 1,000 and 2,000 individuals.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes & Carter, 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 26. Exuma Island rock iguana

5.2.7.6. Acklins rock iguana
(Cyclura rileyi nuchalis)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The Acklins rock iguana is strikingly handsome, resembling the San Salvador iguana, with orange/yellow highlights on a darker grey to brown background (Hayes & Montanucci, 2000). These individuals demonstrate sexual dimorphism, with females averaging only 89% of the male SVL and 69% of male body mass; they also demonstrate head size dimorphism between the sexes, the cause of which is not yet determined (Carter & Hayes, in press).

Distribution

The Acklins iguana occurs naturally only on Fish Cay and North Cay in the Acklins Bight, with the total population estimated to be between 12,500 and 18,800 individuals (Hayes et al., in press). In addition, a small population of five individuals has been introduced to a small (3.3ha) cay of the Exuma Cays Land and Sea Park (ECLSP) (Carter & Hayes, in press).

Status of populations in the wild

The Acklins iguana occurs naturally only on Fish Cay and North Cay in the Acklins Bight, with the total population estimated to be 18,000 or more individuals, which is much higher than original estimates of 400-600 individuals (Hayes et al., in press). Currently, the sex ratio appears to be 1:1, and each age group is adequately represented (Hayes et al., in press). The translocated population in the ECLSP has grown to at least 300 iguanas (Hayes et al., in press).

Ecology and natural history

Little specific information about breeding and nesting of Cyclura cychlura nuchalis is available, as some experts have noted that essentially nothing has been published about the ecology or natural history of the subspecies (Hayes, 2000b). However, much work is currently underway, and should reveal some much needed information soon (S.Buckner, personal communication).

Male *C. rileyi nuchalis* iguanas are highly territorial (Hayes & Montanucci, 2000). Males have been observed in jousting matches involving open-mouthed territorial displays, and they will chase other males out of their defended areas. Scars resulting from bite marks have been observed, and these scars most likely accumulate during these aggressive encounters (Hayes & Montanucci, 2000). Hayes et al. (in press A) have estimated home ranges for gravid and non-gravid females to be 2,047m^2 and 397m^2, respectively.

The mating system appears to be polygynous, (males mating with multiple females), but may even be polygamous (both sexes have multiple partners) (Hayes et al., in press). Because of competition among males for access to females, common strategies seem to mate-guarding and forced copulations (Hayes et al., in press). Nests on North Cay were widely distributed, and females have been observed defending their nests (Hayes et al., in press). Observations of one nest have revealed a clutch size of two to five eggs, with an average value of 3.1 (Hayes et al., in press).

Habitat

The principal habitats used by the Acklins iguana are presumably tropical dry forests, rocky coppice, and sand strands. The specific habitat requirements of this subspecies have only recently been adequately evaluated (S.Buckner, personal communication).

Associated Species- see other conservation target descriptions for details
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

The principal threats to the Acklins rock iguana are predation by exotic species, habitat loss from residential and commercial development and increased sea level, and illegal hunting and smuggling (Hayes et al., in press). *C. rileyi nuchalis* populations are not exposed to feral pests in their habitat, but the introduced ECLSP population is threatened by the introduction of hutia (Geocapromys ingrahami) on an adjacent cay that may be affecting nearby vegetation (Hayes & Montanucci, 2000; S.Buckner, personal communication). Furthermore, with only five founder animals, genetic heterozygosity may be compromised (Hayes & Montanucci, 2000). The potential for illegal poaching of this subspecies remains a threat on all cays where it is found (Hayes & Montanucci, 2000).

Current conservation programs

W. Hayes and R. Carter are currently evaluating the body size and genetic relationships among three populations (Hayes & Montanucci, 2000). They obtained blood samples and measurements from the iguanas and evaluated their status on a 1996 visit to Acklins Bight (Hayes & Montanucci, 2000).

Information Gaps and Research Needs

- Accurately census the three extant populations to determine population size;
- Assess current threats to each population, controlling introduced hutia if they should become a problem;
- Explore the potential for restocking vacant cays in the Acklins Bight with iguanas;
- Conduct genetic studies similar to those being carried out for the San Salvador iguana, paying special attention to the introduced population; and
- Determine reliable estimates of minimum viable population and minimum viable area needed to sustain the species.

Goals

Maintain a population with a minimum size of 18,000 individuals.

Justification

When this sub-species was investigated by D. Blair in 1991, the two remaining populations were deemed to be at healthy levels. Later estimates resulted in a total population of over 18,000 individuals. Thus, although this is a crude estimate of a viable population, the goal is a realistic and reasonable way to assure the persistence of this sub-specie.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes & Carter, 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 27. Acklins rock iguana

5.2.7.7. San Salvador rock iguana
(Cyclura rileyi rileyi)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

Dorsal coloration of San Salvador Rock Iguanas is striking but variable. Dorsum colours of red, orange, yellow, green, or brown are usually punctuated by darker markings and fine vermiculations (Hayes, 2000a). Males generally exhibit more colour and contrast than females, especially at higher temperatures. *C. rileyi rileyi* is the largest subspecies of C. rileyi (Hayes, 2000a), but the subspecies itself is relatively small (Auffenberg, 1976). Recent studies show that many individuals are exceeding the once-established maximum size of 307 mm SVL, and lengths as long as 395 mm SVL are now observed (Hayes, 2000a). These individuals demonstrate sexual dimorphism, with females averaging only 89% of the male SVL and 69% of male body mass; they also demonstrate head size dimorphism between the sexes, the cause of which is not yet determined (Carter & Hayes, in press).

Distribution

Cyclura rileyi rileyi, also known as the Watling's Island ground iguana (Roberts & Roberts, 1976), has been observed on San Salvador Island and on six satellite keys off San Salvador: Green Cay, Man Head Cay, Low Cay, Goulding Cay, Guana Cay and Pigeon Cay (Hayes et al., in press). Sightings are also reported on some southern cays in the Exumas (Schwartz & Henderson, 1991). Sightings on the mainland are rare, and most occur on the eastern side of San Salvador, between Great Lake and Storrs Lake (Hayes, 2000a). Although not very common on San Salvador Island, the subspecies rileyi is abundant on the satellite cays, and moderately abundant in the southern Exumas (Schwartz & Henderson, 1991). The subspecies once occupied Barn, High, and Gaulin Cays, but these populations have been extirpated from these sites in recent decades (Hayes et al., in press).

Status of populations in the wild

The most recent population estimate for the subspecies rileyi indicates that there are between 426 and 639 individuals remaining (Hayes et al., in press). Populations on the isolated cays vary from only 10 individuals to 250 individuals.

Ecology and natural history

Gicca (1980) observed that the subspecies rileyi feeds upon sea grape fruits (*Coccolobo uvifera*). Hartley et al. (2000) collected samples of iguana scat and determined that individuals also feed upon *Ziziphus rignoni*. Recent studies by Hayes et al. (in press A) show that the plants that the Green Cay population feeds preferably on are *Borrichia arborescnes, Rachicallis americana,*and *Opuntia stricta*. Non-plant food items included a purple gallinule, a bridled tern, conspecific hatchlings, unidentified songbirds, land crab, grasshopper, hermit crab, unidentified insect material, and sand and soil, although studies indicate that at least 95% of the diet consists of plant material (Hayes et al., in press).

The reproductive biology of *C. rileyi rileyi* is probably like most other rock iguanas, with courtship and mating occurring in May, followed by nesting and egg-laying during June and July (Hayes, 2000a). The mating system appears to be polygynous, (males mating with multiple females), but may even be polygamous (both sexes have multiple partners) (Hayes et al., in press). Because of competition among males for access to females, common strategies seem to mate-guarding and forced copulations (Hayes et al., in press). Observations of one nest have revealed a clutch size of three to six eggs (Hayes et al., in press). Sandy areas are required for nest construction. In general, Cyclura breeding begins in early spring (when males are most brightly coloured), and females lay their eggs by the middle of June (Auffenberg, 1976). At least 18 of 22 females observed on Green Cay exhibited some degree of nest defence, a strategy that is presumed to mitigate the loss of eggs resulting from the digging of females that prefer to enter a burrow that has already been excavated (Hayes et al., in press).

There is limited information concerning the behaviour of the San Salvador rock iguana. Adult males appear to be territorial throughout the year (Hayes, 2000a). Home ranges were determined to be 439 and $628m^2$ for males and females, respectively (Hayes et al., in press). The maximum distance travelled (373 m) was more than half the length of Green Cay, where the female was observed (Hayes et al., in press).

Habitat

Principal habitats used by the San Salvador iguana are rocky coppice, mangroves, and sandy strands. The habitats occupied by these iguanas are remarkably varied among the main island and nearby cays (Hayes et al., in press). Vegetation on offshore cays is similar in varying degrees to coastal rock, sand strand and sea oat, and coastal coppice plant communities (Hayes, 2000a). San Salvador's vegetation is dominated by *Coccolobia uvifera, Strumphia maritima*, and *Casasia clusiaefolia*, while the vegetation of the four satellite cays known to be inhabited by the San Salvador iguana are dominated by *Coccolobia uvifera* (Hayes & Montanucci, 2000). On some cays, iguanas are numerous in patches of buttonwood mangroves (*Conocarpus erectus*), where they use the foliage to browse (Hayes, 2000a). Presumably, this subspecies requires sandy substrate for nest construction.

Associated Species - see other conservation target descriptions for details

Dry Evergreen Forests

White-crowned pigeon

Beach Strand

Threats

The principal threats to rock iguanas are predation by exotic species and illegal hunting and smuggling. Currently, feral rats pose the biggest threat to the survival of *Cyclura rileyi rileyi* on San Salvador. Feral rats prey upon juveniles and may also affect vegetation, especially on cays with lower plant diversity (Hayes, 2000a). Satellite keys of San Salvador that are not inhabited by feral pests may harbour rock iguana populations that are the last remaining members of the gene pool in the entire world (Gicca, 1980). Additionally, the introduction of a moth, *Cactoblastis cactorum*, to the West Indies has proven to have devastating effects on the subspecies because the moth larvae destroy the prickly-pear cacti, which serve as an important iguana food source (Hayes, 2000a). As with other populations of rock iguanas, the subspecies rileyi is also vulnerable to the negative impacts of human development and feral cats and dogs (Hayes, 2000a). 1999's Hurricane Floyd has also proven to be a threat to these iguanas, as it inflicted substantial damage to the nesting habitat of Green Cay (Hayes et al., in press). Direct human impact may also be a threat, since tourists frequently visit some of the cays inhabited by this subspecies from the nearby ClubMed Resort, as well as students from the Gerace Research Center (Hayes et al., in press). These visitors can potentially trample nests and leave dangerous food-related debris, such as plastic wrap, on the cays (Hayes et al., in press).

Current conservation programs

Presently, W.Hayes and R.Carter are collecting baseline data on all populations of C.rileyi to aid conservation management decisions (Hayes, 2000a). Initial efforts involve population surveys, assessment of threats to survival, and genetic sampling (Hayes 2000a). Genetic analyses are essential to resolve the taxonomic identities of the nominate taxa, to assess the degree of divergence among individual populations, and to evaluate heterozygosity (which may reveal inbreeding depression) (Hayes, 2000a). Further steps include concentrated searches for isolated colonies on the mainland and on the southernmost lakes, as well as reintroductions of iguanas to previously inhabited cays (Hayes, 2000a). At present, no legal breeding programs exist outside of the Bahamas (Hayes, 2000a). The Bahamian government has wisely refused to issue export permits for any rock iguana taxa, but Ardastra Gardens in Nassau currently holds two juveniles and plans to implement an in situ program (Hayes, 2000a). A public relations campaign is planned to heighten awareness and appreciation among island residents for their endemic iguana (Hayes, 2000a).

Information gaps and Research need

- Continue to sample and survey individual populations on an annual or biannual basis;
- Eradicate rats on infested cays;
- Monitor the impact of the Cactoblastis moths and rats on vegetation; and
- Determine reliable estimates of minimum viable population and minimum viable area needed to sustain the species conditions.

Goals

Maintain a total population with a minimum size of 600 individuals.

Justification

This subspecies includes populations on isolated cays that number as few as 10 individuals to as many as 250. In all cases, the populations are small enough that even a seemingly minor threat can incur irreversible damage. Although this is a crude estimate of a viable population, it is estimated that the total population is most likely less than 1,000, and recent censuses suggest that up to 639 individuals remain, so this goal is realistic. Maintaining the population above 600 individuals may help this sub-species tolerate the current threats as well as prevent genetic complications and inbreeding depression. Hayes et al. (in press A) have noted that the lack of significant gene flow between cays may be a significant threat to this subspecies.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes and Carter 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 28. San Salvador rock iguana

5.2.7.8. White Cay rock iguana
(Cyclura rileyi cristata)

Description

Phylum Chordata
Class Reptilia
Order Squamata
Suborder Sauria
Family Iguanidae
Subfamily
Iguninae

The dorsum of adults is usually grey with brown to orange-brown vermiculations; the dorsal crest scales, forelimbs, and portions of the head and face are typically highlighted in orange (Hayes, 2000b). The subspecies cristata is a small iguana, reaching a maximum size of 280 mm SVL (Hayes, 2000b). These individuals demonstrate sexual dimorphism, with females averaging only 89% of the male SVL and 69% of male body mass; they also demonstrate head size dimorphism between the sexes, the cause of which is not yet determined (Carter & Hayes, in press).

Genetically and morphometrically, *C.r.cristata* is the most distinct taxon among the three designated subspecies of C. rileyi (Carey et al., 2001).

Distribution

The subspecies cristata inhabits only White (Sandy) Cay in the Southern Bahamas (Hayes, 2000b).

Status of populations in the wild

The subspecies cristata inhabits only White (Sandy) Cay (Hayes, 2000b), where it has an estimated population of less than 200 individuals (Hayes et al., in press). Sampling efforts indicate that the sex ratio is highly skewed towards males and suggest that less than ten adult females remain (Hayes et al., in press).

Ecology and natural history

C. rileyi cristata has been largely ignored by scientists, and, as such, little is known of the dietary habits of the subspecies. Specific information about breeding and nesting of the subspecies cristata is not available, as some experts have noted that essentially nothing has been published about the ecology or natural history (Hayes, 2000b).

This subspecies appears to utilize large home ranges, with an estimated value of 2656m^2 (Hayes et al., in press).

Habitat

The principal habitats of the White Cay rock iguana are rocky coppice and sandy strands. This subspecies utilizes coastal rock habitat and areas dominated by Strumpfia maritima and sea grape (*Coccoloba uvifera*) interspersed among rock and sand (Hayes, 2000b). Also present in notable densities are Australian pine (*Casuarina litorea*) and seven-year apple (*Casasia clausifolia*) (Hayes, 2000b). Population densities are greatest along the periphery of White Cay, where rocky crevices are most common (Hayes, 2000b).

Associated Species - see other conservation target descriptions for details
Dry Evergreen Forests
White-crowned pigeon
Beach Strand

Threats

The principal threats to the White Cay rock iguana are predation by exotic species and illegal hunting and smuggling.

The *Cyclura cychlura cristata* population that inhabits only Sandy Cay was particularly vulnerable to feral rats, but the feral pests have since been removed from the cay (Hayes, 2000b). Predation by raccoons, which were removed in 1997, also had a negative impact on the survival of this endangered subspecies, especially because these predators may have selectively targeted female iguanas (Carey et al., 2001). Illicit smuggling continues to constitute a significant threat to the population, as at least eight individuals of this subspecies were exhibited in showrooms of several Florida reptile wholesalers in 1993 (Hayes, 2000b).

Current conservation programs

Black rat eradication on White Cay has been facilitated by a grant from the Chicago Zoological Society (Hayes, 2000b), as well as Flora and Fauna International, the Department of Agriculture, and the Department of Environmental Health (S.Buckner, personal communication. Two cays that appear promising as potential sites for establishment of a second wild population of the White Cay iguana have been identified (Hayes, 2000b). W. Hayes and R. Carter visited White Cay in 1996 to obtain blood samples and other measurements from the iguanas and to evaluate their status (Hayes, 2000b).

Information Gaps and Research Needs

- Maintain a program of rat control.
- Assess the current status of the population, and consider candidate cays for establishing a secondary population. Considering a distant location as a safeguard against extinction from weather has been suggested;
- Conduct annual or biannual censuses of the population; and
- Determine reliable estimates of minimum viable population and minimum viable area needed to sustain the species.

Goals

Keep the wild population at levels above 150 individuals.

Justification

This sub-species needs to be maintained at optimal levels since it inhabits only White Cay. Although this is a crude estimate of a viable population, a 1997 survey estimated that the maximum population size reached 200 individuals, making this goal a realistic and plausible one. Such a population may be large enough to tolerate the current threats as well as prevent genetic complications and inbreeding depression.

Because the information regarding current population status is limited, population viability can not be fully understood; repeated surveys that elucidate information on growth, sex rations, reproduction, age of sexual maturation, and survivorship will help make population viability analysis more precise (Hayes and Carter 2000). Developing long-term goals and conservation priorities will require more in-depth studies and census reassessments.

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Figure 29. White Cay rock iguana

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5.2.8. Nassau Grouper *(Epinephelus striatus)*

Description

Phylum Chordata
Class Osteichthyes
Family Serranidae
Subfamily Epinephelinae

The Nassau grouper is a moderate-sized species with large eyes, small scales, and a robust body (Smith, 1971). The nostrils are sub equal, the posterior slightly enlarged, and the vertical fins are rounded. The Nassau grouper is distinguished from other species by the third spine of the dorsal fin, which is longer than the second is. The pelvic fins are shorter than the pectoral fins and are inserted below or behind the ventral end of the pectoral fin base. The inter-radial membranes are deeply notched between the spines and the third dorsal spine is longer than the second is. A dark saddle is present on the caudal peduncle and a single or double row of small black spots is present below and behind the eye. The body has five dark vertical bars. The Nassau grouper is most closely related to *Epinephelus guttatus* and *E. morio* (Smith, 1971). The species name striatus means provided with stripes. Individuals can attain a maximum length of 1.2

m TL and 20 kg, but most fishes caught in commercial fisheries are between 2 kg and 10 kg in weight.

Distribution

The Nassau grouper is primarily an insular species and was historically very common in the West Indies, Bahamas, Gulf of Mexico, and the Caribbean coast of South America (Jory & Iversen, 1989; Carter et al., 1990). Nassau groupers occur in a broad area between the 23° C isotherm that stretches from Bermuda and Florida, throughout the Yucatan Peninsula to Venezuela (Heemstra & Randall, 1993). The Nassau grouper also occurs in southern Florida sympatrically with the red grouper (Epinephelus morio), but their local distribution is essentially disjunct. This species is not known from the Gulf of Mexico, except at the Campeche Bank off the Yucatan coast, and the Dry Tortugas and Florida Keys (Beebe &Tee-van, 1933; Randall, 1965; Heemstra & Randall, 1993). Distribution records north of the Carolinas on the south-eastern U.S. coast are probably a result of larval transport (Jory & Iversen, 1989). Nassau grouper appears to be absent from the Gulf of Mexico, where it is replaced by the red grouper, a species that inhabits broad continental shelf areas. Distribution records for the Bahamian Archipelago include: Cay Sal Bank (Sadovy & Ecklund, 1999), Grand Bahama (Alevizon et al., 1985), New Providence (Sadovy & Ecklund, 1999), Andros (Sadovy & Ecklund, 1999), the Berry Islands (Sadovy & Ecklund, 1999), Eleuthera (Sadovy & Ecklund, 1999), Cat Cay (Smith, 1972), the Exuma Cays (Grover, 1993, 1994; Eggleston, 1995; Sluka et al., 1996b; Eggleston et al., 1997), Long Island (Sadovy & Colin, 1995), Acklins Island (Sadovy & Ecklund, 1999), and the Turks and Caicos (Spotte et al., 1992).

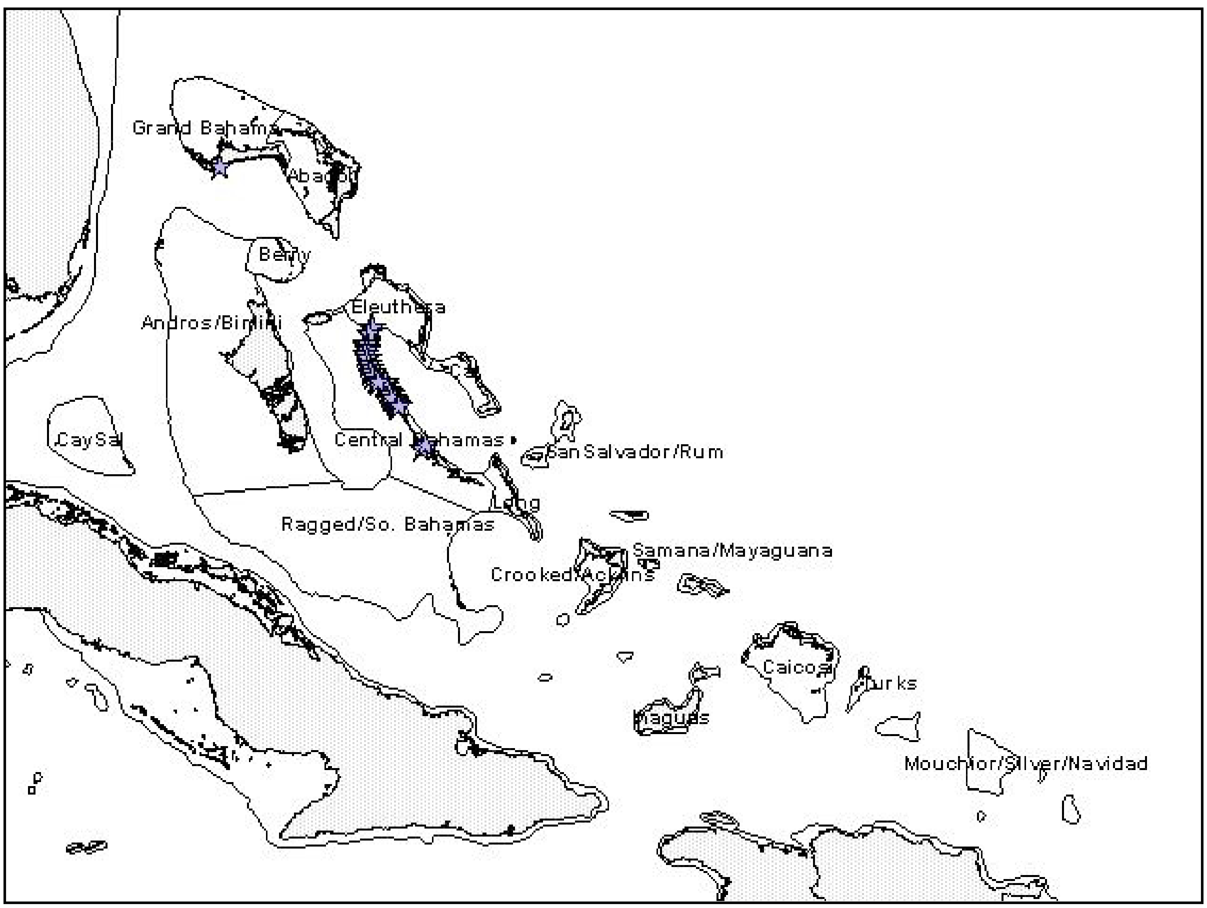

Figure 30. Map depicting locations of high-density Nassau grouper sites (indicated by purple stars) throughout the Bahamas

Status of populations in the wild

Declines in abundance, size, fishery landings, and spawning aggregations since the 1950s are apparent for the Nassau grouper throughout its range, particularly in intensively fished areas of the insular Caribbean (Sadovy, 1990). At least one-fifth of documented spawning aggregations have apparently disappeared over the past two decades, probably the direct result of fishing. Intense fishing of spawning aggregations in the U.S. Virgin Islands prior to 1980 led to commercial extinction, including the total loss of spawning aggregations south of St. Thomas and on Lang Bank northeast of St. Croix (Olsen & LaPlace, 1978; Beets & Friedlander, 1992). A precipitous decline occurred in commercial landings in Bermuda from over 33 tons in 1975 to < 2 tons in 1981, with no evidence of subsequent recovery as of the mid-1990s. The decline is due to the over fishing of spawning aggregations with fish pots (Luckhurst, 1996). Currently, about 60 to 80 spawning aggregations are known or suspected in the wider Caribbean, of which many are located in the Bahamian Archipelago (Sadovy & Ecklund, 1999). Spawning aggregation sites include Andros, the Berry Islands, Bimini, New Providence, Ragged Island, Long Island, Cat Island, Acklins, Eleuthera, Exuma Cays, and Cay Sal Bank. Of these, declines in aggregation size and landings have been noted for Andros and Long Island sites.

Nassau grouper were historically common in Bermuda, the Florida Keys, and the West Indies and were considered a common food fish (Henshall, 1891; Randall, 1965; Starck, 1968; Bohnsack, 1990). Current population levels are low and the species is now rare and considered commercially extinct in the U.S. Virgin Islands, Puerto Rico, Jamaica, and Bermuda (Beebe & Tee-van, 1933; Olsen & LaPlace, 1978; Thompson & Munro, 1983; Bortone et al., 1986; Beets & Friedlander, 1992). This species is present, but not common in the Netherlands Antilles (Nagelkerken, 1981a,b) and only observed in no-fishing zones (Polunin & Roberts, 1993) and very infrequently in the Lesser Antilles (Gobert, 1990). Historically, Nassau grouper was one of the most common groupers east of the Gulf Stream (Smith, 1971). Nassau groupers are less abundant in the Florida Keys than the central Bahamas, potentially indicative of greater fishing pressure (Sluka et al., 1994; Sluka & Sullivan, 1996b, 1998). Prior to 1980, Nassau grouper was common in the U.S. South Atlantic, including the Florida Keys (Starck, 1968), but are now considered extremely rare because of fishing (Huntsman et al., 1990). This species is considered moderately common in shallow-water coral reef environments in the Turks and Caicos Islands (Spotte et al., 1992) and was historically abundant on shallow reefs near Grand Bahama Island (Alevizon et al., 1985). In Belize, from 1972-84, this and other grouper species constituted the second most commonly caught and most valuable marine fishes. Local Belizean fishermen landed in excess of 100,000 lbs. annually in the 1950s, but less than 30,000 lbs. by 1986. The Nassau grouper catch in Belize decreased in size since the 1920s. Males comprise 25% of the population, but comprise 37% of the population elsewhere (Carter et al., 1993). Off the Bay Islands, Honduras, a spawning aggregation declined from intensive fishing (Fine, 1990). Aggregation size and spawning period both decreased off the southern coast of Quintana Roo, Mexico during the last two decades (Aguilar-Perera, 1990; Aguilar-Perera & Aguilar-Davila, 1996).

Ecology and natural history

Nassau groupers are important top-level, resident predators in coral reef environments. The species is characterized as an unspecialised and opportunistic carnivore, feeding on a variety of crustaceans and fishes (Scaridae, Labridae, Pomacentridae, Holocentridae, Lutjanidae, and Haemulidae). Crustaceans dominate the diet of smaller individuals, while fish are more common in stomach contents of larger individuals (Randall, 1965). Feeding is generally most active at dawn and dusk (Randall, 1965). The main diet of juvenile Nassau grouper (21.0-27.1 mm) is dinoflagellates by number and fish larvae by volume (Greenwood, 1991; Grover, 1993, 1994). Large juveniles feed mainly on crabs and fishes (Heck & Weinstein, 1989).

The Nassau grouper life history is characterized by slow growth, large adult size, delayed reproduction, protogyny, low natural mortality, and site-specific aggregated spawning (Sullivan & de Garine, 1990; Sadovy, 1990; Colin, 1992; Sadovy & Colin, 1995; Domeier & Colin, 1997). Nassau grouper can reach at least 100 cm total length and weigh up to 25 kg (Jory & Iversen, 1989, Heemstra & Randall, 1993). Individuals may live for 20 years, attaining sexual maturity at 50 cm TL (1.87 kg) or 5 years of age (Sadovy, 1990). Females change to males at a size of 30-80 cm TL (Jory & Iversen, 1989). Growth rates of individuals measuring 175-250 mm, 251-325 mm, and 326-450 mm TL are 4.55 mm/month, 3.5 mm/month, and 1.92 mm/month, respectively (Randall, 1961). Because fecundity increases exponentially as a function of weight (Olsen & LaPlace, 1978), fishing of spawning aggregations can lead to increases in the female to male ratio, potentially leading to reproductive failure (Colin et al., 1987; Carter et al., 1990). In addition, removal of larger individuals could lead to a lack of experienced adults to lead first time spawners to spawning areas (Stevenson et al., in press). Little is known about possible population subdivision within the species range. Micro-satellite markers using a DNA cloning procedure revealed no conclusive evidence for stock separation among samples taken from Belize, Bahamas, Florida, and Central America (Stevenson et al., in press).

Nassau groupers tend to be site-specific, but have larger home ranges than smaller species (Bardach, 1958; Beaumariage & Bullock, 1976; Sullivan & de Garine, 1990; Beets & Hixon, 1994; Sluka & Sullivan, 1996a). Individuals may move up to 50 km to spawn during the winter months (Colin et al., 1987). Tagged specimens have been documented to travel 110 km to an aggregation site (Carter, 1988; Colin, 1992), but typically move within 15 km (Randall, 1961).

Nassau groupers produce planktonic eggs that are fertilized externally. Predators and currents can dramatically affect larval survival. Eggs are released while fish are in spawning aggregations that form at highly specific sites and times and spawning has not been recorded outside of spawning aggregations (Sadovy & Ecklund, 1999). Individuals recruit from deep oceanic habitats to shallow bank habitats in the Bahamas at 20.2-27.8 mm SL, typically through tidal channels in discrete pulses during early January (Grover, 1993, 1994; Shenker et al., 1993). Early-stage juveniles probably suffer high post-settlement predation (Beets & Hixon, 1994). Water temperature within an ecological range has a pronounced and direct effect on juvenile feeding and growth. The timing of spawning in relation to seasonally changing temperature may be important in determining juvenile growth rates, vulnerability to predation, and hence, year-class strength (Ellis et al., 1997).

Nassau grouper spawning aggregations that form in specific locations throughout the western Atlantic involve the aggregation of hundreds to thousands of individuals. Aggregation sites are generally consistent from year to year and are characteristically found in the vicinity of the shelf break (Burnett-Herkes, 1975; Colin et al., 1987; Colin, 1992). There are at least 60 to 80 past and present spawning aggregations that have been identified in the tropical western Atlantic (Sadovy & Ecklund, 1999). Extant spawning aggregations outside of the Bahamian Archipelago are known from the following locations: Cuba (one on the north-western coast, 3 sites on the southern coast), Mexico (7 known sites off the southern coast of Quintana Roo, including two on the east-southeast coast of Chinchorro Bank), Honduras (1 site of the Bay Islands), Belize (6 sites), Cayman Islands (5 sites total off Grand Cayman, Little Cayman, and Cayman Brac), and British Virgin Islands (1 site along the north-eastern insular shelf) (Smith, 1972; Tucker, 1992; Aguilar-Perera, 1990; Carter et al., 1990; Fine, 1990; Beets & Friedlander, 1992; Colin, 1992; Tucker et al., 1993; Aguilar-Perera & Aguilar-Davila, 1996). At least five spawning aggregations have disappeared because of over fishing from the following areas: Bermuda (2 aggregations), northeastern Puerto Rico (1 site), St. Thomas (1 site), and St. Croix (at least 1 site) (Burnett-Herkes, 1975; Olsen & LaPlace, 1978; Beets & Friedlander, 1992). Spawning aggregation sites in the Bahamas include Andros, the Berry Islands, Bimini, New Providence, Ragged Island, Long Island, Cat Island, Acklins, Eleuthera, Exuma Cays, and Cay Sal Bank (Smith, 1972; Bannerot, 1984; Sadovy and Colin, 1995; Sadovy & Ecklund, 1999). A spawning aggregation was noted off the southern Berry Islands during January full moon (Bannerot, 1984).

Figure 31. Nassau Grouper

Habitat

Nassau groupers were abundant, at least historically, in shallow waters of the tropical western Atlantic, in and about coral reefs, sea grass beds, cuts, rocks, pilings, and seawalls, usually in less than 30 m of water (Voss et al., 1969). Individuals typically occur near high-relief coral reefs and rocky bottoms from the shoreline to 90 m depth (Jory & Iversen, 1989). Larger fish are more common at depths greater than 50 m, while juveniles can be common in sea grass beds (Heemstra & Randall, 1993). Nassau groupers were moderately common on patch reefs and high-relief spur and groove reefs in the Florida Keys (Sluka & Sullivan, 1996b), particularly in those areas protected from spear fishing (Sluka &

Sullivan, 1998). Juveniles can be prevalent on shallow-water patch reefs and appear to migrate to deeper, offshore reefs with size (Carr & Hixon, 1995; Sluka et al., 1996b; Sluka & Sullivan, 1998). In the Exuma Cays, Nassau groupers were abundant in shallow-water (1-20 m) patch reefs, low-relief hard-bottom, channel reefs, and high-relief fringing reefs (Sluka et al., 1996a). In other areas, Nassau groupers occur on patch reefs and fore reef zones from 4-12 m depth in Puerto Rico and the Bahamas, especially in areas with high relief (Alevizon et al., 1985; Turingan & Acosta, 1990; Carr & Hixon, 1995). Nassau groupers also occur on outer continental shelf bank habitats at 45-50 m depth in the north-western Gulf of Mexico (Rezak et al., 1985) and large adults were historically common in the U.S. South Atlantic at 50 m to 80 m depth (Huntsman et al., 1990).

Important nursery habitats for Nassau groupers are shallow-water sites with coral clumps covered with macro algae. Post-settlement fishes reside exclusively within algal-covered coral clumps; early juveniles (6-15 cm TL) reside outside of and adjacent to algal-covered clumps; and larger juveniles exhibit an ontogenetic habitat shift from coral-coral clumps to patch reef habitats at a size of 12 cm to 15 cm TL during the late summer and early fall in the Bahamas (Eggleston, 1995). Spawning aggregations during the winter months (November-February) in the tropical western Atlantic occur in particular habitats. Off the southern coast of Quintana Roo, Mexico, spawning adults occur at 6 m to 35 m depth on fore reef habitats in mainland and offshore bank areas consisting of sand interspersed with hard-bottom or rocky outcrops (Aguilar-Perera, 1990). Spawning aggregations also occur on the edges of banks (29-38 m) over a low-relief hard-bottom (Smith, 1972) and near promontories or ends of island shelves (Tucker, 1992; Tucker et al., 1993). Many aggregation sites have turbulent currents and upwards of 3 m to 5 m of vertical relief at 25 m to 30 m depth (Colin et al., 1987; Colin, 1992).

Threats

Nassau groupers are threatened principally by fishing throughout the tropical western Atlantic, particularly during the formation of winter spawning aggregations (Sadovy, 1990). Evidence of over fishing includes declines in abundance and size, decreases in number and weight of catch, declines in catch per unit, and loss of spawning aggregations (Heemstra & Randall, 1993). Fishing of spawning aggregations has severely threatened the viability of the species in particular locations (Olsen & LaPlace, 1978; Aguilar-Perera, 1990; Fine, 1990; Luckhurst, 1996). The introduction of spear guns in the 1960s led to sharp declines in aggregations size and number and some aggregations are still fished using hook-and-line, spear guns, and gill nets (Aguilar-Perera & Aguilar-Davila, 1996). Nassau grouper catches in most areas often yield only immature (< 40 cm TL) individuals. In Belize, individuals are mainly fished with hand lines, spear guns, and fish pots throughout the year; however, most fishing occurs one to two weeks during the formation of spawning aggregations (Carter, 1988; Carter et al., 1990). Despite an 11-year moratorium on fishing in the Florida Keys, Nassau groupers are considered over fished based upon spawning potential ratio below 30% (Ault et al., 1998). Nassau grouper was considered a candidate coastal species for the U.S. Endangered Species List in 1992 and is being considered for protected species status in Bermuda. Over fishing for at least 20 years has raised concerns that the species could become locally or commercially extinct range-wide (Sadovy & Ecklund, 1999).

Critical conservation initiatives

There are few, if any, spawning aggregations protected in the tropical western Atlantic (Sadovy, 1990). Protected from all forms of the fishing the Exuma Cays Land and Sea Park, central Bahamas, since 1986. Populations are more abundant in shallow-water reef habitats than in similar environments of the Florida Keys (Sluka et al., 1994) and significantly greater density, size, biomass, and reproductive output compared to adjacent fished areas (Sluka et al., 1996b, 1997). Minimum size regulations are in effect in the Bahamas.

Information gaps and research needs

More research into the species population dynamics and reproductive biology is needed. A greater understanding of reproductive biology would greatly facilitate stock management. There is a need to know whether most annual reproduction occurs at spawning aggregations and the geographic location and duration of significant aggregations. There is also a need to know how aggregation fishing is likely to affect courtship or spawning behaviour. Relatively little is known concerning the minimum size of sexual maturation relative to the size of entry into the fishery. It is also not known to what extent individuals recruit locally or from larvae from up-current and/or off-island locations. Little is known concerning the characteristics neither of critical juvenile habitat nor of the principal settlement periods (Sadovy, 1990).

More detailed inventories on the species distribution and abundance are needed. There is a paucity of data region-wide for tracking stock history and assessing stock status. Aggregation catches and annual landings (recreational and commercial), including catch per unit effort, sex ratios, and sizes, should be collected. There is a need to standardize and improve data collection protocols and also to identify major data gaps. Information on the condition of stocks is patchy and largely incomplete (Sadovy, 1990). Long-term landings and catch per unit effort are available from only a few western Atlantic locations.

Conservation goals

Target densities for particular habitat types are the best available information for establishing population goals of the Nassau grouper. For the Bahamian Archipelago, target density ranges are 100-115 individuals/ha for patch reefs, 40-50 individuals/ha for channel reefs, 30-40 individuals/ha for fringing reefs, and 20-30 individuals/ha for windward, low-relief hard-bottom. These estimates are based upon surveys during 1995 in the Exuma Cays, including surveys in the Exuma Cays Land and Sea Park, a marine reserve closed to fishing since 1958 (Sluka et al., 1996b). Sex ratios should not differ from unity (1:1 male to female) in relatively undisturbed populations (Sadovy & Ecklund, 1999). Spawning stock biomass should be maintained above a minimum of 30% - that is, stocks should be maintained at 30% of their virgin spawning stock biomass.

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5.2.9. Spiny lobster (*Panulirus argus*)

Description

Phylum Arthropoda
Class Crustacea
Order Decapoda
Family Palinuridae

Approximately 35 species of lobsters (Crustacea, Decapoda) in six families occur worldwide, commonly called rock lobster, Caribbean spiny lobster, West Indian spiny lobster, and Florida spiny lobster (Moe, 1991). The Caribbean spiny lobster (*Panulirus argus*) is a ubiquitous inhabitant of subtropical and tropical Caribbean environments, highly valued as a source of food, revenue, and recreational value (Lipcius & Cobb, 1993). The spiny lobster is one of the largest marine invertebrate species inhabiting shallow-water environments, capable of attaining a size greater than one meter in total length and an age of 15 to 20 years (Moe, 1991). Spiny lobsters are critical links in the marine food web and are a key predator of various benthic invertebrates, and conversely, important prey of large predators. Spiny lobsters prey upon a diverse assemblage of epifaunal and infaunal species such as molluscs, smaller crustaceans, echinoderms, and polyachaete worms, in addition to algae and detritus. Adults may travel up to 300 m during the night to feed.

Distribution

The Caribbean spiny lobster (*Panulirus argus*), of the Family Palinuridae, is one of three species in the genus that occurs in the wider Caribbean. The species is distributed from Brazil, the Caribbean Sea, Bermuda, and south Florida to North Carolina, including the Gulf of Mexico (Moore, 1962; Lyons, 1981).

Status of populations in the wild

Spiny lobsters are or once were ubiquitous inhabitants of wider Caribbean shallow-water environments, and in many locations are still highly valued as a source of food and revenue (Lipcius & Cobb, 1993). In the wider Caribbean, including the Bahamian Archipelago, spiny lobsters support some of the largest commercial fisheries, while also sustaining smaller scale artisan fisheries for local consumption and sale on remote islands, as well as locally important sport fisheries (Davis, 1977; Davis & Dodrill, 1989). Lobster fishing has been important in the wider Caribbean since at least the 1800s (Davis, 1981b) and is now the most economically valuable fishery in the Bahamian Archipelago (Richards & Bohnsack, 1990; Cruz et al., 1991; Puga et al., 1991). In many countries, the spiny lobster fishery is fully exploited or over-fished, with evidence of changes in fishing effort, catch per unit effort, and economic return (Haughton & King, 1989; Puga et al., 1991). Some of the major obstacles to lobster management include too much fishing effort and hence low economic return, illegal harvest, mortality and increased injury, ineffective regulations such as inappropriate minimum size, and inadequate fishery statistics (Beardsley et al., 1975; Davis, 1980; Davis & Dodrill, 1980; Cruz et al., 1995). Because the absolute duration of the larval phase is not known, it is difficult to identify management or stock units (Menzies & Kerrigan, 1978, 1980; Farmer et al., 1986). Stock-recruitment relationships are poorly understood and cannot be managed, optimal larval production is not guaranteed, and uncertainties regarding stock origin are major management obstacles (Davis, 1980; Menzies & Kerrigan, 1980; Lyons, 1986). Intense spiny lobster fishing is known to have several direct and indirect effects on populations, including reduced abundance (Davis, 1977), decreased size (Haughton & King, 1989), increased incidence of injury and hence lower growth (Hunt & Lyons, 1986), lower fecundity or egg production (Gregory et al., 1982), and a shift in age at first reproduction (Gregory et al., 1982).

Figure 32. Spiny lobster

Ecology and natural history

Due to its economic importance (Simmons, 1980; Cruz et al., 1991; García et al., 1991), the life history of the Caribbean spiny lobster, and hence its habitat usage, is relatively well known (Warner et al., 1977; Moe, 1991). The major stages or phases of the spiny lobster life cycle are as follows: adult (80 - >200 mm CL, > 10 years), egg, phyllosoma (0.5-12 mm CL, 9-12 months?), puerulus postlarva (5-7 mm CL, 2-6 weeks?), and juvenile, further separated into early benthic or algal phase (5-15 mm CL, 2-5 months) and older or post-algal phase juvenile (15-45 mm, 6-18 months) (Davis, 1978; Butler & Herrnkind, 1997; Butler et al., 1997). Adults frequently aggregate during the day in crevices of coral and rocky reefs, emerging at night to forage in nearby habitats. Molting primarily occurs between September and March, or during the non-reproductive period. For up to four weeks prior to spawning, females carry fertilized eggs and are at this time referred to as being 'berried' (Simmons, 1980). Mating behaviour is initiated by males searching for receptive females (Lipcius et al., 1983). Females migrate to areas populated with males for mating, and then move to deeper reef areas to incubate and release larvae. Reproduction in the wider Caribbean can occur year-round, while in more northerly locations such as the Florida Keys, reproduction occurs almost exclusively during the summer (April to September) (Lyons, 1981; Gregory et al., 1982). Peak reproduction in the Bahamas is usually during the spring, typical of other northern subtropical spiny lobster populations, as evidenced by external, fertilized eggs (Herrnkind & Lipcius 1986).

Females move to deep bank fringe areas to mate, then carry and release their eggs (Kanciruk & Herrnkind, 1976). Fertilization is external, in which the male deposits a spermatophoric mass on female's sternum, which is then rasped to release sperm for fertilization of eggs from the female. Adult lobsters spawn offshore in deeper (> 20 m) reef habitats, presumably so predation pressure is reduced and larvae are dispersed away from the adult habitat (Lyons, 1981; Herrnkind & Lipcius, 1986). At Bimini, northwestern Bahamas, lobster reproduction was exclusively in deep reef areas, with no evidence of reproduction on the bank (Kanciruk & Herrnkind, 1976). Larger females are more fecund than smaller females, but typically comprise a smaller percentage of the population. Egg masses are generally spawned and hatched in the spring and summer, and the early phyllosoma are transported offshore by wind-driven surface currents into oceanic habitats.

Spiny lobsters are the only decapod crustaceans possessing phyllosoma (leaf-like and transparent) larvae in the life history. Phyllosoma are adapted for passive horizontal transport, and the larvae usually consist of seven to 13 stages. Spiny lobster larvae develop in the water column and may be carried hundreds to thousands of kilometres by ocean currents (Lewis, 1951; Sims & Ingle, 1967; Lyons, 1981). Lobster larvae are transparent and are referred to as phyllosomes (Moe, 1991). Larvae spend at least 6 months (probably 9-12) in the plankton and go through a series of 10 to 12 developmental stages (Cruz et al., 1995). At the termination of the larval phase, lobster go through a non-feeding, puerulus stage (postlarvae) and take on the shape of the adult lobster as they move onshore to settle to the benthos (Marx & Herrnkind, 1985).

The puerulus stage of the lobster links the plankton and benthic phases in the life cycle (Lyons, 1981; Marx, 1986). Spiny lobster settle from the plankton to benthic habitats at 6 mm CL. Settlement can occur year-round, although greater recruitment often occurs during the early to late summer (Cruz et al., 1995). Settlement of lobster pueruli from the plankton is typically very patchy and locally unpredictable and postlarval supply along cannot reliably predict local settlement density (Butler et al., 1997). Lobster settlement exhibits significant inter-annual variation, possibly related to wind direction and speed (Acosta et al., 1997) and oceanographic phenomena such as gyres (Ward, 1986). Postlarval influxes typically peak monthly around the new moon, although pulses may occur at other times (Marx, 1986). There is usually distinct lunar periodicity in settlement, which generally occurs during the new moon and first quarter (Heatwole et al., 1987; Acosta et al., 1997). In the Florida Keys, the annual peak in postlarval abundance usually occurs during March (Acosta et al., 1997). Lobster pueruli settle in architecturally complex habitats such as algal-covered hard-bottom (Marx & Herrnkind, 1985) and can occur both inshore and offshore (Heatwole et al., 1987). Upon arrival into near shore habitats, lobster metamorphose in benthic habitats covered with macro algae and go through a series of molts in nursery areas for up to 1.5 to 2 years (Lipcius & Herrnkind, 1982; Lyons, 1986). In nursery habitats, small lobsters (6-17 mm CL) inhabit clumps of algae, particularly the red algae *Laurencia intricata* and *L. poitei*, and feed upon several invertebrate groups (gastropods, isopods, amphipods, polychaetes) (Marx & Herrnkind, 1985; Herrera et al., 1991). Juveniles also use sponges or urchins for shelter (Khandker, 1964; Davis, 1971). Shelter is generally a limiting resource for juveniles in sea grass beds (Lipcius & Cobb, 1993). In south Florida, the most productive sites in the nursery area of Florida Bay have abundant red macro algae as a settlement substrate and numerous sponges as a benthic juvenile shelter (Herrnkind & Butler, 1994). There is very high post-settlement mortality (upwards of 97%) the year following settlement from the plankton (Herrnkind & Butler, 1994), mainly due to predation on small juveniles (Butler & Herrnkind, 1997). Predators of juvenile lobster include octopus, crabs, snappers, and grunts (Moe, 1991; Eggleston et al., 1997). Lobster pueruli remain for a few months in vegetation, where they are sheltered from predators and have abundant prey (Butler et al., 1997). The preference for settlement habitats is mediated by their structural complexity and not by food availability, although environmental conditions such as temperature extremes and salinity fluctuations can affect postlarval survival (Field & Butler, 1994).

Two ecologically distinct phases are recognized for juvenile spiny lobsters: an early benthic phase (recently settled) and a later benthic phase. Early benthic phase juveniles (< 15 mm CL) are found in habitats similar to the recently settled puerulus. At the later benthic phase (15-20 mm CL), juvenile lobsters move out of algal clumps to small crevices in algal-covered rock rubble, then eventually become gregarious with larger juveniles in dens formed by rocky outcrops, coral heads, sponges, limestone solution holes, and undercut banks of sea grass beds. Juveniles prefer dens with shaded cover and multiple den openings, as well as proximity to food and an appropriate scaling between shelter size and body size. Shelter is a limiting resource in sea grass beds for juveniles, not food availability, as evidenced by experiments using artificial shelters at Lee Stocking Island (Eggleston & Lipcius, 1990; Eggleston et al., 1990). When lobsters are abundant, smaller spiny lobsters prefer to reside in large shelters with large conspecifics, rather than solitarily in small shelters scaled to their body size (Eggleston & Lipcius, 1992). If lobster abundance is low, small lobsters prefer to reside in small shelters that are scaled to body size. As juveniles become larger, they depart to reef areas for breeding.

During the juvenile and adult stages, spiny lobsters may make random movements among habitats, as well as long-distance migrations (Davis & Dodrill, 1980; Lyons et al., 1981; Gregory & Labisky, 1986). In the Bahamian Archipelago, especially in the western Bahamas, juvenile and adult spiny lobsters may make single file migrations from shallower bank to deeper fringe habitats. The migrations are annual events that occur in the fall after strong north-eastern storms and are known to occur near Bimini, Abaco, Grand Bahama Island, Andros Island, and Eleuthera (Herrnkind & Cummings, 1964; Kanciruk & Herrnkind, 1978). Migrations consist of single-file chains or queues of dozens to thousands of lobsters moving from shallow, sand bottom to deeper water, often to > 30 m depth. Both female and male lobsters partake in the migrations, but females are not egg bearing (Herrnkind & Cummings, 1964; Herrnkind, 1969). The direction of migration appears to be characteristic for a given population. For example, migrations observed in Bimini move southwest from bank to deeper fringe habitats in the western Bahamas (Herrnkind, 1969), and the individual lobsters originate from shallow areas east of Bimini (Kanciruk & Herrnkind, 1978). The possible reasons for this behaviour include attainment of better feeding grounds, attainment of maximum shelter for molting, local dispersal, and/or reduction of population pressure (Herrnkind, 1969). Autumnal storms are correlated with the mass migrations, and the triggering mechanism may be a storm-induced decline in water temperature (Kanciruk & Herrnkind, 1978).

Habitat

The spiny lobster is complex and requires three distinct habitats: coral reef and offshore hard-bottom, open ocean, and shallow vegetated coastal areas (Butler & Herrnkind, 1997). A very difficult management objective for the spiny lobster is to ensure that juvenile nursery areas and adult or reproductive habitats are not adversely impacted by human activities (Davis, 1981a). Juvenile and adult spiny lobsters used a diversity of habitats in the Bahamian archipelago: patchy sea grass (juveniles), dense sea grass (juveniles), bank patch reefs (juveniles/adults), near shore patch reefs (juveniles/adults), near shore hard-bottom (juveniles), channel hard-bottom (adults), channel reefs (adults), fringing reefs (adults), barrier reefs (adults), platform margin hard-bottom (adults), and deep reef resources (adults).

Spiny lobsters undergo ontogenetic shifts in habitat before reaching adulthood, moving from near shore nursery habitats to deeper coral reef and hard-bottom habitats where reproduction occurs (Lipcius & Cobb, 1993). In general, the life history of the spiny lobster is the ultimate manifestation of multiple habitat use by a demersal organism in the Bahamian Archipelago, encompassing open-ocean, near shore, and offshore benthic habitats. Coral reefs and rocky outcrops provide good to very good shelter for adults from 6 m to 20 m depth in Bimini (Kanciruk & Herrnkind, 1976). During the adult stage, lobsters can occur on bank habitats (1-3 m depth), inshore (1-3 m), and offshore (2-10+ m) throughout the Bahamian Archipelago. At Lee Stocking Island, central Bahamas, spiny lobsters occur in all of these habitats, but are only found in crevices in hard substratum (Herrnkind & Lipcius, 1986). Near Bimini, lobsters primarily utilize sponges and gorgonians for shelter, because there are relatively few rock or coral dens (Kanciruk & Herrnkind, 1976). Adults occur both individually and communally with up to 20+ individuals per den. Offshore dens tend to have single, large males found in residence with numerous egg-bearing females, and offshore habitats have significantly more large lobsters than inshore areas and bank areas, such as the Brigantine Cays. Reproductive activity is usually confined to lobsters occupying offshore hard-bottom and coral reef habitats (Herrnkind & Lipcius, 1986). Juveniles occupy shallow bank areas dominated by sea grass and algal patches, as in Bimini (Kanciruk & Herrnkind, 1976). Sub adults and transient, or molting, adults, and those in reproductive condition occur throughout offshore reef habitats, as documented in Bimini (Kanciruk & Herrnkind, 1976) and the Florida Keys (Davis, 1977; Warner et al., 1977; Lyons et al., 1981).

The movement patterns of spiny lobster have been extensively studied in the Florida Keys and Cuba to evaluate the role of nursery areas and ontogenetic habitat shifts during the juvenile and adult stages (Warner et al., 1977; Davis, 1978; Davis & Dodrill, 1980, 1989; Gregory & Labisky, 1986; Rodríguez-Portal et al., 1990). Spiny lobsters are not nomadic, nor do they exhibit cyclical or migratory patterns of movement (Herrnkind, 1969). Seasonal offshore migrations are environmentally cued according to temperature and/or wind speed (Herrnkind, 1969; Simmons, 1980; Rodríguez-Portal et al., 1990). Single-file chains of dozens to thousands of individuals have been observed in the Bahamas after a strong north-easterly storm during the winter (Herrnkind & Cummings, 1964; Kanciruk & Herrnkind, 1978). Lobsters migrate with age (1-2 years) to reef habitats (e.g. dens) further offshore (Lyons et al., 1981; Marx & Herrnkind, 1985) at rates of 0.02 to 0.57 km per day (Gregory & Labisky, 1986). Both juveniles and adults congregate in dens comprised of caves, holes, and crevices during the day, and forage in sea grass and reef habitats at night (Berrill, 1975; Simmons, 1980). Habitat patterns of den (shelter) selection appear to be regulated by social structure, the scaling between den size and lobster size, and predation risk (Eggleston et al., 1990; Eggleston & Lipcius, 1990, 1992).

Associated Species

The spiny lobster is an important prey item for Nassau grouper (*Epinephelus striatus*) and other predatory reef fishes. In turn, many benthic invertebrates are important food items of the spiny lobster.

Threats

In order of importance, the threats to spiny lobsters are mortality from fishing, injury from fishing methods, and degradation of nursery habitats. The Caribbean spiny lobster is one of the most heavily fished and commercially significant shellfish throughout its range, from Bermuda to southern Brazil. Spiny lobsters are or once were ubiquitous inhabitants of wider Caribbean shallow-water environments, and in many locations are still highly valued as a source of food and revenue (Lipcius & Cobb, 1993). In the wider Caribbean, including the Bahamian Archipelago, spiny lobsters support some of the largest commercial fisheries, while also sustaining smaller scale artisan fisheries for local consumption and sale on remote islands, as well as locally important sport fisheries (Davis, 1977; Davis & Dodrill, 1989). Lobster fishing has been important in the wider Caribbean since at least the 1800s (Davis 1981b) and is now the most economically valuable fishery in the Caribbean, including the Bahamian Archipelago (Richards & Bohnsack, 1990; Cruz et al., 1991; Puga et al., 1991).

Methods of capture for commercial purposes primarily include wooden or wire traps, but also hooks (Cruz et al., 1995). For many countries such as Cuba and Jamaica, the export market for spiny lobster has become increasingly important in the past 20 years

(Haughton & Shaul, 1986; Cruz et al., 1991). In many areas, the spiny lobster fishery is fully exploited or overfished, with evidence of changes in fishing effort, catch per unit effort, and economic return (Haughton & King, 1989; Puga et al., 1991). This pattern is particularly evident in the Florida Keys, where the fishery has been fully exploited and overcapitalised for at least two decades (Beardsley et al., 1975; Austin, 1981), resulting in the annual removal of 95% to 99% of all legal-size (76 mm CL) individuals (Davis, 1981b). The minimum size at maturity for spiny lobster is generally considered to be 80 to 95 mm CL (Cruz et al., 1991), but intense fishing can reduce the minimum size at maturity (Gregory et al., 1982). An important aspect of spiny lobster reproductive biology is the relationship between size and fecundity (egg production), illustrating the potential problems of fishing the largest, and hence most fecund, individuals in a population (Cruz et al., 1991). In the Bahamas, spiny lobster fishing is prohibited from April 1 to July 31, the period of maximum reproduction. The minimum size is 3 ¼ in carapace length (8.3 cm) and 5 ½ in tail length (14 cm), and it is illegal to take females with eggs.

The spiny lobster fishery is heavily managed in many wider Caribbean areas, with regulations pertaining to gear restrictions, seasonal closures, area closures (nursery areas), and minimum size (Davis, 1980; Zuboy et al., 1980; Cruz et al., 1991, 1995). Some of the major obstacles to lobster management include too much fishing effort and hence low economic return, illegal harvest, mortality and increased injury, ineffective regulations such as inappropriate minimum size, and inadequate fishery statistics (Beardsley et al., 1975; Davis, 1980; Davis and Dodrill, 1980; Cruz et al., 1995). Because the absolute duration of the larval phase is not known, it is difficult to identify management or stock units (Menzies & Kerrigan, 1978, 1980; Farmer et al., 1986). Stock-recruitment relationships are poorly understood and cannot be managed, optimal larval production is not guaranteed, and uncertainties regarding stock origin are major management obstacles (Davis, 1980; Menzies & Kerrigan, 1980; Lyons, 1986). Intense spiny lobster fishing is known to have several direct and indirect effects on populations, including reduced abundance (Davis, 1977), decreased size (Haughton & King, 1989), increased incidence of injury and hence lower growth (Hunt & Lyons, 1986), lower fecundity or egg production (Gregory et al., 1982), and a shift in age at first reproduction (Gregory et al., 1982). Spiny lobsters use several benthic habitat types from post-settlement through adult stages (i.e. ontogenetic habitat shifts). Therefore, degradation of near shore habitats from human activities can prove detrimental to fisheries production (Davis, 1980). Juvenile lobsters prefer clear water in algae and sponge-dominated habitats close to shore. Dredge-and-fill activities associated with coastline development, for example, often result in increased sedimentation in near shore habitats. Heavily silted habitats affect the settlement and survival of lobster postlarvae, presumably by affecting prey abundance (Herrnkind et al., 1988). Water quality degradation from land-based pollution sources may also potentially affect recruitment of lobster into near shore habitats, since excess nutrients may cause changes in algal composition upon which postlarval and juvenile life are dependent.

Information gaps and research needs

- Accurate catch and effort and length-frequency data, as well as dockside value by trip and area of capture (Davis 1975);
- Development of efficient recruitment indices for predicting future catch levels (Lipcius and Cobb 1993);
- Restrictions upon catch and effort through size limits, catch quotas or seasons, no-fishing zones; and
- Stock recruitment relationships, specifically the origin of larval recruitment.

Conservation goals

Larval stage

- Exuma Sound provides long-term retention of larvae, resulting in a closed population both ecologically and genetically (Lipcius & Cobb, 1993). This has implications for the conservation of spawning stock biomass in the central Bahamas; and
- Postlarvae need architecturally complex habitats such as red algae of the Genus Laurencia (Marx & Herrnkind, 1985).

Juvenile stage

- Small juveniles require large clumps of red algae in bank habitats (Herrnkind & Lipcius, 1986; Lipcius & Cobb, 1993). This habitat provides food and refuge until 17 mm, when individuals move to dens in hard substrate areas (Marx & Herrnkind, 1985; Herrnkind et al., 1988);
- Juveniles require shallow bank areas dominated by sea grass and algal patches (Herrnkind & Lipcius, 1986); and
- Lee Stocking Island probably represents a poor recruitment area. No extensive nursery areas

exist in the Exumas.

Adult stage

- The Little and Great Bahama Banks support an immense lobster population (Kanciruk & Herrnkind, 1976);
- Sub adult transient or molting lobsters seasonally occupy fringe of offshore islands, while large adults occur throughout offshore reefs (Herrnkind & Lipcius, 1986);
- Larger lobsters occur offshore and reproductively active females may only occur offshore (Herrnkind & Lipcius, 1986), occupying crevices in hard substrate (singly and communally up to 20+ per den);
- Reproductive stocks are limited to deep-water areas; and
- Female fecundity is a power function of size; that is, larger females, which comprise a smaller percentage of the population, are more fecund as a group than smaller, sexually mature females (Kanciruk & Herrnkind, 1976).

Population targets are available in terms of male to female sex ratios and length-frequency characteristics. For bank habitats in the Bahamas, historical surveys revealed a population comprised of 46% females, with a mean carapace length of 81.5 mm for females and 86.8 mm for males (Kanciruk & Herrnkind, 1976). On fringing reefs at 8 to 15 m depth, historical populations were 54% female, with a mean carapace length of 80 mm for females and 88 mm for males. On deep reefs of the Bahamas, 55% to 63% of the population should be female, of which 91-95% of the females should be sexually mature. Mean carapace length targets are 82.8-86.7 mm for females and 91.1-97.8 mm for males in deep reef areas. A protected population in the Dry Tortugas, Florida yielded a mean carapace length of 101 mm, with a modal size class of 95-100 mm CL (Warner et al., 1977). In the Lee Stocking Island area, including the Brigantine Cays, Herrnkind and Lipcius (1986) recorded a mean size of juveniles in bank habitats of 75.7 mm. Inshore areas and channels yielded a mean size of 80.8 mm. Offshore areas, including fringing reefs and hard-bottom habitats, yielded mean sizes of 114.4-120.3 mm for males and 98.5-106.2 mm for females.

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5.2.10.1. Acroporid Corals (*Acropora palmata*)

Description

Phylum Cnidaria
Class Anthozoa
Subclass Hexacorallia
Order Scleractinia
Family Acroporidae
Genus Acropora

Elkhorn coral (*Acropora palmata*) is one of three branching coral species in the Family Acroporidae found in the tropical northwestern Atlantic. The blades are flattened and palm-shaped, but may be rounder in rougher water conditions (Porter, 1987). The branches emerge at acute angles and are generally in the same plane of growth as the parent blade. Blades can be greater than 0.5 m in length. Elkhorn coral colonies exhibit considerable variation in colour, ranging from very light tan to brown, with polyps about 0.1 cm in diameter.

Distribution

Elkhorn coral is widely distributed in the tropical northwestern Atlantic, including the Florida Keys, Bahamas, Central Caribbean, southern Gulf of Mexico, and the Lesser Antilles. Elkhorn coral does occur on the Florida Middle Grounds, eastern Gulf of Mexico, the Florida Garden Banks, northwestern Gulf of Mexico, or Bermuda. The northern extension of this species is Fowey Rocks, east of northern Biscayne Bay (Burns, 1985), but it does not form extensive reefs until further south (Porter, 1987). Specific records for the Bahamian Archipelago include Bimini (Squires, 1958), Andros Barrier Reef (Kramer et al., 1998), Eleuthera (Zankl & Schroeder, 1972), Exuma Cays (Lang et al., 1988; Sluka et al., 1996), San Salvador Island (Bottjer, 1980; Greenstein & Moffat, 1996), and the Caicos Bank (Sullivan et al., 1994; Chiappone et al., 1996).

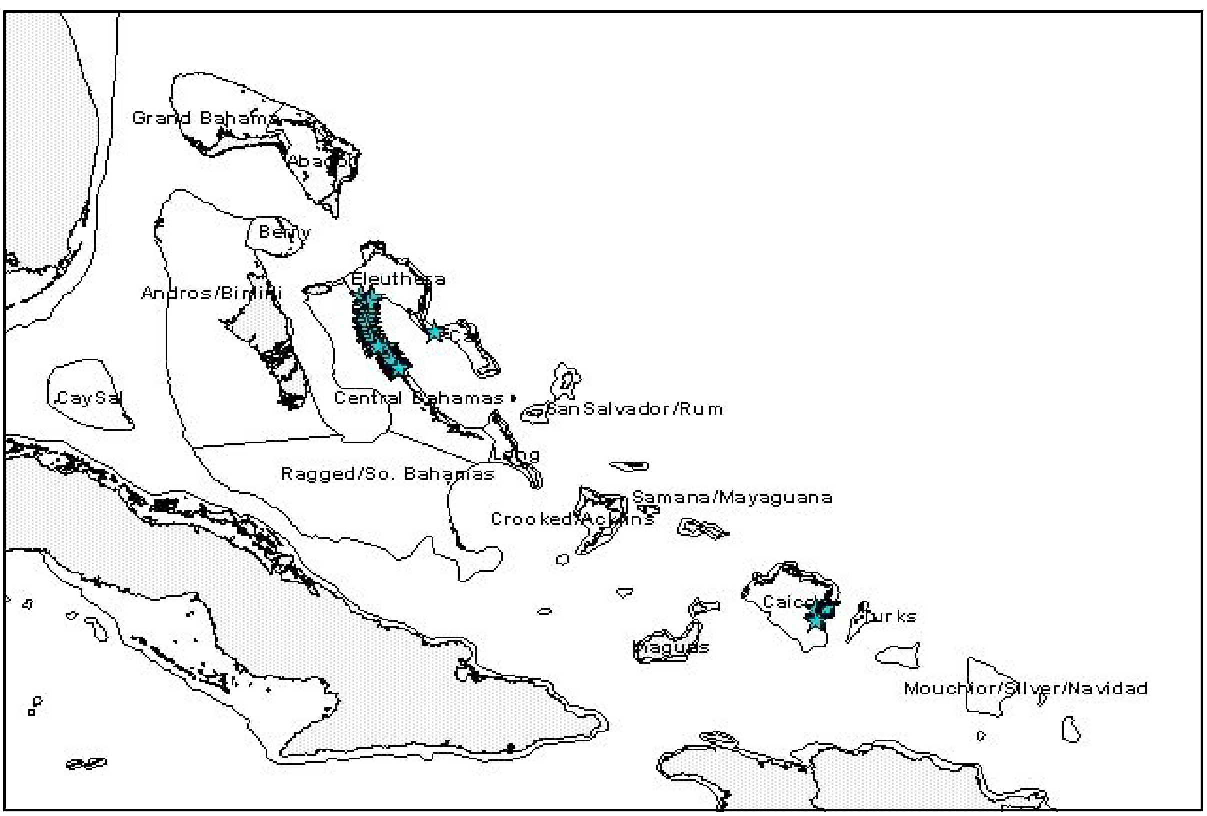

Figure 33. Map depicting locations of high-density elkhorn coral sites (indicated by turquoise stars) throughout the Bahamas

Status of populations in the wild

Once a ubiquitous component of many wider Caribbean reefs, elkhorn coral has experienced large-scale population declines since the 1970s (Aronson & Precht, 2001a). The principal causes of decline are white-band disease, hurricane damage, increased predation pressure, hypothermic and hypothermic events, reduced water quality, overgrowth by macroalgae, and physical impacts such as anchoring and vessel groundings (Aronson & Precht, 2001b; Precht et al., 2002). Elkhorn coral was the principal frame builder of reef flat and reef crest environments in many western Atlantic coral reef ecosystems, providing high topographic complexity for a diversity of other fauna. Although the causes of population declines are not fully understood, the loss of this important constructional component has resulted in a phase shift of many wider Caribbean reefs from coral dominance to algal dominance.

Information on the status of elkhorn coral populations in the Bahamian Archipelago is limited. This species apparently never formed extensive reefs near Bimini (Squires, 1958), but was considered abundant on the western side of Turtle Rocks in 1956 (Squires, 1958). In the 1990s, a well-developed elkhorn coral reef still persisted off the northern coast of San Salvador (Curran et al., 1993). Off northern Eleuthera, elkhorn coral was a dominant frame-builder at 3 m depth (Zankl & Schroeder, 1972). In the mid-1990s, elkhorn coral was mostly absent from fringing reefs in the Exuma Cays, where it does not form extensive reef crests or reef flats (Chiappone et al., 1997). In this region, large-scale surveys indicated that this coral was only found at 30% of fringing reef sites surveyed along 90 km of the Exuma Cays. Probably the best remaining occurrence in the entire Bahamian Archipelago is Andros Barrier Reef (Kramer et al., 1998). Large-scale surveys in 1997 indicated a dominance of elkhorn coral at 3 m depth on the seaward slope of Andros. Population characteristics recorded during these surveys indicated relatively high densities, large colony sizes, and low recent mortality (< 5%). Some recent mortality due to white-band disease or predation was noted, and less recent mortality estimates ranged from 25% to 56% (Kramer et al., 1998).

Ecology and natural history

Although this species has very fast growth rates (up to 10 cm per year), elkhorn coral is generally restricted to very shallow depths, especially shallow back reef, reef flat, and reef crest environments (Gladfelter et al., 1978). This species is considered environmentally sensitive, requiring relatively clear, well-circulated water (Jaap et al., 1989; Coles & Jokiel, 1992). Despite relatively rapid colony growth, recruitment by sexually produced larvae is extremely low, with local stands derived principally from asexual reproduction via fragmentation.

Growth rates of elkhorn coral, measured as rates of linear extension of particular branches, can be very high. Specific growth rate records in the wider Caribbean include 4.7 to 10.2 cm/yr in St. Croix (Gladfelter & Monahan, 1977), 6 to 10 cm/yr in Curacao (Bak, 1976), and 5 to 9.5 cm/yr in southern Florida (Vaughan, 1915). Elkhorn coral is a simultaneous hermaphrodite, with a short spawning season during August, usually six days after the full moon. Planula larvae develop externally and may be advected long distances from the parent colonies. Rates of recruitment by sexually derived planula larvae are very low (Bak & Engle, 1979; Rogers et al., 1984). This species primarily depends upon asexual reproduction, especially fragmentation, to form new colonies (Porter et al., 1981) and is only moderately resistant to storm damage and other physical disturbances (Porter, 1987).

Figure 34. Elkhorn coral

Habitat

Elkhorn coral can occur from < 1 m to 15 m depth in the tropical northwestern Atlantic, but is usually most common where it occurs from < 1 m to 7 m depth in turbulent shallow waters (Goreau & Wells, 1967). Relative to its congener Acropora cervicornis, elkhorn coral has a much narrower depth range where it occurs. This species was an important constructor of reef flat, reef crest, and spur and groove reefs throughout the wider Caribbean, but does not generally form an interlocking reef framework below 5 m depth (Lighty et al., 1982).

Relative to the expansive, shallow-water marine area of the Bahamian Archipelago, elkhorn coral is characterized by a very restricted habitat distribution in the region, even more so than its congener. In general, elkhorn coral is primarily restricted to the leeward and marginal sides of islands in the Bahamian Archipelago (Adey, 1978) and is principally distributed on reefs, except for isolated occurrences in channels. It does not form extensive reefs near Bimini (Squires, 1958). In the Exuma Cays, the absence of reef crest development by elkhorn coral is likely related to wave energy conditions and/or sediment transport from bank to oceanic environments (Sluka et al., 1996). This species is primarily restricted to the leeward and marginal sides of islands in the Bahamas (Adey, 1978), where it forms a reef framework from 1 m to 3 m depth such as Grand Bahama Island (Alevizon et al., 1985). Specific habitat occurrences for elkhorn coral in the Bahamian Archipelago are as follows. In Bimini, historical observations from shallow-water areas only yielded one occurrence from the western side of Turtle Rocks (Squires, 1958). On the Andros Barrier Reef, this coral is abundant at 3 m depth (Kramer et al., 1998). This species is also the dominant frame-builder at 1 m to 3 m depth on the inner shelf platform on the northern side of Eleuthera (Zankl & Schroeder, 1972). In the Exuma Cays, central Bahamas, elkhorn coral is relatively rare and patchily distributed on the windward, platform margin, and does not form extensive reef flat or reef crest structures (Chiappone et al., 1997b). In the Exumas, this coral may occur in channel reefs and fringing reefs, but is relatively rare (Chiappone et al., 1997a). At San Salvador Island, elkhorn coral was documented near shore on a reef crest north of Graham's Harbour (Bottjer, 1980), as well as offshore of the south-western end of the island (Greenstein & Moffat, 1996). On the Caicos Bank, this coral may occur incidentally in channel reefs (Chiappone et al., 1996), but does not form extensive reef flat or reef crest structures on the windward margin (Sullivan et al., 1994).

Associated Species

Elkhorn coral was formerly a key structural component of western Atlantic reefs that contributed substantially to coral reef accretion and framework development (Precht et al., 2002). Large, upright colonies provide critical habitat for a diversity of reef fishes and benthic invertebrates. Major predators of elkhorn coral include damselfishes (Pomacentridae), the polyachaete bristle worm (*Hermodice caruncullata*), and the coral-shell gastropod (*Coralliophila abbreviata*).

Threats

Pollution or water quality changes and physical impacts from habitat destruction/habitat loss are the principal anthropogenic threats to elkhorn coral. Because of its relatively delicate skeleton compared to massive, boulder-shaped corals, elkhorn coral is especially susceptible to physical impacts such as anchoring and vessel groundings, but also water quality degradation. Large-scale, Caribbean-wide population declines began during the 1970s and continued into the 1990s in most reef systems (Precht et al., 2002). The principal cause of decline was white band disease (Aronson & Precht, 2001b), reaching epidemic proportions in St. Croix and south Florida (Gladfelter, 1982; Jaap, 1984). Other causes of mortality include algal tumours from damselfish predation and gastropod predators. Records of white-band disease prevalence in the Bahamian Archipelago include Andros Barrier Reef during the 1980s, New Providence during the 1980s, and San Salvador during the 1980s (Ritchie & Smith, 1998; Aronson & Precht, 2001b). Elkhorn coral is also very susceptible to environmental changes such as hypothermic events, manifested in relatively high rates of tissue bleaching or loss of zooxanthellae (Shinn, 1976; Porter et al., 1982; Lang et al., 1988).

Information gaps and research needs

- Stock recruitment patterns, specifically the relationship between local reproduction and recruitment;
- Recovery patterns on major reef systems; and
- Causes of continued mortality in populations, particularly with respect to white-band disease.

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5.2.10.2. Acroporid Corals (*Acropora cervivornis*)

Description

Phylum Cnidaria
  Class Anthozoa
    Subclass Hexacorallia
      Order Scleractinia
        Family Acroporidae

Staghorn coral is one of three coral species in the Family Acroporidae distributed in the tropical northwestern Atlantic. Staghorn coral is a branching coral, with thin cylindrical branches that commonly show several orders of branching (Bottjer, 1980).

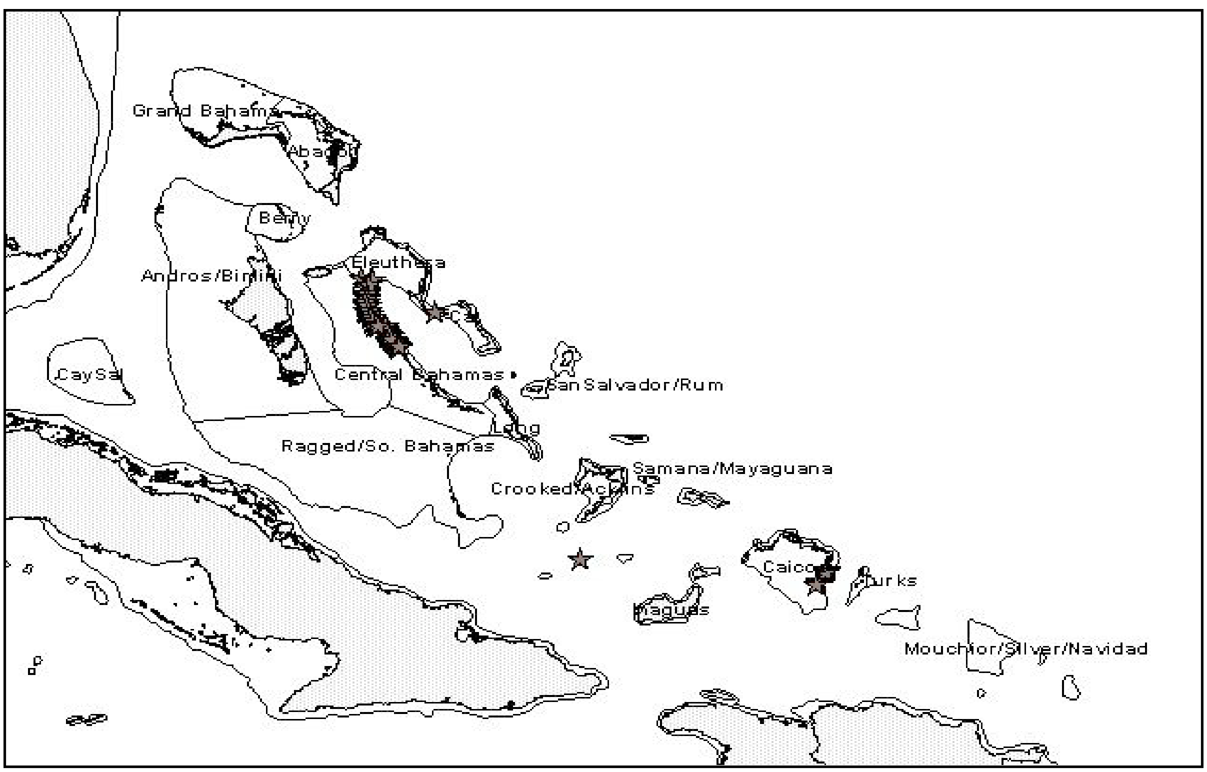

Figure 35. Map depicting locations of high-density staghorn coral sites (indicated by pink stars) throughout the Bahamas

Each blade emerges at right angles, and generally in a different plane of growth from most of the other blades. Colonies are usually brownish-yellow and relatively uniform in colour, with polyps about 0.1 cm in diameter.

Distribution

Staghorn coral is widely distributed in the tropical northwestern Atlantic, including the Bahamian archipelago, southeastern Florida and the Florida Keys, the southern Gulf of Mexico, the Central Caribbean, and the Lesser Antilles. Isolated colonies occur at 16 m to 30 m depth as far north as Palm Beach, Florida, but do not form interlocking frameworks (Goldberg, 1973). Staghorn coral is absent from the Florida Middle Grounds, eastern Gulf of Mexico, the Florida Garden Banks, the northwestern Gulf of Mexico, and Bermuda, principally due to low winter temperatures (Porter, 1987). Distribution records for the Bahamian archipelago include Bimini (Smith, 1971), Andros Barrier Reef (Kramer et al., 1998), Exuma Cays (Lang et al., 1988; Chiappone & Sullivan, 1991; Sullivan & Chiappone, 1992; Chiappone et al., 1997a), San Salvador Island (Bottjer, 1980; Curran et al., 1993), Hogsty Reef (Milliman, 1967a), and the Caicos Bank, Turks and Caicos Islands (Sullivan et al., 1994; Chiappone et al., 1996).

Status of populations in the wild

Formerly a ubiquitous element of wider Caribbean coral reef ecosystems, staghorn coral has been decimated throughout much of its range beginning in the 1970s (reviewed in Aronson & Precht, 2001a). The principal causes of this demise are white band disease, a pathogen with a still unknown etiology and cause (Aronson & Precht, 2001b), storm damage, predation, and some local human disturbances such as water quality and physical impacts from anchoring and vessel groundings. Studies in the Bahamian archipelago mirror wider Caribbean declines since the 1970s. On the leeward coast of San Salvador (Telephone Pole Reef), staghorn coral was virtually absent by 1992, despite dominating the reef in 1983 (Curran et al., 1993). In a large-scale study of the Exuma Cays, staghorn coral was only present at seven of 17 fringing reefs surveyed along 90 km of the archipelago (Chiappone et al., 1997). On deeper (> 10 m) spur and groove reefs, mean percent cover by staghorn coral was < 2% at all sites surveyed. Historical surveys on the eastern platform margin of the Caicos Bank, south-eastern Bahamas, also indicated low coverage by staghorn coral (Sullivan et al., 1994; Chiappone et al., 1996). Probably the last reef system with any substantial areas of this species is Andros Barrier Reef, where staghorn coral occurs at 3 m depth on the seaward slope (Kramer et al., 1998).

Ecology and natural history

Staghorn coral is among the most rapidly growing corals in the world, with a range in annual linear extension of 10 cm to 27 cm (Porter, 1987). Growth rate estimates for specific localities include 5-10 cm/yr in the Dry Tortugas and upper Florida Keys (Vaughan, 1915; Shinn, 1966) and 5.9-10 cm in St. Croix, US Virgin Islands (Gladfelter et al., 1978). This species principally relies upon photosynthesis for nutrition. Despite high growth rates, staghorn coral are poorly resistant to storm damage and other forms of physical disturbance (Porter, 1987). The life history of staghorn coral, like most corals, consists of essentially two stages: a sessile stage of juvenile and parental colonies and a dispersive larval stage. Staghorn coral is a simultaneous hermaphrodite, with a short spawning season during August, which usually occurs six days after the full moon. Larval development is external and recruitment by sexually derived planula larvae is typically low (Bak & Engel, 1979; Rogers et al., 1984). Although it is one of the fastest growing reef corals in the wider Caribbean (5 to 27 cm/yr. linear extension), staghorn coral has low rates of sexually produced planula, and colonies are easily damaged (Shinn, 1976; Gladfelter et al., 1978). Once established in a particular area, staghorn coral principally depends upon asexual reproduction via fragmentation to propagate new colonies (Porter et al., 1981). Important predators of staghorn coral include the fire worm (*Hermodice caruncullata*) and the mollusc *Coralliophila abbreviata* (Dustan, 1977; Tunnicliffe, 1983). Staghorn coral is highly susceptible to tissue bleaching from hyperthermic events, but is also sensitive to lower temperatures associated with cold fronts (Shinn, 1976; Porter et al., 1982) and sedimentation (Kendall et al., 1985).

Habitat

Staghorn coral is distributed from < 1 m to 30 m depth, but usually occurs from 3 m to 20 m depth on wider Caribbean fringing and barrier reef systems (Goreau & Wells, 1967). Staghorn coral usually occurs at its greatest abundance in zones deeper than its congener (*Acropora palmata*), often referred to as the mixed zone or terrace zone, but the species may also be abundant in back reef environments and lagoon patch reefs.

Relative to the expansive, shallow-water marine area of the Bahamian archipelago, staghorn coral is characterized by a very restricted habitat distribution in the region. It principally occurs on offshore reefs, as well as isolated occurrences on near shore and bank patch reefs. The species is generally limited to leeward environments where it does not form extensive, interlocking reef frameworks. Specific habitat occurrences in the Bahamian archipelago include near shore patch reefs, channel reefs, fringing reefs, and barrier reefs. Documented records of habitat usage are numerous for the Bahamian Archipelago. Throughout the region, staghorn coral is generally limited to the leeward sides of islands, such as leeward or lagoon patch reefs. This species is relatively abundant at 3 m depth on the Andros Barrier Reef (Kramer et al., 1998), but only occurs incidentally on shallow (1-20 m) fringing reefs (Chiappone & Sullivan, 1991), near shore patch reefs, and in channel environments (Chiappone et al., 1997a) in the Exuma Cays. Staghorn coral does not form extensive reefs near Bimini on the western Great Bahama Bank (Squires, 1958). Recent large-scale surveys in the Exumas indicate that staghorn coral is relatively rare and patchily distributed on the windward, platform margin. In this environment, the species does not form extensive fore reef terrace structures (Chiappone et al., 1997b). At San Salvador Island, staghorn coral historically occurred in high densities at 1 m to 6 m depth north of Graham's Harbour (Bottjer 1980), as well as on patch reefs in Fernandez Bay, but declined by the 19990s, principally from white-band disease (Curran et al., 1993). On the Caicos Bank, staghorn coral may occur on near shore patch reefs (Chiappone et al., 1996), but does not form extensive mid-depth reef terraces on the bank margins (Sullivan et al., 1994) as in the western Caribbean (e.g. Cayman Islands, Jamaica).

Associated Species

Staghorn coral and its congener provide critical habitat for a large diversity of fishes and benthic invertebrates. Major staghorn coral predators include damselfishes (Pomacentridae), the polyachaete bristle worm (*Hermodice caruncullata*), and the coral-shell gastropod (*Coralliophila abbreviata*). Various species of hermit crabs are common between colony branches.

Threats

The principal threats to staghorn coral are pollution or water quality changes, habitat destruction/habitat loss, and disease. From the late 1970s to the present, staghorn coral populations have suffered a regional decline (Precht et al., 2002), principally from white-band disease, a presumed bacterial infection (Aronson & Precht, 2001b). White-band disease is known to have affected most populations in the Bahamian Archipelago (Ritchie & Smith, 1998). Prevalence of white-band disease in the Bahamian Archipelago includes Andros Barrier Reef during the 1980s, New Providence during the 1980s, San Salvador during the 1980s, and Lee Stocking Island during the 1980s and 1990s (Aronson & Precht, 2001a).

Staghorn coral is also highly susceptible to bleaching during hypothermal events, and may suffer substantial mortality from severe bleaching episodes (Lang et al., 1988). Staghorn coral is also high susceptible to depressed oxygen levels and even moderate levels of sedimentation (Porter, 1987).

Information gaps and research needs

- Stock recruitment patterns, specifically the relationship between local reproduction and recruitment;
- Recovery patterns on major reef systems; and
- Causes of continued mortality in populations, particularly with respect to white-band disease.

Figure 36. Staghorn coral

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5.2.11. Queen conch (*Strombas gigas*)

Description

Phylum Mollusca
Class Gastropoda
Order Archaeogastropoda
Family Strombidae

The queen conch is one of six species of molluscs in the Family Strombidae found in the wider Caribbean. The queen conch is distinguished from other strombid species by its large size (up to 300 mm shell length, > 3 kg in weight) and deep pink colour of the aperture (Randall, 1964). Anatomical descriptions are provided in Little (1965). The snout of the queen conch is long and extremely extensible. From the base of the snout rise two eyestalks. The entire head region is mottled in black and yellow and the eyes are large with a black iris. The queen conch foot is large and powerful, coloured brown with white spots and markings.

Distribution

The queen conch is distributed throughout the tropical northwestern Atlantic, including Bermuda, Bahamas, Florida Keys, Greater and Lesser Antilles, and the Caribbean coasts of Central and South America (Brownell & Stevely, 1981). Throughout its range, queen conch is known by a variety of names, including botuto or guarura (Venezuela), cambombia (Panama), carrucho (Puerto Rico), cobo (Cuba), caracol (Mexico and Colombia), and lambí (Hispaniola).

Status of populations in the wild

The queen conch is still heavily fished in many locations (Richards & Bohnsack, 1990; Appeldoorn, 1994) and signs of over fishing are prevalent throughout the wider Caribbean (Adams, 1970; Siddall, 1984; Appeldoorn et al., 1987; Berg & Olsen, 1989). The use of SCUBA and hookah, combined with the increased demand, high market value, ease of capture, and aggregated behavior, have led to severe stock depletion in many localities (Brownell & Stevely, 1981; Hunt, 1987; Appeldoorn, 1994; Coulston et al., 1985). Ineffective enforcement and protection in nursery grounds has led to over-exploitation of juveniles (Ferrer & Alcolado, 1994; Rodríguez & Posada, 1994). Small coastal shelf areas (lower production) except in Belize, the Bahamas, and the Turks and Caicos naturally limit potential conch production (Appeldoorn, 1994; Ninnes, 1994). Market demand and the increased economic value of conch meat have driven over fishing (Appeldoorn, 1987).

In the Bahamian Archipelago, stocks have been depleted in some areas of the Bahamas, especially near Bimini, New Providence, and Grand Bahama Island (Robertson, 1959). Major fishing grounds include Abaco, Andros, Eleuthera, and the Exuma Cays. Evidence of decline in conch landings in some areas of the Bahamas was apparent by the late 1970s (Brownell & Stevely, 1981). During 1983-84, a large-scale survey on the Little and Great Bahama Banks indicated densities of 367kg/km^2 and 131 kg/km^2, respectively (Higgs, 1985). Fisheries analysis suggested that the potential yield for the Little Bahama Bank was between 152 and 263 kg/km^2 and 54 to 93 kg/km^2 for the Great Bahama Bank. Reported landings for 1982 represented only 6-7% of the minimum yield estimates (Higgs, 1985).

By the 1980s, adults were no longer found in shallow water where they were once abundant in the southern Exuma Cays, although large aggregations still occur, such as those near Children's Bay Cay (Wicklund et al., 1987). As of the early 1980s, adults in the southern

Exumas were in relatively deep water (> 6 m) in channels with high concentrations of sea grass and offshore on sand relict coral reef outcroppings (Wicklund et al., 1987). Extant aggregations with densities up to 196 juveniles/100 m^2 were still present in the 1980s in the Berry Islands near Bird Cay, but their present status is unknown (Iversen et al., 1987). A large, persistent aggregation normally more than 10 ha in area occurs in the Adderly tidal flow field west of Lee Stocking Island (Stoner & Ray, 1993a). As of 1991, the following conch aggregations, defined as concentrations of conch 80-140 mm long in densities of at least one individual per 10 m^2, were identified in a large-scale study by Stoner and Ray (1993b):

- Normans Cay-Wax Cay inlet: 65.15 ha, with 70% of all conch in one large aggregation;
- Wax Cay-Little Wax Cay inlet: 192.17 ha, with 99% of all conch in two large aggregations;
- Shroud Cay-Hawksbill Cay inlet: 10.92 ha, comprising nine small aggregations within 1.5 km of the inlet;
- Warderick Wells-Hall's Pond Cay inlet: 124.50 ha, with 64% in two large aggregations;
- Pasture Cay-O'Brien Cay-Bells Cay inlet: 53.89 ha, with 73% in one large aggregation; and
- Little Bells Cay-Compass Cay inlet: 252 ha, with 99% in three large aggregations.

Stoner and Ray (1993b) estimated that there were between 0.5-2.0 million juvenile conch between south Warderick Wells and the southern boundary of the park in the early 1990s.

The Turks and Caicos, especially on the Caicos Bank, has supported conch fishing for at least 350 years (Ninnes, 1994l; Stager & Chen, 1996). In the Turks and Caicos, an important fishery for conch has existed since the late 1800s, initially to supply dried conch meat to Haiti (Brownell & Stevely, 1981). Nearly 3 million conchs were being exported from the Caicos Bank by the mid-1970s (Hesse, 1979). Exportations from the Caicos Bank through Miami, Florida, increased from 6,590 kg during 1975 to 26,280 kg during 1978 (Brownell & Stevely, 1981). Sustained landings were evident in the early 1990s, but there was some indication of over fishing due to low catch per unit effort (Ninnes, 1994). Informal conversations with conch fishermen from South Caicos in 1992 revealed a widespread perception that conch catch per unit effort had declined (Stager & Chen, 1996). The perception is that conch

Figure 37. Queen Conch

Ecology and natural history

Queen conchs play an important ecological role in marine benthic communities, feeding principally upon dead or detrital remains of sea grasses, sea grass epiphytes, and macroalgae, as well as appreciable amounts of sand (Randall, 1964; Berg, 1975; Hensen, 1984). Conchs greatly affect the benthic community structure of sea grass meadows, especially the abundance of detritus and algae (Stoner, 1989), as well as the abundance and types of invertebrates in the community. Experimental studies in the southern Exuma Cays found that conch grazing has an important effect on the abundance of sea grass detritus (Stoner et al., 1995). In turn, areas devoid of conch show greater densities of macro fauna such as free-living amphipods and ostracods due to greater detritus. Major predators of juvenile conchs (Iversen et al., 1986), as determined from surveys in the Berry Islands during 1980-83, include a diversity of invertebrates and vertebrates. In the Berry Islands, tulip snails (*Fasciolaria tulipa*) were the most important gastropod predator. The giant hermit crab (*Petrochirus diogenes*) and spiny lobster (*Panulirus argus*) are probably the most important crustacean predators. Small crabs (Xanthidae, Majidae, Portunidae, Paguridae) are probably active predators on young-of-the-year conchs, while the cushion star (*Oreaster reticulatus*) is an important scavenger. Predators on larger conchs include spotted eagle rays (*Aetobatis narinari*), southern stingrays (*Dasyatis americana*), lemon sharks (*Negaprion brevirostris*), permit (*Trachinotus falcatus*), bonefish (*Albula vulpes*), and loggerhead turtles (*Caretta caretta*) (Randall, 1964; Berg, 1975; Iversen et al., 1986).

The life history of the queen conch can be divided into larval, juvenile, and adult stages. Adults typically occur in deeper hard-bottom and sandy habitats from 10 m to 30 m depth (D'Asaro, 1965; Berg et al., 1992b; Stoner & Schwarte, 1994). Deep-water adult populations are an important source of larvae to down-current areas (Coulston et al., 1985; Stoner & Ray, 1996a). Adults reach sexual maturity at 3 to 3.5 years of age and can live up to six or more years (Brownell & Stevely, 1981; Coulston et al., 1985) and thus may have a reproductive span of 2 to 2.5 years (Berg, 1976). Sexual maturity occurs after a few months of lip formation (Stoner et al., 1992). Fertilization is internal and initial copulation may occur several weeks prior to spawning (D'Asaro, 1965). The spawning season is concentrated during the warmer months (also longer photoperiod), but may occur year-round in some locations (Brownell & Stevely, 1981). In the southern Exuma Cays, the reproductive season extends from mid-April to early October (Stoner et al., 1992). In the Turks and Caicos, the egg-laying season occurs from late March to early September, with a distinct seasonal variation in the number of eggs produced (Davis et al., 1984). Female conch may spawn several times during the reproductive season (Stoner et al., 1996). Egg masses are deposited by females in clean, calcareous sand (low organic content), but may also be deposited in sea grass beds (Robertson, 1959; Brownell, 1977). Egg masses are produced over a 24-36 hour period and may contain 300,000 to 500,000 eggs (D'Asaro, 1965).

Conch larvae or veligers emerge or hatch from the egg masses after five days and begin their life in the plankton (D'Asaro, 1965). Conch veligers are planktotrophic, exhibit positive photo taxis (Barile et al. 1994), feed upon zooplankton, and may remain in the water column for 75 days, but typically settle in nursery habitats within 60 days of hatching (D'Asaro, 1965; Davis et al., 1993; Posada & Appeldoorn, 1994). Larval development is greatly influenced by temperature and the supply of phytoplankton upon which the larvae feed (Brownell & Stevely, 1981; Stoner, 1997). If conditions are suitable, larvae can settle to benthic habitats as quickly as 17 to 22 days after hatching, but may remain in the plankton for up to two months (Posada & Appeldoorn, 1994; Stoner, 1997). Larvae are competent to metamorphose 18 to 26 days after hatching (Davis et al., 1993). Usually within five days of settlement, veligers undergo metamorphosis in which the proboscis develops and the velar lobes disappear. Larval conch require a cue to initiate settlement and metamorphosis, and are capable of undergoing metamorphosis during a short competence period of six days (Davis, 1994). An earlier study demonstrated that the green alga *Batophora oersetedi*, a food source of juvenile conch, induced the highest percentage of metamorphosis in veligers in the laboratory (Davis & Stoner, 1994). The most effective inducers to metamorphosis are associated with red algae (*Laurencia poitei*) and epiphytes found on turtle grass detritus (Boettcher & Targett, 1996).

Upon settlement from the plankton, early juvenile queen conchs (20-50 mm SL) inhabit shallow, non-vegetated habitats where they burrow in sand during the day and surface at night (Sandt & Stoner, 1993). Early juveniles are usually buried in sand down to 20 cm (Iversen et al. 1986), possibly to avoid predators (Brownell & Stevely, 1981; Coulston et al., 1985). A study in the Berry Islands showed a significant positive correlation between survival rates and burial for conch 3.5 cm to 22.0 cm shell length (Iversen et al., 1989). Juveniles can suffer high mortality from predation (4-63% annually) (Alcolado, 1976), primarily from crustaceans such as xanthid crabs (Appeldoorn & Ballantine, 1982; Appeldoorn, 1985a). In the Berry Islands, significant differences in burial activity with the tidal cycle were noted, with more conch buried on high tides than on low tides, possibly due to increased predator activity (Iversen et al., 1987). Mortality rates of conch decrease exponentially with age until the onset of sexual maturity (Appeldoorn 1988). Juveniles one to two years old (8-14 cm SL) make ontogenetic habitat shifts, by moving from non-vegetated zones to deeper, adjacent sea grass beds (Sandt & Stoner, 1993). Although juveniles prefer moderate to dense sea grass beds in relatively shallow water (< 10 m), nursery areas can also comprise shallow algal flats or deep submerged banks (Stoner, 1997). Growth rates parallel temperature trends during the year (Alcolado, 1976; Appeldoorn, 1985a), with the highest growth (0.4-1.2 cm/month) during May to October (Alcolado, 1976; Iversen et al., 1987). At 2.5-3 years of age, conchs cease to build their shell in a spiral fashion and start to build the flaring lip. Home ranges for conchs vary from 1,000 m^2 for 10-13 cm SL individuals, 2,500-5,000 m^2 for 13-16 cm SL individuals, to even larger ranges above 17 cm SL (Randall 1964, Hesse 1979). Age and length relationships are as follows: 1 year old = 7.6-10.8 cm SL, 2 years of age = 12.6-17.0 cm SL, and 3 years of age = 18.0-20.5 cm SL (Berg, 1976; Brownell, 1977).

One feature of juvenile queen conch is their tendency to form large (> 100 ha), dense (0.2-2 conch/m^2), and recurrent aggregations (Stoner & Ray 1993a, reviewed in Stoner, 1997b). Aggregations are common in areas with significant tidal circulation, shallow depth (1.5-4 m), moderate to dense sea grass coverage, and high algal productivity (Stoner & Waite, 1990; Stoner et al., 1996;

Jones, 1996) and may contain 100,000 juveniles as documented in the Exuma Cays (Stoner & Lally, 1994; Stoner et al., 1996). Field experiments show that those areas with similar depth, sediment, and plant abundance do not provide equivalent food and refuge for queen conch (Stoner, 1994; Jones, 1996). Juvenile aggregations are usually limited to a few particular sites in seemingly uniform sea grass beds, reflecting water circulation and the production of certain species of macroalgae that juveniles graze upon (Hesse, 1979; Stoner & Ray, 1993b, Stoner et al., 1994). In the Bahamas, juvenile queen conch aggregations typically occur within 2-4 km of tidal inlets (Stoner & Ray, 1993b) and are present year-round (Stoner & Lally, 1994). These aggregations, however, may comprise less < 1% of the available sea grass habitat, reflecting spatial variations in larval recruitment or habitat suitability (Jones, 1996; Stoner, 1997). High-density aggregations may serve to reduce predation or disperse natural mortality (Iversen et al., 1986; Stoner & Sandt, 1991; Stoner & Ray, 1993a). Movement patterns of juveniles are related to seasonal changes and episodic storms, and may function to reduce mortality from predation or efficiently utilize food resources (Hesse, 1979; Lipcius et al., 1987). Juvenile aggregations may also shift position from year to year (Stoner & Lally, 1994). Several studies provide evidence that conch actively select among habitats (Sandt & Stoner, 1993). Research has shown that conch density and biomass increase directly with sea grass cover, sea grass shoot density, and macroalgae productivity, up to an optimal level, and that juveniles are much more selective than adults in the choice of habitat (Stoner & Waite, 1990).

Habitat

Queen conchs are distributed from 1 m to 76 m depth, but usually occur shallower than 30 m to 40 m depth (Randall, 1964; Stoner & Schwarte, 1994). Specific benthic habitats in the Bahamian archipelago inhabited by queen conch include bare sand (newly settled juveniles), patchy sea grass (juveniles/adults), dense sea grass (juveniles/adults), channel hard-bottom (adults), and platform margin hard-bottom (adults) (Stoner & Waite, 1990; Sandt & Stoner, 1993). A review of research on queen conch biology and ecology in the Caribbean is provided in Siddall (1984) and Stoner (1997). Queen conchs prefer sandy and hard substrates with algae and sea grasses and specifically prefer intermediate densities of turtle grass (Randall, 1964; Stoner & Waite, 1990). They also occur on gravel, coral rubble, or beach rock bottoms (Friedlander et al., 1994; Appeldoorn, 1997). The limited depth distribution of conch is probably related to the amount of light necessary to support plant growth. Juveniles exhibit a strong preference for intermediate densities of turtle grass (Stoner & Waite, 1990, Stoner & Sandt, 1991). Adults, on the other hand, show less habitat specificity. In the Exuma Cays, adults are mostly found in deeper water close to tidal inlets or on the platform margin bordering Exuma Sound to 20 m depth (Stoner & Ray, 1993b). Spawning habitats are typically at 15 to 23 m depth on carbonate sand partially covered by a thin algal mat adjacent to deeper reefs (Wicklund et al., 1987). In the Berry Islands, adults with flared lips almost without exception occur in deeper (> 3 m) water (Iversen et al., 1987).

Smaller juvenile conchs (< 10 cm) occur on shallow (< 1 m) tidal flats, mostly on sandy bottoms with depressions (Iversen et al., 1987). Larger juveniles are usually found associated with cays having tidal flats, available food (micro algae and detritus), beaches with a gradual slope, and good water circulation. The apparent preference of juvenile queen conchs for sparse sea grass communities is likely a function of food availability and predator avoidance (Stoner & Waite, 1990; Ray et al., 1994b). Sparse sea grass habitats presumably provide the necessary detritus, high algal production, and structural complexity needed for food resources and refuge from predators (Stoner et al., 1994; Ray et al., 1994b). Queen conch density and biomass increase directly with increasing macrophyte cover up to an optimal level of moderate sea grass density (608-864 shoots/m^2), as determined in earlier experiments in the southern Exuma Cays (Stoner & Waite, 1990; Stoner & Sandt, 1991). Up to this optimal level, conch density and biomass are closely correlated with sea grass and detritus biomass, depth, and especially shoot density. Juvenile aggregations in the Exuma Cays, defined as a large group of conch with > 0.2 individuals/m^2, typically occur 2.5 to 5 km from Exuma Sounds in regions of high algal productivity (Stoner & Ray, 1993a). Aggregations are associated with areas flushed on every tide with clean oceanic water (Stoner & Ray, 1993b). Aggregations are typically arranged in long (15 to 200 m), narrow (1 to 3 m) bands, which lie across the axis of the tidal current and persist for several months (Stoner & Lally, 1994). Large aggregations tend to be associated with inlet systems that have deep passes and less landmass to block water flow. They tend to be oriented with the axis of the tidal flow field and are usually located on the shallow (2-4 m) bank side of islands in moderate density sea grass meadows with a sand bar (unstable ooid shoal) nearby (Wicklund et al., 1987).

Associated Species

Juvenile and adult queen conchs are a primarily source of food for a diversity of invertebrates and vertebrates in shallow-water tropical environments (Randall, 1964; Berg, 1975; Iversen et al., 1986). Major predators of juveniles include tulip snails (*Fasciolaria tulipa*), the giant hermit crab (*Petrochirus diogenes*), spiny lobster (*Panulirus argus*), smaller crabs (Xanthidae, Majidae, Portunidae, Paguridae), and cushion stars (*Oreaster reticulatus*). Important larger predators include spotted eagle rays (*Aetobatis narinari*), southern stingrays (*Dasyatis americana*), lemon sharks (*Negaprion brevirostris*), permit (*Trachinotus falcatus*), bonefish (*Albula vulpes*), and loggerhead turtles (*Caretta caretta*).

Threats

The principal threats to queen conch populations in the Bahamian archipelago and elsewhere in the wider Caribbean are over fishing, water quality degradation in nursery habitats, and physical impacts to sea grass habitats. An economic and cultural symbol of the wider Caribbean, the queen conch has supported subsistence, artisanal fisheries and more recently commercial fisheries throughout much of its range (Siddall, 1984). Populations of queen conch have been exploited for at least 500 years in the wider Caribbean, first in pre-Columbian times by tribal groups such as the Lucayan and Taino Indians, then as a commercial fishery to support local and foreign demand (Brownell & Stevely, 1981; Appeldoorn, 1997). Conch are valued as a protein source, second only to finfish in many native diets, and were also used historically as bait in lobster fisheries. The queen conch fishery represents the second most valuable fishery after the spiny lobster, both in the Caribbean (Richards & Bohnsack, 1990) and in the Bahamas (Stoner, 1997a). In 1990, the economic value of queen conch taken from the Caribbean region was estimated at US$40 million (Appeldoorn, 1994). Queen conchs are fished using poles or conch hooks from sailing sloops (Bermuda, Bahamas, Turks and Caicos), free diving (Colombia, Dominican Republic, Turks and Caicos, Venezuela), hookah (compressor) and SCUBA (Bahamas, Dominican Republic). Fishing for queen conch in the Bahamas is restricted primarily to free diving, but there is some use of hookah or compressor systems. In the Bahamas, conch may be taken only if they have a well-formed lip, representing individuals at least 3.5 to 4 years of age. In many countries conch are consumed locally. Most of the harvest catches from the Turks and Caicos is exported to the United States as frozen meat (Ninnes, 1994). In addition to the meat, the colourful shell is often sold for ornamental purposes and was once used in the manufacture of lime and porcelain (Randall, 1964).

The queen conch is still heavily fished in many locations (Richards & Bohnsack, 1990; Appeldoorn, 1994) and signs of over fishing were evident by the mid-1970s (Adams, 1970; Siddall, 1984; Appeldoorn et al., 1987; Berg & Olsen, 1989). In the Bahamian Archipelago, stocks have been depleted in some areas of the Bahamas, especially near Bimini, New Providence, and Grand Bahama Island (Robertson, 1959). The use of SCUBA and hookah, combined with the increased demand, high market value, ease of capture, and aggregated behavior, have led to severe stock depletion in many localities (Brownell & Stevely, 1981; Hunt, 1987; Appeldoorn, 1994; Coulston et al., 1985). Ineffective enforcement and protection in nursery grounds has led to over-exploitation of juveniles (Ferrer & Alcolado, 1994; Rodríguez & Posada, 1994). Small coastal shelf areas (lower production) except in Belize, the Bahamas, and the Turks and Caicos naturally limit potential conch production (Appeldoorn, 1994; Ninnes, 1994). Also, the removal of conch at a size (marketable size is 18-19 cm SL) before sexual maturity (18-27 cm SL) can reduce reproductively viable individuals (Berg, 1976). Degradation of nursery habitats from coastal development can affect larval settlement and juvenile survival (Friedlander et al., 1994; Appeldoorn, 1997).

Finally, market demand and the increased economic value of conch meat have driven over fishing (Appeldoorn, 1987). Exceptions to this trend are areas with low fishing pressure, alternative employment opportunities, or effective management (Appeldoorn, 1994). Regulations imposed to protect, conserve, or restore conch stocks include closed seasons (Belize, Grenada, US Virgin Islands), minimum size (Bahamas, Belize, Cuba, US Virgin Islands), catch quotas (Mexico, US Virgin Islands), gear restrictions such as a ban on the use of SCUBA (Colombia, Martinique), export limitations and sale of undersized shells (Bahamas, Belize, US Virgin Islands), and temporary or permanent closures (Bermuda, Florida Keys, Cuba, Belize, US Virgin Islands, Venezuela) (Hunt, 1987; Chavez, 1990; Appeldoorn, 1994; Beets & Appeldoorn, 1994). In areas protected from conch fishing, populations show significantly greater densities of adults, juveniles, and larvae (Ray et al., 1994a; Rodríguez & Posada, 1994; Stoner & Ray, 1996a). As a result of severe over-fishing throughout much of its range, queen conch was considered commercially threatened worldwide in 1983, and in 1992, it was added to Appendix II of the

Convention on International Trade in Endangered Species (CITES). Fisheries are now closed seasonally or for multi-year periods in Venezuela, Colombia, Belize, Mexico, Cuba, Florida Keys, Bermuda, and the US Virgin Islands. Despite closures in the Florida Keys (since 1985) and Bermuda (since 1978), stocks have not recovered (Appeldoorn 1994, Berg and Glazer 1995). Some scientists have called for the implementation of a temporary Caribbean-wide moratorium on conch fishing until stocks can recover (Orlando Mora, 1994).

Recently, water quality degradation has been implicated in the reproductive failure of near shore stocks in locations such as the Florida Keys (Glazer & Quintero, 1998). In laboratory studies, growth rates and densities of conch larvae over a 7-year period were enhanced by ozonation of water, which increases the oxidation-reduction potential (ORP) of seawater. Low ORP is indicative of increased eutrophication. Eutrophication may be negatively affecting conch reproductive potential in near shore waters of the Florida Keys. Conch reportedly used to spawn in near shore waters. Recent histological examinations indicate deficits in the condition of gonads of near shore animals compared of offshore counterparts. There is no evidence of near shore reproduction in the Florida Keys since 1987 (McCarthy et al., in press). Reciprocal transplants indicated failure of near shore conch to spawn, while offshore conch transplanted closer to shore exhibited reduced frequencies of mating and spawning.

Current conservation programs

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Existing legislation

- Existing legislation prohibits the export of conch meat from the Bahamas, but not from the Turks and Caicos, where one of the largest export fisheries for conch still persists;
- Conch products in the Bahamas may be exported under special license (Higgs, 1985); and
- In the Bahamas, it is illegal to take or sell conch that do not have a well-formed lip on the shell (Higgs, 1985).

Management strategies need to be markedly different if the source of recruits is local rather than pandemic (i.e. the origin of the recruits) (Glazer & Berg, 1995).

Information gaps and research needs

Data are needed on the recruitment of juveniles into nursery areas and information on the factors necessary for the survival of the youngest conch (Wicklund et al., 1987; Stoner et al., 1992). There is only sparse information on conch predators and the impact of food availability on populations. Long-term monitoring data on density and population trends are needed, but this will be challenging because of the highly aggregated distribution of the species and the high variances associated with population estimates (Glazer & Berg, 1994). Besides fishing impacts, little is known concerning the effects of other anthropogenic activities on various life stages.

Conservation goals

Larvae (recruitment areas)

- Pelagic conch veligers spend 18 to 40 days in the water column 18-40 days prior to settlement and the density of larvae exhibits a direct correlation with the percentage of females copulating and egg-laying at any one site (Stoner et al., 1992); and
- Water quality degradation in close proximity to spawning sites could affect larval survival, as is suspected in the Florida Keys (Glazer & Quintero, 1998).

Juveniles (nursery areas)

- Juveniles congregate in shallow areas adjacent to cays with strong currents (Iversen et al., 1987) and most are located in shallow sea grass habitats (Stoner et al., 1992);
- Early juveniles primarily inhabit shallow unvegetated zones where they burrow into the sediment during the day (Sandt & Stoner, 1993);
- Conch one to two years of age (80-140 mm SL) move to adjacent, deeper sea grass beds (Sandt & Stoner, 1993);
- Most juveniles on the northern Great Bahama Bank (northern) are concentrated (0.2-2 conch/

m^2) in large aggregations (to > 100 ha in surface area) in relatively few locations (Stoner & Ray, 1993a). Juvenile aggregations in the Exuma Cays occur 2.5-5 km from Exuma Sound in regions of high algal productivity, associated with vast areas flushed by tides and characterized by shallow depth (2-3.5 m) and sea grass meadows of intermediate biomass (Iversen et al., 1987; Stoner & Waite, 1990; Stoner et al., 1994);

- Aggregations are elliptical in shape, with the long axis oriented parallel to tidal currents. Such aggregations may only occupy a fraction of the total amount of habitat that is optimal for feeding and growth (Stoner & Ray, 1993a). In general, the large-scale boundaries of conch nursery areas are set by specific physical and biological conditions such as circulation, depth, sea grass shoot density, and food production (Stoner & Ray, 1993a);
- Juvenile queen conch require adequate food availability, good water quality, and bottom sediments suitable to allow the youngest conch to bury and avoid predation (Iversen et al., 1989);
- Juvenile aggregations in the Exuma Cays are probably critical for recruitment into the northern Great Bahama Bank (Wicklund et al., 1987); and
- Target juvenile/adult density in bank habitats of 4.93-10.09 individuals/100 m^2, as recorded during 1974-1975 on the eastern Caicos Bank (Hesse, 1979).

Adults (reproductive phase)

- The densities of adult conchs in the Exuma Cays occur at 10 m to 18 m depth on the platform margin (Stoner et al. 1992, Stoner and Schwarte 1994);
- Adults are very rare below 25 m and few are presently found shallower than 10 m, principally due to fishing pressure (Stoner and Schwarte 1994);
- The most important sources for deep-water stocks are small, near shore nurseries on island shelves, probably the primary source for queen conch in the Exumas Cays (Stoner and Schwarte 1994); and
- A critical substrate for egg-laying is clean, carbonate sand with coarse grain size (Stoner et al. 1992).

Average densities for Little Bahama Bank and Great Bahama Bank during 1983-84 was 28.50 conch/ha and 20.79 conch/ha, respectively (Smith and van Nierop 1984)

Justification

Marine protected areas

- Marine protected areas, particularly those design to encapsulate both bank and offshore habitats containing conch, afford the protection of juvenile nursery areas and reproductive stocks (Stoner and Ray 1996a).

Mariculture

- The use of mariculture to enhance depleted stocks has been proposed by numerous investigators, but the practicality of this approach has yet to be demonstrated (Davis et al. 1985, Glazer and Berg 1995). Declining catch rates have led to increase interest in mariculture techniques (Iversen et al. 1989);
- Heterozygosity may be advantageous, thus high mortality reported for field-released, hatchery-reared juveniles may be selection for heterozygosity and may be unavoidable (Glazer and Berg 1994);
- The Caicos Conch Farm was established in 1983 to facilitate mass production of conch larvae, veliger culturing, and rearing of post-larval juveniles (Davis et al. 1985);
- Knowledge of the factors affecting conch survival are critical if mariculture techniques are to succeed (Iversen et al. 1989). Predation is probably the most important source of mortality on stocks of > 1 year old juveniles (Iversen et al. 1986) and survival of hatchery-reared small conch (2-7 cm in shell length) has been extremely low (Iversen et al. 1986). Previous studies suggest juvenile conch should be released at a minimum size of 75-90 mm (Ray et al. 1994) and that wild conch have greater survival than hatchery-reared individuals (Stoner and Davis 1994);
- Previous attempts at conch mariculture have generally been met with high hatchery costs, lack of dependable mass-rearing techniques, high predation on young released in the wild, and slow growth of penned conchs (Iversen et al. 1987, Stoner and Davis 1994); and
- Factors to consider in stock-enhancement endeavours include the optimum time to release young juveniles, size at release, habitat into which outplants are released, lunar phase,

density of outplants, presence of wild conch, and seed-stock condition.

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III. OVERVIEW OF THE CLASSIFICATION OF ENVIRONMENTS

1. Introduction

The Bahamian archipelago is a system of carbonate banks and islands with a common geological origin and related ecology. Ecological boundaries rarely coincide with political jurisdictions or national boundaries. The archipelago includes territories of three countries; The Bahamas, the Turks and Caicos Islands and the Dominican Republic. All of the land areas in the archipelago are part of The Bahamas or the Turks and Caicos Islands, but the Dominican Republic claims the submerged reefs of the Silver and Navidad Banks to the extreme south-eastern extent of the chain. There is no comprehensive assessment of the archipelago as a whole, and the biological diversity of the archipelago is often undervalued in regional studies because of the small size of the islands. The challenge in natural resource management and conservation is to, first, carefully describe the natural communities and environments that occur both above and below water. Formal habitat or vegetation classification systems are presented in this section of the Ecoregional Plan for readers to fully appreciate the scope of natural environments that do occur, and the spatial gradients that exist with both latitude and bank geography.

Table 6: Classification systems used in describing and defining the environments of the Bahamas.

Environment Groups	Classification References
Marine Benthic Sub-tidal Habitats (> 200m in depth)	Allee et al. (2000) Marine and Estuarine Ecosystem and Habitat Classification. NOAA Technical Memorandum NMFS-F/SPO- 43.
Coastal Environments Beaches, rocky shores, mangrove wetlands	A combination of Allee et al. (2000), Areces-Mallea et al. (1999) and references on the geology and coastal characterization of the Bahamas.
Vegetation Environments Upland and freshwater wetland vegetation communities	Areces-Mallea et al. (1999). A Guide to the Caribbean Vegetation Types - Classification Systems and Descriptions. The Nature Conservancy.
Wetlands and Deep-Water Environments	Cowardin, L, V. Carter, F. Golet and E. LaRoe. (1979). Classification of wetlands and deepwater habitats of the United States. Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C.

An overview of the environments begins with formal classification schemes and definitions. Environments span from deep reefs and caves to small seasonal ponds and wetlands. To understand the component of biological diversity, the physical and biological environment needs to be described and characterized by natural community classification systems. The integration of land, coastal and marine environments in the Bahamian archipelago requires a special challenge to integrate traditional classification schemes for wetlands, vegetation, marine and estuarine systems. The ability to recognize and catalogue different types of environments is the first step in understanding the ecology of the large bank system. Three established hierarchical classification systems, providing standard terminology and a framework for describing the observed environments, were used to describe the landcover of the entire Bahamian archipelago. These classifications included areas of overlap in coastal wetlands, rocky shore, and beach strand and mangrove communities. Habitat classification schemes to describe four groups of environments, namely marine benthic habitats, vegetation communities, wetlands and coastal environments were based on three sources (see Table 6). These classifications provide a starting point for mapping, and assessment of natural resources. Technical or scientific names are used as part of the defined terminology associated with each classification system, but local terms and names may be for education and management purposes. When possible, images are used to help the reader visualize the habitat being described. The selected classification systems had to meet several requirements. They had to

- Be in a recognized format, with some work completed in the Bahamian archipelago;
- Overlap with each other, for an integrated approach to landscape ecology; and
- Develop an over-arching organization, designed to include the unique differences between bank and island morphology and energy.

Differences between bank systems are perhaps the most important environmental component in describing the ecology of the archipelago. The classification of the carbonate bank environment can be based on geomorphology, energy exposure and bank size, with a latitudinal gradient (Figure 38).

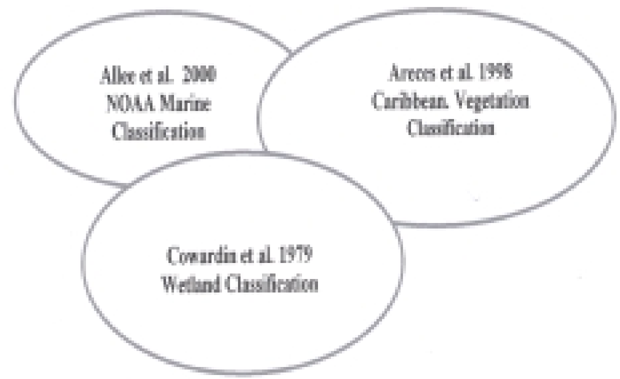

Figure 38. Three different classification systems used to describe the environments in the Bahamas

Based on energy and exposure, five types of bank systems can be distinguished:

- Sheltered banks with continuous, larger cays along the eastern bank margin;
- Sheltered banks with discontinuous island chains along the eastern bank margin;
- Island-occupied banks with large island and small bank areas energy;
- Exposed banks with small islands or no land; and
- An anomalous bank system, the Western Little Bahama Banks.

The archipelago stretches almost seven degrees in Latitude (420 nautical miles or 770 kilometres), from the tropical dry islands of the Turks and Caicos, to the subtropical island of Grand Bahama. The weather in the entire region is influenced by frontal systems from North America, however snowfall was only recorded once at West End, Grand Bahama Island, in 1977.

The bank systems, and their associated islands, are the fundamental components of biodiversity in the archipelago. The total shallow water bank area (in square kilometres) extends from the shoreline to the 200-meter bathymetric contour. Land areas (in square kilometres) include the area of coastal mangroves, but not large creeks and bights. There is roughly a ten to one ratio of marine bank to terrestrial island areas in the archipelago (134,447 square kilometres of bank habitat to 12,972 square kilometres of land). The bank perimeter (in kilometres) includes only platform margin length. The platform margin is characterized as the area of barrier and fringing reef growth, up welling and sediment transport events critical in marine faunal distributions. The length of shoreline (given in kilometres) can be much larger than bank perimeter length due to convolutions and embayments on many of the islands. The geography of the five bank systems is presented in Table 7.

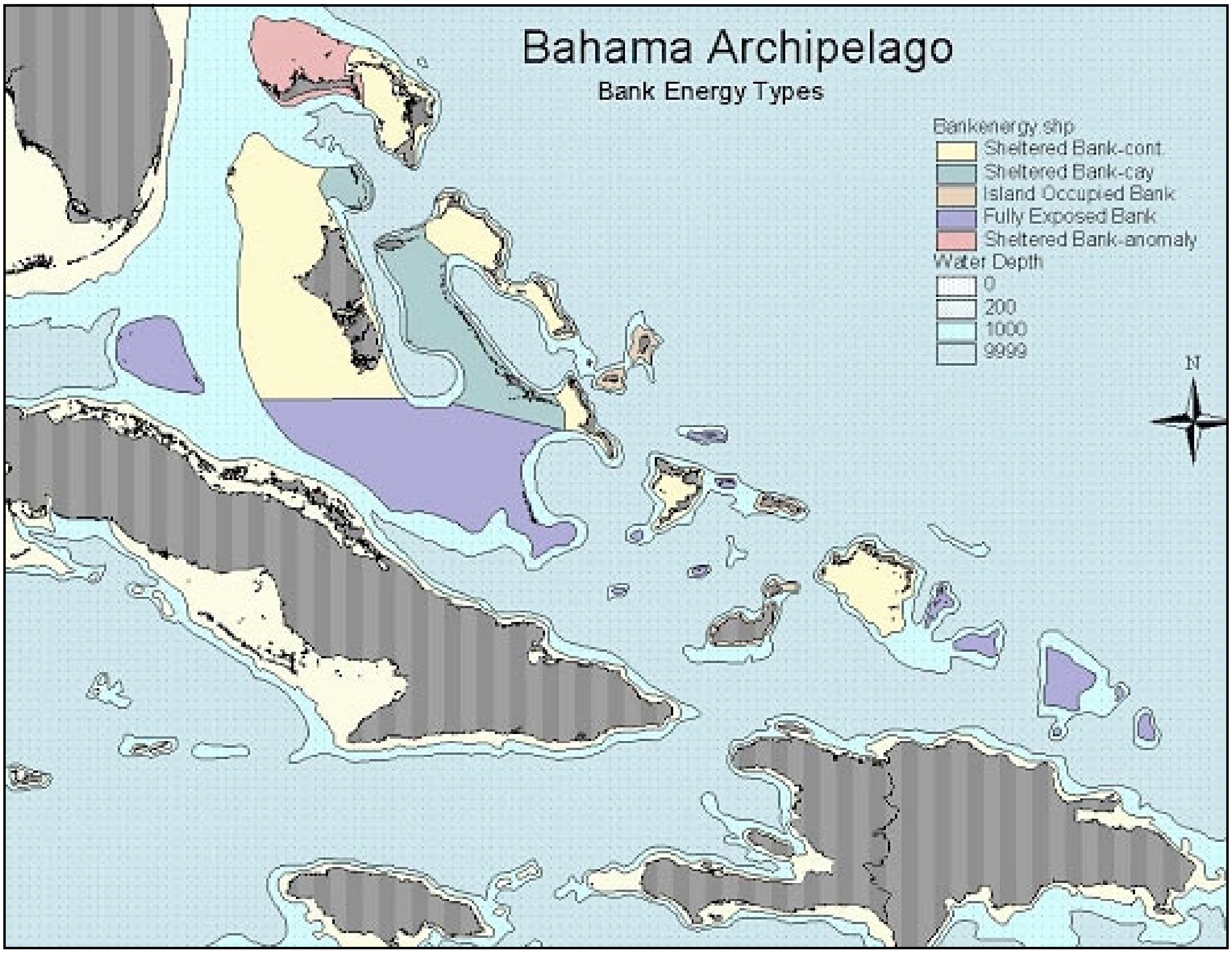

Figure 39. Map of the Bank Energy Types in the Bahamian archipelago

1.1. The Geography of the Bank and Island Systems

There are five bank types with 23 bank systems in the Bahamian archipelago. In the following, we describe the five types and some of the systems.

Sheltered banks with continuous cays

Long, often narrow, islands that stretch along the eastern platform margin dominate the sheltered banks. The islands comprise high energy, wind-blown environments along their eastern shore, and protected coastal wetlands and beaches along the western shores. The island also provides a barrier to wave energy, and creates extensive soft sediment habitats to its west. Sheltered banks with continuous cays include the Western Great Bahama Bank (Andros, the largest island, and the Biminis), Caicos Bank, Eastern Little Bahama Bank (Abacos), Eleuthera, Crooked and Aiklins Bank, Cat Island and Long Island.

Table 7: Bank Classification Areas and Perimeters
[Based on UTM 18 projected base map of the archipelago]

Bank type	**Bank name**	**Bank area** [sqkm]	**Bank perimeter** [km]	**Island area** [sqkm]	**Shoreline-** [km]
Sheltered	Western Great Bahama	35,564	704	5,124	1,665
	Caicos	6,856	375	489	568
	Eastern Little Bahama	6,053	302	1,359	1,315
	BankEleuthera	5,191	317	448	512
	Crooked and Aiklins	3,034	258	758	476
	Cat Island	1,917	233	354	242
	Long Island	1,698	220	485	321
Total		60,313	2,409	9,017	5,099
Sheltered with cays	Central Bahamas	14,586	538	586	763
	Berry Islands	2,473	144	45.3	152
Total		17,059	682	631.3	915
Islands occupied	Great Iguana	962	229	1,479	228
	San Salvador	780	142	149	73
	Mayaguana	599	144	268	127
	Rum Cay	511	104	83	54
	Samana	339	100	33.5	31.5
	Little Iguana	335	99	113	48
	Plana Cays	206	61	16.2	33.4
	Conception Island	16	18	7.9	13.5
Total		3,748	897	2,149.6	891.9
Fully exposed	Southern Great Bahamas	33,389	733	29.4	95
	Cay Cal	6,040	306	8.8	48
	Silver Banks	2,833	226	0	0
	Mouchoir	958	149	0	0
	Turks Islands	607	137	22.7	41.2
	Navidad	434	83	0	0
	Mira Por Vos	134	44	0	0
	Hogsty	133	47	1	4.1
	Brown	83	38	0	0
Total		44,611	1,783	61.9	188.3
Anomalous	Western Little Bahama	8,716	353	1,112	657
Totals for the Archipelago		**134,447**		**12,972**	

Western Great Bahama

The western Great Bahama bank includes the largest island (Andros) and bank area. Andros and the Biminis include important island environments. Andros is by far the largest Bahamian island, although this is somewhat misleading, as it comprises a number of separate islands. For this reason the area described here as North Andros is limited to the contiguous territory stretching from Morgan's Bluff to Behring Point. The remainder, described as *South Andros*, comprises a considerable number of separate islands separated by a large number of bights and creeks.

North Andros

Despite being considered a single island, North Andros nevertheless has a high percentage of completely or partially enclosed water bodies. These include a number of lengthy tidal creeks, which, although they do not separate the landmass, create quite an impediment to free movement along the populated east coast. Best known of these are Fresh Creek, Stafford Creek and Staniel Creek.

Although North Andros has a well-defined coastal ridge, which reaches just over 30.5 meters, and exceeds 18.3 meters at many locations north of Fresh Creek, it is similar in origin and structure to Grand Bahama. South of Fresh Creek the landscape is less distinguished with fewer creeks, lower relief, and smaller lakes. Apart from the east coast, little of North Andros exceeds 6 meters in altitude. The interior is flat and heavily forested with Caribbean Pine. About halfway across the island forested areas give way to extensive mangroves as the water table reaches the surface, and eventually even this landscape is reduced to extensive mud flats that account for about one third of the land area. Here, the marine influence is often overwhelming, with complete inundation during storms being on record, a condition we find on West Abaco as well.

It has been reported that in one winter in the 1970s a pond in North Andros froze over, certainly a rare event for the Bahamas. North Andros is sufficiently close to the North American continent to be chilled by cold air masses in winter, and as such has a more extreme winter than nearby New Providence further east. In addition, its considerable land mass allows for radiative cooling during the night to a greater extent than any other island, most of which are narrow and easily penetrated by warm, moist oceanic winds. Similarly fog is not uncommon either.

The eastern shores of Andros are exposed to the almost continuous NE Trade winds blowing year round, but is quite sheltered inland. In the summer, excessive heating inland leads to considerable convection and the creation of thunderstorms. These reach sufficient height that they can be seen from Nassau, and they add to the rainfall total for the island. North Andros receives some 152.4 centimetres of rain a year, which helps sustain the by far largest reservoirs of fresh water in the country. One of these lenses is known to have a central thickness in excess of 30.5 meters.

Most of the areas located more than two feet below the water table support Caribbean Pine Forest, which was extensively logged until the 1970s. In the far north, several commercial farms were established in the1960s, and North Andros continues to be a major farming area today.

No account of Andros would be complete without mentioning its remarkable blue holes. Over 100 of these have been identified on land and in the sea, with depths exceeding 121.9 meters in a few cases. Blue holes are the present expressions of large solution holes dating back to the Pleistocene and have been widely researched for evidence of past sea levels.

South Andros

This section of Andros is defined as all those islands south of the North Bight, namely Big Wood Cay, Mangrove Cay and South Andros, plus all adjacent smaller islands and cays. Like in North Andros there are many creeks that penetrate far inland, notably Deep Creek and Little Creek. More striking, however, are the numerous islands 1.5 to 4.6 meters above sea level created by the channels and their numerous branches, known as North Bight, Middle Bight and South Bight. These broad, shallow channels are navigable by small boat all the way through to the Great Bahama Bank. The area is noted for its sponge fishing, and the Bights contain a number of blue holes.

Mangrove Cay and South Andros proper are substantial islands with permanent settlements. Like North Andros, they have a coastal ridge, reaching 27.4 meters in height. The interior is flat, forested, and grades into marls on the west coast. The total land area is, however, substantially less than in North Andros.

The main characteristic of the east coast is a striking fault line running just inland from the shoreline, clearly visible from South Bight south to Mars Bay, where it continues offshore. This probably accounts for the relative straightness of the coast, and is also the location for many elongated blue holes along its line. The fault seems to be in the nature of a cleft related to slippage of the bank edge along this part of the tongue of the Ocean.

With the exception of settlements along the coast, this entire area is probably the largest, unexplored and least known part of the Bahamas.

The Kemp's Bay meteorological station in South Andros recorded an annual average of only 89.9 centimetres of rain for the period 1978-90, and this part of Andros is clearly drier and warmer in winter than North Andros. Otherwise summer temperatures are similar, and the Trade Winds reach the east coast throughout the year.

Bimini Islands

The cays and islands of the Bimini chain are unusual in that they are located on the lee side of a major bank. Altogether there are about ten small islands, but only North and South Bimini and Cat Cay are of any size. This is the result of the limited wind and wave action from the west across the Gulf Stream.

Most of North Bimini is a thin ridge reaching about 6 meters in elevation, although quite steep despite its low height, and this is the occupied area. To the north and west the land is without hills, and the western section is exclusively very low land, wetland and tidal creeks. The limited dry land in this area is the remains of a complex spit, although the large eastern limb is well formed and active at the present time.

South Bimini has developed rather differently, consisting of a similar low ridge facing the Florida Straits. But in this case it is backed by a mile or so of extensive wetland, and then by rock land, the total being some four miles of a very flat topography.

The rainfall reflects the northern location and averages 112 centimetres per year. Being well to the west on the Great Bahama Bank, it is not especially exposed to the NE trade winds, but is vulnerable to cold air masses from the nearby Florida peninsula throughout the winter months, resulting in quite variable weather conditions during that season.

North Bimini is essentially cleared of all vegetation apart form the uninhabited western sector, which is mostly mangrove swamp, although invasive casuarinas occupy much of the drier ground. South Bimini is cleared of vegetation in the west, with much of the wetland having been reclaimed. It is still home to extensive broadleaf woodland, fairly luxurious as a result of the heavier rainfall, but vulnerable to salt water intrusion.

Eastern Little Bahama Bank

Grand Bahama Island is anomalous in its orientation in the archipelago. The island extends along the southwestern margin of Little Bahama Bank and covers 1,112 km^2. Grand Bahama has extensive mangrove wetlands along the northern and eastern margins of the island. Most of the development in the cities of Freeport and Lucaya occur along the southern coast, an area dominated by pine woodlands with coastal strand and beaches.

Eleuthera

This is a typical long narrow Atlantic margin island, measuring about 144.8 kilometres in length, and rarely exceeding 4.8 kilometres in width. The largest landmasses and widest areas of the island are in the north and south, which also hold the largest water lenses, and to a lesser extent in the south, between Tarpum Bay and Rock Sound. Most of the island is narrow, with hills, especially in the north where there is a breach at Glass Window. Between Glass Window and Savannah Sound the island has substantial cliffs on both shorelines. The geological structure in this area is a series of overlapping fossil sand dunes forming a low table and frequently exceeding 30.5 meters in height. The highest point is 51.2 meters. Notably outlying islands, usually detached ridges, include Russell Island/St George's Island (Spanish Wells), Current Island, Harbour Island and Windermere Island, all of which are inhabited. Low-lying rock land is limited in extent, but most evident in North Eleuthera, the name given to the triangular area north of the Glass Window, around Tarpum Bay, and in the far south.

The island forms the north-eastern extremity of the Great Bahamas Bank, and has a strongly eroding coastline, with some evidence for bank margin collapse in the recent geological past, notably at Glass Window where the scalloped margin suggests bank margin retreat. The karstified surface limestone is generally sufficiently young to be scarified for agricultural purposes, and the island has been significantly transformed by early plantation settlers, and later by subsistence farmers. Even today, Eleuthera is an important agricultural producer with several large commercial farms.

Being in the northern part of the Bahamas, Eleuthera has a distinct mild winter season and is affected by cold fronts from North America. This also increases the amount of rain in an otherwise dry season. However, total annual rain averages amount to only 127 centimetres at Rock Sound. Being on the Atlantic fringe, Eleuthera is in the direct path of the Northeast Trade Winds, which blow steadily year round, although they take on a more southerly (E-SE) orientation in summer. Summers are hot and relatively wet with most of the rain falling as heavy showers, or from tropical storm or hurricane activity. Eleuthera is in a higher hurricane risk zone than the southern Bahamas and was struck by both Andrew and Floyd in recent years.

<u>Long Island</u>

Long Island is the southernmost of the trio of Atlantic islands on the edge of Great Bahama Bank, and shares many characteristics with its neighbours to the north. The entire length of the island is dominated by a ridge with rolling hills, often exceeding 30 meters in height, with a maximum of 54 meters. The complex ridge is most consistent along the eastern shores, but there are many sections where hills span the entire width of the island. The northern and southern extremities terminate in cliffs at Cape Santa Maria and Cabo Verde respectively, and there are many cliffs along the eastern coast. The western coast does have some unusual features however, most notably the extensive wetlands along the southern half of the island. The most northern of these is known as Grand Pa's Channel, and abandoned salt works occupies a large part of the southern area. Numerous canals and dykes serving these salt works have altered much of this landscape.

A somewhat exceptional feature of Long Island is the presence of two substantial cave systems. All islands have caves, this being a normal consequence of karst erosion, but Salt Pond Cave and the Cartwright Cave in central Long Island are among the two largest in the Bahamas.

The largest flatland areas are in the vicinity of Deadman's Cay and Grays, and further north around Simms. Past and present farming has altered much of the vegetation.

Being further south Long Island is relatively dry with an average rainfall of around 89 centimetres per year. While the dryness was the reason for the solar salt operations, occasional tropical storms and hurricanes created severe flooding leading to the demise of the salt operations and serious restrictions on agriculture. Temperatures are tropical all the year round with exposure to NE Trade Winds accounting for the extensive modern sand dunes along most of the eastern shores. Vegetation is generally broad-leaved tropical hardwood with extensive mangroves along the western shores.

Sheltered banks with discontinuous cays

Some eastern margins of the banks are made up of island chains. The Exumas, with their chain of small islands, are unique in the archipelago with channel habitats and creeks between the islands. The bank systems allow water to move on and off the banks through these channels, and create unique oolitic banks and bars. The Exuma and Berry island chains represent this bany type. New Providence Island falls into this bank type. The most populated island is near the platform margin, with many smaller cays nearby, and strong tidal currents sweeping around the island in channels. For New Providence, this setting provides a strong "cleaning" effect of removing land-based sources of pollution from waters adjacent to the capital, Nassau.

<u>Central Bahamas</u>

Great Exuma, together with its southern extension, Little Exuma, is a fairly small island similar in size to New Providence and San Salvador, but lacking their compactness of shape. Exuma lies on the southern half of the Great Bahamas Bank, and owes its existence to Exuma Sound, across which the NE Trade Winds blow to create the hilly ridges, which are the basis of the island, except in the west.

The outermost ridge, the youngest, forms mostly islands off the eastern shore, such as Stocking Island, which in turn creates Elizabeth Harbour in its lee. This ridge is responsible for most of the Exuma Cays, and Little Exuma, which are joined to its neighbour by a causeway. A second complex dune structure is the basis for most of the eastern shore of Great Exuma, and reaches over 30 meters in several places, although this island is neither as high nor as hilly as its Atlantic counterparts further east.

As a result of its generally greater amount of lowland, this island supports a fair amount of agriculture, including an unusual area of reclaimed freshwater marshland. Unlike the three Atlantic Islands, also on the Great Bahama Bank, but more like Abaco in the north, the fringing islands provide shelter for the coast, and settlement is concentrated along the eastern shores.

Rainfall in the Exumas is close to 102 centimetres per year on average, a bit more than the easterly islands in this latitude. This is accounted for by its closer proximity to the US and winter frontal systems, and its wider landmass, which allows convection cells to develop and rain to fall on the island rather than offshore. The Atlantic islands often see similar cells producing rain over the sea to the west of them. Despite this, Little Exuma in the far south is much drier and supports salt pans that are still productive.

Temperatures are not as extreme as in the northern Bahamas, but overall the Exumas experience tropical summers and warm winters. Extensive broadleaf woodland exists, but since this area was a major destination for Loyalist plantation farmers, extensive cutting has removed all the original growth. Land clearance, for farming and speculative development, has also reduced even secondary growth, but despite this there is a widespread vegetational cover over the island, which includes extensive wetland in the west, as well as significant wetland areas in the north of the island immediately behind the ridge land.

Island occupied banks

Great and Little Inagua

Great Inagua is the largest of the southern islands, roughly similar in size to Abaco and Grand Bahama. Being so far south, the dominant wind direction is more easterly and southerly due to the orientation of the NE Trades in summer, and the fact that Inagua occupies its own bank. Ridges line the eastern and southern coasts, reaching over 30 meters in several places, and also occupy the central part of the north coast. The rest of the island is extremely flat and lakes, of which the largest is Lake Rosa, occupy large parts of it. Little of this area is more than five feet above sea level.

Little Inagua is a substantial (79 square kilometres) but uninhabited outlier on this bank, quite hilly around its shoreline, and heavily forested. It was declared a National Park in its entirety in 2002. Great Inagua is also largely uninhabited, despite a substantial settlement in the far southwest at Matthew Town. The main attraction of this island has been its natural salt lakes, which have been raked for salt for centuries, first in natural saltpans south of Matthew Town, but for the last 50 years the main production has been from a giant manmade solar salt system laid out over the western half of Lake Rosa. This area is quite different from the natural wetland elsewhere, partly because of the causeways and dykes that control the movement of water, but also because of the increased salinity. The eastern half, which is part of a National Park, retains its original character, and is noted for its large flocks of West Indian Flamingos.

This is one of the driest islands in the whole region with an average annual rainfall of just 66 centimetres, hence the survival of the salt works. These semi-arid conditions, combined with the pervasive NE Trade Winds, have led to the development of xerophytic vegetation over much of the island. On the somewhat wetter ridges the stunted broadleaf woodland has been described as a ‘bonsai forest’.

Being well below the Tropic of Cancer, the Inagua islands have hot summers and winters, the main difference being in the higher humidity of summer, which brings most of the limited rainfall, and clouds of mosquitoes. January is the coolest month and averages about 75F, while August Averages 83F, the average range of 8F being the smallest in the Bahamas (New Providence range is 15F).

San Salvador Island

With 101.3 square kilometres, this island is somewhat similar in size to New Providence, and also fairly compact in shape. In all other respects it is quite different from its northern counterpart; it is the sole occupant of its bank and the most easterly of the central Bahamian Islands.

The higher ground, maximum elevation 37 meters, is composed of arcuate ridges clearly identifiable in all parts of the island. These ridges have led to the formation of a large number of lakes, arcuate in shape as they are trapped between the curving ridges. Together these ridges occupy about half of the inland surface. Away from the ridges there are extensive areas of less hilly rock land, and the east coast is an almost continuous beach flanked by a modern dune behind which a number of lakes, often hyper saline, are trapped. An unusual feature is Pigeon Creek in the south, providing limited small boat access well inland. Research suggests that Storr’s Lake to the north of Pigeon Creek, and some other smaller lakes, were also creeks that have subsequently had their outlets silted up.

Three-quarters of the island is surrounded by a fringing reef, creating a large natural harbour in the north. There are a number of offshore cays in the north and south, some of which contribute to the northern harbour. This is the most studied island in the Bahamas and excellent detailed accounts of its geology exist.

With a rainfall averaging 90 centimetres per year, San Salvador is a bit wetter than its northern neighbours, and this may be accounted for by its shape, and the extensive water bodies inland, both conducive to convection currents. It is also more exposed to oceanic forces and receives additional rain from passing tropical storms, although this is not a regular feature.

Temperatures are normal for the central Bahamas, but exposure to weather from all points of the compass makes the island rather windier than for instance Exuma. The NE Trade Winds are strong and relatively uninterrupted apart from high-pressure systems travelling south in winter, when a northwesterly wind is common.

The island was among the earliest inhabited and, although abandoned by the Lucayans and Spanish explorers, planters who created a number of large cotton estates resettled it. Much of the vegetation was cleared for this purpose, but otherwise the island is now well-wooded and only parts of the coastal fringe are farmed on a casual basis.

Rum Cay

Rum Cay is about half the size of its neighbour San Salvador, which lies about 40 kilometres to the northeast. It occupies its own bank, and like san Salvador is comprised of multiple ridges that occupy all parts of the island.

Ridges reaching over 30 meters line the north, south, and east coasts, and parts of the interior, notably in the centre. Elsewhere there is low-lying swampy ground between the hills, but only one significant lake, Lake George, close to east coast. The Port Nelson Salt Lake in the southeast is actually open to the sea and tidal, but even bigger than Lake George and almost entirely landlocked. As its name implies, this area has been used for salt raking, a practice still undertaken in recent times. There are many ponds scattered throughout the interior, most notably in the south centre where several large ponds follow the line of prominent accurate ridges reminiscent of San Salvador. The only settlement is adjacent to the salt ponds.

Being on an isolated bank the climate is essentially the same as San Salvador's, and the island is well vegetated. There have been few settlement in recent years. The original plantations are limited to the southern areas.

Mangrove swamps are common inland around the ponds and in depressions, and especially along the western edge of Lake George, but like all the islands on isolated banks there is little coastal wetland.

Fully exposed banks

Fully exposed or submerged banks in the archipelago present unique habitats. Islands, if present are small, and persist along the platform margins (e.g. Cay Sal and Ragged Islands). The bank ecology is dominated by ocean processes and up welling.

The anomalous bank system

Grand Bahama

Grand Bahama shares the Little Bahama Bank with Abaco, but unlike that island it is very flat, the highest point being just 20.7 meters above sea level. It also lacks the long ridges that characterize most other islands, and even small cays. This is to a large extent due to its location along the southern margin of the Little Bahama Bank, where it is sheltered from the prevailing NE Trade Winds and winter northerlies. Only the gentler south-eastern winds of summer have created land from the sea at the edge of this bank, and initially the island was little more than a series of low-lying cays. In this respect it has a lot in common with Andros, and the Joulter cays are probably proto-island masses of this type. To the east, the sequence of about eight large cays stretching from McLean's Town to East End Point are relicts of what the rest of the island must have once looked like.

The topography is unusual, lacking even a low coastal ridge. The shoreline is often swampy, and the higher elevations of 6-9 meters are scattered inland to create a very gently undulating plain. These discontinuous minor swells in the surface represent the earlier dry land of the original cays, and there is still much evidence of the former separating creeks in strips of wetland, and even creeks such as Hawksbill Creek, now much altered by the creation of Freeport Harbour.

The northern part of the island, especially in the middle, is always less than ten feet above sea level and grades into marshland and scattered cays, some quite large and even inhabited, notably Water Cay. The apparent spit of land terminating in West End is extremely low and rarely exceeds 3 meters.

The northerly location of Grand Bahama ensures a more marked winter-summer regime, and greater rainfall, than the islands to the south. Annual rainfall averages 152.4 centimetres. The winter months are markedly cooler than elsewhere in the Bahamas, this being the only island ever recording falling snow! During the passage of cold fronts temperatures in the 40s are not uncommon, but once summer has set in the temperatures are little different than elsewhere in the Bahamas.

The extent of level land and higher rainfall has ensured the development of large water lenses, and associated with these, extensive Caribbean Pine forests. Many were logged in the 20th century but were left to recuperate since the 1970's. Abundant water and the logging industry led to the establishment of a new town in the 1960's and today Freeport/Lucaya is the second largest city of the Bahamas. The flat topography facilitated the construction of numerous sub-divisions with canals, and marinas, which at the same time provided much needed landfill material.

2. Classification of Natural Communities: Uplands

2.1. Introduction

A recent characterization of the major ecological zones of the Earth into ecoregions (Bailey, 1998) has resulted in a change in the current approach to land conservation and management. As a result of this change, the need to understand and document landscape-scale natural systems and land use changes over time has become a major focus of both conservation groups and government agencies, particularly the US Geological Survey. The primary source of information used in ecosystem documentation is remote sensed imagery, or satellite imagery. Status assessment of documented landscape-scale natural systems has required the use of a standardized vegetation classification system, which is needed both to compare the status of vegetation cover across ecosystems or across regions, and to conduct a gap analysis to assess the protected status of particular species or particular vegetation types (for more information on gap analysis see the website at http://www.gap.uidaho.edu). In the following, we describe vegetation classification and classification systems, particularly those developed for use in the Caribbean (Areces-Weakley et al., 1999).

Characterizing and differentiating vegetation communities involves grouping observations into classes, the members of which share common characteristics. Historically, vegetation communities have been grouped by physiognomic and environmental characteristics, but the great variety of those characteristics that exist meant that no classification system could be used to compare across different regions. In the 1980's, a push to standardize the way plant communities are classified resulted in the development of a framework for classifying vegetation at course scales. The proposed system established physiognomically and environmentally characterised vegetation types in a multiple-tiered classification hierarchy, which allows for possible comparisons at each successive level. A modified version of this framework, the International Classification of Ecological Communities (ICEC), adds finer levels of classification to incorporate floristic characteristics or vegetation composition. The hierarchical levels incorporated in the ICEC are as follows:

- Class
  - Subclass
    - Group
      - Subgroup
        - Formation
          - Alliance
            - Association

The first five levels in the classification hierarchy separate vegetation types according to physiognomic differences and include some environmental characteristics. The remaining two levels, Alliance and Association, represent the finest classification of vegetation. The ICEC was selected by the United States Federal Geographic Data Committee as the national standard for describing vegetation in the United States, where it is also known as the National Vegetation Classification and Information Standard (http://www.fgdc.gov/Standards/Status/sub2_1.html). The ICEC system was refined for use in a recent system of classification and description of Caribbean vegetation (Areces-Weakley et al., 1999) as a part of the Caribbean Vegetation and Landcover Mapping Initiative.

2.2. Overview of Caribbean vegetation Classification Effort

Over the centuries, most botanical expeditions and research efforts conducted in the Caribbean have targeted individual islands. Very few regional vegetation studies have been completed that cover the entire Caribbean archipelago and are sufficiently detailed to be of practical value in the assessment of vegetation community status and distribution. Various systems of classification have however, been proposed for the vegetation of a few groups of Caribbean islands, or for individual islands themselves. None of these have sufficient detail to prove useful for landscapes with the high variability and degree of endemism that exists in the Caribbean. Neither do they provide the classification structure needed for assessments of conservation status or distribution of vegetation types.

Accurate and up-to-date land cover/vegetation information is essential for conservation and management of natural resources and biodiversity. The Caribbean Vegetation and Landcover Mapping Initiative, which is a result of collaboration between The Nature Conservancy, the International Institute of Tropical Forestry, the US Forest Service, EROS Data Center, and the US Geological Survey, developed partly out of concern for the lack of such information in the Caribbean. The purpose of this initiative is to produce vegetation/land cover maps for the islands of the Caribbean based on satellite imagery and other remote sensed data, and to produce a standardized vegetation classification system for the greater Caribbean region. To date, a region-wide standard vegetation classification system and a preliminary atlas of existing vegetation/ landcover maps for the region have been completed. Here we use a subset of the Caribbean vegetation classification system in describing vegetation communities of the Bahamas at the formation level.

2.3. Standardized Terminology for Classifying Vegetation

The following terms and definitions, adapted from 'A Guide to Caribbean Vegetation Types; Classification Systems and Descriptions' (Areces-Weakley et al., 1999), are used in the International Classification of Ecological Communities (ICEC). We include this glossary here, prior to presentation of the classification system, to simplify understanding of the vegetation descriptions for the Bahamian Archipelago.

Assemblages - Vegetative communities composed of several to many different species of plants that assemble themselves based on specific site conditions and the presence of seed. Plants that occur along a rocky shoreline in the Bahamas are considered an assemblage.

Association - The finest level of the classification standard. The association is a physiognomically uniform group of vegetation stands that share one or more diagnostic (dominant, differential, indicator, or character) over story and under story species. These elements occur as repeatable patterns of assemblages across the landscape, and are generally found under similar habitat conditions. (the association refers to existing vegetation, not a potential vegetation type). A seaside community dominated by sea oats (*Uniola paniculata*) is considered an association in the Bahamas.

Brackish - Tidal water with a salinity of 0.5-30 parts per thousand.

Broad-leaved - A plant with leaves that have well defined leaf blades and are relatively wide in outline (shape) as opposed to needle-like or linear; leaf area is typically greater than 500 square millimetres or 1 square inch. Examples of broad-leaved plants in the Bahamas are Sabal palm (*Sabal palmetto*) and Pigeon Plum (*Coccoloba diversifolia*).

Canopy Cover - The proportion of ground, usually expressed as a percentage that is occupied by the perpendicular projection down on to it of the aerial parts of the vegetation or the species under consideration. The additive cover of multiple strata or species may exceed 100%.

Classification - The grouping of similar types (in this case - vegetation) according to criteria (in this case - physiognomic and floristic), which are considered significant for this purpose. The rules for classification must be clarified prior to identification of the types within the classification standard. The classification methods should be clear, precise, where possible quantitative, and based upon objective criteria, so that the outcome would be the same whoever performs the definition (or description). Classification necessarily involves definition of class boundaries (UNEP/FAO, 1995).

Closed Tree Canopy - A class of vegetation that is dominated by trees with interlocking crowns (generally forming 60-100% canopy cover). A closed tree canopy can be found in many coppice communities in the Bahamas.

Cover - The area of ground covered by the vertical projection of the aerial parts of plants of one or more species.

Cover Type - A designation based upon the plant species forming a plurality of composition within a given area (e.g., Mangrove-Buttonwood).

Deciduous - A woody plant that seasonally loses all of its leaves and becomes temporarily bare-stemmed. An example of a deciduous tree in the Bahamas: Mahogany (*Swietenia mahagoni*).

Deciduous Cover - Vegetation classes where 75% or more of the diagnostic vegetation is made up of tree or shrub species that shed foliage simultaneously in response to environmental conditions.

Division - This is the first level in the classification standard separating Earth cover into either vegetated or non-vegetated categories (see also Order).

Dominance - The extent to which a given species or life form predominates in a community because of its size, abundance or cover, and affects the fitness of associated species. Dominance is interpreted in two different ways for vegetation classification purposes:
Where one or more vegetation strata (life form) covers greater than 25% (represented by the —— line), the life form greater than 25% which constitutes the uppermost canopy is referred to as the dominant life form.

100% 25% 0%
|————————————————————————|------------------------|

Where no vegetation life form covers greater than 25% (represented by the - - - line), the life form with the highest percent canopy cover is referred to as the dominant life form. In the case of a 'tie', the upper canopy will be referred to as the dominant life form.

100% 25% 0%
|- -- - - - |————————|

Dominant - An organism, group of organisms, or taxon that by its size, abundance, or coverage exerts considerable influence upon an association's biotic (such as structure and function) and abiotic (such as shade and relative humidity) conditions. Mangrove communities are often dominant along low energy, low profile shorelines in the Bahamas.

Drought Deciduous - Vegetation in which the leaves drop in response to annual environmental conditions characterized by drought. Applied to vegetation from climates with seasonal drought and little cold-season influence (tropical-subtropical). In the Bahamas, the season characterized by drought is late winter.

Dwarf Shrubland - A class of vegetation dominated by a life form of shrubs and/or trees under 0.5 m tall. These types generally have greater than 25% cover of dwarf shrubs and less than 25% cover of trees and shrubs. Herbs and non-vascular plants may be present at any cover value. Dwarf shrub lands are associated with wind-exposed rocky shorelines in the Bahamas.

Dwarf Shrubs - Multi-stemmed woody plants with a life form at a height of less than 0.5 m due either to genetic or environmental constraints.

Evergreen- A plant that has green leaves all year round; or a plant that, in xeric habitats, has green stems or trunks and never produces leaves. Examples in the Bahamas are the Caribbean pine tree *Pinus caribaea* var. *bahamensis* and the Turk's cap cactus *Melocactus intortuous*.

Evergreen Cover - Vegetation classes where 75% or more of the diagnostic vegetation consists of trees or shrubs having leaves all year. Canopy is never without green foliage. Palm or pine-dominated associations are evergreen.

Forb - A broad-leaved herbaceous plant. *Ipomoea pes-caprae* or goat's foot vine is one Bahamian forb.

Forest - A class of vegetation defined by areas dominated by trees generally greater than 5 m tall with individual crowns interlocking. Tree canopy coverage is at 100%. Other vegetation classes may be present at any coverage in the under story. Forests are found in inland areas on islands that hold significant freshwater lenses in the Bahamas.

Formation - A level in the classification based on ecological groupings of vegetation units with broadly defined environmental and additional physiognomic factors in common. This level is subject to revision as the vegetation alliances and associations are organized under the upper levels of the hierarchy. Different variables are applied to this hierarchical level in the sparsely vegetated class.

Fresh Water - Water with a salinity of less than 0.5 parts per thousand.

Graminoid - Grasses and grass-like plants, including sedges and rushes.

Grassland - Vegetation dominated by perennial graminoid plants. Shorelines dominated by sea oats are considered grasslands.

Hemi-sclerophyllous - A plant with stiff, firm, leathery leaves that retain their rigidity during wilting; for example, sea grape (*Coccoloba uvifera*).

Herb - A vascular plant without significant woody tissue above or at the ground; an annual, biennial, or perennial plant lacking significant thickening by secondary woody growth. Herbs can be feras grasses, grass-like plants, or forbs.

Herbaceous - A class of vegetation dominated by non-woody plants known as herbs. Herbs generally form at least 25% cover. Trees, shrub and dwarf shrub generally have less than 25% cover. In rare cases, herbaceous cover exceeds the combined cover of trees, shrubs, dwarf shrubs, and non-vascular plants and is less than 25% cover. Height classes for the graminoids are short (<0.5 m), medium-tall (0.5-1 m) and tall (>1 m). Height classes for the forbs are low (<1 m) and tall (>1 m). For both graminoids and forbs, the height classes are measured when the inflorescences are fully developed.

Hydrophyte - A plant that has evolved adaptations to live in aquatic or very wet habitats, e.g., cattail (*Typha domingensis*).

Hydromorphous Herbs - Herbaceous plants structurally adapted for life in water-dominated or aquatic habitats, e.g., cattail (*Typha domingensis*).

Lowland - A large land area with vegetation reflecting limits set by regional climate and soil/site conditions; an area where elevation is not the primary gradient affecting vegetation zonation. In the Bahamas, due to the proximity of the water table, small elevational differences may separate lowland vegetation from other vegetation.

Mixed Evergreen-deciduous - Vegetation in which evergreen and deciduous species each generally contribute 25-75% to the total canopy cover.

Mixed Evergreen Deciduous Cover - A class of vegetation types where trees (or shrubs) are the dominant life form and neither deciduous nor evergreen species represent more than 75% of cover present.

Natural/Semi-natural - Areas dominated by native or established vegetation that has not been cultivated or treated with any annual management or manipulation regime. In cases where it cannot be assessed whether the vegetation was planted or cultivated by humans, the vegetation is considered 'Natural/Semi-Natural'.

Needle-leaved - A plant with slender, elongated leaves; or leaf-like structures. For example, Caribbean pine trees (*Pinus caribaea* var. *bahamensis*).

Open Tree Canopy - A class of vegetation types dominated by trees with crowns not touching, generally forming 25-60% cover. Pine rock lands have an open tree canopy.

Order - This is the next level in the hierarchy under Division. The Orders within the Vegetated Division are generally defined by dominant life form (tree, shrub, dwarf shrub, herbaceous, or non-vascular).

Perennial - Plant species with a life cycle that characteristically lasts more than two growing seasons and persist for several years.

Physiognomic Class - A level in the classification hierarchy defined by the relative percent canopy cover of the tree, shrub, dwarf shrub, herb, and nonvascular life form in the uppermost strata during the peak of the growing season.

Physiognomic Group - A level in the classification defined by a combination of climate, leaf morphology, and leaf phenology. Different variables are applied to this hierarchical level in the sparsely vegetated class.

Physiognomic Subclass - A level in the classification determined by the predominant leaf phenology of classes defined by tree, shrub, or dwarf shrub stratum (evergreen, deciduous, mixed evergreen-deciduous), and the average vegetation height for the herbaceous stratum (tall, medium, short). Different variables are applied to this hierarchical level in the sparsely vegetated class.

Physiognomy - The structure and life form of a plant community.

Plantations - Areas dominated by trees planted with generally consistent row and plant spacing. Stands are planted for the purpose of producing a crop of timber or other products. Examples include planted pine or papaya stands.

Planted/Cultivated - Areas dominated with vegetation that has been planted in its current location by humans and/or is treated with annual tillage, modified conservation tillage, or other intensive management or manipulation. This includes: vegetation planted in built-up settings, for recreation, erosion control, or aesthetic purposes, all areas used for the production of crops of any kind, orchards, vineyards, or tree plantations. In cases where one cannot assess whether it was planted by humans (e.g., some mature forests), the vegetation is considered 'natural/semi-natural'.

Saltwater - Water with a salinity of greater than 30 parts per thousand.

Saturated - Surface water is seldom present, but substrate is saturated to the surface for extended periods during the growing season. Equivalent to Cowardin's (1979) 'Saturated' modifier. Pine rock lands with palm under stories grow on saturated limestone.

Scrub - Vegetation dominated by shrubs, including thickets. Scrub is common on undeveloped, elevated coastlines in the Bahamas.

Seasonal - Showing periodicity related to the seasons; applied to vegetation exhibiting pronounced seasonal periodicity marked by conspicuous physiognomic changes.

Seasonally Flooded - Surface water is present for extended periods during the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is variable, extending from saturated to a water table well below the ground surface. Includes Cowardin's (1979) Seasonal, Seasonal-Saturated, and Seasonal Well Drained modifiers. Some palm-dominated communities in the Bahamas are seasonally flooded.

Semi-deciduous Vegetation - Associations (tropical and subtropical) in which most of the upper canopy trees are drought-deciduous and many of the under story trees and shrubs are evergreen. Layers do not always separate the evergreen and deciduous woody plants.

Semi-evergreen Vegetation - Associations in which evergreen and deciduous species each generally contribute 25-75% of total tree cover; specifically, this term refers to tropical and subtropical vegetation in which most of the upper canopy trees are evergreen mixed with drought-deciduous trees.

Semi-permanently Flooded - Surface waters persists throughout growing season in most years except during periods of drought. Land surface is normally saturated when water level drops below soil surface. Includes Cowardin's (1979) 'Intermittently Exposed' and 'Semi-permanently Flooded' modifiers. In the Bahamas this refers to fresh or brackish-water flooded depressions.

Shrubland - A class of vegetation defined by areas dominated by shrubs greater than 0.5 m tall with individuals or clumps not touching to interlocking. Shrub canopy cover is greater than 25% while tree cover is less than 25%.

Shrubs - Woody plants greater than 0.5 m in height that generally exhibit several erect, spreading, or prostrate stems; and have a bushy appearance. In instances where life form cannot be determined, woody plants greater than 0.5 m in height, but less than 5 m in height will be considered shrubs.

Sparsely Vegetated - A class of vegetation types that are defined as having a surface area with 1-10% vegetation cover over the landscape at the peak of the growing season. Many tidal mudflats are sparsely vegetated.

Subgroup - A level of the hierarchy that splits Natural/ Semi-Natural vegetation types from the Planted/ Cultivated vegetation types.

Subtropical - Pertains to areas within tropical regions with variable (seasonal) temperature and moisture regimes; climatically, it has seasonal variation marked by dry/wet seasons rather than cold/hot seasons; parts of this region are subject to sub-0º C (32º F) temperatures but rarely have freezing periods of 24 hours or longer; in the United States this term includes southern Florida and the southern tip of Texas. The Bahamas lies at the border between tropical and subtropical.

Succulent - A plant with fleshy stems or leaves with specialized tissue for the conservation of water; a xeromorphic strategy for tolerating long periods of drought. Saltwort (*Batis maritima*) is succulent, as are cacti (e.g. *Opuntia, Cereus*).

Temporarily Flooded - Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Often characterizes flood-plain wetlands. Equivalent to Cowardin's (1979) Temporary modifier. Mudflats are often temporarily flooded.

Tidally Flooded - Areas flooded by the alternate rise and fall of the surface of oceans, seas, and the bays, rivers, etc. connected to them, caused by the attraction of the moon and sun [or by the back-up of water caused by winds].

Trees - Woody plants that generally have a single main stem and have more or less definite crowns. In instances where life form cannot be determined, woody plants equal to or greater than 5 m in height will be considered trees.

Tropical - Geographically, the area between the Tropic of Cancer (23º 27' N) and the Tropic of Capricorn (23º 27' S); climatically, the tropics are described as either the equatorial limits of freeze or, in temperate marine locations without freezing, the 65º F isotherm for the coldest month of the year; generally, tropical regions are characterized by high mean temperatures, small annual variation in temperature, and abundant rainfall throughout the year. Though the Bahamas are north of the Tropic of Capricorn, the maritime, warm water environment dominates the climate, making conditions borderline between tropical and subtropical.

Vegetation - The collective plant cover over an area.

Vegetation Cover - Vegetation that covers or is visible at or above the land or water surface. It is a sub-category of Earth cover. The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants.

Woody Plant - Plant species life form with woody tissue and buds on that woody tissue near or at the ground surface or above; plants with limited to extensive thickening by secondary woody growth and with perennating buds.

Woody - Containing lignified of hardened plant tissue.

Woodland - A class of vegetation defined by areas dominated by trees greater than 5 m tall with individual canopies not interlocking, leaving open gaps. Tree canopy coverage is usually not greater than 75%. Other vegetation classes may be present at any coverage in the under story. An example of woodland in the Bahamas is pine rockland.

Xeromorphic (Scleromorphic) - Having structural characteristics common among plants adapted to drought, i.e., small thick leaves with sunken stomata or revolute margins, surfaces that are heavily pubescent, waxy or highly reflective and small vein islets. Cacti, which are common in the Bahamas, are xeromorphic

2.4. Vegetation Formations Occurring in the Bahamas

Adapted from Areces-Mallea et al. (1999). We have kept the numerical system designated by the original document to avoid confusion in cross-referencing (Note: Pictures of example formations may not be the same as the described one. *Alliances may be completely dominated by non-native vegetation).

Order:		Tree dominated
Class:	I.	Closed Tree Canopy
Subclass:	I.A.	Evergreen Forest
Group:	I.A.3.	Tropical and sub-tropical seasonal evergreen forest
Subgroup:	I.A.3.N.	Natural/Semi-natural
Formations:	I.A.3.N.a.	Lowland tropical or subtropical seasonal evergreen forest

Figure 40. Coppice community on Andros

Group:	I.A.5.	Tropical and subtropical broad-leaved evergreen sclerophyllous closed tree canopy forest
Subgroup:	I.A.5.N.	Natural/Semi-natural
Formations:	I.A.5.N.f.	Semi permanently flooded tropical or subtropical broad-leaved evergreen sclerophyllous forest

Figure 41. Mangrove Forest on Andros

Group:	I.A.7.	Tropical or subtropical needle-leaved or needle stemmed evergreen forest
Subgroup:	I.A.7.C.	Planted/Cultivated
Formations:	I.A.7.C.b.	Casuarina forest plantation*

Figure 42. Shoreline Casuarina on New Providence

Subclass:	I.C.	Mixed evergreen-deciduous forest
Group:	I.C.1.	Tropical or subtropical semi-deciduous forest
Subgroup:	I.C.1.N.	Natural/Semi-natural
Formations:	I.C.1.N.a.	Lowland semi-deciduous forests

Figure 43. Dry Coppice community on New Providence

Class:	II.	Woodland
Subclass:	II.A.	Evergreen woodland
Group:	II.A.1.	Tropical or subtropical broad-leaved woodland
Subgroup:	II.A.1.N.	Natural/Semi-natural
Formations:	II.A.1.N.c.	Seasonally flooded/saturated tropical or subtropical broad-leaved Evergreen woodland

Figure 44. Sabal Palm community on Bell Island

Formations: II.A.1.N.f. Hemisclerophyllous tropical or subtropical broad-leaved evergreen Woodland

Figure 45. Sea grape community on Andros

Formations: II.A.1.N.h. Solution-hole evergreen woodland

Figure 46. Sinkhole growth on Eleuthera

Formations: II.A.1.N.x. Saturated tropical or subtropical broad-leaved evergreen woodland

Figure 47. Wetland community on Andros

Subgroup: II.A.1.C. Planted/Cultivated
Formations: II.A.1.C.a. Orchards

Figure 48. Fruit tree orchard on Andros

Group:	II.A.3.	Tropical or subtropical needle-leaved evergreen woodland
Subgroup:	II.A.3.N.	Natural/Semi-natural
Formations:	II.A.3.N.a.	Tropical or subtropical needle-leaved evergreen woodland

Figure 49. Pine woodland with shrub under story on Abaco

Formations: II.A.3.N.d. Saturated tropical or subtropical needle-leaved evergreen woodland

Figure 50. Pine rock land, with a palmetto under story on New Providence

Subgroup:	II.A.3.C.	Planted/Cultivated
Formations:	II.A.3.C.a.	Casuarina woodland plantation

Figure 51. Casurina along shoreline on Grand Bahama Island

Subclass:	II.C.	Mixed evergreen-deciduous woodland
Group:	II.C.1.	Tropical or subtropical semi-deciduous woodland
Subgroup:	II.C.1.N.	Natural/Semi-natural
Formations:	II.C.1.N.a.	Tropical or subtropical semi-deciduous woodland

Figure 52. Dry coppice community on Andros

Class:	III.	Shrub land (scrub)
Subclass:	III.A.	Evergreen shrub land (scrub)
Group:	III.A.1.	Tropical and subtropical broad-leaved evergreen shrub land
Subgroup:	III.A.1.N.	Natural/Semi-natural
Formations:	III.A.1.N.a.	Tropical or subtropical broad-leaved evergreen shrub land (includes bamboos and tuft-trees)

Figure 53. Coastal Palm, sand substrate on Andros

Formations:	III.A.1.N.b.	Hemisclerophyllous tropical or subtropical broad-leaved evergreen shrub land

Figure 54. Scrubby coastal sea grape community on Andros

Formations: III.A.1.N.f. Seasonally flooded tropical or subtropical broad-leaved evergreen shrub land

Figure 55. Palm dominated wetland on Eleuthera

Formations: III.A.1.N.g. Semi-permanently flooded tropical or subtropical broad-leaved evergreen shrub land

Figure 56. Mangrove community on Andros

Formations: III.A.1.N.h. Tidally flooded tropical or subtropical broad-leaved evergreen shrub land

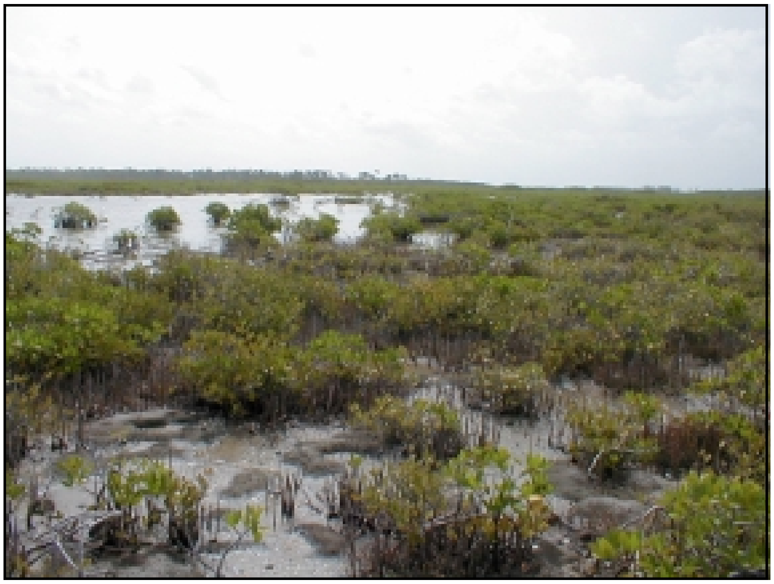

Figure 57. Tidal mangrove community on Abaco

Group: III.A.4. Microphyllous evergreen shrub land
Subgroup: III.A.4.N. Natural/Semi-natural
Formations: III.A.4.N.a. Lowland microphyllous evergreen shrub land

Figure 58. Wild thyme (*Rachicallis americana*) on a rocky shoreline on Andros

Subclass:	III.C.	Mixed evergreen-deciduous shrub land (scrub)
Group:	III.C.1.	Mixed evergreen - drought-deciduous shrub land
Subgroup:	III.C.1.N.	Natural/Semi-natural
Formations:	III.C.1.N.a.	Mixed evergreen - drought-deciduous shrub land with succulents

Figure 59. Mixed evergreen shrub land with cacti on Andros

Class:	IV.	Dwarf-shrub land (dwarf-scrub)
Subclass:	IV.A.	Evergreen dwarf-shrub land
Group:	IV.A.2.	Extremely xeromorphic evergreen dwarf-shrub land
Subgroup:	IV.A.2.N.	Natural/Semi-natural
Formations:	IV.A.2.N.c.	Tidally flooded needle-leaved or microphyllous evergreen dwarf-shrub land

Figure 60. Xeromorphic evergreen shrub land on a salt flat on Andros

Class:	V.	Herbaceous
Subclass:	V.A.	Perennial graminoid vegetation (grasslands)
Group:	V.A.1.	Tropical or subtropical grassland
Subgroup:	V.A.1.N.	Natural/Semi-natural
Formations:	V.A.1.N.b.	Medium-tall sod tropical or subtropical grassland

Figure 61. Cord grass (*Spartina patens*) community on Andros

Formations: V.A.1.N.c. Medium-tall bunch tropical or subtropical grassland

Figure 62. Grassland on Andros

Formations: V.A.1.N.g. Seasonally flooded tropical or subtropical grassland

Figure 63. Saw grass wetland on Andros

Formations: V.A.1.N.h. Semi-permanently flooded tropical or subtropical grassland

Figure 64. Cat tail (*Typha domingensis*) community on Andros

Formations: V.A.1.N.i. Tidally flooded tropical or subtropical grassland

Figure 65. Beach grass shoreline on Abaco

Subclass: V.B. Perennial forb vegetation
Group: V.B.1. Tropical or subtropical perennial forb vegetation
Subgroup: V.B.1.N. Natural/Semi-natural
Formations: V.B.1.N.b. Low tropical or subtropical perennial forb vegetation

Figure 66. Beach strand with forb vegetation on Abaco

Formations: V.B.1.N.e. Tidally or seasonally flooded tropical or subtropical perennial forb vegetation

Figure 67. Giant Fern on Andros

Subclass:	V.C.	Hydromorphic vegetation
Group:	V.C.1.	Tropical or subtropical hydromorphic vegetation
Subgroup:	V.C.1.N.	Natural/Semi-natural
Formations:	V.C.1.N.a.	Permanently flooded tropical or subtropical hydromorphic vegetation

Figure 68. Hydromorphic vegetation on Andros

Formations:	V.C.1.N.b.	Tidal permanently flooded tropical or subtropical hydromorphic rooted vegetation

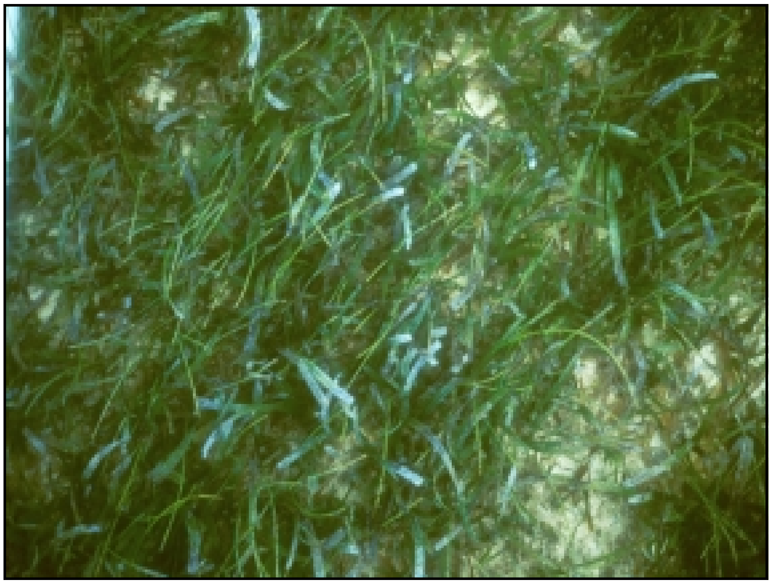

Figure 69. Sea grass meadow on Little Bahama Bank

Class:	VII.	Sparse Vegetation
Subclass:	VII.C.	Unconsolidated material sparse vegetation
Group:	VII.C.2.	Sparsely vegetated sand flats
Subgroup:	VII.C.2.N.	Natural/Semi-natural
Formations:	VII.C.2.N.b.	Intermittently flooded sand beaches and shores

Figure 70. Sparsely vegetated beach strand on Abaco

Group: VII.C.4. Sparsely vegetated soil flats
Subgroup: VII.C.4.N. Natural/Semi-natural
Formations: VII.C.4.N.c. Seasonally/temporarily flooded mud flats

Figure 71. Mud flats on Abaco

Formations: VII.C.4.N.d. Tidally flooded mud flats

Figure 72. Mud flats on Abaco

3. Classification of Natural Communities: Wetlands

3.1. Introduction

There is no single, indisputable and ecologically sound definition for wetlands. This is primarily due to the great diversity of wetlands and the difficulties of distinguishing dry from wet environments. In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. For purposes of this classification, wetlands must have one or more of the following three attributes (Cowardin et al., 1979):

- At least periodically, the land supports predominantly hydrophytes;
- The substrate is predominantly undrained hydric soil; and
- The nonsoil is saturated with water or covered by shallow water at some time during the year.

Wetlands are essential breeding, rearing, and feeding grounds for many species of fish and wildlife. They also play a significant role in flood protection and pollution control. Increasing national and international recognition of these functions has intensified the need for reliable information on the status and extent of wetland resources. To develop comparable information over large areas, a clear definition and classification of wetlands is required. The Bahamian archipelago is no exception in the need for wetland protection; wetlands are an important component of the biological diversity of the archipelago. The Bahamian archipelago is described as having few surface water resources; there are no large river systems or fresh water lakes. However, there are a wide variety of wetlands that include seasonal and ephemeral freshwater wetlands, coastal and tidal wetlands, inland blue holes, and anchaline ponds. The carbonate geology of the archipelago allows salt water to penetrate under all the islands, and thus, freshwater is often layered over seawater in larger ponds, lakes and inland blue holes. The variety of wetlands is poorly described, and the classification of wetlands for this document uses the established terms and definitions listed in the 'Classification of Wetlands and Deep Water Habitats of the United States' (see Cowardin et at., 1979). This classification originally included marine systems, but a discussion of a marine benthic classification will follow with more recent work. The characterization of wetlands in the archipelago will focus on estuarine, lacustrine and palustrine systems.

In the Bahamas, the term "wetland" includes a variety of areas that fall into the following categories:

- Areas with hydrophytes ("water-loving" or wetland plants) and hydrogeology, such as those commonly known as marshes, swamps, and bogs;
- Areas without hydrophytes but where the geomorphology of an island includes a solution hole, depression, pond or swale — for example, blue holes, inland ponds and lands or salt flats where drastic fluctuation in water level, turbidity, or high concentration of salts may prevent the growth of hydrophytes; and
- Areas with hydrophytes but nonhydric soils, such as margins of impoundments or excavations where hydrophytes have become established but hydric soils have not yet developed.

Wetlands in the Bahamian archipelago represent the greatest single contribution to endemic species; blue hole and cave fauna, as well as freshwater fishes and invertebrates are only recently being described and catalogued. Scientists are only beginning to appreciate the diversity of saline or anchialine pond systems throughout the islands. Anchialine or saline ponds are best studied on the islands of San Salvador and Andros near field research stations. Anchialine ponds are land-locked saline bodies of water with permanent connections to the open ocean (Por, 1985). Most anchialine ponds are sedimentary, lying in ancient inter-dunal low areas (such as Lake Cunningham on New Providence Island). However, some ponds can include caves and crevices, and the definition of 'anchialine ponds' includes inland blue holes. The ponds can range from polyhaline to euhaline, and thus do not fit the traditional definition of lacustrine (lakes) and palustrine (ponds) systems. The classification serves as only a framework to capture the abiotic and biotic zonal associated with ponds and wetlands, and deserves more attention to develop modifiers appropriate for the archipelago.

3.2. Classification System

Our classification is based on the system developed by the *Fish and Wildlife Service* (Cowardin et al., 1979), which is hierarchical in nature, progressing from Systems and Subsystems, at the most general levels, to Classes, Subclasses, and Dominance Types. There is no systematic inventory of wetlands in The Bahamas or the Turks and Caicos Islands, but research and inventory work has been done on mangrove wetlands and inland blue holes. The classification should provide a framework of the types of wetlands occurring in the archipelago, and along with the landcover mapping, provide the basis for a national wetlands inventory.

Table 8. Subclass distribution within the classification hierarchy for wetlands of the Bahamian Archipelago

	Estuarine		**Lacustrine**		**Palustrine**
	Subtidal	Intertidal	Limnetic	Littoral	
Rock Bottom					
Rind rock	X		X	X	X
Unconsolidated Bottom					
Mud	X		X	X	X
Sand	X		X	X	X
Emergent Wetland					
Persistent	X	X		X	X
Non-persistent				X	X
Shrub (non-mangrove)				X	X
Herbaceous				X	X
Palm				X	X
Mangroves	X	X		X	X

3.3. Wetland Systems in the Bahamian Archipelago

All figures after Cowardin et al., 1979

3.3.1. Estuarine System

The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines there is appreciable dilution of seawater. Offshore areas with typical estuarine plants and animals, such as red mangroves (*Rhizophora mangle*) are also included in the Estuarine System. Estuarine Systems can be inland, but periodically flooded by salt water with storm surges or permanently connected to open ocean through a subterranean connection to the ocean. Estuarine habitats are often hyper saline or salinity is influenced by rainfall.

Description

The Estuarine System includes both estuaries and lagoons. It is more strongly influenced by its association with land than is the Marine System. In terms of wave action, estuaries are generally considered to be low-energy systems (Chapman, 1977:2). One or more of the following forces affects estuarine water regimes and water chemistry: oceanic tides, precipitation, and freshwater runoff from land areas, evaporation, and wind. Estuarine salinities range from hyperhaline to oligohaline. The salinity may be variable, as in hyperhaline lagoons (e.g. salt ponds).

Subsystems

Sub-tidal - The substrate is continuously submerged

Inter-tidal - The substrate is exposed and flooded by tides; includes the associated splash zone.

Classes

Rock Bottom (Rind Rock), Unconsolidated Bottom (Mud), Emergent Wetlands with herbs, shrubs, palms or mangroves.

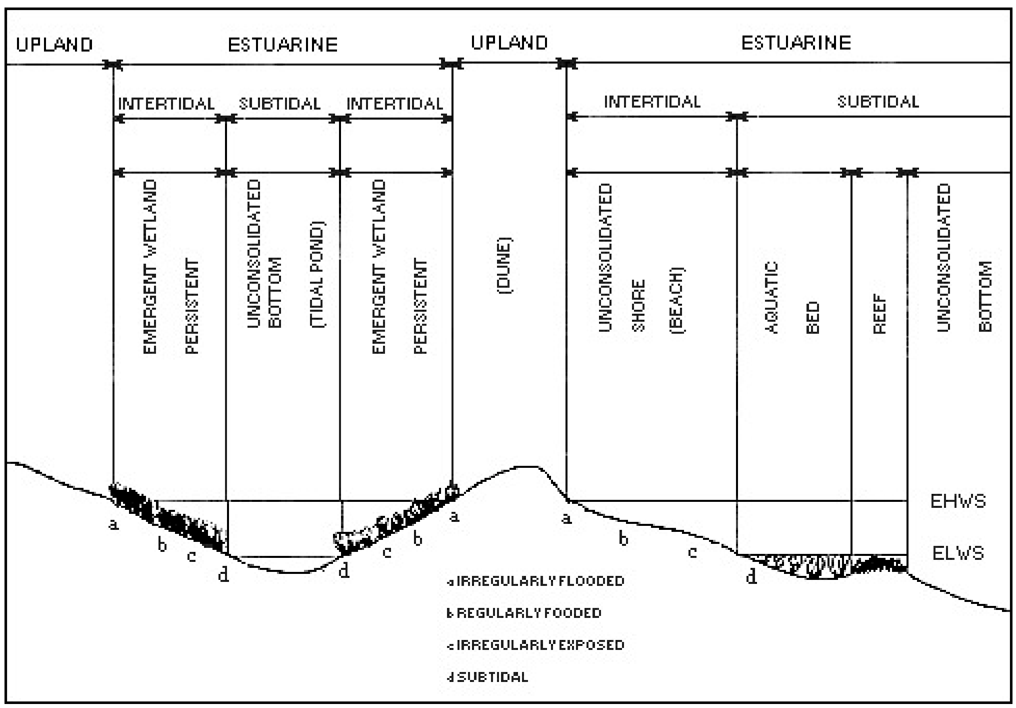

Figure 73. Distinguishing features and examples of habitats in the Estuarine System
[EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides]

3.3.2. Lacustrine System

The Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: (i) situated in a topographic depression, (ii) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (iii) total area exceeds 8 ha (20 acres). These are large inland lakes that are likely polyhaline (freshwater at the surface, salt water below). Similar wetland and deepwater habitats totalling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water, this includes inland blue holes. Lacustrine waters may be tidal or nontidal.

Description

The Lacustrine System includes permanently flooded lakes, intermittent lakes and tidal lakes. Typically, there are areas of deep water and there is considerable wave action. Islands of Palustrine wetlands may lie within the boundaries of the Lacustrine System.

Subsystems

Limnetic - All deepwater habitats within the Lacustrine System; many small Lacustrine Systems have no Limnetic Subsystem.

Littoral - All wetland habitats in the Lacustrine System. Extends from the shoreward boundary of the system to a depth of 2 m (6.6 feet) below low water or to the maximum extent of nonpersistent emergents, if these grow at depths greater than 2 m.

Classes

Rock Bottom, Unconsolidated Bottom (Muds), Sedges, Shrub, and mangroves (buttonwood).

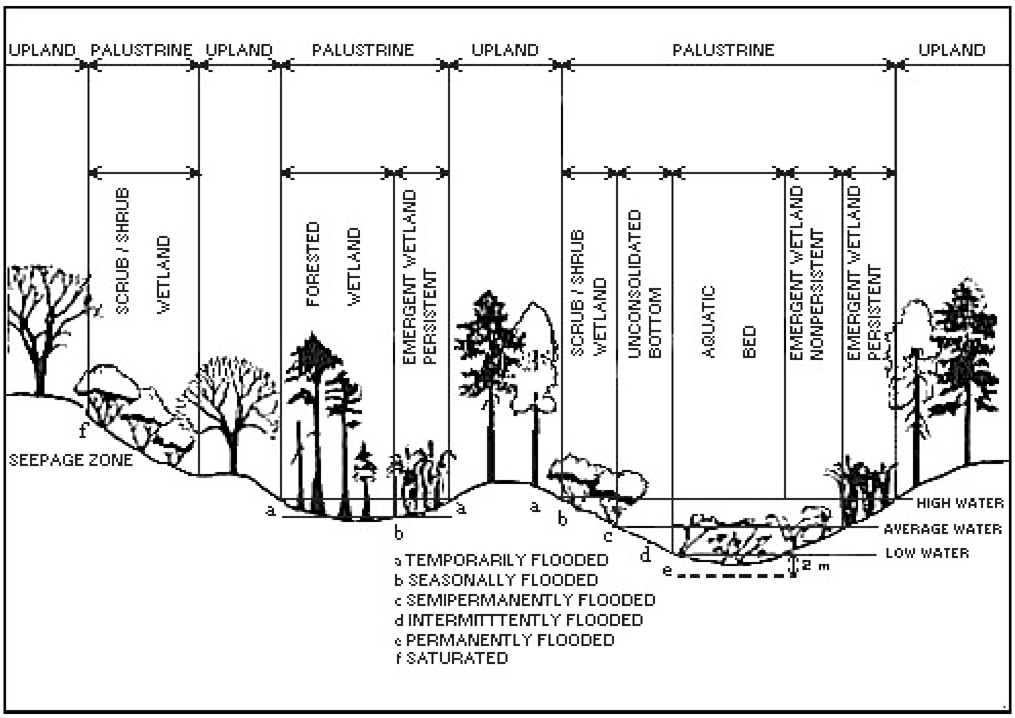

Figure 74. Distinguishing features and examples of habitats in the Lacustrine System

3.3.3. Palustrine System (Ponds)

The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, and persistent emergents, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ‰. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (i) area less than 8 ha (20 acres), (ii) active wave-formed or bedrock shoreline features lacking, and (iii) water depth in the deepest part of basin less than 2 m at low water.

Description

The Palustrine System was developed to group the vegetated wetlands traditionally called by such names as marsh, swamp, and bog, which are found throughout the archipelago. It also includes the small, shallow, permanent or intermittent water bodies often called ponds. Palustrine wetlands may be situated in isolated catchments or on

slopes. They may also occur as islands in lakes. The erosive forces of wind and water are of minor importance except during severe floods.
The emergent vegetation adjacent to lakes is often referred to as ‘the shore zone’ or the ‘zone of emergent vegetation’ (Reid & Wood, 1976), and is generally considered separately from the lake.

Subsystems -None.

Classes

Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, Emergent Wetlands (herbaceous, shrub, palm or mangrove).

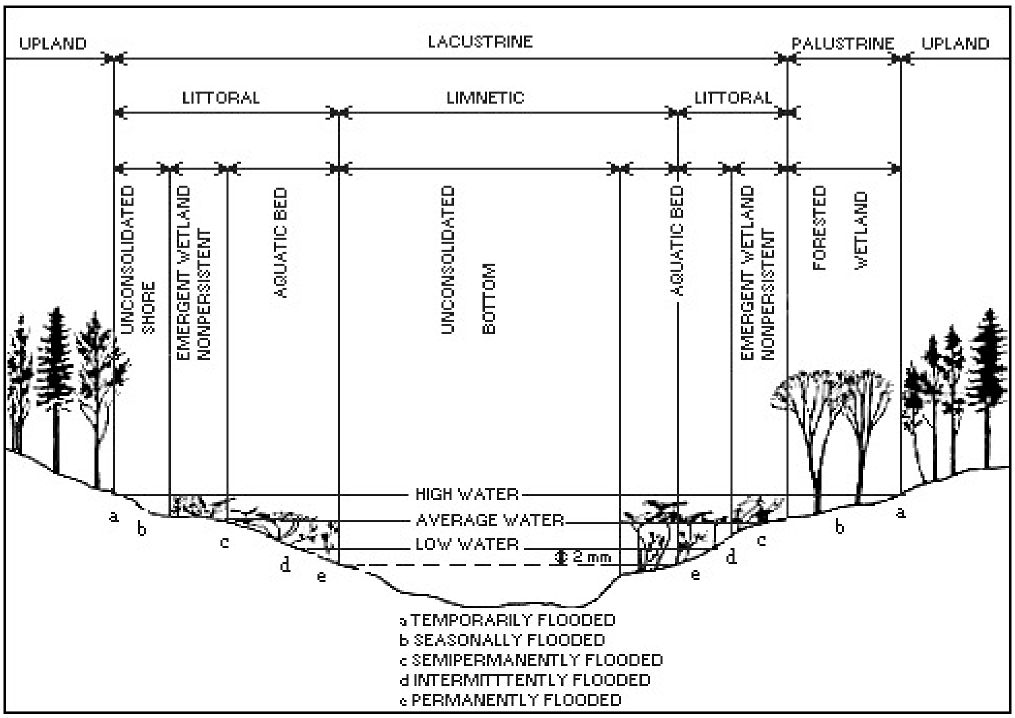

Figure 75. Distinguishing features and examples of habitats in the Palustrine System

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4. Classification of Natural Communities: The Coastal Zone

The coastal environment is the area where the land meets the sea. The coastal zone includes areas of dunes, beaches, rocks, low cliffs, wetlands, bays and coves, and often refers to both the marine and terrestrial habitats that occur near the shoreline. Because of the effects of currents, waves, tidal changes, storms, and hurricanes, the coastal zone is a dynamic environment. The Bahamas is essentially all coastal zone, which means that most people live within two kilometres of the sea. Coastal zones are extremely important environments because of their economic importance and proximity to human settlement and development (B.E.S.T., 2002).

The coastal zone includes many diverse and interconnected ecosystems and communities so that any impact on one ecosystem or community can directly affect all others that are connected to it through the life histories of species that travel between them (B.E.S.T., 2002). The coastal zone provides critical habitats and resources for many species, such as seabirds, sea turtles, and marine mammals. Additionally, coastal zones also provide people with benefits, which include hurricane buffer zones, tourist attractions, educational opportunities, and living resources (B.E.S.T., 2002).

4.1. Classification System

This classification system attempts to combine the present marine classification system (see Allee et al., 2001) and terrestrial classification system (see Areces-Mallea et al., 1999) into a system appropriate for classifying coastal zones. The intersection of these two classification systems allows for better descriptions of coastal zones by addressing both the physical environment and the vegetation types present. Because the water level of a coastal zone area is constantly changing so that an intertidal area can be an aquatic environment at one moment and a terrestrial environment at the next, these areas deserve a specialized classification system, and are thus characterized by the following system of modifiers:

- Type of sediment
    - Soft, unconsolidated sand or mud, found on beaches and mangrove communities; and
    - Consolidated carbonate sediments, found on rocky shores.

      Unconsolidated sediment is comprised mainly of sand, but also contains silt, mud, and stones; specific sources for these materials are the skeletal remains of many sea creatures and calcareous algae (B.E.S.T., 2002). In addition grains of calcium carbonate are precipitated in heated seawater, depositing fine, sandy, rounded oolite grains onto beaches. Coarser sand is the result of the erosion of coral reefs during storm events (B.E.S.T., 2002).
- Wave energy
    - High Energy shorelines; and
    - Low Energy shorelines

      Generally, higher wave energy corresponds with a wider beach, since the magnitude of the waves determines how far sand can be transported up the coast (Sealey, 1985). Each type of shoreline has associated subtidal, intertidal and terrestrial components. The terrestrial component determines what type(s) of plants grow adjacent to the shore to form and stabilize the coastal zone (B.E.S.T., 2002).

The different combinations of sediment type and wave energy create a variety of environments that react differently to erosional and depositional processes, with some of the environments better suited for human habitation and development (B.E.S.T., 2002).

4.1.1. Classes

4.1.1.1. High Energy Soft Sediment Coastal Zones

(1a, 2a) Examples of coastal zones in this category can be found on the ocean side of Eleuthera.

Beaches and Beach Strands

This class consists of high relief beaches and beach strand communities that are shrub or herb-dominated, with varying widths and heights of dune systems. These high relief beach strands slope to *Uniola paniculata* herb-shrub lands, then to lowland subtropical evergreen forests/woodlands/shrub lands (Sealey et al., 1999).

An element common to beaches is the sand dune. The coastal dunes that build up behind a beach are inhabited by salt-tolerant plants including railroad vine, sea purslane, stunted sea grape, and the exotic casuarina (Sealey, 1990). The dune vegetation plays an important role in fixing the soft sand sediments and preventing the spread of sandy sediments inland (Sealey, 1990). The dunes themselves store fresh water and provide a natural sea wall against storms (Sealey, 1990).

Figure 76. Beach strand on Exuma Cays

Figure 77. Beach rock on San Salvador

Beaches can be described as HIGH or LOW relief, based on the shore profile. Beaches can also be described with the following modifiers:

- With or without beach rock underlying sand;
- With or without exotic plant invasion; and
- With or without offshore reefs, barrier islands, or tambolas.

On some soft sediment coastal zones, such as those of South Iguana Cay and North Bimini, the occurrence of beach rock can be observed. Beach rock is the result of sand slightly below the surface being cemented into rock; it becomes exposed on coastlines when the sandy surface of the beach is stripped away (B.E.S.T., 2002). Pores are common and large in beach rock, which weathers to form a smooth surface. Most beach rock has a sandy colour, although the presence of blue-green encrusting algae can cause the surface to be stained black (Sealey, 1985). Beach rock is an excellent indicator of the littoral zone for paleoenvironmental interpretation (Multer, 1971). Beach rock is exposed beneath, shoreward, and seaward of modern beach sands, and exists in tabular, laminated beds that dip gently seaward (Shapiro et al., 1995). Laminations are defined by slight variations in grain size between fine and medium sand (Shapiro et al., 1995). There are three main components to beach rock: (i) boulders of rock from the cliff bordering the beach, (ii) conch shells, coral, and glass debris, and (iii) fine sand, but it may also include mollusks, *Halimeda*, coral, and encrusting algal debris as well (Multer, 1971). The amount of cementation varies, with the finer grained phases being better cemented; cementation occurs as coatings around the individual constituent grains and as fillings between groups of grains (Multer, 1971). Cementation most likely occurs when there are alternating wet and dry saltwater spray conditions, with skeletal grains providing nuclei for precipitation from a supersaturated calcium carbonate solution (Multer, 1971). Sealey (1985) noted that beach rock could form rather rapidly, as modern rubbish such as bottles and cans can be found in some deposits.

4.1.1.2. Low Energy Soft Sediment Coastal Zones

(1a, 2b) are low relief beach strands, coastal wetlands, and mangrove communities. Examples of this type of coastal zone can be found in western Andros Island and the south-western parts of New Providence.

Beaches and Beach Strands

Low relief beaches can be present in two forms: (i) beach to lowland subtropical evergreen forest/woodland/shrub land transition, (ii) beach to palm dominated lowland subtropical evergreen shrub and transition (Sealey et al., 1999). As with high-energy beaches and beach strands, dunes and beach rock can be observed (refer to A1 for details).

Figure 78. Beach strand on San Salvador

Mangrove Communities

Although their specific structural and functional characteristics may vary greatly (Cintron-Molero & Schaeffer-Novelli, 1992), mangroves are generally found in areas sheltered from high-energy waves (Kendall et al., 2001). Coastal mangrove areas can be divided into three subclasses based upon their hydrology and geomorphology.

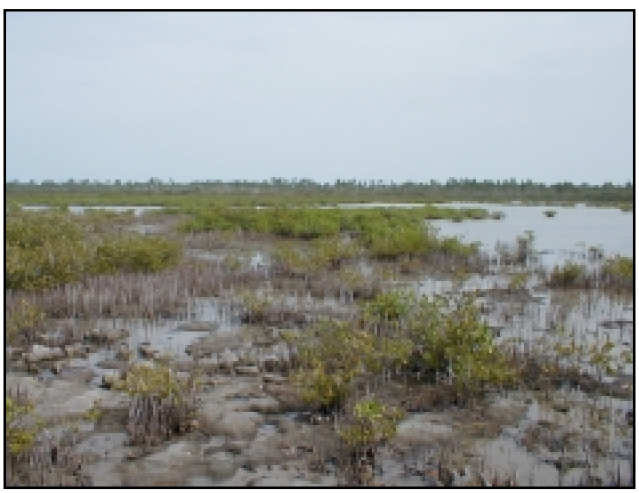

Figure 79. Tidal mangrove on Abaco

<u>Over wash and creek systems</u>

Water flow and nutrient input is high and interstitial salinities are low, which mean that these areas have the highest degree of structural development (Cintron-Molero & Schaeffer-Novelli, 1992). Riverine strands occur in arid environments along the margins of estuaries, but the mangrove vegetation is backed by extensive salt flats (Cintron-Molero & Schaeffer-Novelli, 1992).

<u>Fringe</u>

Fringe mangroves occur along the seaward edges of protected shorelines or around over wash islands (Cintron-Molero & Schaeffer-Novelli, 1992). Fringe areas are characterized by salinity levels similar to seawater and lower nutrient input than riverine systems (Cintron-Molero & Schaeffer-Novelli, 1992). Fringe forests can develop in dry environments, backed by hypersaline lagoons, salt flats, or xeromorphic vegetations (Cintron-Molero & Schaeffer-Novelli, 1992). Because most fringes are flooded by most tides, they do not suffer pronounced salt accumulation (Cintron-Molero & Schaeffer-Novelli, 1992).

<u>Isolated and inland basins</u>

Basin forests develop over inland basins influenced by seawater and occupy the highest levels subject to tidal intrusion (Cintron-Molero & Schaeffer-Novelli, 1992). Tidal flushing is less frequent than in fringes or riverine systems, and is sometimes limited to the highest tides of the year (Cintron-Molero & Schaeffer-Novelli, 1992).

Mangrove communities can serve many purposes, including: removal of excess nutrients and heavy metals from runoff, storm buffers, sites of fish recruitment, nurseries and feeding, bird sanctuaries, honey bee havens, and homes for orchids and bromeliads (B.E.S.T., 2002).

<u>4.1.1.3. High Energy Consolidated Sediment Coastal Zones</u>

(1b, 2a) are high relief rocky shores and cliffs, such as the cliffs along the ocean side of Eleuthera and Clifton, New Providence. Such cliffs are close to the ocean or deep-water channels and get little or no protection from shallow water or coral reefs, which means that the waves strike the coast with full force (Sealey, 1990). These rocky shores are characterized by an abrupt transition from a *Microphyllous* evergreen shrub land to a lowland subtropical evergreen forest/ woodland/shrub land (Sealey et al., 1999).

<u>4.1.1.4. Low Energy Consolidated Sediment Coastal Zones</u>

(2a, 2b), also called low relief rocky shores, are *microphyllous* evergreen shrub lands. These rocky shores demonstrate a wide, long transition from a *Microphyllous* evergreen shrub land to a lowland subtropical evergreen forest/woodland/shrub land (Sealey et al., 1999). Examples of this kind of coastal zone can be found along much of the developed shores of New Providence off Eastern Road.

These rocky shores have a clearly visible tidal zonation of white, grey, black, and yellow zones, which provide the habitat for many intertidal snails, mussels, and crabs.

Figure 80. High relief rock shore on Exuma Cays

Figure 81. Low relief rocky shore on San Salvador

4.1.2. Threats to Coastal Zones

There are many factors that can threaten the otherwise healthy condition of the intact coastal zones that remain in the Bahamas today. A major threat is the loss of sand from the coastal zone. Sand can be removed from driving on beaches, developing on coastlines, sand mining, and removing vegetation. Removal of vegetation destabilizes the dune structure so that sand can be carried away more easily, thereby reducing the protective value of dunes and beaches. It should be noted that there is a limited supply of sand; if sand is removed from its place, it must be replaced by a dwindling, limited reservoir of sand (B.E.S.T., 2002). Another potential threat to coastal zones is erosion. Erosion, a phenomenon in which the action of the sea wears away the shoreline, can result from activities that alter the shape of the coastline and increase the exposure of the coast to wave action. Destruction of mangrove forests, sea grass beds, and coral reefs for tourism development, construction, or landfill operations are examples of such activities that can promote unhealthy erosion. The development of penetrating structures such as docks, marinas, sea walls, and canals poses as another threat to coastal zones because these structures interfere with the lateral movement of sand along a beach (B.E.S.T., 2002). Lastly, pollution is a serious threat to Bahamian coastal zones because pollution harms coastal flora and fauna, as well as reducing the aesthetic value of coastal zones. Sources of pollution are widespread and include dumping of trash (e.g. plastic), marine debris, sewage, sedimentation, agricultural runoff, oil, and excess nutrients (B.E.S.T., 2002).

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5. Classification of Natural Communities: Marine

The Ecological Society of America (ESA) and the National Oceanography and Atmospheric Administration (NOAA)'s Office of Habitat Conservation worked collaboratively to develop a hierarchical marine and estuarine ecosystem and habitat classification framework. The objectives of this project were to i) review existing global and regional marine classification systems, ii) develop a framework for a national classification system, and iii) propose a plan to expand the framework into a comprehensive system to characterize marine and estuarine ecosystems (Allee et al., 2000).

Level 1:	Life Zone
Level 2:	Water/Land
Level 3:	Marine/Freshwater
Level 4:	Continental/Non-continental
Level 5:	Water column/Benthic
Level 6:	Shelf, slope, abyssal
Level 7:	Regional wave/wind energy
Level 8:	Hydrogeomorphic features
Level 9:	Hydrodynamic features
Level 10:	Photic/aphotic
Level 11:	Geomorphic types
Level 12:	Ecotype
Level 13:	Ecounit location and description

This framework was considered to be the most appropriate for the classification of marine benthic communities in the Bahamian archipelago for several reasons. First, the hierarchy allows for the unique modifiers needed to characterize this carbonate archipelago. Second, the hierarchy developed by ESA and NOAA will be widely used in fisheries and marine resource management, thus familiar to a larger audience of scientists and managers. Lastly, the ESA and NOAA classification framework has the input of many regional scientists and provided a good starting point to examine both the ecological classification of natural communities as well as identifying 'mappable' habitat units. The entire hierarchy describes a benthic community through 13 'levels', the lowest level describing a specific 'eco-unit' or location of a particular habitat type.

Some natural communities could only be mapped down to Level 11 (geomorphic types); other communities could be mapped to Level 12 (eco-types). The upper levels of the classification hierarchy are defined for the entire Bahamian archipelago as being a tropical, marine, non-continental, benthic, shallow water system. All marine benthic classifications are consistent through level 6 with the following distinctions:

Level 2:	Water/Land	Water
Level 3:	Marine/Freshwater	Marine
Level 4:	Continental/Non-continental	Non-continental
Level 5:	Water column/Benthic	Benthic
Level 6:	Shelf, slope, abyssal	Shallow (< 200 m)

The lower levels of the hierarchy include specific modifiers for the Bahamian archipelago, and address the particular environmental conditions across and between bank systems.

Level 7: Regional wave/wind energy

Wind/wave energies in the Bahamas are site conditional and rated strong, medium, and weak depending on degree of exposure, primarily to north and/or north eastern trade winds and seasonal storm conditions.

Level 8: Bank energy

There are five types of bank energies found in the Archipelago (each is described elsewhere in this report):

- Sheltered Bank, continuous
- Sheltered Bank, with cays
- Island Occupied Bank
- Fully Exposed Bank
- Sheltered Bank, anomalous

Level 9: Hydrodynamic features - Subtidal

Level 10: Photic/aphotic - Photic

Level 11: Geomorphic types

There are four marine geomorphic types found in the Bahamian Archipelago:

- **Soft Sediment**
- Reefal Hard-Bottom
- Non-Reefal Hard Bottom
- Deep Reef Resources

Soft Sediment

Sedimentation is the base of the Bahamian environment, both terrestrial and marine. Essentially the Bahamas is a depositional landscape, created by long-term sedimentation and lacking igneous, volcanic, and metamorphic rock (Sealey, 1994). A wide range of banks and islands exposed to currents and winds and influencing the physical energy of specific regions lead to the great variability in the amount and type of sediment observed on the Bahama Banks (Carew & Mylroie, 1995). Even so, the quality of sedimentation in the area can be generally defined by five major groups; skeletal or coralgal, oolitic, grapestone, pellet mud, and mud/silt (Sealey, 1994). The substrates of underwater habitats are dominated by one of these sedimentation groups which, when modified to include vegetation and/or human alteration, can be distinguished by the eight ecotypes listed below:

Level 12: Ecotype

- Sand Bores, Oolite Banks
- Anthropogenic
- Mud, Bare Bottom
- Mud, with Sea grass
- Sand, Bare Bottom
- Sand, with Patch Sea grass
- Sand, with Sparse Sea grass
- Sand, with Dense Sea grass

Level 12: Ecotype - Sand bores, oolite banks

There are two types of sand oolite concentrations in the Bahamas: the pure and the mixed oolite sediment (Multer, 1971). Oolite is sediment of rounded grains precipitated directly from seawater that commonly deposits where deeper, cooler water flows across shallow bank margins (Ball, 1967; Sealey, 1994). The pure oolite areas have a higher content of non-skeletal grains and a lower percentage of particles smaller than 1/8 mm, than those found in mixed oolite facies. The bores are generally found along the shoals or shallow crest of the bank edge and therefore, are optimum for the process of agitation or oolite formation through precipitation. Transverse tidal channels with deltaic end are characteristic of sand bores. Oolite banks are characteristic of a large number of localities in the Bahamas, including, but not limited to: Joulter Cay, Cat Cays, Schooner Cays, Lily Bank, the northern end of Exuma Sound, the southern end of Tongue of the Ocean, and east of the southern coast of Andros (Purdy, 1961; Budd 1984,1988). Ooid development and deposition are also reported from the Turks and Caicos Islands (Lloyd et al., 1987).

Level 13: Ecounit location and description - Schooner Cays Oolite Banks, west of south Eleuthera

A discontinuous belt of oolitic, cross-bedded lenticular sand is in the formation stages along the shallow north-eastern edge of Exuma Sound. The bank platform margin from south Eleuthera northwest to Dog Rocks is a series of oolite banks. These banks include the Schooner Cays, an important white- crowned pigeon roost. The oolitic banks are clearly visible in NASA space shuttle photography as a series of parallel white lines moving away from the platform margin.

Figure 82. Oolite banks along north-eastern Exuma Sound

Level 12: Ecotype - Anthropogenic

Human altered sedimentation resulting from activities including coastal development and marine mining/dredging are included in the anthropogenic classification. Physical impacts to the substratum or bottom occur through direct mining and dredging for sand and alterations in flow through tidal channels. The ephemeral nature of the sediments deposited precludes many biota from colonizing the substrate. Other environmental effects include increased turbidity (decreased water clarity) and increased sediment scouring if the sediments are disturbed, for example, during storm events.

Level 13: Ecounit location and description - Nassau Harbour, New Providence

Nassau Harbour is a specific example of a benthic habitat altered by dredging and channel construction. The cruise ship port, container ship dock, and mail boat dock within the harbour all required dredging of shallow water sand and sea grass beds. The resulting benthic communities are highly disturbed, often unvegetated with mostly infauna. The harbour can be up to 30 meters deep in areas, turbidity is high with suspended sediments, and thus the bottom can be obscured. Shallow, near-shore areas within the harbour are dominated by soft sand-mud. Calcareous green algae often dominate (*Halimeda* spp.)

Figure 83. Nassau Harbour on New Providence

Level 12: Ecotype - Mud, bare bottom

Mud is a general term for particles, which are less than 0.125 mm in diameter. Mud pellets are smaller than grains of sand (Sealey, 1994). This habitat is characterized by a rocky substrate covered in organic material, predominately skeletal/coralgal-dominated lithofacies (Sealey, 1994; Carew & Mylroie, 1995).

According to Lowenstam and Epstein (1957) and Neumann and Land (1975), calcareous green algae are the presumed source of the mud (micrite) in the Bahamas. This ecotype typically occurs in areas of restricted circulation in relatively shallow water (< 8 m). Large areas are devoid of macrophytes such as sea grasses and macroalgae. At the northwestern margin of Grand Bahama Bank, the Bimini Islands are bounded to the south by habitat dominated by pellet-mud (Multer, 1971).

Level 13: Ecounit location and description - Kemp's Creek, South Eleuthera

Carbonate mud-dominated areas are found in supratidal and intertidal tidal-flats, creeks, and subtidal regions, and in well-protected regions, such as the lee of islands, i.e. southern Eleuthera. Kemp Creek is a typical bare mud bottom habitat. The creek mud flats are exposed at low spring tides, and are devoid of macroalgae and sea grasses. The muds are worked by infaunal annelids and crustaceans, as indicated by mounding and burrows seen in these habitats.

Figure 84. Kemp's Creek on Eleuthera

Level 12: Ecotype - Mud, with sea grass

Mud is a general term for particles that are less than 0.125 mm in diameter. Mud pellets are smaller than grains of sand (Sealey, 1994). This habitat is characterized by the same rocky substrate covered in organic material found in bare mud habitats, but with the presence of sea grasses (Sealey, 1994; Carew & Mylroie, 1995). This ecotype typically occurs in areas of restricted circulation in relatively shallow water (< 8 m).

Level 13: Ecounit location and description - Kemp's Creek, South Eleuthera

Deeper channels in the mangrove creek are a mud substrate with moderate to dense sea grass coverage. Sea grass coverage is sparse to dense, dominated by turtle grass, Thalassia testudinum. Mud substrates dominate in low energy, near shore areas, especially in mangrove creeks and bights.

Level 12: Ecotype - Sand, bare bottom

Large expanses of subtidal clean white 'sand' composed of skeletal and oolite sediments with less than 10% coverage by sea grasses and algae are identified as the sand bare bottom ecotype. Often described as underwater deserts, with little or no overtly apparent flora or fauna, they are home to burrowing fish and crustaceans. On the banks of the Bahamian Archipelago, bare sand areas may be influenced by vigorous wave action. Sandy bottoms located relatively far from reefs derive their sediments principally from lithogenic processes, while bare sand areas closer to reefs may be composed of oolitic and skeletal sand particles.

Figure 85. Bare sand on Little Bahama Bank

Level 13: Ecounit location and description - White Sand Ridge, Little Bahama Bank

Bare sand bottom is the dominant substrate of little Bahama Bank and Grand Bahama Bank (Carew & Mylroie, 1995). One example can be found near the eastern edge of Little Bahama Bank in an area known as White Sand Ridge. A known habitat of resident dolphin populations, the ridge is characterized by large expanses of apparently deserted sand, bordered with patch reefs and occasional wrecks. The depth ranges from 1 m to 30 m, with a relatively steep slope on the northern edge of the bank.

Level 12: Ecotype - Sand, patchy sea grass

Sandy bottom substrate with between 10% and 30% vegetation is defined as the patchy sea grass in sand ecotype. Representative vegetation consists mainly of Sea grass or *Sargassum* algae, distributed on platforms of calcareous rock and layers of oolitic and skeletal sediment. At shallower water depths and depending upon the disturbance regime, individual or assemblages of up to three sea grass species may occur: turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*). At greater depths, manatee grass may replace turtle grass. In disturbed near shore patchy sea grass beds, shoal grass may predominate.

Level 13: Ecounit location and description - Sandy Cay, West End, Grand Bahama

Often associated with the shallow side of platform margins and reefal hard bottom substrates, for example along the western edge of Little Bahama Bank and northern edge of Grand Bahama Bank.

Figure 86. Patch sea grass on Little Bahama Bank

Level 12: Ecotype - Sand, sparse sea grass

Sandy bottom substrate with 30-60% vegetation is defined as sand sparse sea grass ecotype. Representative vegetation consists mainly sea grasses or *Sargassum*, over platforms of calcareous rock and layers of oolitic and skeletal sediment.

Level 13: Ecounit location and description - Bimini Banks

Northern Grand Bahama Bank, east of Bimini, is characterized broad expanses of sparse sea grass meadows.

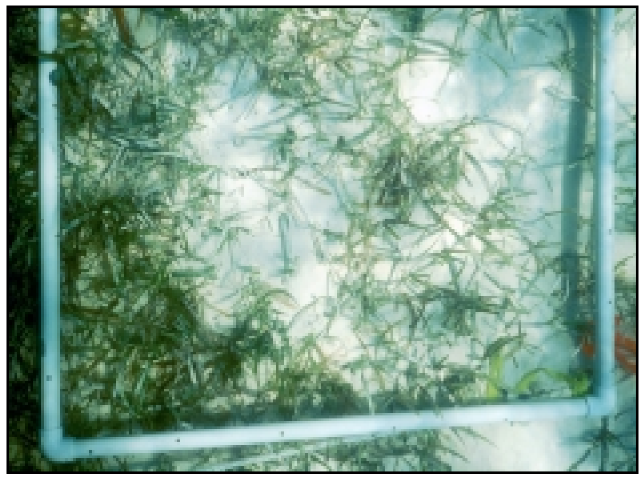

Figure 87. Sparse sea grass on Little Bahama Bank

Level 12: Ecotype - Sand, dense sea grass

Sandy bottom substrate with over 60% vegetation is defined as sand dense sea grass ecotype. Representative vegetation is characterized by meadows of sea grass (*Thalassia*, *Syringodium*, *Halodule*) and calcareous green algae (especially *Halimeda*, *Penicillus*, *Rhipocephalus* and *Udotea*), with interspersed areas of hard ground corals. The combined coralgal/skeletal sediment is the main substrate, but mud concentrations can vary, from totally absent to high, depending on the energy of the area (Carew and Mylroie 1995).

Level 13: Ecounit location and description - Sandy Cay, off West End, Grand Bahama

Sea grass meadows can be found scattered along the western edge of Little Bahama Bank, for example, around Sandy Cay near the west end of Grand Bahama Island.

Level 11: Geomorphic types

There are four marine geomorphic types found in the Bahamian Archipelago:

- Soft Sediment
- **Reefal Hard-Bottom**
- Non-Reefal Hard Bottom
- Deep Reef Resources

Figure 88. Dense sea grass on Little Bahama Bank

Reefal Hard-Bottom

In the Bahamas, the transformation of soft sediments into hard bottom or rock is not only common but also remarkable. The marine cementation of sedimentary material can be a result of crystal formations, usually aragonite, around oolite particles. In areas where fresh groundwater joins the sea, a process of precipitation of calcium carbonate around grains of sand, results in beach rock. This cementation process is rapid in the Bahamas. Sediments created by some algae found on the banks, especially *Halimeda*, *Penicillus*, *Udotea*, and *Rhipocephalus*, are 'cemented' together through the root systems in patch reefs. This process is combined by the presence of sponges and corals to make for a hard bottom community. Reefal hard bottom can be distinguished by the eight ecotypes listed below:

Level 12: Ecotype
- Patch reef on banks
- Patch reef near shore
- Channel reef
- Platform margin reef
- Platform margin barrier

Level 12: Ecotype - Patch Reef on banks

Bank patch reefs are one of two types or forms of patch reefs found in the Bahamian Archipelago and are common in leeward and lagoonal environments (Alevizon et al., 1985; Sullivan et al., 1994). Bank patch reefs are distributed typically on the leeward sides of islands and far (> 1 km) from shore on the Little and Great Bahama Banks. In addition to distance from any landmass, bank patch reefs differ from near shore patch reefs in that patches tend to be clustered instead of isolated circular patches. Massive head corals provide the framework of the bank patch reef and there can be great variability in the contributions of algae, sponges, gorgonians, and hard corals to the patch reef surface.

Level 13: Ecounit location and description - Yellow Banks

Yellow Banks is an example of a bank patch reef occurring in the central Bahamas west of the Exuma Cays archipelago (Sluka et al., 1996). Located at 24º 58.189'N and 76º 53.052'W, this cluster of patch reefs is found approximately 4 km west of Sail Rocks, the northern extension of the Exuma Cays archipelago. The patch reefs occur in shallow water (1-5 m depth) and are bounded by sand and sparse to moderate turtle grass beds. Roughly circular in shape, patch reefs in the Yellow Banks are small (200 m^2) to moderate (1,000 m^2) in size. Vertical relief is as high as 3.5 m and is due to large coral colonies. Previous surveys of the Yellow Banks patch reef environment indicated a predominance of hard corals (45% cover) and algae (42%), with minor contributions by sponges (6%) and gorgonians (7%) (Sluka et al., 1996).

Figure 89. Bare patch reef on Yellow Banks

Level 12: Ecotype – Patch reef near shore

Near shore patch reefs are one of two-patch reef types found in the Bahamian Archipelago and are usually distributed on the leeward sides of islands at 1 m to 6 m depths (Chiappone et al., 1996). This patch reef type is distinguished from bank patch reefs primarily due to the proximity to shore (< 1 km). In addition, near shore patch reefs tend to be adjacent to sparse to dense sea grass and are usually isolated and smaller than the clusters of bank patch reefs found further on the banks. Near shore patch reefs are typically small, averaging 20 m to 30 m in diameter, and roughly circular in shape, but may be quite variable in size (Chiappone et al., 1996). Near shore patch reefs are similarly structured by massive frame-building corals, but can exhibit substantial variability in the relative abundance patterns of algae, corals, sponges, and gorgonians (Sullivan & Chiappone, 1992).

Level 13: Ecounit location and description - Norman's Cay

Several near shore patch reefs occur near the south western end of Norman's Cay in the northern Exuma Cays archipelago, central Bahamas, located at 24° 35.162'N and 76° 49.795'W. Sluka et al. (1996) surveyed two patch reefs ranging in depth from 2 to 5 m. Maximum vertical relief ranges from 1 to 1.5 m and is due to living or dead massive corals that comprise the structure of the patch. In terms of community composition, a single patch reef surveyed by Sluka et al. (1996) revealed dominance by algae (63% cover), but also some corals (28%) represented mostly by massive species.

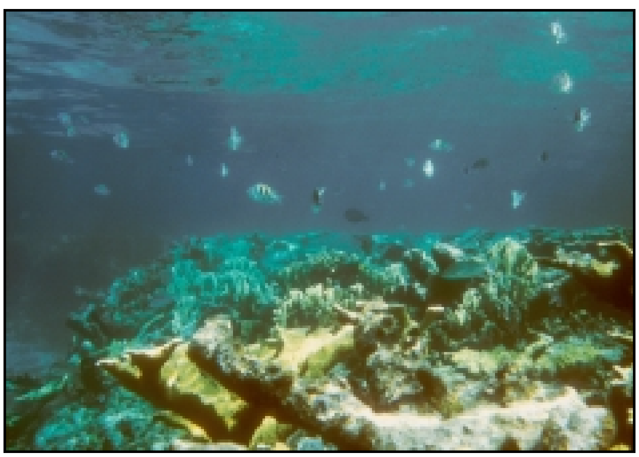

Figure 90. Near shore patch reef, Exuma

Level 12: Ecotype - Channel Reef

Channel reefs are prevalent in the Bahamian Archipelago, especially in the central Bahamas (Exuma Cays), but also as far southeast as the Caicos Bank, Turks and Caicos. Channels serve as major conduits between deep water and bank water. Essentially four bottom types can occur in channels (sand, sea grass, hard-bottom, or reef) and community composition is dependent upon the length, width, and depth of the channel (Sullivan et al., 1994; Sluka et al., 1996). Channels with coral reefs tend to be wider and deeper, and are dominated by massive coral species. The sizes of channel reefs can vary substantially (< 1 to > 3 ha). Reef development opposite of tidal channels that funnel inimical water between shallower embayments or banks is mostly prohibited. Major factors associated with the lack of reef development in such systems are attributed to turbidity, sediment transport, and extreme fluctuations in water temperatures (Lang et al., 1988).

Level 13: Ecounit location and description - Jeep Reef

Located in the Exuma Cays near Halls Pond Cay at 24° 20.997'N and 76° 35.357'W, Jeep Reef is an example of a channel reef in the Bahamian Archipelago. This reef consists of a main ridge oriented east to west that parallels the long axis of Halls Pond Cay, a low-lying island in the central Exumas, and terminates in a sand slope and trough at 8 m to 9 m depth. Sand and sea grass border the reef (Sluka et al., 1996). The top of the ridge consists of coalesced and isolated coral heads interspersed with hard-bottom or sand. The reef ranges in depth from 2 to 9 m and vertical relief is as high as 2.5 m. Previous surveys reveal that this reef is dominated by algae (58%) and hard corals (29%), with minor contributions by sponges (5%) and gorgonians (1%). Hard coral cover is dominated by massive, boulder-shaped species such as Montastraea faveolata, M. cavernosa, and Siderastrea siderea, but also finger corals of the Genus Porites.

Figure 91. Channel reef on Little Bahama Bank

Level 12: Ecotype - Platform margin reef

Fringing reefs are one of four coral reef types (fringing, barrier, channel, and patch) found in the Bahamian Archipelago and are the dominant platform margin reef type in the region. Fringing reefs are represented by three structural types: 1) those occurring immediately offshore on an island platform, 2) those that form ridges parallel to shore, and 3) fringing reefs, both shallow (< 5 m) and deeper (> 10 m) with spur and groove topography (Zankl & Schroeder, 1972; Sullivan et al., 1994; Sluka et al., 1996). Fringing platform reefs consisted of outcrops on an extension of the island platform, prevalent in areas such as the southern Exuma Cays, central Bahamas. Spur and groove or buttress reefs are comprised of elongate coralline spurs or coral bars oriented perpendicular to shore. No spur and groove reefs are reported from the archipelago that are directly exposed to the Atlantic Ocean (Bunt et al., 1981). Spurs or coralline fingers are greater than 100 m in length in some reefs, with the spur surfaces typically found in 8 m to 16 m depth, or sometimes shallower. Spurs are separated by sand grooves from 13 m to 18+ m depths. The deeper spur and groove sites extended to the fore reef escarpment, or drop-off zone, at 20+ m depth. At several locations in the archipelago, spur and groove topography occurs on reef terraces, ranging from wide, gently sloping surroundings to narrow and steeply sloping includes (Zankl & Schroeder, 1972; Bunt et al., 1981).

The three fringing reef types exhibit considerable variability in community structure and framework contributors. For example, spur and groove reefs in the Exuma Cays are composed of relict and living head corals and in some cases are capped with relict staghorn coral (Sluka et al., 1996), while on the eastern Caicos Bank, spur and groove reefs are usually dominated by massive head corals (Chiappone et al., 1996). Fringing reefs comprised of ridges are structured by massive head corals and are capped with finger corals in the Exuma Cays (Chiappone & Sullivan, 1991), but are dominated by head corals and occasionally elkhorn coral in shallower depths in other locations such as northern Eleuthera (Zankl & Schroeder, 1972).

<u>Level 13</u>: Ecounit location and description - Brad's Reef

Located at 24° 24.362'N and 76° 39.547'W near Warderick Wells Cay, Brad's Reef is an example of a fringing reef ridge (Chiappone & Sullivan, 1991). A relatively concentrated line of reef running parallel to shore characterizes near shore ridge reefs. Inshore of the ridges is a low profile limestone platform with algae, scattered coral heads, and gorgonians. Brad's Reef is approximately 50 m wide and several hundred meters in length. The ridge is 3 m to 5 m in depth, while the adjacent low-relief hard-bottom area is slightly deeper (5-8 m). The ridge consists of coalesced coral heads, especially *Montastraea faveolata*, and large areas of finger corals, especially *Porites porites*. Vertical relief is as high as 2 m. Previous surveys indicated dominance by algae (62%) and hard corals (34%), with minor contributions (< 1 %) by sponges and gorgonians (Sluka et al., 1996).

Figure 92. Platform margin fringe reef, Exuma

<u>Level 12</u>: Ecotype - Platform margin barrier

Barrier reefs are one of four coral reef types (barrier, fringing, channel, and patch) found in the Bahamian Archipelago. Structurally, barrier reefs in the Bahamas may exhibit similar community composition as fringing reefs such as reef crest or breaker zone and spur and groove topography. However, barrier reefs differ from fringing reefs in their proximity to shore and thus the presence of a back reef lagoon separating the shoreline from the reef. In the Bahamian Archipelago, the only known barrier reef is Andros Barrier Reef, which runs almost continuously along the eastern shore of the island in the western Bahamas.

<u>Level 13</u>: Ecounit location and description - Andros Barrier Reef

Andros Barrier Reef is the third largest barrier reef in the world (200 km), stretching along most of the eastern margin of Andros Island in the northwestern Bahamas. The barrier reef is the second largest in the wider Caribbean, following the Belize Barrier Reef, and is also one of the most remote. Two main reef zones occur from 3-10 m depth (Kramer et al., 1998). The first at 3 m depth is a shallow slope with abundant stands of elkhorn coral (*Acropora palmata*). Other dominant corals at 3 m depth are fire coral (*Millepora* spp.) and staghorn coral (*A. cervicornis*). Algal turfs and crustose coralline algae comprise the majority of the algal cover. The second zone at 10 m depth is a buttress or head-coral zone dominated by the star corals *Montastraea faveolata* and *M. annularis*, as well as finger corals (*Porites porites*). In contrast to the 3 m depth zone, macroalgae are more prevalent at 10 m depth.

Figure 93. Barrier reef, Andros

Level 11: Geomorphic types

There are four marine geomorphic types found in the Bahamian Archipelago:

- Soft Sediment
- Reefal Hard-Bottom
- **Non-Reefal Hard Bottom**
- Deep Reef Resources

Non Reefal Hard-Bottom

There are four ecotypes found in reefal hard-bottom communities::

Level 12: Ecotype

- Channel, Algal dominated
- Channel, Octocoral / Sponge dominated
- Platform Margin, Algae dominated
- Near shore

Level 12: Ecotype – Channel, Algae dominated

Tidal channels or cuts in the Bahamian Archipelago are represented by four major ecotypes and consist of either sand, coral reef, or non-reefal hard-bottom. Channels dominated with hard-bottom can either be algal dominated or sponge-gorgonian dominated. The substratum is typically scoured and very low profile, with little or no active reef accretion, and consists of exposed and lithified oolite of Pleistocene or Holocene age. Maximum vertical relief is generally < 1 m and the bottom is dominated by several functional forms of algae.

Level 13: Ecounit location and description - Little Major's Channel

Located south of Sampson Cay in the Exuma Cays, central Bahamas, Little Major's Channel is an example of an algal-dominated hard-bottom community within the tidal channel environment. Located at 24° 11.213'N and 76° 26.950'W, Little Major's Channel is 3 m to 4 m in depth and exhibits up to 1.5 m of vertical relief. Previous surveys indicate dominance by algae (80% cover), with very minor contributions by sponges (6%), corals (2%), and gorgonians (5%) (Sluka et al., 1996). The dominant forms of algae are turf species and the green algae *Batophora*. The underlying bedrock of limestone is very low profile and heavily scoured.

Figure 94. Algae dominated channel reef on Little Bahama Bank

Level 12: Ecotype - Channel, octocoral / sponge dominated

Tidal channels or cuts in the Bahamian Archipelago are represented by four major ecotypes and consist of either sand, coral reef, or non-reefal hard-bottom. Channels dominated with hard-bottom can be algal or sponge-gorgonian dominated. The substratum is typically scoured and very low profile, with little or no active reef accretion, and consists of exposed

Pleistocene lithified oolite. Maximum vertical relief is generally < 1 m and the bottom is dominated by sponges and gorgonians.

Level 13: Ecounit location and description = Sampson Cay Channel

Sampson Cay Channel, located near Sampson Cay in the Exuma Cays at 24º 12.020'N and 76º 27.825'W, central Bahamas, is an example of a tidal channel environment with sponge-gorgonian dominated hard-bottom. The site is located on the southern side of Sampson Cay Cut. The channel hard-bottom community has upwards of 2.5 m of vertical relief. Previous surveys indicated very high coverage by sponges (40% cover), represented mostly by turf species, corals (12%), and gorgonians (1%). Surveys found algae (36%) in smaller concentrations than algal dominated channels (Sluka et al., 1996). Conspicuous sponges include *Verongula rigida*, *Ircinia felix*, *I. strobilina*, and *Callyspongia vaginalis*.

Figure 95. Octo-coral-sponge dominated channel reef on Little Bahama Bank

Level 12: Ecotype - Platform margin, Algae dominated

The platform margin or rims of bank systems in the Bahamian Archipelago consist of a matrix of bare sand, fringing or barrier reefs, and low-relief hard-bottom. Low relief hard-bottom is the dominant, shallow-water (< 20 m) community type found on the platform margin in region, especially on the exposed sides of banks such as the western Exuma Sound. The substratum consists of exposed, lithified sand-rock and is not of reef origin as in other locations such as the Florida Keys. Platform margin hard-bottom is the least variable of the hard-bottom community types, both reefal and non-reefal, in the Bahamian Archipelago. This community type is consistently dominated by algae with occasional patches of sand, and is also referred to as "hard-bar" or windward hard-bottom (Sluka et al., 1996). The substratum is very low profile, although occasional ledges and fissures in the substratum surface may occur. Variations in relief are due principally to the presence of isolated and small (< 0.5 m) coral heads that may occur.

Level 13: Ecounit location and description - East of Warderick Wells

The island platform east of Warderick Wells in the Exuma Cays, central Bahamas, is an example of an algal-dominated, platform margin hard-bottom community. Located at 24º 23.375'N and 76º 36.540'W, the site is characterized by a substratum consisting of a consolidated limestone platform with numerous holes, crevices, and occasional undercuts. Maximum vertical relief is < 0.5 m and the depth ranges from 3 m to 6 m. Previous surveys indicate a dominance by algae (87%), with very minor contributions to the substratum surface by sponges (5%), hard corals (1 %), and gorgonians (< 1 %) (Sluka et al., 1996). Dominant algae include turf species and the green alga *Microdictyon marinum*. Species richness of sessile invertebrate taxa is among the lowest of all reefal and non-reefal hard-bottom types in the archipelago.

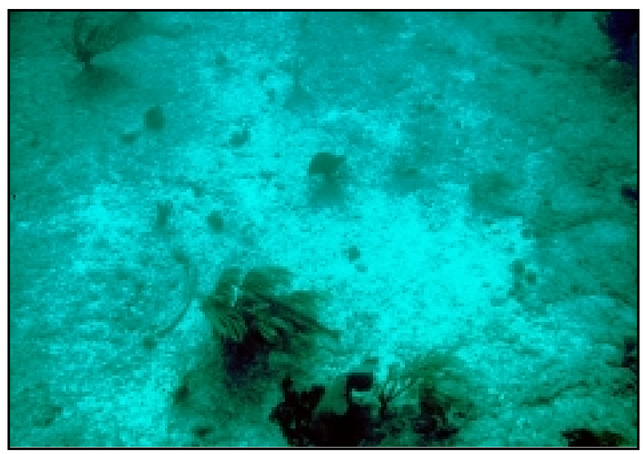

Figure 96. Platform margin on Little Bahama Bank

Level 12: Ecotype - Near shore

Several natural processes of cementation, lithification, and levels of chrystalization result in a hard underwater surface. Mixed facies of oolite with skeletal or coralgal, sediments are dominant base sediments in many areas, and sponge and coral are indicative. Near shore hard-bottom communities in the Bahamian archipelago are typically expressed as an extension of island platforms.

Level 13: Ecounit location and description -

Figure 97. Near shore hard bottom, Exuma

Level 11: Geomorphic types

There are four marine geomorphic types found in the Bahamian Archipelago:

- Soft Sediment
- Reefal Hard-Bottom
- Non-Reefal Hard Bottom
- **Deep Reef Resources**

Deep Reef Resources

An important influence on all aspects of the Bahamian Archipelago is the surrounding open ocean areas of the Gulf Stream and the Greater Atlantic basin. Wind and wave energies have predominantly influenced the production of the bank system and island formation. The interface of the archipelago and the ocean energies are, in many ways interrelated and represent a defining characteristic of the island system.

Level 12: Ecotype – Deep Reef resources

Characterized by deep water (20+ meters), this classification serves as a transition area from the shallow bank system and the open Atlantic Ocean.

Level 13: Ecounit location and description - Andros Reef Wall and Caves

The platform margin off Andros Island includes deep reef resources beyond the 20 meters visible in LandSat imagery. Deep reef resources are largely undescribed in the Bahamas, but may represent large areas of important fisheries habitats. The following figure prepared by the U. S. Navy for the Tongue of the Ocean illustrates the complexity of the deep reef habitats.

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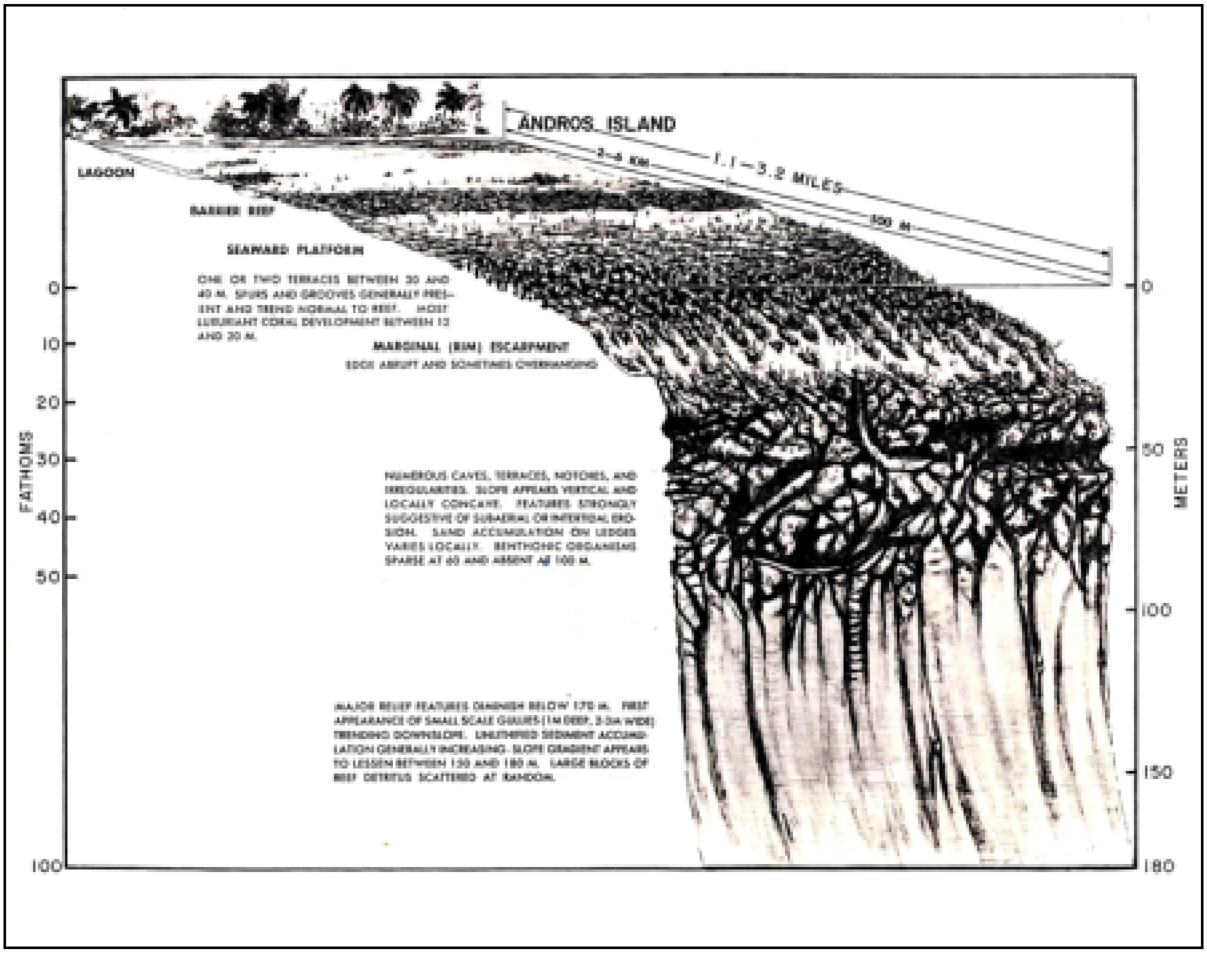

Figure 98. Deep reef habitat [Andros]

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IV. LAND COVER MAPPING OF THE BAHAMIAN ARCHIPELAGO

1. Introduction

The objective of landcover mapping of the Bahamian Archipelago is to characterize both landscapes and shallow seascapes, based on available LANDSAT thematic Mapper (TM) satellite images, other remote sensed data, and a standardized vegetation classification system for the greater Caribbean region, developed by the Caribbean Vegetation and Landcover Mapping Initiative (CVLMI). The major steps undertaken by this initiative include:

- Review of existing vegetation classification efforts;
- Convene Caribbean Vegetation Ecology Working Group;
- Develop standard classification system for the Caribbean.

The Caribbean Vegetation Classification and Atlas Project has been a key step towards characterizing the natural vegetation and landcover of the region, island-by-island, based on the newly derived standardized vegetation and classification system. Once the distinct natural vegetation types that occur on Caribbean islands are accurately understood, described, and mapped in a manner that is accepted and respected by all constituents in the region, the resulting vegetation/land cover maps for the islands of the Caribbean become valuable tools in natural resource management and conservation.

The Bahamian Archipelago Landcover Mapping Project was conducted in collaboration with The Nature Conservancy (TNC), the International Institute of Tropical Forestry (IITF), the US Forest Service, the EROS Data Center (EDC), and the United States Geological Service (USGS). It integrates the mapping of vegetation (based on the developed standard vegetation classification system) with the mapping of marine benthic communities, and has relied exclusively on the LANDSAT 7 image analysis methods developed by the EROS data Center (EDC) in Sioux Falls, North Dakota.

2. Methodology

2.1. Selection of Images

Atlas-scale mapping projects require a base map and data source appropriate for the area of coverage. The Bahamian archipelago covers about 400,000 square kilometres of oceans, shallow banks and islands. Mapping at such a scale requires imagery that can be manipulated for working over large areas. LANDSAT 7 Images are best suited for this project because the imagery is already geo-rectified, facilitating the mapping process. Scenes are recorded continuously by satellite, circling the globe in predefined paths, which repeat every 16 days. Each path is divided into rows; therefore, every scene is distinguished by path, row, and date of acquisition. Twenty scenes that best met the chosen criteria, including limitations in cloud cover, tide, daylight, season, and relation to significant weather events, while providing the most complete representation of the entire Bahamian archipelago, were selected from the USGS/EROS website. Some duplicate scenes from the same path and row, but from different dates, were chosen to provide complete representation. For example, in one scene Grand Bahama Island is well represented but the Bimini Islands are under cloud cover, whereas in another scene the opposite is true, so both were ordered. Additional scenes were added by recommendation by USGS.

Table 9. List of LANDSAT 7 images used in the landcover mapping project

Selected LANDSAT 7 Scenes				
Scene #	Date	Islands	Path	Row
7008045000001950	10/19/00	TURKS	8	45
7009045000001050	01/10/00	CAICOS	9	45
7010044000106750	03/08/01	RUM KEY	10	44
7010045000103550	02/04/01	ANAGUA	10	45
7011043009929350	10/20/99	SAN SAL	11	43
7011044000110650	04/16/01	LONG ISLAND	11	44
7011045000110650	04/16/01	RAGGED	11	45
7012043000103350	02/02/01	ELUTHRA	12	43
7012044000004750	02/16/00	GREAT EXUMA	12	44
7012044000011150	04/20/00	GREAT EXUMA	12	44
7013041000016650	06/14/00	GREEN TURTLE	13	41
7013041000105650	02/25/01	GREEN TURTLE	13	41
7013042000008650	03/26/00	ABACO	13	42
7013043000008650	03/26/00	ANDROS	13	43
7013044000008650	03/26/00	So. ANDROS	13	44
7014041000103150	01/31/01	L. BAHAMA BANK	14	41
7014042000104750	02/16/01	GRAND BAHAMA	14	42
7014042100004550	02/14/00	BIMINI	14	42
7014044000010950	04/18/00	CAYSAL	14	44
Additional duplicate scenes were added to the collection				
7013041000113650	05/17/01	GREEN TURTLE	13	41
7013042000113650	05/17/01	ABACO	13	42
7013043000113650	05/17/01	ANDROS	13	43
7014041000106350	03/04/01	L. BAHAMA BANK	14	41
7014041000005950	06/10/01	L. BAHAMA BANK	14	41
7014042000005950	06/10/01	BIMINI	14	42

2.2. Import and Calibration of Scenes

Each of the scenes were imported into an ERDAS Image program and given label numbers indicating the path, row, and Julian date of acquisition. Data was requested in the NLAPS format, and 6 band wavelengths were imported (H1 spectral, H2 Thermal, H3 Pan, and bands 1,5,7, for land) with UTM (x, y), projection and units in meters, resulting in an image file (.img). Each imported image and associated information from the header file (.gmb), including mapping projection parameters, date and time, UTM zone, orientation, solar spectral irradiance values, band wavelength, gains and biases etc. were included in a meta-data file.

Calibration models were provided by the EROS Data Center and applied to each image to correct solar irradiance in the raw NLAPS data. For each image, the sun elevation, along with gain and bias information provided from the header file, were entered into the model as function definitions. All images were projected in UTM Zone 18, to correlate with the base map dataset. A copy of each calibration model, and the resulting calibrated image, were included in the meta-data. The calibrated image was also used in the processing protocol, the result of which was the primary data source for landcover determination.

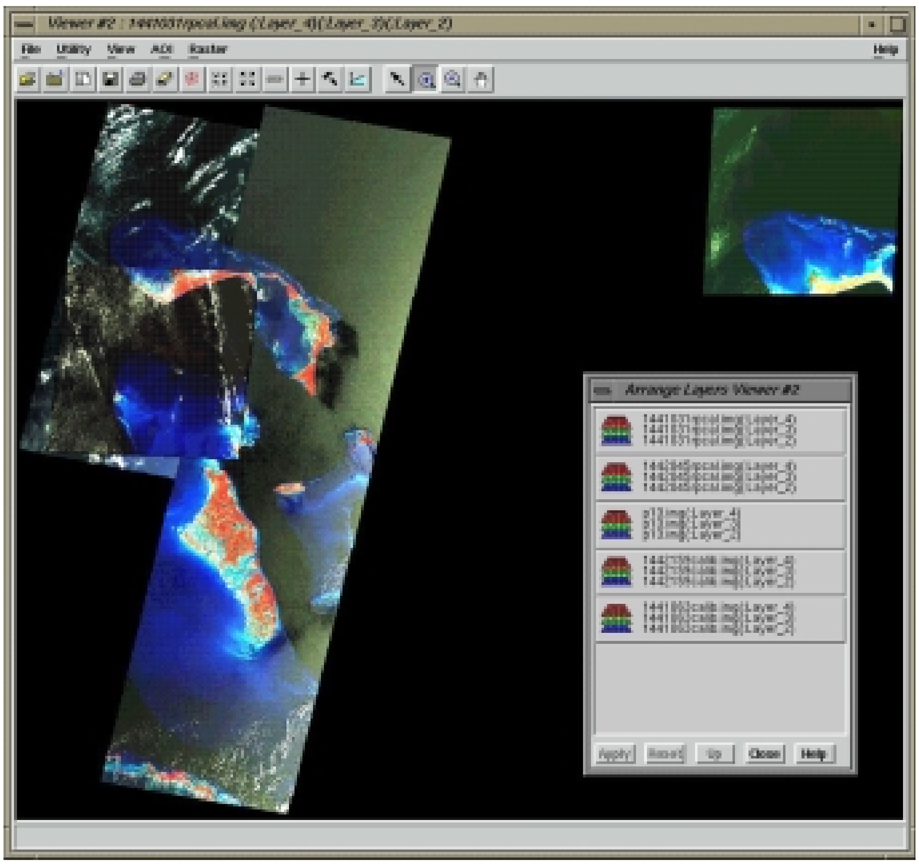


Figure 99. LANDSAT 7 scenes from paths 13 and 14, rows 41 – 44 pasted together in one image
[Note duplicate scene layer over Southern Grand Bahama Island]

2.3. Unsupervised Classification

The unsupervised classification process allows assigning a habitat characteristic to the spectral values of each pixel in an image. Each calibrated image was run through the ERDAS Image software's unsupervised classification function, for 25 classes and 75 iterations. Although the classification function can be run with as many as 100 classes, it is difficult to determine useful distinctions from the satellite images with reasonable accuracy when using that many classes. Through trial and error, and taking into consideration the time factor, we determined that 25 classes best defined the discernable habitats of the Bahamas, and that 75 iterations best met the needs of this project within sensible time limitations. The resulting images were added to the meta-data file.

2.4. Masks

Masks and ancillary data were developed to eliminate features from an unsupervised image in order to facilitate analysis. In remote sensing terms, a mask is simply a data set that identifies a specific feature (e.g. clouds or cloud shadows) while being transparent in other areas of the image. The purpose of the mask is to remove data that would not be useful to the classification objectives. We created masks to extract existing clouds and corresponding cloud shadows from each scene, to isolate all marine habitats from the terrestrial maps, and to remove deep-water resources that were unnecessary for evaluation. The models for these masks are included in the meta-data file, and are required to run the USGS ‘decision-tree’ model prior to training classification.

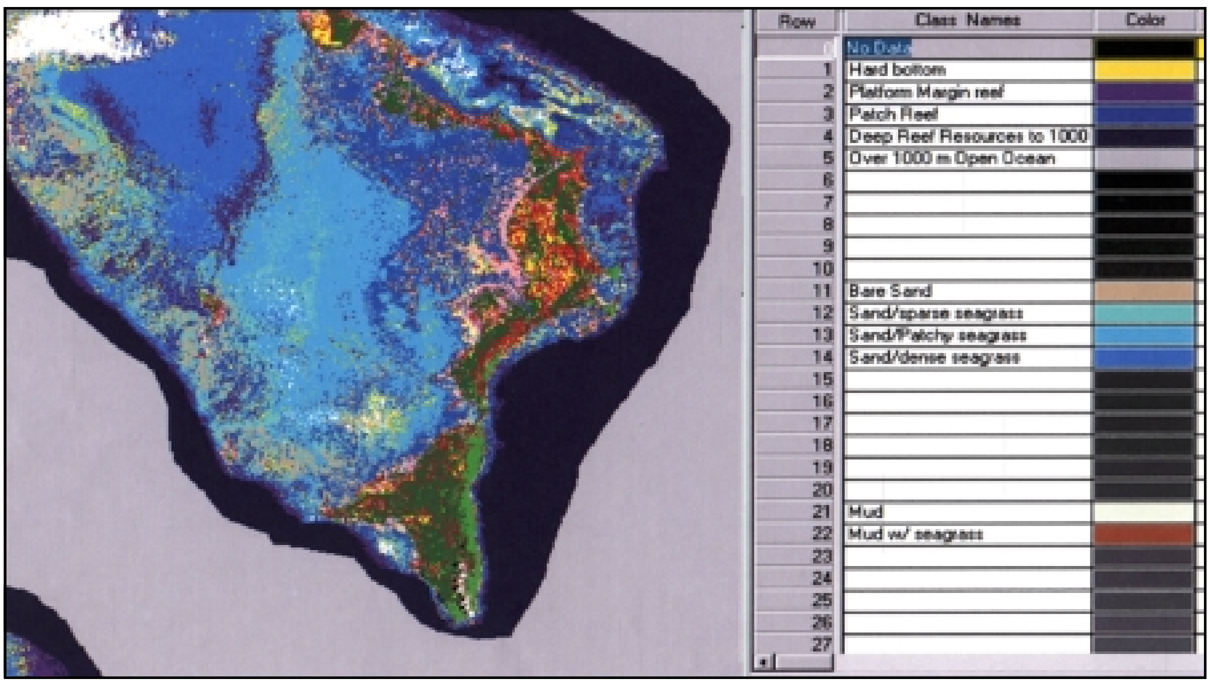


Figure 100. False colour of marine and terrestrial habitat classifications of the Abaco Islands
[A mask was used to remove deepwater resources from this image]

2.5. Habitat Descriptions

The specific habitat types that occur in the archipelago were defined, indexed and included in this mapping process. A long list of very distinct and elaborate habitat descriptions was reduced to terrestrial and marine habitats (environments) that were both mappable and discernable from the LANDSAT images. This is a coarse classification scheme applied over the entire archipelago, which can be refined further for future large scale mapping projects.

2.6. Band Combination (Raster Layer)

In the raster layer, changing the band combination representation can provide views that may facilitate viewing and distinguishing different habitats, especially marine versus terrestrial.

Table 10. Habitat mapping classes used in the Bahamian Archipelago Landcover mapping project

Index #	Terrestrial	Index #	Marine
32	Creek	01	Hard bottom
46	Human altered landscape (HAL)	02	Platform reef
47	Bare sand - above water	03	Patch reef
60	Palm	04	Deep water resources
61	Pinelands	11	Bare sand - submerged
62	Dry evergreen forest coppice	12	Sand w/sparse sea grass
63	Coastal strand	13	Sand w/patch sea grass
64	Wetland/pond	14	Sand w/dense sea grass
65	Agriculture	21	Mud bottom
66	Dense mangrove	22	Mud bottom w/sea grass
67	Sparse mangrove		
68	Conocarpus		
70	Cloud		
71	Cloud shadow		

Table 11. Raster layer Band Combinations used in the land/seascape mapping

	Conventional default	Realistic	Good marine	Good Terrestrial
Red	4	3	5	6
Green	3	2	4	4
Blue	2	1	3	2

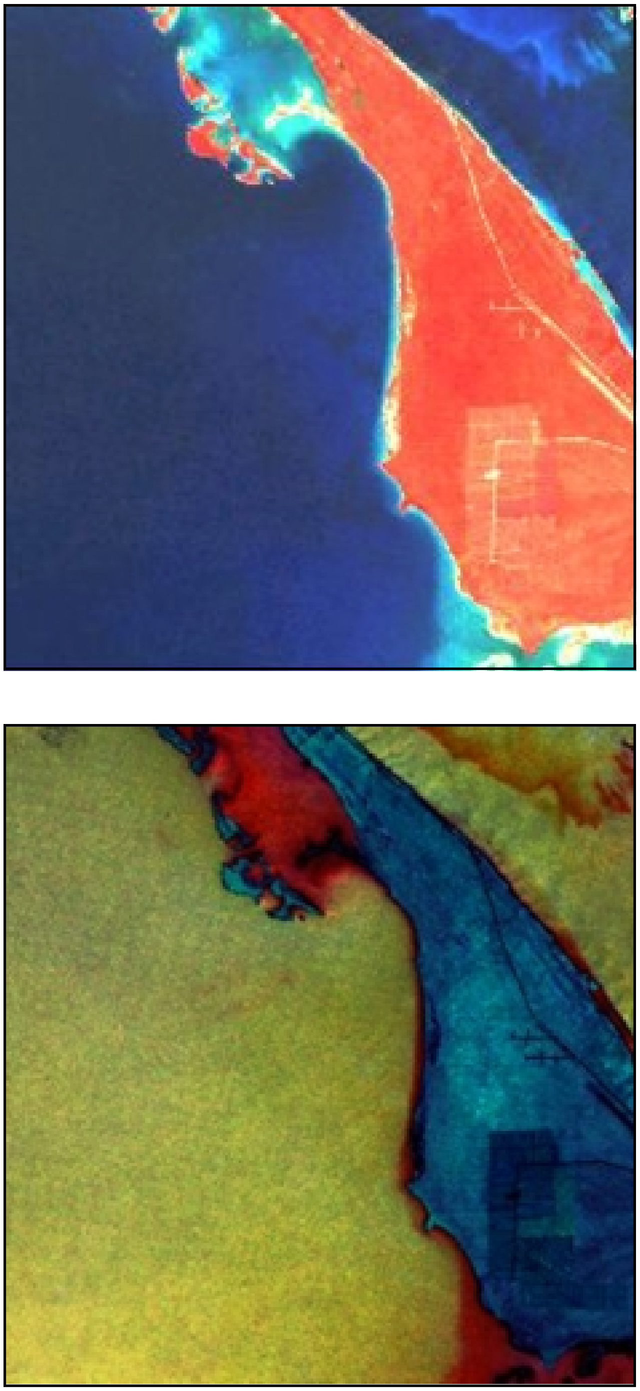


Figure 101. Examples of how different band combinations in the Raster layer of a LANDSAT 7 image can be used to highlight different characteristics

[One example on the left, with the band combination 4,3,2, was chosen as default for this report]

Ancillary data sources were used to help determine which habitat classes were visible from the imagery, and to develop priority sites for ground-truthing efforts. Ancillary data sources included:

- Aerial photography obtained from the Bahamian Government Department of Lands and Surveys;
- Research projects and reports that identified habitat types in specific locations providing Global Positioning Systems (GPS) information from each sampling station;
- NOAA nautical charts;
- Land Resources of the Bahamas report series;
- Land Survey of the Bahamas map series (1:25,000) for the four largest islands; and
- Older LANDSAT imagery used in previous research projects.

These data sources were used to compile training data sets. Often older information was used to evaluate the newer imagery. Different band combinations were used to correlate the position of reefs, wetlands or other various habitat types.

Figure 102. Aerial image used to verify and recode marine habitat classification near New Providence

To conduct the supervised and unsupervised classification of images, we developed a false colour scheme for both the landcover and sea cover maps that best visualize the different habitats.

Figure 103. Colour scheme for land cover mapping
[Top: Colours used for vegetation communities, wetlands, and human altered landscapes.
Bottom: Colours used for marine benthic habitat classes]

2.7. Ground Truth Points (Field collected)

The USGS mapping initiative focused on the four largest islands: Abaco, Andros, Grand Bahama and New Providence. These islands were the primary targets for testing the USGS landcover mapping models. Although there was a great deal of information collected from existing reports, there was also a need to collect new ground truth points. Therefore, points from the four islands were collected, representing as many of the habitat classes as possible. During multiple research expeditions, ecoregional planning team members, researchers, and local residents collected GPS readings and habitat descriptions, which were combined into data stacks for each mapping image. Habitat definitions, and the mapping process, both require extremely high numbers of training points to assure accuracy. Ground truth points collected in the field are the most reliable datasets for use in the training models.

Protocol for collecting landcover data (ground-truthing)

OBJECTIVES

This is a simple protocol for collecting new field survey data as well as converting previous field data into a uniform format for landcover 'training' model using LANDSAT 7 images. The information compiled from new fieldwork, and previous research projects in the Bahamian archipelago, will be used to complete a habitat map of all island and shallow bank areas. This map will be raster-based and allow the rapid assessment of change with successive LANDSAT image analysis.

EXPECTED PRODUCTS FROM THIS EXERCISE

Sufficient information for habitat mapping in collaboration with USGS-EROS Caribbean landcover mapping initiative, and

A habitat classification and characterization system for the production of a 'landcover atlas' for use in research and natural resource management in the Bahamas.

MATERIAL AND METHODS

Basic equipment for Ground-truthing include:_Global Positioning System (GPS) receiver; Compass; Digital camera; Data sheets; Maps and copies of imagery; and Marine and terrestrial classification list.

GPS Verification Points

Using a printout of the LANDSAT 7 image at the appropriate scale, and a reference map, 3 to 4 landmarks should be marked, including GPS waypoints and descriptions. One image per batch of field data forms is sufficient for each ground truthing effort.

Field Data Forms

Each waypoint is taken no less than 100 feet (30 meters) from any one edge of the general environment in which the waypoint is located. The form is completed by checking only ONE selection from each category. Only parameters that represent the dominant condition for the survey site should be marked. The forms should be numbered by the GPS Waypoint, an alpha-numeric code based on the following codes: Island code (AB, AN, GB, NP), marine samples are identified as adjacent island group. GPS waypoint number (starting at one). Persons initials. *EXAMPLE: Ethan Freid's 305th waypoint on New Providence (NP) is NP305EF.*

Additional information may be collected at each point, including plant specimens, algae checklists, fauna surveys, or more detailed substrate-life form coverage data. Field data forms should indicate if additional information was collected at the survey point.

Batches of field data collection forms from one expedition should be stapled together for easy computer data entry, and include a locator map indicating GPS verification points. Verification points need only be taken once, thus there may be many field survey points taken from the western end of New Providence, but only one set of reference points.

Photographs and Images

At each terrestrial and wetland field survey point, and using a digital camera, the surveyor should take four images, one from each compass direction: North (0º), East (90º), South (180º), and West (270º), in that order. JPEG codes will be the waypoint code plus an additional letter signifying the direction they were facing (N, E, S, W). Underwater images will be identified by roll and frame numbers.

Figure 104. Collecting waypoint information from a marine habitat designation

2.8. Remote sensing training points (Vector layer)

A list of points that represent a specific habitat can also be generated using remote sensing techniques on the vector layer of a calibrated image, saved with double precision. With the vector tools icon option on the menu bar locked for multiple point selections, the point selection tool (+) allows for marking multiple points of a specific habitat directly on the satellite image. The appropriate point choice requires a review of the image, and information from ancillary source data such as aerial photographs, input from local residents, and personal experience. The UTM (x, y) projection information from the chosen points is recorded in an attribute list that is exportable into Excel or other database files. Once attached to habitat designations these training points are included in meta-data files. Training points gathered in this manner were kept separate from field collected ground truth points, and provided vital classification data to the model.

2.9. Decision (Tree model)

Each data stack was provided to Mr. Mike Coan of Raytheon/USGS to be used in the 'decision-tree' model prior to training classification. This process is a supervised process where ground truth points, training points, and habitat data are aligned into spectral information.

2.10. Classification Training Model

Once a suitable decision-tree is completed, it is possible to run an extensive 'classification training' model of the unsupervised images. This process converts spectral information into colour-coded pixel representation of consistent characteristics (defined habitats) in a scene. The training model is unique for each date, and it was fortunate that several of the selected scenes from the Bahamas were acquired by satellite on the same, nearly cloudless, day. Therefore, in the first training model run, unsupervised images of Abaco, New Providence, Andros, and east Grand Bahama were assembled into a single file and classified together.

2.11. Review of Training Classification Model

The resulting training classification image was reviewed for accuracy and consistency. The inspection process begins by super imposing ground-truthing points over a section of the image with known landcover. Often the classified image can be compared to the calibrated image to detect any problems in the classification. This review can expose situations that require the addition, combination, and/or reassignment, of habitat distinctions.

During early field expeditions, some habitat types were defined by characteristics that are not discernable from the satellite and had to be re-addressed. For instance, habitats originally defined as residential, recreational, hotel/resort, and business district, were combined into the single habitat called 'Human Altered Landscapes'.

The model characterizes land cover by spectral signatures, and there was the occasional mistaken classification of areas with similar signatures. For example, white sand beaches (Coastal Strand) and some exposed banks (Bare Sand above water) are both highly reflective surfaces, and have similar signatures to recently cleared or scarified area, paved parking lots and construction sites, (Human Altered Landscapes). Some habitat distinctions had subjective aspects that the model could not determine. For instance, the benthic marine habitat 'Mud with sea grass' has a similar signature to the terrestrial class 'Creek'. Ancillary data and additional ground truth expeditions were used to identify and distinguish such areas.

The review ultimately allowed for the detection of areas where supplemental training points were necessary. Additional field expeditions were scheduled to collect more ground truth points, and additional training point lists were complied directly from the vector layers.

2.12. Recoding Classified Images (Production of Final Rasters)

After the inconsistencies discussed above were addressed, and the required additional ground truth and remote sensing data collected, it became necessary to recode some parts of the map, including cloud cover and shadow. Section by section, each misclassified pixel was reassigned the correct classification in the recoding process. Recoded images were included in the metadata of the final image.

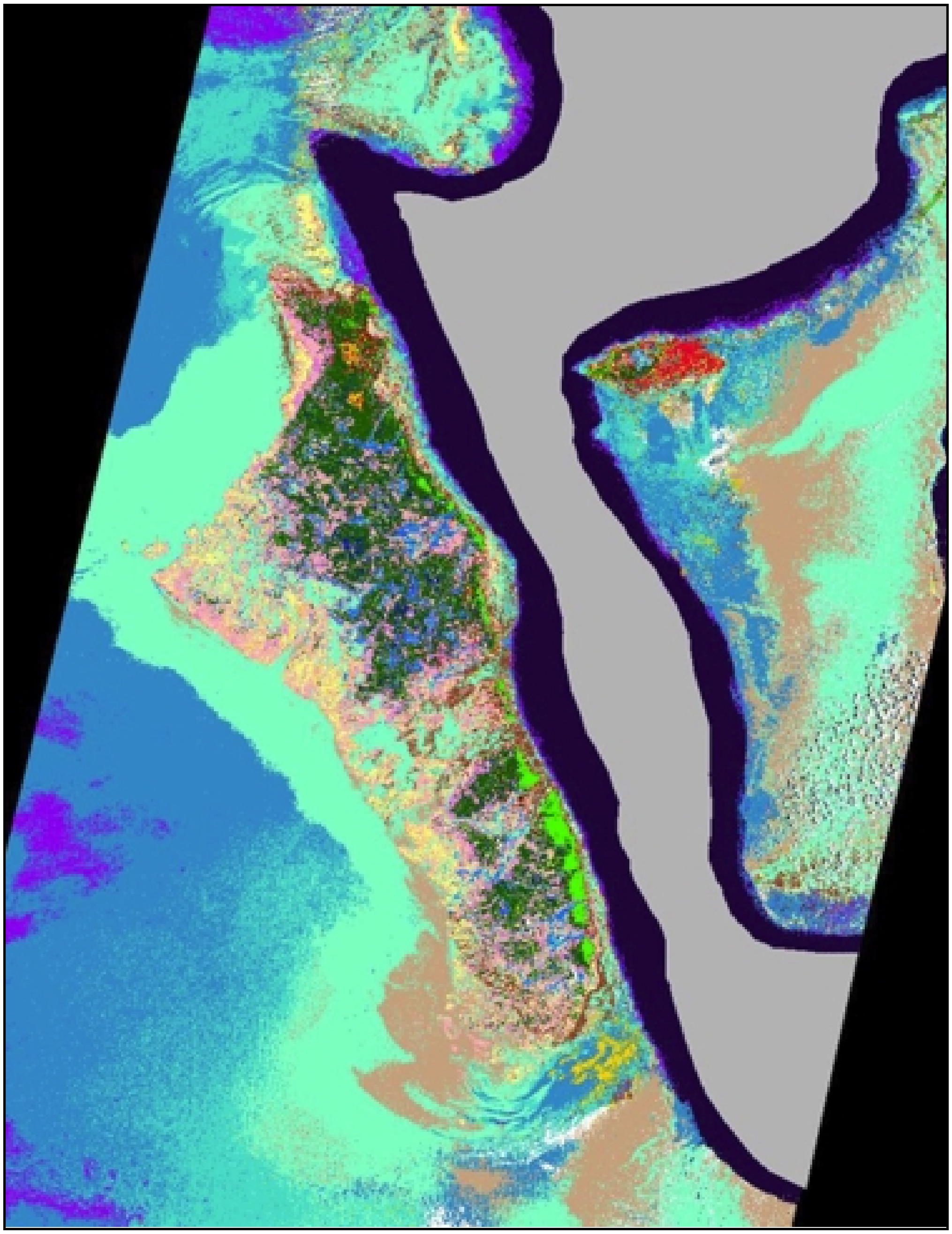


Figure 105. False colour classification of marine and terrestrial habitat classifications of Andros and New Providence Islands [A mask was used to remove deepwater resources from this image]

2.13. Realign Bank bathymetry from Projected Map and Sat Images

To establish a distinction of the shallow marine areas, a base map with bathymetric characteristics became necessary. Such a map was constructed from the World Digital Data Set and converted into Geographic Information Systems (GIS) datasets, in ESRI ARCVIEW 3.2a with the Spatial Analyst extension. Themes included an islands layer and a bathymetry contour layer to 200 meters.

Although the archipelago extends into three UTM zones (the extreme western portion of the archipelago is in

UTM Zone 19, and east of the Turks Bank is in UTM Zone 17), the majority of the islands are in UTM 18. Base maps were re-projected into UTM Zone 18, and corrected for distortions in the coastline and platform margins. All images were projected in UTM Zone 18, to correlate with the base map dataset. In ARCVIEW, the base map was layered over the unsupervised image, including the need for time-consuming revisions to bank and island polygons, resulting in a more accurate representation of bathymetric and island contours including mangrove wetlands and human altered landscape.

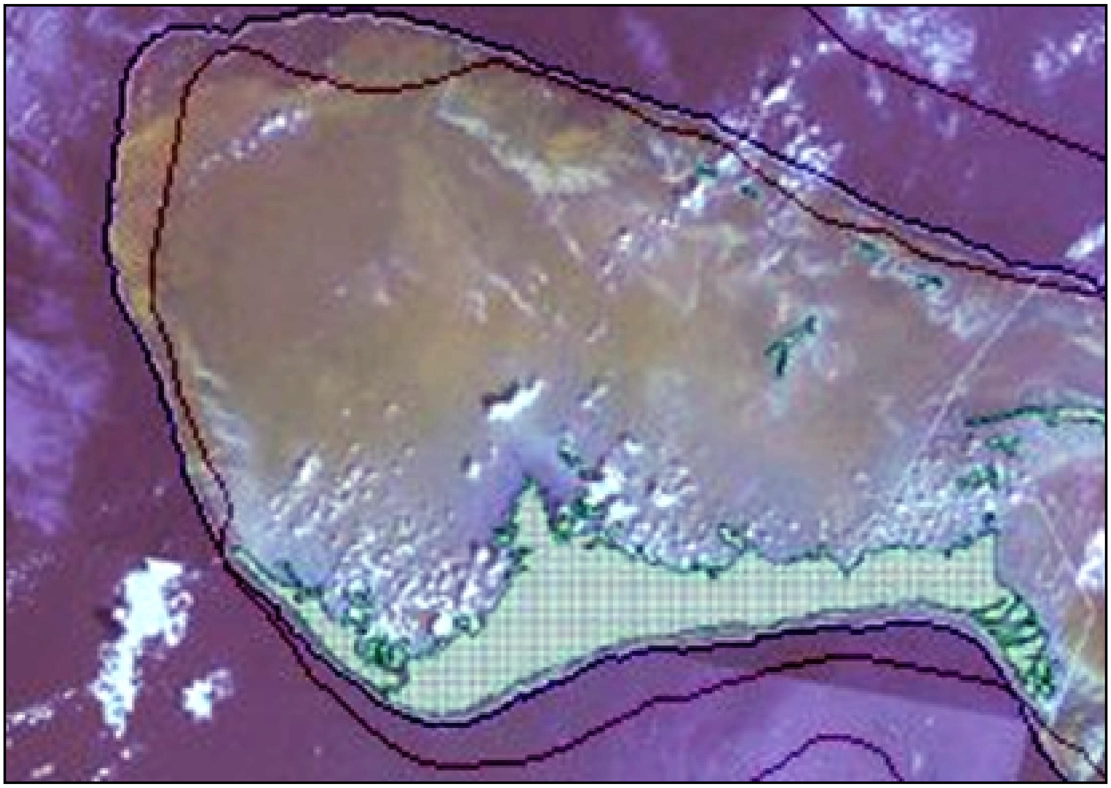


Figure 106. LandSat 7 images of western Little Bahama Bank
[green line represents outline of Grand Bahama Island, red line represents bathymetry before correction, and blue line represents corrected bathymetry]

2.14. Creation of Island Subsets in GIS (Map Products and Layouts)

Map layouts were organized by island group with particular focus on the largest islands in the archipelago: Andros, Grand Bahama, Abaco and New Providence. The layouts presented the island subsets at a scale between 1:150000 and 1:250000, and separated the land and sea cover maps for easier interpretation.

Three different maps are presented for each location: the unclassified satellite image, and the false colour composites of classified terrestrial and seafloor images. The false colour composite maps were prepared using bands 4, 3, and 2 of the enhanced thematic mapper plus data. Using ArcView 3.2 image analysis software, classifications of individual islands were accomplished with the help of the training model image. Pie charts, associated to each scaled terrestrial layout, provide an easily discernable illustration of habitat type relationship per island or island group. Metadata tables were maintained containing reference information for each island system.

Table 12. Abaco Island System Metadata

[The false colour composite maps were prepared using LANDSAT 7 enhanced thematic MAPPER plus data with bands 4, 3, and 2 chosen for the map. The imagery was acquired on March 26, 2000. The path 13 data has an image ID of LE70130443000113650. The data were recalibrated using a model prepared by Mike Coan from the U. S. Geological Survey in Sioux Falls, SD]

Map type	File name	Segment name	Scale
False color composite	ab1_bands432_a.apr	Little Abaco/Green Turtle Cay	1:380631
Land use/land cover	ab1_pie_a.apr	Little Abaco/Green Turtle Cay	1:380631
Seafloor cover	ab1_marine.apr	Little Abaco/Green Turtle Cay	1:380631
False color composite	ab2_bands432_a.apr	Marsh Harbour	1:259925
Land use/land cover	ab2_pie_a.apr	Marsh Harbour	1:259925
Seafloor cover	ab2_marine.apr	Marsh Harbour	1:259925
False color composite	ab3_bands432_a.apr	Central Abaco	1:246577
Land use/land cover	ab3_pie_a.apr	Central Abaco	1:246577
Seafloor cover	ab3_marine.apr	Central Abaco	1:246577
False color composite	ab4_bands432_a.apr	Cherokee Bay	1:178115
Land use/land cover	ab4_pie_a.apr	Cherokee Bay	1:178115
Seafloor cover	ab4_marine.apr	Cherokee Bay	1:178115
False color composite	ab5_bands432_a.apr	Hole-in-the-wall/Sandy Point	1:264071
Land use/land cover	ab5_pie_a.apr	Hole-in-the-wall/Sandy Point	1:264071
Seafloor cover	ab5_marine.apr	Hole-in-the-wall/Sandy Point	1:264071

	Easting Left	Easting Right	Northing Top	Northing Bottom
Little Abaco/Green Turtle Cay	199914	279468	3001091	2948855
Little Abaco/Green Turtle Cay	199914	279468	3001091	2948855
Little Abaco/Green Turtle Cay	199914	279468	3001091	2948855
Marsh Harbour	252638	306979	2957589	2931454
Marsh Harbour	252638	306979	2957589	2931454
Marsh Harbour	252638	306979	2957589	2931454
Central Abaco	255118	306648	2936721	2915113
Central Abaco	255118	306648	2936721	2915113
Central Abaco	255118	306648	2936721	2915113
Cherokee Bay	265926	303163	2916699	2893687
Cherokee Bay	265926	303163	2916699	2893687
Cherokee Bay	265926	303163	2916699	2893687
Hole-in-the-wall/Sandy Point	244244	283490	2896075	2859246
Hole-in-the-wall/Sandy Point	244244	283490	2896075	2859246
Hole-in-the-wall/Sandy Point	244244	283490	2896075	2859246

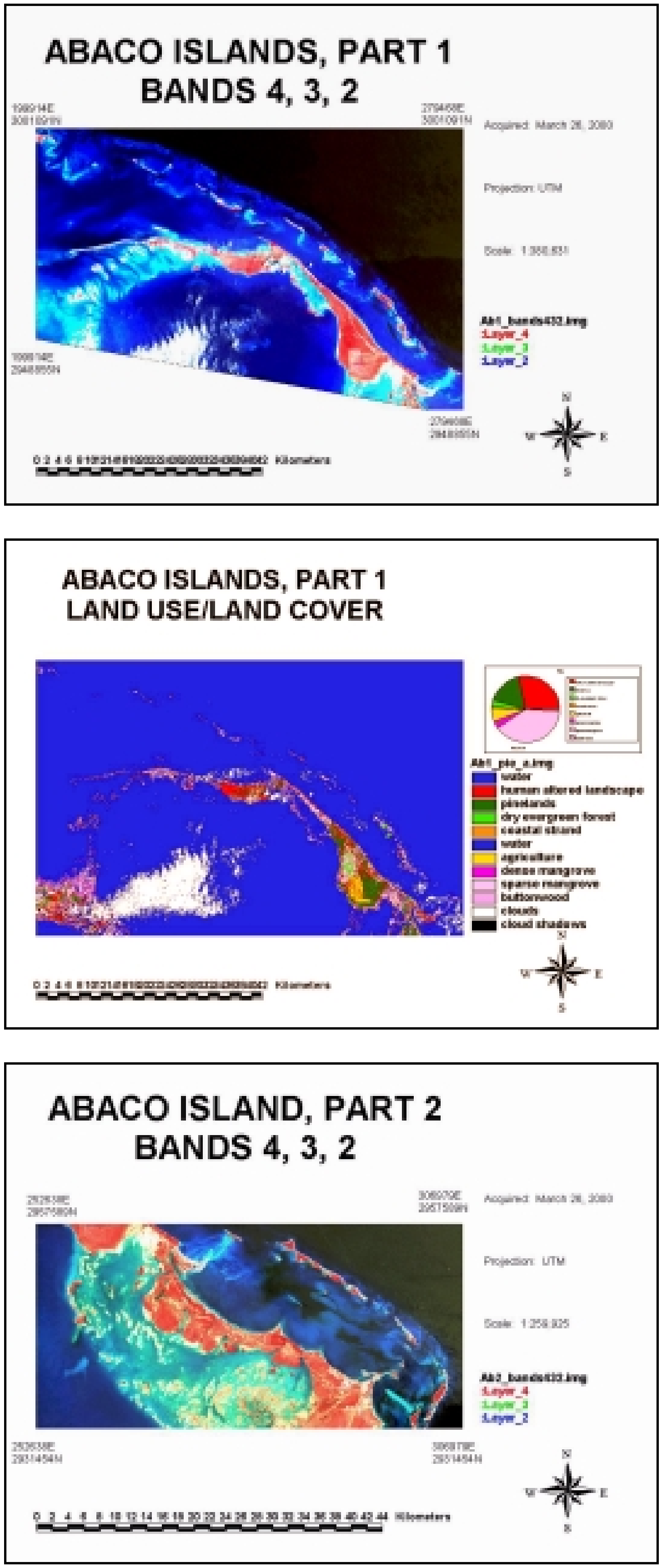


Figure 107. Three map layouts used to illustrate the satellite imagery and false colour composites of land and sea.

These maps can be widely disseminated over the internet as image files (.jpg). A website http://islands.bio.miami.edu was set up for dissemination of the landcover and sea cover information. These maps can be downloaded from the website and reviewed by a wide range of users. A standard colour scheme was used to represent the different coverage classes.

3. Review Landcover Maps of Island Groups

Landcover mapping is a process of repeated application of classification models and subsequent recoding of the resulting image, using both programmed models and manual recode techniques. Mapping was most successful for the bigger islands, where a greater number of training points representing vast areas of each landcover class were available.

The selection of landcover classes is critical to the mapping process, and ideally, classes are chosen because they have both ecological significance and unique spectral qualities. Unfortunately, this is not always possible since some important ecological features, both marine and terrestrial, are a combination of structures or coverage. The scale of this heterogeneous quality determines if a class is distinguishable at the accuracy level (30 meters per pixel) of satellite imagery.

Therefore, selected landcover classes are simple and tend to cluster together a wide diversity of natural communities. For example, ‘dry evergreen formations’ (referred to locally as coppice or simply ‘bush’ in the Bahamas) are by their nature patchy and heterogeneous in composition and include forests, shrub lands and dwarf shrub lands, and consist of hundreds of broadleaf, evergreen plant species. A coarse mapping of dry evergreen formations provides a general picture of intact plant communities, but limited information on their condition or structure.

Fortunately, this hierarchical approach to classification allows, with a minimum of effort, for future subdivisions of the class polygons into more refined community types by the application of a modicum of additional information. For example, the current class of ‘human altered landscapes’ (HAL) is the combination of many smaller distinct classes that were originally defined as residential areas, commercial properties, roads, industrial parks, and cleared land.

There were primarily two issues addressed in the discussion of mapping accuracy. First, how well did the training model capture the landcover classes, and/or are there locations where the coverage was not identified in what is commonly referred to as missed classes? Second, did the landcover mapping process result in a correct representation or were there consistent errors in classification?

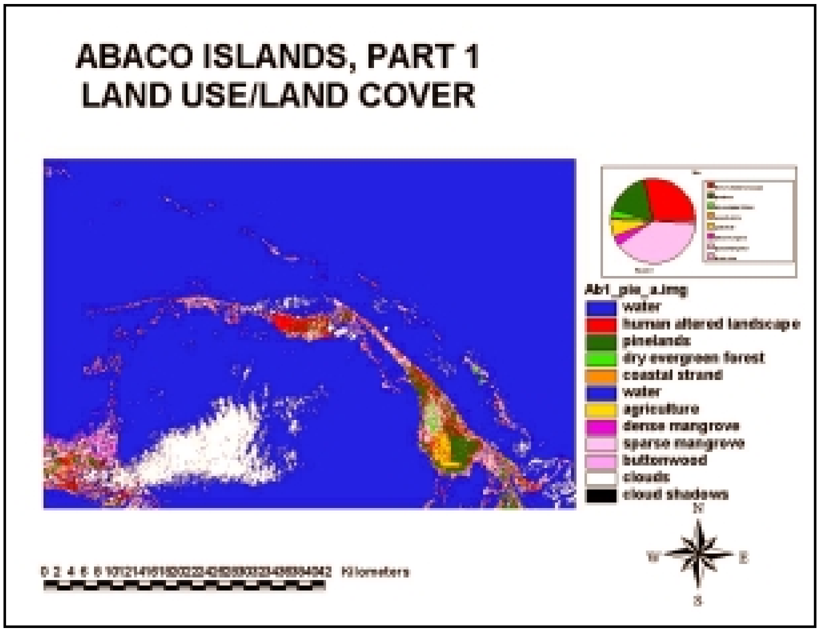
The training model worked best for highly represented vegetation classes, including mangroves, but did have problems with the classification of wetlands, which are small inter-connected habitats distributed over large areas. Although the mapping process was successful in capturing the primarily inland bodies of both fresh and saline water, and areas that are likely to contain more hydrophilic vegetation, the attempt to represent the ecological feature ‘wetlands’ as a single heterogeneous class, failed. This is primarily due to the fact that wetlands tend to be small in size, highly diverse in vegetation structure, and subject to extreme variability and seasonality in levels of standing water, which makes them difficult to identify from satellite images. Human altered landscapes were well captured, and a wide variety of landscape alterations were included in this class. Figure 108 illustrates an example of the landcover mapping for Abaco. The map clearly shows the general patterning of natural communities across the island as well as the extent of HAL.

Was the landcover classified correctly or where there consistent errors in classification? The mapping process resulted in a good coarse assessment of landcover. The model characterizes land cover by spectral signatures, and there was the occasional mistaken classification of areas with similar signatures.

This may occur for several reasons. Many of the misclassified beaches had dune areas lined with Australian pine, an invasive tree commonly associated with human altered landscapes, and white sand beaches and some exposed banks are both highly reflective surfaces, as are recently cleared or scarified landscapes, paved parking lots, roads, and construction sites which are all HAL training points. This is illustrated in landcover maps of Andros island (Figure 109), where beaches were often mistakenly classified as HAL.

Seafloor cover, in general, was more difficult to map employing the same process used for terrestrial environments, even though images were selected with a minimum of sun glare. Ultimately, water depth changed the spectral signal for any given class. Even when including high numbers of training points from both shallow (2 meters) and deep water (up to 20 meter) sites, class resolution was not consistent. This was especially evident for dense and sparse sea grass beds. And although most reef and hard bar areas were represented clearly, deep reef resources (from 20 meters to 200 meters), required additional bathymetric information in the mapping process.

There was however, a fairly good resolution of soft sediment bare sand compared to consolidated or lithofied substrates. Patch reefs with distinguishable take out halos that are often located within stretches of bare sand adjacent to sea grass beds, were often misclassified as patchy sea grass.



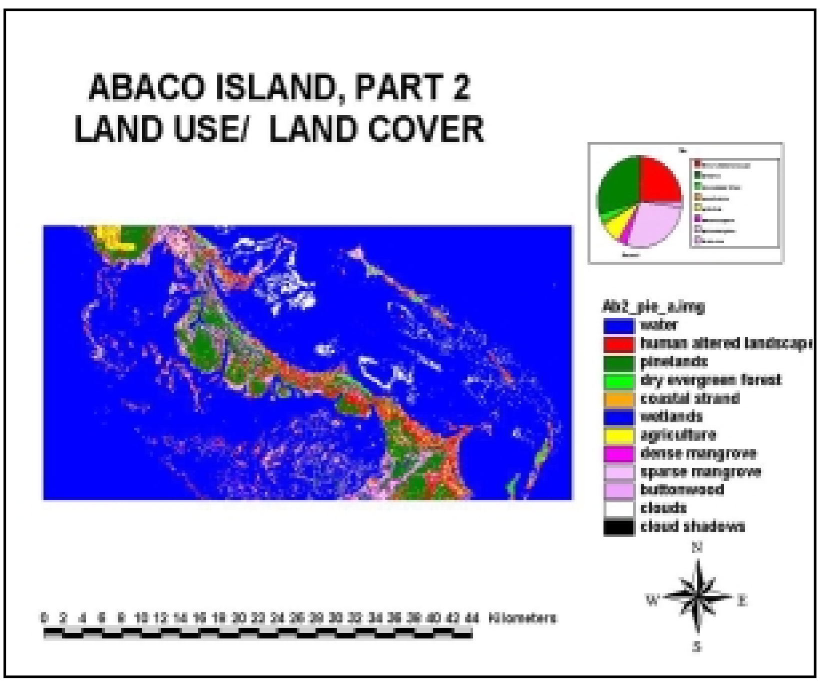
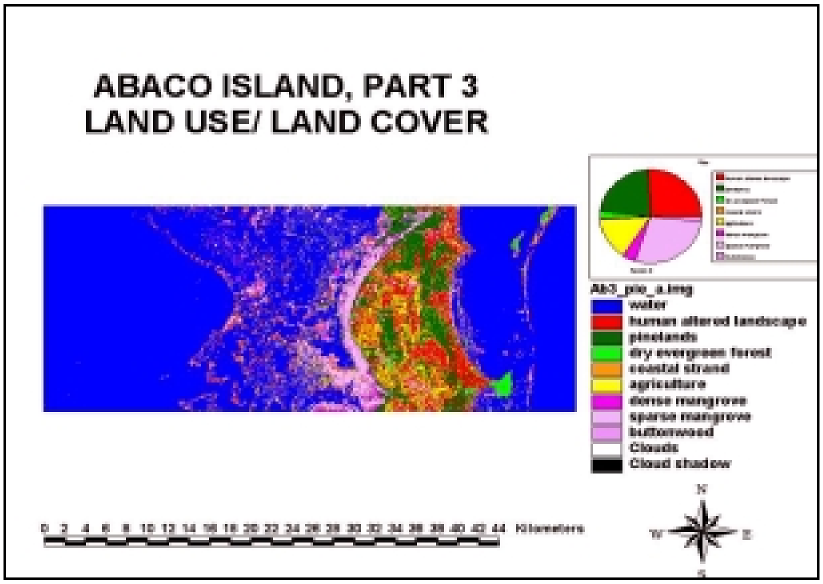
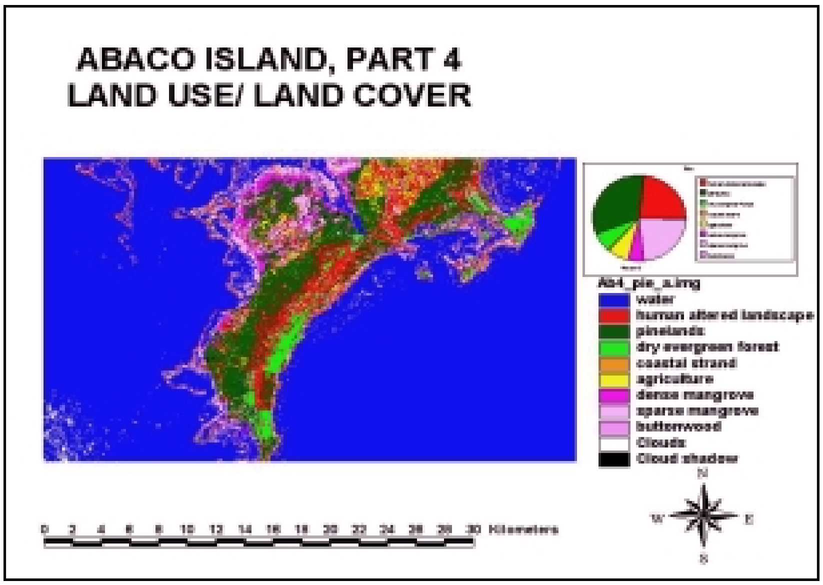
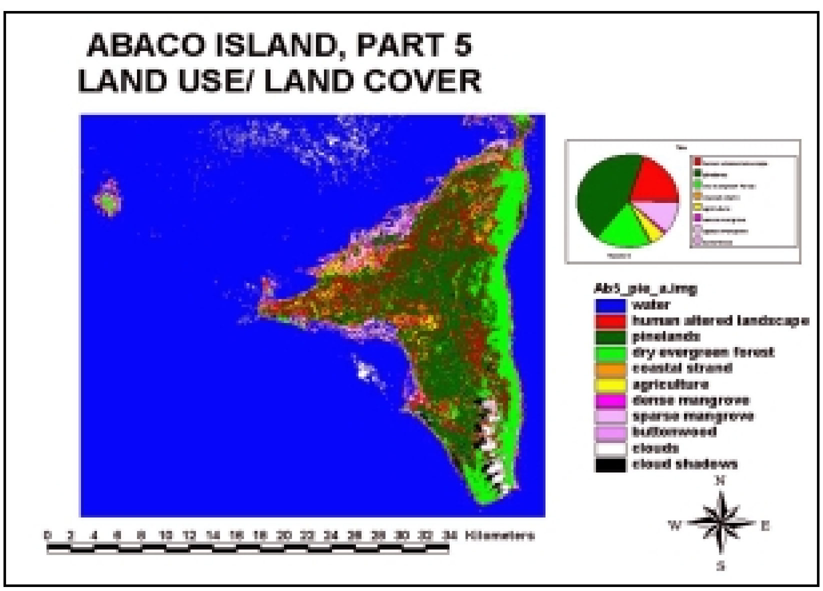


Figure 108: Composite of final landcover maps for Abaco (above and next page)
[The largest landcover classes are human altered landscapes and mangroves]


ABACO ISLAND, PART 3
LAND USE/ LAND COVER
Ab3_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
Clouds
Cloud shadow
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 Kilometers
N
W
E
S


ABACO ISLAND, PART 4
LAND USE/ LAND COVER
Ab4_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
Clouds
Cloud shadow
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 Kilometers
N
W
E
S


ABACO ISLAND, PART 5
LAND USE/ LAND COVER
Ab5_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
clouds
cloud shadows
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 Kilometers
N
W
E
S

Class resolution was also not consistent for the anthropogenic seabed classes, consisting mainly of dredged channels or altered seafloor cover. This is not surprising given that the alterations of an area such as Nassau Harbour usually result in mud bottoms, dominated by algae. This class was determined to be a poor selection for classification and removed from the model, based on a lack of distinguishing features that are visible to the satellite sensors.

Another consistent misclassification was related features that simply were not discernable by the satellite sensors. The habitat creek bed has basically the same spectral signature as mud with sea grass, with differences related to the spatial relationship to land. This became obvious when several creeks appeared to be far at sea, a considerable distance from the Grand Bahama Island, on the map of Little Bahama bank.

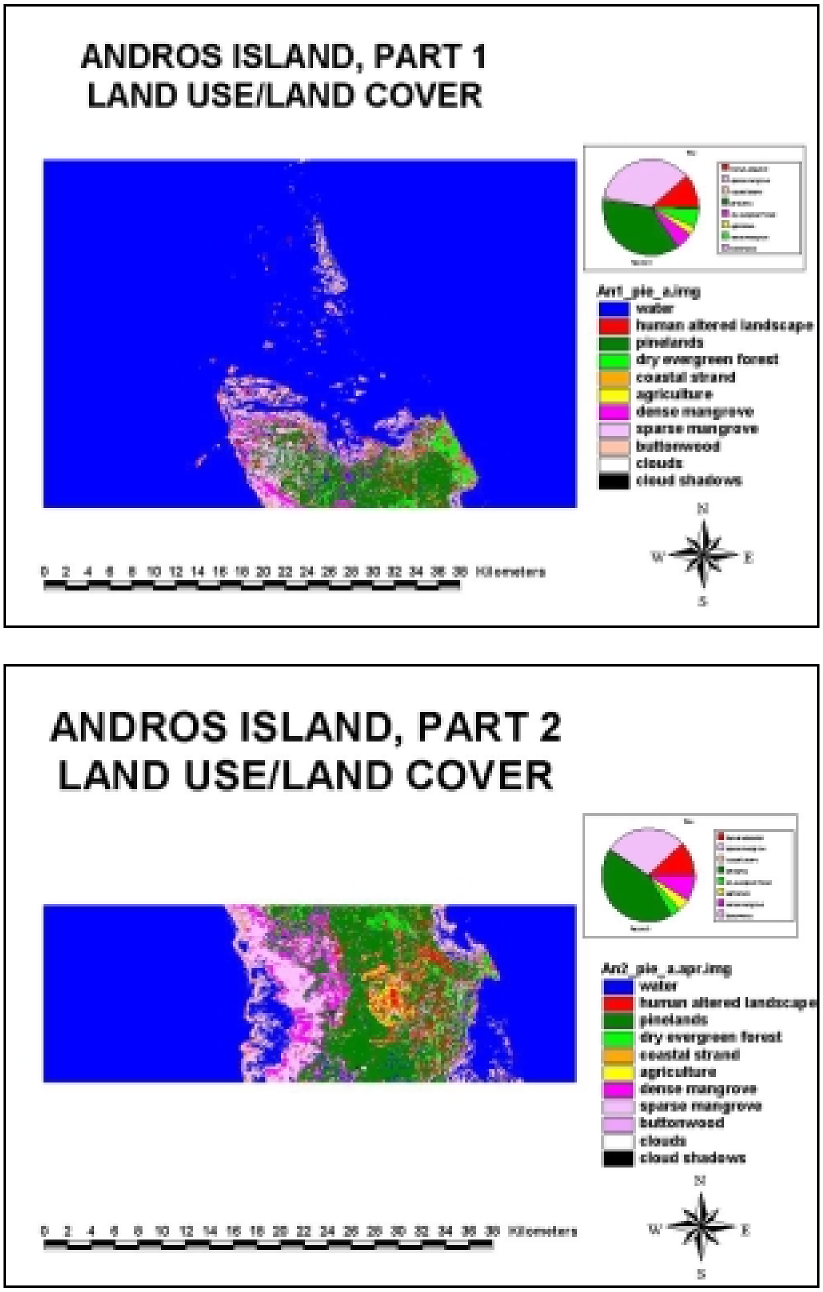
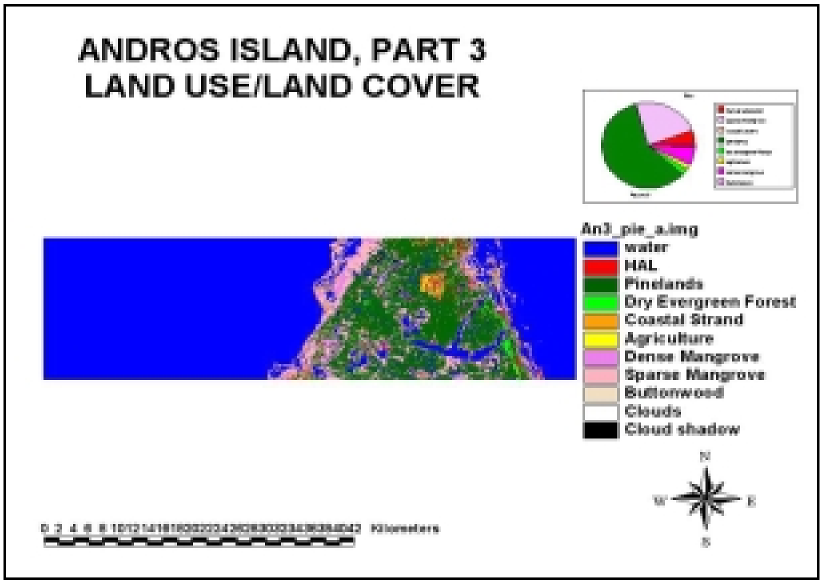
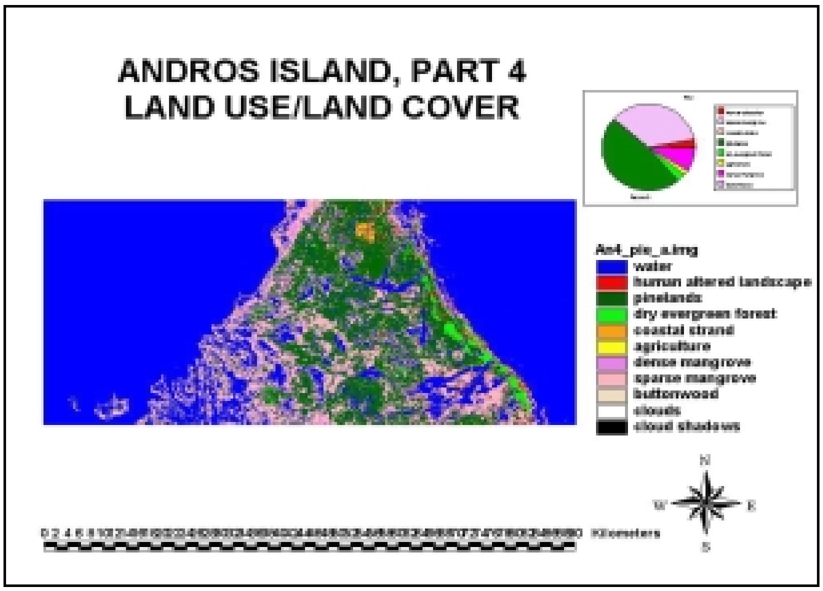
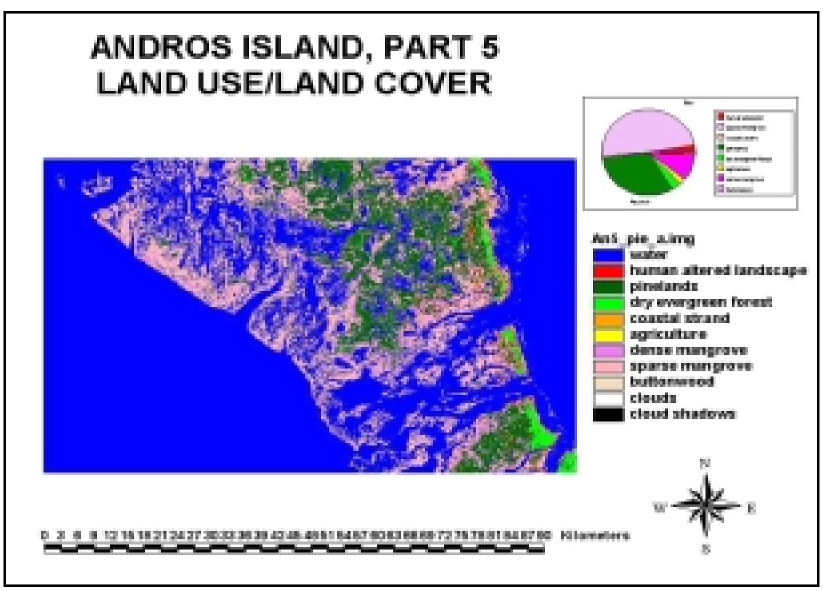
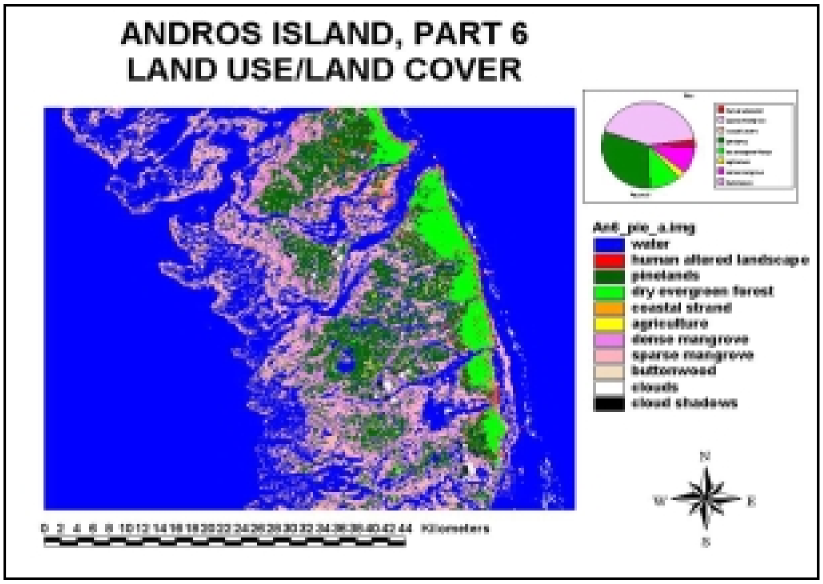


Figure 109: Composite of final landcover maps for Andros (above and next two pages)
[Beaches along the eastern coast of the island were consistently classified as 'Human Altered Landscapes']


ANDROS ISLAND, PART 3
LAND USE/LAND COVER
An3_pie_a.img
water
HAL
Pinelands
Dry Evergreen Forest
Coastal Strand
Agriculture
Dense Mangrove
Sparse Mangrove
Buttonwood
Clouds
Cloud shadow
N
W
E
S
Kilometers


ANDROS ISLAND, PART 4
LAND USE/LAND COVER
An4_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
clouds
cloud shadows
N
W
E
S
Kilometers


ANDROS ISLAND, PART 5
LAND USE/LAND COVER
An5_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
clouds
cloud shadows
N
W
E
S
Kilometers


ANDROS ISLAND, PART 6
LAND USE/LAND COVER
An6_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
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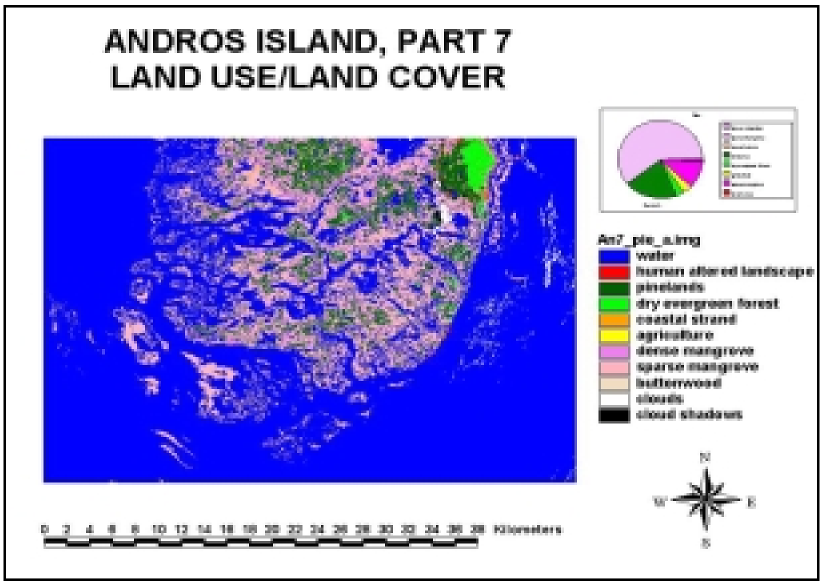
sparse mangrove
buttonwood
clouds
cloud shadows
N
W
E
S
Kilometers


ANDROS ISLAND, PART 7
LAND USE/LAND COVER
An7_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
clouds
cloud shadows
N
W
E
S
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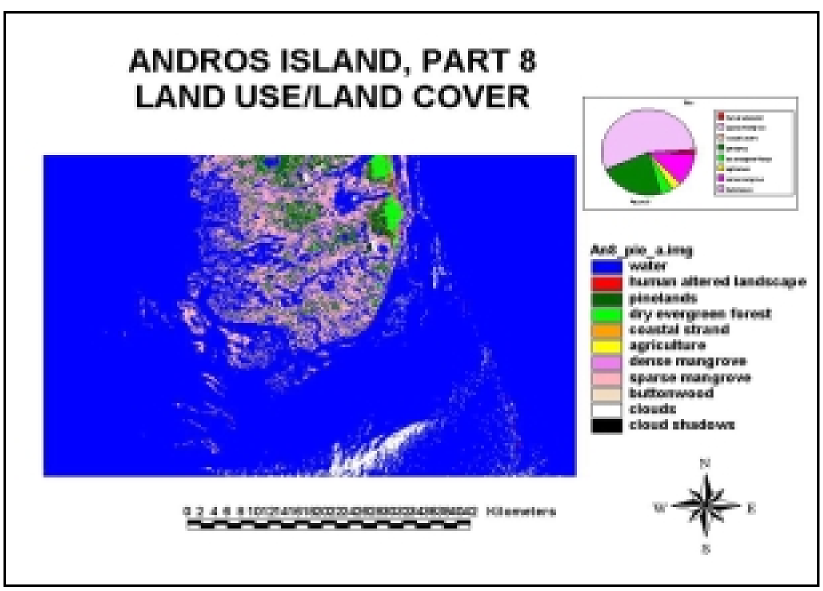
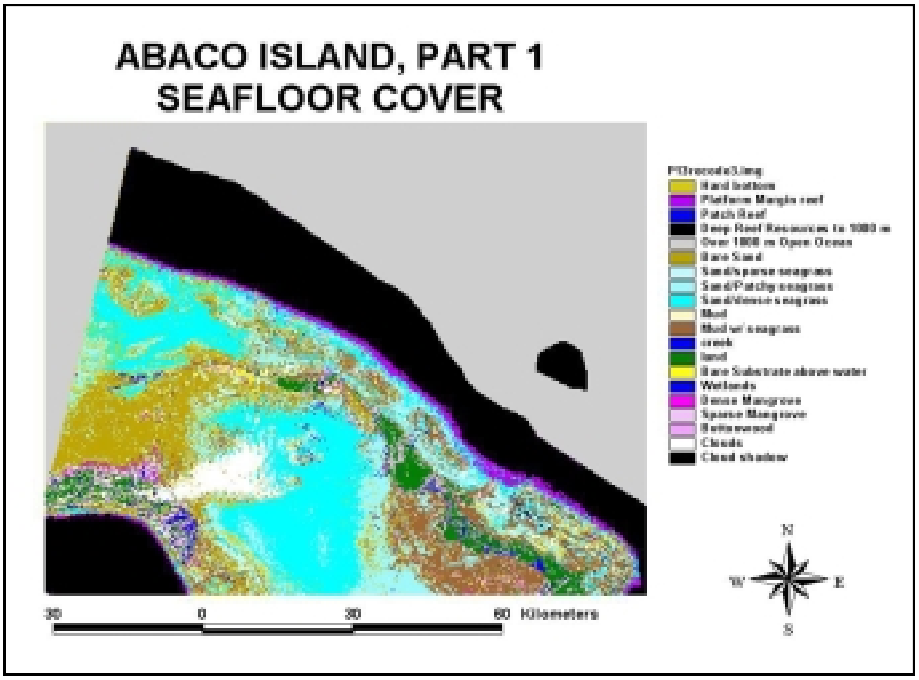

ANDROS ISLAND, PART 8
LAND USE/LAND COVER
An8_pie_a.img
water
human altered landscape
pinelands
dry evergreen forest
coastal strand
agriculture
dense mangrove
sparse mangrove
buttonwood
clouds
cloud shadows
N
W
E
S
Kilometers

The landcover mapping was very dramatic for the island of New Providence. There was a great deal of ancillary data and training points for the classification of this island, therefore, this was likely the best product from the larger islands. New Providence is, at first sight, quite different in structure from the other eastern Atlantic islands, but on closer inspection exhibits some of similar features. The amount of HAL is remarkable. Seafloor cover is clearly illustrated as well, and mapping accuracy of the cover classes is good. Again, the classes of patch reefs, and sea grass in mud areas are underrepresented.



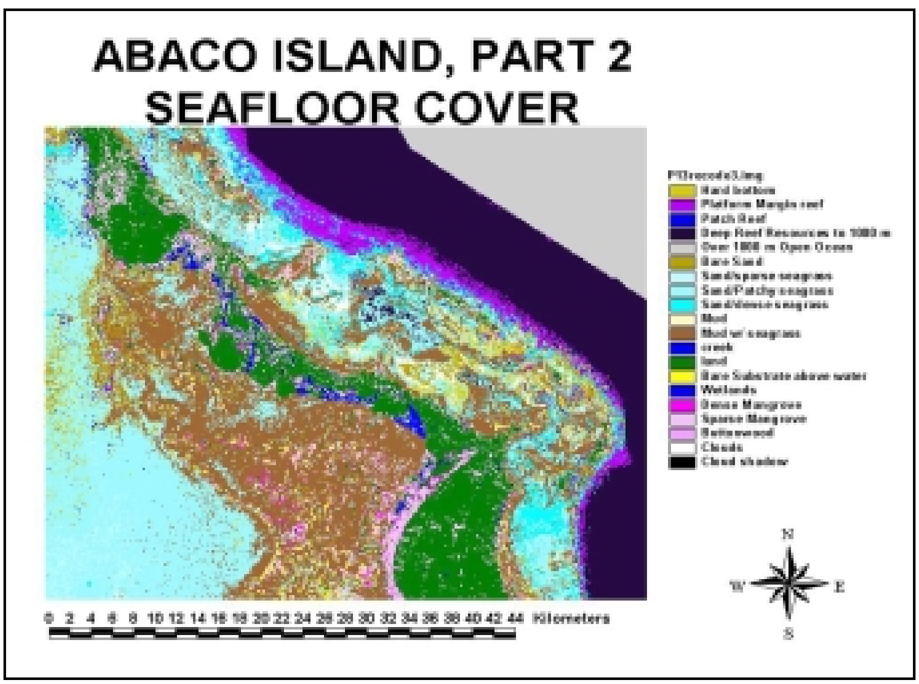
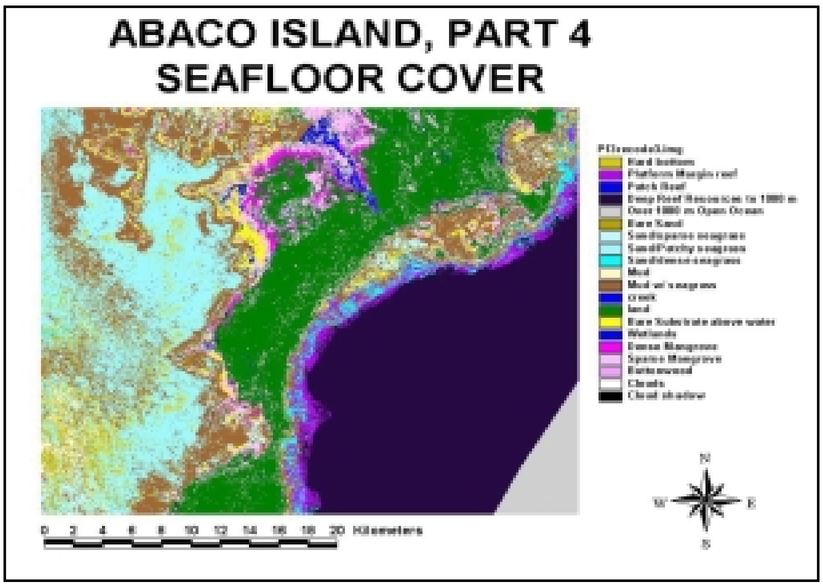
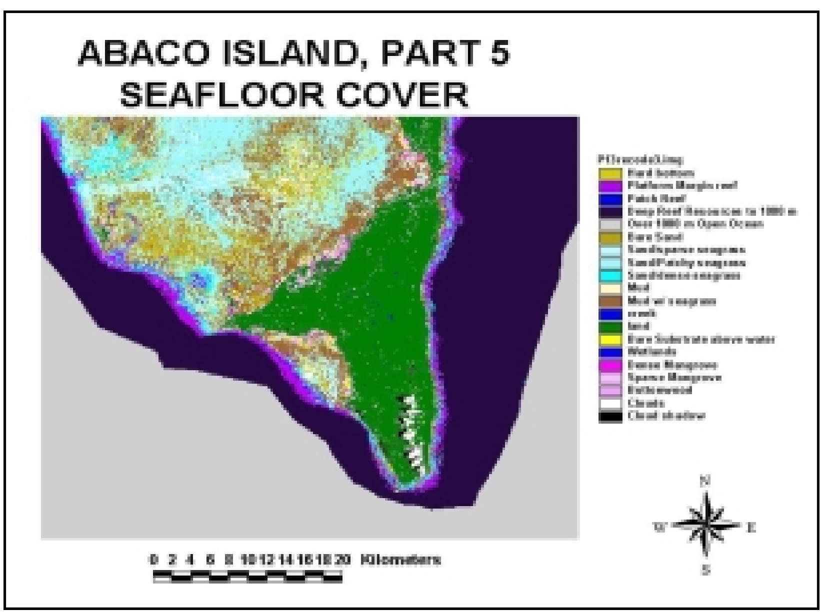


Figure 110. Composite of final seafloor cover maps for Abaco(above and next page)
[The largest coverage classes include sparse sea grass and sea grass classes]


ABACO ISLAND, PART 3
SEAFLOOR COVER
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 Kilometers
N
W
E
S


ABACO ISLAND, PART 4
SEAFLOOR COVER
0 2 4 6 8 10 12 14 16 18 20 Kilometers
N
W
E
S


ABACO ISLAND, PART 5
SEAFLOOR COVER
0 2 4 6 8 10 12 14 16 18 20 Kilometers
N
W
E
S

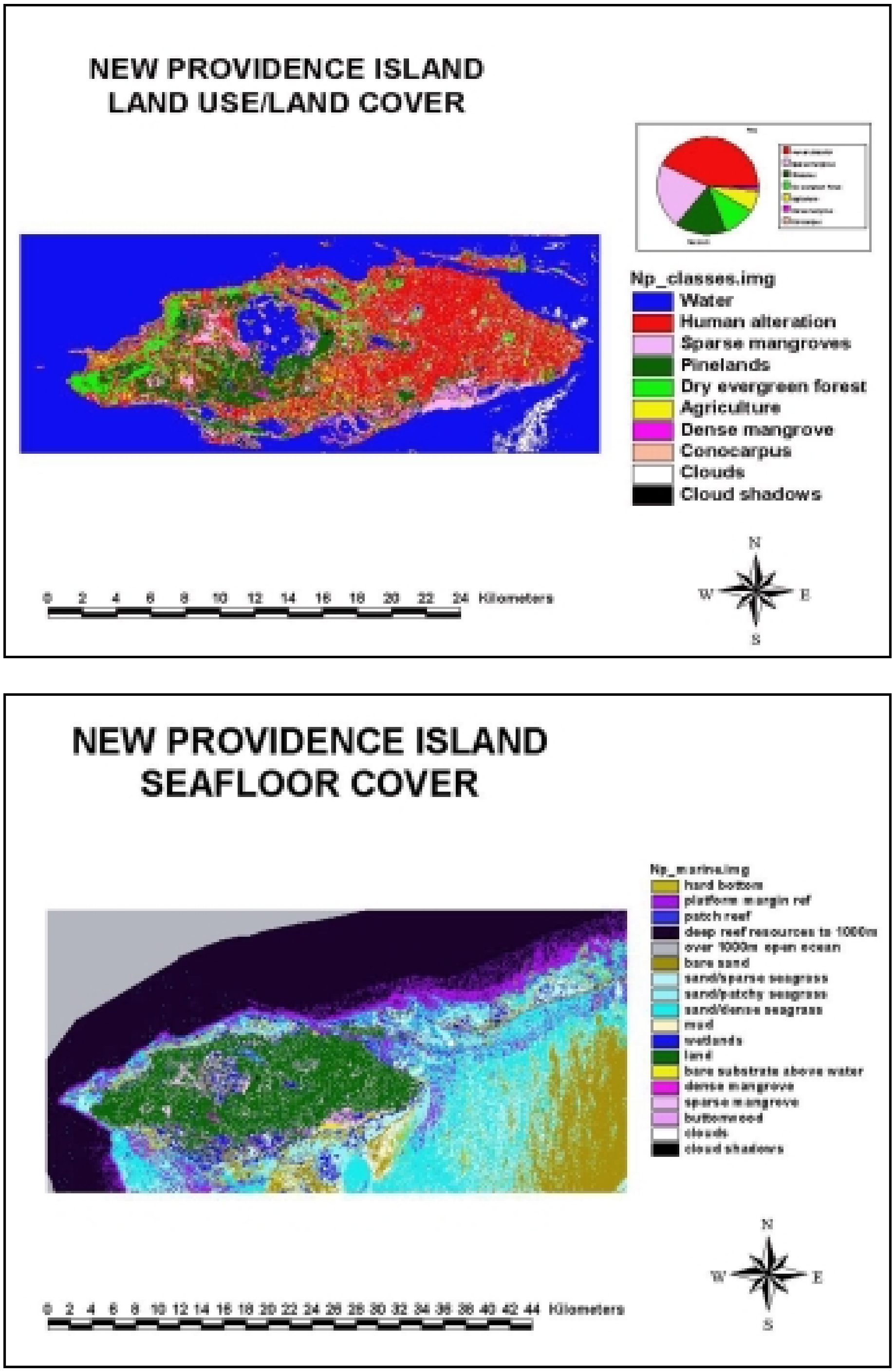


Figure 111. Land- and sea floor cover map of New Providence Island

The mapping component of the ecoregional planning was limited, in this initial phase, by a contract with USGS, and is an on-going project. The process of building the training datasets, and defining coverage classes, consumed most of the available time on this project.

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V. ANALYSIS OF PRIORITY BANK SYSTEMS

1. Introduction

Throughout this document, the area referred to as 'the Bahamian archipelago' describes a system of carbonate banks and islands with common geological origin and related ecology. The two defining environmental factors, bank energy and latitude, dictate that a comprehensive conservation plan includes bank systems representing all five bank categories or types.

The bank systems are fundamental components of biological diversity in the archipelago based on the close physical and ecological interactions between land and sea. We have used the term 'bank system' to represent large areas of shallow marine environments with associated islands and cays that are technically ecosystems (Table 13) that encompass a mosaic of natural communities. Although many of the same species occur throughout the archipelago, different processes and communities account for variations in species abundance and ecological production.

Table 13. Definitions of the terms 'Ecosystems', 'Natural Communities or Habitats' and 'Environments' as used in this chapter

ECOSYSTEMS	'Ecosystems' is a term invented to capture the concept of large-scale physical and biological interactions. Ecological systems or 'ecosystems' are interacting habitats or natural communities that share cycles and processes to exchange energy and matter. Ecosystems tend to be large and self-sustaining over long periods of time. The shallow banks and islands of the archipelago, or 'bank systems', are large ecosystems, sharing hydrological (water) and nutrient cycles. Many of the conservation targets share common processes and gradients maintained by the larger ecosystem
NATURAL COMMUNITIESOR HABITATS	Natural communities or habitats are described as repeating units of species assemblages - for example, pine forests are recognized by a group of plant and animal species commonly found in close association - pine trees, palmetto palm, certain bird species etc. Natural communities depend on the exchange of energy and matter with adjacent habitats.
ENVIRONMENTS (Landscapes, seascapes)	'Environment' is a more general term designed to include areas on the landscape that we as humans can readily identify - such as beaches, or sea grass meadows. By using the word 'environment' we are recognising that we may not know the details of ecology, but want to refer to an area with a visual identity. Thus, the mapping classes are often referred to as 'environments' and have a visual identify.

Scientists often describe groups of related ecosystems in areas of similar physical, geological and climatic conditions as ecoregions (see Bailey, 1999). This ecoregional plan is based on data collected from a wide variety of sources, comprising many areas of investigation. A complete study of the Bahamian archipelago has yet to be written, however this plan is an attempt to provide a platform of protection for all known components of biological diversity in the archipelago. With much of the real estate being underwater, and with small low-lying island areas influenced by, and vulnerable to, coastal and oceanic processes, bank systems are the basic working 'unit' for resource management and conservation.

The compilation of information on conservation targets, and the classification of habitats in, above, and below the water, gives us a basis for ranking the bank systems, and establishing some priority sites for conservation actions. Few targets occur on every bank system, and any landscape scale conservation initiative in the archipelago will be based not on a few sites selected as parks or protected areas, but on the actions of the people dependent on this archipelago for their homes and livelihood. More important than protected area planning is a dramatic change in policies and attitudes on how we live on dry tropical islands. Issues of sustainable development, endurable resource use, local stewardship, and national capacity for ecological monitoring and management all need to be brought to the forefront of public awareness and discussion.

2. Processes, States and Gradients

Processes, states and gradients refer to abiotic and biotic circumstances necessary to maintain and perpetuate the target species or natural communities. The environments on land and sea are arranged in predictable patterns, controlled by the 'master variables' of temperature and rainfall, but modified locally by landforms and vegetation. Landscape-level conservation initiatives will need to consider the patterns of natural communities, all the way from upland forests and coastal mangroves to sea grass meadows and deep platform reefs. A summary of important processes, states, and gradients are summarized in the Appendix (for a review of the ecoregional planning process and definitions of these terms, see 'Designing a Geography of Hope', TNC, 2000).

Although the islands of the archipelago represent only one tenth of the area of the shallow seas, there are high levels of diversity and endemism yet to be described and recorded. The archipelago itself is a mosaic of bank systems, and unique environments; thus many of the conservation targets do not occur on all bank systems, or represent different community alliances or populations. For example, coppice, or 'bush' in the Bahamas, is included as a natural community conservation target described in the technical term 'dry evergreen formations'. Dry evergreen formations actually include many plant associations and alliances that evolved in a response to gradients in environmental conditions such as the decrease in rainfall from north to south. Bahamian vegetation is extremely diverse with over 1000 vascular plant species identified. Of these, only some 3-4% are of Bahamian origin (i.e. endemic species), but this is generally consistent with the known rate of evolution of new species on isolated islands. The Bahamas, as a whole, enjoys a distinct flora and fauna from the rest of the Caribbean. Each island, and more importantly each bank system, has assembled its own particular mix of the available flora.

Extensive mangroves and creek systems often dominate the coastal ecology of the islands. Mangroves usually occur on the western margins of the islands; however on Grand Bahama Island they are found on the northern margin. Mangroves can include creeks or basin systems, with dwarf shrub lands to woodlands to forests. The structure and extent of the mangrove is again unique to bank systems. In addition, there are smaller wetlands described as 'anchialine ponds' that also play an important role in coastal ecology. Many of these ponds have some underground connection to the sea, or are filled with soft sediments; however they are not blue holes. They can host a variety of unique and unusual creatures, some endemic to the Bahamas.

The processes that create and maintain the environments of the archipelago are described generally, but not specifically for many bank systems. Much of the natural history and ecological information compiled to date has not been evaluated on the scale of an entire "bank system". A comprehensive inventory and assessment program is a vital key step, especially as new conservation initiatives begin on specific bank systems.

3. Bank Systems and Conservation priorities

The size, distribution of islands, and latitudinal placement of individual bank systems, all impact their ecological processes. Therefore, a conservation portfolio that captures the diversity of the Bahamian archipelago must reflect the diversity of these bank systems. The conservation targets were evaluated for each bank system based on three criteria: Size, Condition and Landscape Context. Definitions for each criterion are taken from the Nature Conservancy's Geography of Hope (2nd Edition):

- **Size -** refers to the size of the target population or natural community, and is a measure of target abundance and density
- **Condition -** an integrated measure of the quality of biotic and abiotic factors, which may include regularity of reproductive success, degree of anthropogenic impacts, and biological legacies. Biological legacies are critical features of a system that require generations or centuries to develop
- **Landscape Context -** takes into account an integrated measure of connectivity and intactness of surrounding ecological processes.

These are subjective evaluations based on the best available information and expert opinion. The criteria are ranked as 'very good' (VG), 'good' (G), 'fair' (F), 'poor' (P), 'unknown' (U) and 'not present'. These rankings can change with the addition of new information. A more detailed explanation of assessing the viability of conservation targets, and setting priorities, can be found in the Nature Conservancy publication 'Designing a Geography of Hope: A Practitioner's Handbook to Ecoregional Conservation Planning' (TNC, 2000).

A review of the conservation targets and their spatial viability in the archipelago is presented in the following series of tables. For each category, the most important banks for the target are italicised. More information is needed especially in the Island-occupied Banks and Fully-Exposed Banks.

The marine targets are: Acroporid corals, Atlantic spotted dolphin, Audubon's shearwater, Queen conch, Nassau grouper, Spiny lobster, Hawksbill turtles and Green sea turtles.

The terrestrial targets species include Rock Iguanas, West Indian flamingos, and White-crowned pigeons.

The following three conservation targets are natural communities: Pine Woodlands, Dry Evergreen Formations and Beach Strands. All vary between bank systems, and are dependent on some minimum size or extent to persist. Much of what is know about the management of these tropical inland or coastal plant communities comes from long-term studies done in Florida or Latin America. Few long-term ecological studies exist for the Bahamian archipelago.

Acroporid corals have been studied on only a handful of islands, and their condition throughout the archipelago is unknown. For many of the more remote islands and banks there simply is no information on the status of these corals. Overall, the larger bank systems, especially within the Sheltered Banks categories are important for staghorn and elkhorn corals.

Table 14. Ranking by Bank Systems for Acroporid Corals
[Italics indicate priority bank systems for this target]

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G**	**G to F**
	Eastern Little Bahama Banks	VG	G	G
	Western Great Bahama Bank	VG	F	G
	Eleuthera	G	F	G
	Cat Island	F	U	U
	Long Island	F	U	U
	Crooked Island and Acklins	F	U	U
	Caicos Bank	G	G	G
Sheltered Banks with island chains and cays	**Overall average rating**	**G to F**	**F**	**F**
	Exuma Cays	G	G	G
	Berry Islands	F	P	U
Island-Occupied Banks	**Overall average rating**	**U**	**U**	**U**
	Great Inagua	U	U	U
	Little Inagua	U	U	U
	Mayaguana/Samana	U	U	U
	Rum Cay	U	U	U
	San Salvador	F	P	P
Fully Exposed Banks	**Overall average rating**	**F**	**F**	**U**
	Cay Sal	G	F	U
	Southern Great Bahama Banks	U	U	U
	Plana Cays	U	U	U
	Mira Por Vos Cays	U	U	U
	Hogsty Reef	P	F	F
	Brown Bank	U	U	U
	Turks Islands	F	G	U
Anomalous Bank	**Overall average rating**	**G**	**F**	**U**
	Western Little Bahama Bank	G	F	U

The Atlantic Spotted Dolphin is restricted in its distribution, likely having specific prey and habitat requirements. Eastern Little Bahama Banks and Western Great Bahama Banks are two sheltered bank systems important to this target. Its biology is best known from long-term studies north of Grand Bahama Island, in the Abacos, and near Bimini. These areas appear unique and critical to the spotted dolphin ecology in the archipelago. Much of the southern Bahamas has not been inventoried for the numbers and movement of this species.

Table 15. Ranking by Bank System for Atlantic Spotted Dolphins
[Italics indicate priority bank systems for this target]

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G**	**G**
	Eastern Little Bahama Banks	G	G	G
	Western Great Bahama Bank	G	G	G
	Eleuthera	U	U	U
	Cat Island	U	U	U
	Long Island	U	U	U
	Crooked Island and Acklins	U	U	U
	Caicos Bank	U	U	U
Sheltered Banks with island chains and cays	**Overall average rating**	**U**	**U**	**U**
	Exuma Cays	U	U	U
	Berry Islands	U	U	U
Island-Occupied Banks	**Overall average rating**	**U**	**U**	**U**
	Great Inagua	U	U	U
	Little Inagua	U	U	U
	Mayaguana/Samana			
	Rum Cay	U	U	U
	San Salvador	U	U	U
Fully Exposed Banks	**Overall average rating**	**U**	**U**	**U**
	Cay Sal	U	U	U
	Southern Great Bahama Banks	U	U	U
	Plana Cays	U	U	U
	Mira Por Vos Cays	U	U	U
	Hogsty Reef	U	U	U
	Brown Bank	U	U	U
	Turks Islands	U	U	U
Anomalous Bank	**Overall average rating**	**VG**	**VG**	**VG**
	Western Little Bahama Bank	VG	VG	VG

Audubon's shearwater has been reported on only a few bank systems. The fully exposed bank systems are apparently important in the distribution of this species, and Eastern Little Bahama Bank, Western Bahama Bank and the Exuma Cays appear important for nesting sites. The Audubon's shearwater is the most restricted target in distribution throughout the archipelago.

Table 16. Ranking by Bank Systems for Audubon's Shearwaters
[Italics indicate priority bank systems for this target]

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**F to G**	**F to G**	**G**
	Eastern Little Bahama Banks	G	G	G
	Western Great Bahama Bank	not present	not present	not present
	Eleuthera	not present	not present	not present
	Cat Island	F	F	G
	Long Island	not present	not present	not present
	Crooked Island and Acklins	not present	not present	not present
	Caicos Bank	not present	not present	not present
Sheltered Banks with island chains and cays	**Overall average rating**	**G to VG**	**G**	**G**
	Exuma Cays	VG	G	G
	Berry Islands	G	G	G
Island-Occupied Banks	**Overall average rating**	F to G	G	F
	Great Inagua	not present	not present	not present
	Little Inagua	not present	not present	not present
	Mayaguana/Samana	not present	not present	not present
	Rum Cay	not present	not present	not present
	San Salvador	F to G	G	F
Fully Exposed Banks	**Overall average rating**	**G**	**G**	**G**
	Cay Sal	G	G	G
	Southern Great Bahama Banks	G	G	G
	Plana Cays	F to G	G	G
	Mira Por Vos Cays	F	G	G
	Hogsty Reef	not present	not present	not present
	Brown Bank	not present	not present	not present
	Turks Islands	F	G	G
Anomalous Bank	**Overall average rating**	**not present**	**not present**	**not present**
	Western Little Bahama Bank	not present	not present	not present

Queen Conch is heavily fished throughout the archipelago. This species is probably less abundant and more vulnerable on island-occupied banks. Recruitment patterns between bank systems are unclear, but this large mollusc is key in maintaining ecological diversity in soft sediment environments. The Queen Conch is potentially necessary in maintaining ecological function on all bank systems, and thus, its abundance should be monitored and maintained archipelago-wide.

Table 17. Ranking by Bank Systems for Queen Conch
[Italics indicate priority bank systems for this target]

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**F**	**F**
	Eastern Little Bahama Banks	G	F	F
	Western Great Bahama Bank	G	G	G
	Eleuthera	G	F	F
	Cat Island	F	F	P
	Long Island	G	U	G
	Crooked Island and Acklins	F	U	U
	Caicos Bank	G	G	G
Sheltered Banks with island chains and cays	**Overall average rating**	**G**	**G**	**G**
	Exuma Cays	G	G	VG
	Berry Islands	G	F	F
Island-Occupied Banks	**Overall average rating**	**P**	**U**	**U**
	Great Inagua	P	U	U
	Little Inagua	P	U	U
	Mayaguana/Samana	P	U	U
	Rum Cay	P	U	U
	San Salvador	P	U	U
Fully Exposed Banks	**Overall average rating**	**P**	**U**	**U**
	Cay Sal	F	U	P
	Southern Great Bahama Banks	G	U	U
	Plana Cays	P	U	U
	Mira Por Vos Cays	P	U	U
	Hogsty Reef	P	U	U
	Brown Bank	P	U	U
	Turks Islands	F	U	U
Anomalous Bank	**Overall average rating**	**G**	**F**	**U**
	Western Little Bahama Bank	G	F	U

Spiny Lobster is a key species in the ecology of hard bottom and coral reef environments. Reproductive rates are high in healthy populations and, therefore, this species is very responsive to a network of marine reserves and protected areas. Spiny lobster should be monitored and maintained on all bank systems, both for ecological and economic importance.

Table 18. Ranking by Bank Systems for Spiny Lobsters
[Italics indicate priority bank systems for this target]

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G**	**G**
	Eastern Little Bahama Banks	G	U	U
	Western Great Bahama Bank	VG	VG	VG
	Eleuthera	G	F	G
	Cat Island	F	U	F
	Long Island	F	U	G
	Crooked Island and Acklins	U	U	U
	Caicos Bank	VG	G	VG
Sheltered Banks with island chains and cays	**Overall average rating**	**G**	**G**	**G**
	Exuma Cays	VG	VG	VG
	Berry Islands	F	U	U
Island-Occupied Banks	**Overall average rating**	**P**	**U**	**U**
	Great Inagua	P	U	U
	Little Inagua	P	U	U
	Mayaguana/Samana	P	U	U
	Rum Cay	P	U	U
	San Salvador	P	U	U
Fully Exposed Banks	**Overall average rating**	**F**	**U**	**U**
	Cay Sal	F	U	U
	Southern Great Bahama Banks	G	U	U
	Plana Cays	F	U	U
	Mira Por Vos Cays	F	U	U
	Hogsty Reef	F	U	U
	Brown Bank	F	U	U
	Turks Islands	G	U	U
Anomalous Bank	**Overall average rating**			
	Western Little Bahama Bank	G	F	G

Nassau Grouper are a key predator on coral reefs and hard-bottom communities. Their status is dynamic, ever changing with the success of annual reproduction and recruitment processes. The Nassau grouper is relatively long-lived and slow growing, but faces many threats beyond over-harvesting. Loss of habitat and degradation of water quality are known threats to juveniles, but have not been evaluated throughout much of the Bahamian archipelago. A pattern of fisheries collapses in other areas of the Caribbean suggests that 'large and healthy' populations on reefs are necessary to sustain the species through annual variability in spawning and recruitment processes. If 'large and healthy' translates into the conservation goal of 30 to 40 adult groupers per hectare on windward fringing reefs, then much of the archipelago falls well below this benchmark. It is possible to fish this species below a critical population level. For The Bahamas and the Turks and Caicos Islands, the need for action is clearly immediate to reduce harvest of sub-adults and reproductively active adults in spawning aggregations is clearly immediate.

Table 19. Ranking by Bank Systems for Nassau Grouper
[Italics indicate priority bank systems for this target]

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G to F**	**G to F**
	Eastern Little Bahama Banks	G	F	F
	Western Great Bahama Bank	VG	G	G
	Eleuthera	G	F	G
	Cat Island	G	F	F
	Long Island	G	G	G
	Crooked Island and Acklins	F	U	F
	Caicos Bank	G	F	G
Sheltered Banks with island chains and cays	**Overall average rating**	**G**	**G**	**G**
	Exuma Cays	VG	G	G
	Berry Islands	F	U	F
Island-Occupied Banks	**Overall average rating**	**F**	**U**	**U**
	Great Inagua	F	U	U
	Little Inagua	F	U	U
	Mayaguana/Samana	F	U	U
	Rum Cay	F	U	U
	San Salvador	F	U	U
Fully Exposed Banks	**Overall average rating**	**F**	**U**	**U**
	Cay Sal	G	F	F
	Southern Great Bahama Banks	G	U	U
	Plana Cays	F	U	U
	Mira Por Vos Cays	U	U	U
	Hogsty Reef	P	U	U
	Brown Bank	U	U	U
	Turks Islands	F	U	U
Anomalous Bank	**Overall average rating**	**G**	**U**	**U**
	Western Little Bahama Bank	F	F	F

Sea turtles may be good indicators of the relative health of tropical, shallow water ecological systems. Assessment information is limited, and apart from nesting sites, sea turtles need protection throughout the archipelago for juvenile and adult foraging habitats. Conservation strategies and actions are needed on both the regional and international level. There are no known priority bank systems for sea turtles. Priority bank systems could be identified for nesting beaches through a national inventory and assessment exercise. Although research efforts may be ongoing in the archipelago, maps of nesting sites are rarely available due to concerns that poachers could use them.

Table 20. Ranking by Bank Systems for Hawksbill and Green Sea Turtles

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**P**	**P**	**P**
	Eastern Little Bahama Banks	P	P	P
	Western Great Bahama Bank	P	P	P
	Eleuthera	P	P	P
	Cat Island	P	P	P
	Long Island	P	P	P
	Crooked Island and Acklins	P	P	P
	Caicos Bank	P	P	P
Sheltered Banks with island chains and cays	**Overall average rating**	**P**	**P**	**P**
	Exuma Cays	P	P	P
	Berry Islands	P	P	P
Island-Occupied Banks	**Overall average rating**	**P**	**P**	**P**
	Great Inagua	P	P	P
	Little Inagua	P	P	P
	Mayaguana/Samana	P	P	P
	Rum Cay	P	P	P
	San Salvador	P	P	P
Fully Exposed Banks	**Overall average rating**	**P**	**P**	**P**
	Cay Sal	P	P	P
	Southern Great Bahama Banks	P	P	P
	Plana Cays	P	P	P
	Mira Por Vos Cays	P	P	P
	Hogsty Reef	P	P	P
	Brown Bank	P	P	P
	Turks Islands	P	P	P
Anomalous Bank	**Overall average rating**	**P**	**P**	**P**
	Western Little Bahama Bank	P	P	P

Rock Iguanas represent one conservation target with a dedicated group of researchers and conservationists already monitoring the species. The iguana is assumed to be very important historically in seed dispersal and coastal ecology of many islands. Current distribution is dramatically reduced to a few fragmented populations that require annual inventory and protection. The difficulty and challenges to initiate or boost these populations, by re-introduction techniques, makes each individual all the more valuable. Bank systems with iguana populations are all considered 'high priority'.

Table 21. Ranking by Bank Systems for Rock Iguanas
[Italics indicate priority bank systems for this target]

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**VG**	**F**	**F**
	Eastern Little Bahama Banks	not present	not present	not present
	Western Great Bahama Bank	G	F	F
	Eleuthera	not present	not present	not present
	Cat Island	not present	not present	not present
	Long Island	not present	not present	not present
	Crooked Island and Acklins	VG	F	F
	Caicos Bank	VG	F	F
Sheltered Banks with island chains and cays	**Overall average rating**	**F to G**	**F**	**F**
	Exuma Cays	F to G	F	F
	Berry Islands	not present	not present	not present
Island-Occupied Banks	**Overall average rating**	**P**	**F**	**F**
	Great Inagua	not present	not present	not present
	Little Inagua	not present	not present	not present
	Mayaguana/Samana	P	F	F
	Rum Cay	not present	not present	not present
	San Salvador	P to F	F	F
Fully Exposed Banks	**Overall average rating**	**VG**	**F**	**F**
	Cay Sal	not present	not present	not present
	Southern Great Bahama Banks	not present	not present	not present
	Plana Cays	not present	not present	not present
	Mira Por Vos Cays	not present	not present	not present
	Hogsty Reef	not present	not present	not present
	Brown Bank	not present	not present	not present
	Turks Islands	VG	F	F
Anomalous Bank	**Overall average rating**	**not present**	**not present**	**not present**
	Western Little Bahama Bank	not present	not present	not present

The West Indian Flamingos like the Rock Iguana is a species with a greatly reduced range within the archipelago. It is unknown just how important Flamingos are in the ecology of inland salt ponds and flats. As numbers of Flamingos increase, potential habitats decrease through dredge and fill development of wetlands. The priority bank systems include only those where the Flamingos are reported to exist. There is not enough ecological information available to base population levels or determine if appropriate habitats are protected archipelago-wide. Flamingos are the national bird of the Bahamas, yet few Bahamians have ever seen the bird outside of captivity.

Table 22. Ranking by Bank Systems for West Indian Flamingos
[Italics indicate priority bank systems for this target]

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G**	**G**
	Eastern Little Bahama Banks	not present	not present	not present
	Western Great Bahama Bank	G	G	F
	Eleuthera	not present	not present	not present
	Cat Island	not present	not present	not present
	Long Island	not present	not present	not present
	Crooked Island and Acklins	G	G	G
	Caicos Bank	G	G	G
Sheltered Banks with island chains and cays	**Overall average rating**	**not present**	**not present**	**not present**
	Exuma Cays	not present	not present	not present
	Berry Islands	not present	not present	not present
Island-Occupied Banks	**Overall average rating**	**G**	**G**	**G**
	Great Inagua	VG	G	G
	Little Inagua	G	G	G
	Mayaguana/Samana	G	G	G
	Rum Cay	not present	not present	not present
	San Salvador	not present	not present	not present
Fully Exposed Banks	**Overall average rating**	**F**	**G**	**G**
	Cay Sal	not present	not present	not present
	Southern Great Bahama Banks	not present	not present	not present
	Plana Cays	not present	not present	not present
	Mira Por Vos Cays	not present	not present	not present
	Hogsty Reef	not present	not present	not present
	Brown Bank	not present	not present	not present
	Turks Islands	F	G	G
Anomalous Bank	**Overall average rating**	**not present**	**not present**	**not present**
	Western Little Bahama Bank	not present	not present	not present

White-crowned pigeons are protected from hunting on a series of offshore nesting cays and islands. However, these critical habitats are not protected, often privately owned (e.g. the Schooner Cays), and subject to development. Although numbers of white-crowned pigeons have remained stable (with some slow increase in some areas), current populations represent only a fragment of the large flocks that once dominated the landscape. These birds have not recovered to levels appropriate for their key ecological role in seed dispersal for dry evergreen formations (coppice). Nesting efforts are highly susceptible to stochastic disturbances (such as hurricanes) thus populations need to be large, with widely scattered nesting sites. For priority bank systems, the linked roosting and foraging habitats need to be protected.

Table 23. Ranking by Bank Systems for White Crown Pigeon

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**VG**	**G**	**F to G**
	Eastern Little Bahama Banks	not present	not present	not present
	Western Great Bahama Bank	VG	G	F
	Eleuthera	VG	F	F
	Cat Island	G	G	G
	Long Island	VG	G	F
	Crooked Island and Acklins	G	G	G
	Caicos Bank	VG	G	G
Sheltered Banks with island chains and cays	**Overall average rating**	**G to VG**	**G**	**F**
	Exuma Cays	VG	G	F
	Berry Islands	G	G	F
Island-Occupied Banks	**Overall average rating**	**G**	**F to G**	**F to G**
	Great Inagua	not present	not present	not present
	Little Inagua	not present	not present	not present
	Mayaguana/Samana	G	G	G
	Rum Cay	not present	not present	not present
	San Salvador	G	F	F
Fully Exposed Banks	**Overall average rating**	**G**	**G**	**F to G**
	Cay Sal	G	G	F
	Southern Great Bahama Banks	G	G	G
	Plana Cays	U	U	U
	Mira Por Vos Cays	U	U	U
	Hogsty Reef	U	U	U
	Brown Bank	U	U	U
	Turks Islands	U	U	U
Anomalous Bank	**Overall average rating**	**not present**	**not present**	**not present**
	Western Little Bahama Bank	not present	not present	not present

Pine Woodland or 'pine yards' are restricted to the larger northern islands of the archipelago with the exception of the Caicos Island. They need large contiguous tracts that include areas of different successional stages and fire cycles. There are only four bank systems that include pine woodland communities, and all are pressured with development.

Table 24. Ranking by Bank Systems for Pine Woodlands

BANK SYSTEM		**Size**	**Condition**	**Landscape Context**
Sheltered Banks with continuous cays	**Overall average rating**	**P to VG**	**F to G**	**G**
	Eastern Little Bahama Banks	VG	F	G
	Western Great Bahama Bank	VG	F	G
	Eleuthera	not present	not present	not present
	Cat Island	not present	not present	not present
	Long Island	not present	not present	not present
	Crooked Island and Acklins	not present	not present	not present
	Caicos Bank	P	G	G
Sheltered Banks with island chains and cays	**Overall average rating**	**F**	**P**	**P**
	Exuma Cays	F	P	P
	Berry Islands	not present	not present	not present
Island-Occupied Banks	**Overall average rating**	**not present**	**not present**	**not present**
	Great Inagua	not present	not present	not present
	Little Inagua	not present	not present	not present
	Mayaguana/Samana	not present	not present	not present
	Rum Cay	not present	not present	not present
	San Salvador	not present	not present	not present
Fully Exposed Banks	**Overall average rating**	**P**	**G**	**G**
	Cay Sal	not present	not present	not present
	Southern Great Bahama Banks	not present	not present	not present
	Plana Cays	not present	not present	not present
	Mira Por Vos Cays	not present	not present	not present
	Hogsty Reef	not present	not present	not present
	Brown Bank	P	G	G
	Turks Islands	not present	not present	not present
Anomalous Bank	**Overall average rating**	**G**	**F**	**G**
	Western Little Bahama Bank	G	F	G

Dry Evergreen Formations include many different vegetation habitat types: forests, woodlands, and shrub lands. Coppice or 'bush' is found on every island with the exception of the smallest rocks and cays. High-priority bank systems include larger islands with large tracts of relatively undisturbed coppice. Coppice varies tremendously from island to island, and is poorly characterized beyond plant species present. Traditional slash-and-burn agriculture in dry evergreen formations is usually done by rotating plots, and can be accomplished with small impacts on the habitat quality for associated birds and wildlife.

Table 25. Ranking by Bank Systems for Dry Evergreen Formations

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**G**	**G**	**G**
	Eastern Little Bahama Banks	VG	G	G
	Western Great Bahama Bank	VG	G	VG
	Eleuthera	G	G	G
	Cat Island	G	G	G
	Long Island	G	G	G
	Crooked Island and Acklins	G	G	G
	Caicos Bank	G	F	F
Sheltered Banks with island chains and cays	**Overall average rating**	**P to F**	**F**	**P to F**
	Exuma Cays	F	F	F
	Berry Islands	P	F	P
Island-Occupied Banks	**Overall average rating**	**G**	**G**	**G to VG**
	Great Inagua	VG	G	VG
	Little Inagua	G	G	VG
	Mayaguana/Samana	G	G	G
	Rum Cay	G	G	G
	San Salvador			
Fully Exposed Banks	**Overall average rating**	**P**	**G**	**G**
	Cay Sal	P	G	G
	Southern Great Bahama Banks	P	G	G
	Plana Cays	P	G	G
	Mira Por Vos Cays	P	G	G
	Hogsty Reef	P	G	G
	Brown Bank	P	G	G
	Turks Islands	F	F	G
Anomalous Bank	**Overall average rating**	**F**	**F**	**F**
	Western Little Bahama Bank	F	F	F

Beach Strand communities include many types of vegetation associated with the coastal zone. This can include dune plants, such as sea oats, as well as coastal coppice plants, such as joe wood. Coastal development, sand mining and invasions of exotic plants such as the Australian pine fragment beach strand communities. High priority bank systems include systems with substantial extents of undisturbed coastal zone.

Table 26. Ranking by Bank Systems for Beach Strand communities
[Italics indicate priority bank systems for this target]

BANK SYSTEM		Size	Condition	Landscape Context
Sheltered Banks with continuous cays	**Overall average rating**	**F to G**	**F to G**	**F to VG**
	Eastern Little Bahama Banks	G	F	F
	Western Great Bahama Bank	F	F	F
	Eleuthera	F	F	F
	Cat Island	G	G	VG
	Long Island	G	G	VG
	Crooked Island and Acklins	G	F	F
	Caicos Bank	G	F	G
Sheltered Banks with island chains and cays	**Overall average rating**	**F**	**P**	**F**
	Exuma Cays	F	P	F
	Berry Islands	F	P	P
Island-Occupied Banks	**Overall average rating**	**F to G**	**F**	**F**
	Great Inagua	G	F	F
	Little Inagua	G	F	F
	Mayaguana/Samana	F	F	F
	Rum Cay	F	F	F
	San Salvador	F	F	F
Fully Exposed Banks	**Overall average rating**	**P**	**F**	**G**
	Cay Sal	P	G	G
	Southern Great Bahama Banks	P	G	G
	Plana Cays	P	G	G
	Mira Por Vos Cays	P	G	G
	Hogsty Reef	P	F	F
	Brown Bank	P	F	F
	Turks Islands	F	P	F
Anomalous Bank	**Overall average rating**	**G**	**F**	**F**
	Western Little Bahama Bank	G	F	F

The analysis of all target viability scores can be combined to rank the bank systems within the five categories. Obvious gaps in information occur for two of the bank system categories: Fully-Exposed Banks and Island–Occupied Banks. Fully exposed banks have limited accessibility with small islands and no settlements. Many of the island-occupied banks (with the exception of San Salvador) have very small settlements, and limited access. More work is needed to refine priority setting within these two categories of bank systems.

Ranks of ‘High’ (H), ‘Medium’ (M), and ‘Low’ (L) are given to bank systems within the five bank energy categories. The high ranks indicate a strong viability analysis for the marine or terrestrial targets; though again, no bank systems have ALL targets. To protect biological diversity archipelago-wide, conservation initiatives will need to be focused on a network of bank systems. The priority setting exercise establishes a justification for initiating new conservation programs, and does not suggest that only priority systems are in need of conservation action.

Table 27. Summary analysis of bank systems based on biological criteria
[High priority bank systems are indicated by ranks of ‘1’, ‘2’, and ‘3’]

ANALYSIS SUMMARY		**Marine**	**Terrestrial**	**Overall Rank**
Sheltered Banks with continuous cays	**Overall average rating**			
	Eastern Little Bahama Banks	H	M	2
	Western Great Bahama Bank	H	H	1
	Eleuthera	L	L	3
	Cat Island	L	L	3
	Long Island	M	L	3
	Crooked Island and Acklins	M	H	2
	Caicos Bank	H	H	1
Sheltered Banks with island chains and cays	**Overall average rating**			
	Exuma Cays	H	M	1
	Berry Islands	M	L	2
Island-Occupied Banks	**Overall average rating**			
	Great Inagua	L	H	2
	Little Inagua	L	L	
	Mayaguana/Samana	L	L	
	Rum Cay	L	L	
	San Salvador	M	H	1
Fully Exposed Banks	**Overall average rating**			
	Cay Sal	H	M	1
	Southern Great Bahama Banks	H	M	1
	Plana Cays	L	L	3
	Mira Por Vos Cays	L	L	3
	Hogsty Reef	L	L	3
	Brown Bank	L	L	3
	Turks Islands	M	M	2
Anomalous Bank	**Overall average rating**			
	Western Little Bahama Bank	H	M	1

4. Summary

At the minimum, eight bank systems would require substantial and significant landscape-level conservation programs to protect the biological diversity of the entire archipelago. Strategies for conservation are outlined for each target, but include a comprehensive program of sustainable development, advanced wastewater treatment for sewage, appropriate solid waste disposal or recycling, education programs, and an effective network of protected areas. In short, the minimum effective unit for conservation initiative is the bank system, and land-scape scale programs will need to address a comprehensive change in how people fundamentally populate and use these shallow-water island systems.

The Biodiversity Support Program (BSP) manages many projects and programs around the world, with the goal of having real conservation impact. Since 1994, the BSP has structured the success and challenges of conservation programs into case studies, and what has emerged is an action plan for conservation that details five critical conditions for success. Successful conservation interventions and application of scientific information will make a long-term difference in the ecological systems of a region only IF the following conditions can be met:

- Conservation goals and objectives must be clear, and understood by all;
- There must be effective social processes for comments and reviews of conservation plans, with clear benefits for local communities to join conservation efforts develop;
- There must be appropriate incentives for evaluation of the environment and conservation;
- There must to be international, national, and local policies that support conservation goals and objectives and;
- There must be sufficient awareness, knowledge, and capacity to conserve biological diversity.

Table 28. High priority bank systems for conservation in the Bahamian archipelago

Sheltered banks with continuous cays	Western Great Bahama Bank (Andros and Bimini) Caicos Bank
Sheltered Banks with island chains and cays	Exuma Cays
Island-Occupied Banks	San Salvador
Fully Exposed Banks	Cay SalSouthern Great Bahama BanksTurks Islands
Anomalous Bank	Western Little Bahama Bank

These conditions present a considerable challenge to small island nations such as the Bahamas and the Turks and Caicos Islands. Conservation goals and objectives must be clear, and understood by all, but in reality, the impacts of development on the environment are poorly understood. There is a ‘credibility gap’ between conservation groups and decision-makers, with no clear understanding by the general public of what environmental issues and problems face these two countries. Only specific user groups, such as fishermen, often face the serious impacts of conservation issues.

There must be effective social processes for comments and reviews of conservation plans, with clear benefits for local communities to join conservation efforts. The geography of these two countries makes this condition difficult. A smaller community on an outer-island may have the land and resources, but little political clout or input to management. There is no public process to review development or even land use plans. Public access to up-to-date and useful information is limited, despite the high education level and independent motivation of people.

There must be appropriate incentives for the evaluation of the environment and conservation. The archipelago has been poorly managed in terms of natural resources throughout its history. The very nature of a colony was to provide resources to the mother country, and thus, the landscape is already highly modified despite a low population density. Who pays for the environmental sins of the past? How can a new system of environmental valuation be initiated? Few Bahamians have travelled through the Caribbean and Latin America to view real environmental disasters. Americans flock to the Bahamas to avoid the perceived 'over-regulation' of the United States, particularly the Florida Keys. The loss of Nassau grouper stocks, or disappearance of rock iguanas, has little to no impact on the day-to-day life of someone living in Nassau or Providenciales.

There need to be international, national, and local policies that support conservation. Conservation issues have already been brought to national attention in the Bahamas with the controversies on mega-resort developments in the Biminis, and the development of Clifton Bluff on New Providence. Already, local communities have started the public discussions of the value of the environment, and the future of island communities. A national discussion needs to ensue on the value of the environment as a national asset, and a vision of what the islands are to become in the future. National interest needs to prevail over the short-term gain of individuals.

Conservation of the Bahamian archipelago involves cooperation between three national jurisdictions: the Commonwealth of The Bahamas, the Turks and Caicos Islands, and the Dominican Republic. Although the Dominican Republic only has authority over several small banks at the extreme southern end of the archipelago, the population of this country is in excess of 7 million people. The population alone poses a serious threat to the archipelago in general in terms of the illegal fishing pressure and immigration pressures (immigration pressures are significant from both Haiti and the Dominican Republic). Regional (Caribbean-wide) fisheries and economic policies will impact conservation initiatives in the Bahamian archipelago.

National capacity for effective conservation programs will include building government capacity and policy, non-government organizations that focus on both advocacy and management issues, as well as a substantial network for outreach and education. Outreach and education programs need to span not only schools and traditional educational settings, but also make information, access to experts, and technical support, available to communities or resource user groups such as fishermen. The single largest long-term problem may be the ability to finance, install, and maintain the appropriate infrastructure for a widely dispersed population. New alternatives in waste management, power generation and sustainable resource use must be explored.

National Parks and protected areas systems

Site protection can be accomplished in many ways throughout the archipelago. All three countries have designated national parks with varying degrees of management and enforcement. Parks and protected areas are one component of landscape-scale conservation initiatives. The major issues are those of funding, capacity and co-management. A short inspection of the national park system within The Bahamas illustrates the problem in building a comprehensive protected area system in an island archipelago.

The Bahamas National Trust is a non-profit, non-governmental organization that has been given statutory authority by The Bahamas Government. Established by the Bahamas National Trust Act in 1959, the Trust has a parliamentary mandate to build and manage the country's national park system.

Consisting of some 3,300 members, a 21-member council governs the Trust; nine are elected annually from among the general membership and six are government representatives. The remaining six are representatives from the following institutions – the American Museum of Natural History, the New York Zoological Society (also known as Wildlife Conservation International), the Smithsonian Institution, the National Audubon Society, the United States National Parks Service and the University of Miami's Rosenstiel School of Marine Science. The council serves in an advisory capacity, and neither receives payment from nor contributes funds to the Trust outside of private donations. Funding for the Trust's activities is generated through membership fees, special functions, entrance fees and shop sales.

Many of the national parks are without staff and management plans, thus the Bahamas National Trust faces a formidable challenge to develop both the capacity and funding structure to manage additional parks. Parks and protected areas are not well distributed between bank types, and tend to be clustered around a few islands.

Table 29. List of existing protected areas and National Parks by Bank System

BANK CATEGORY	BANK SYSTEM	PROTECTED AREAS Existing National Parks, Newly created National Parks, and Proposed Marine Reserves
Sheltered Banks with continuous cays	Eastern Little Bahama Banks	Abaco National ParkPelican cays Land and Sea ParkTilloo Cay National ReserveBlack Sound Cay National ReserveWalkers Cay Marine Park
	Western Great Bahama Bank	Central Andros National ParksProposed Bimini Marine Reserve
	Eleuthera	Proposed South Eleuthera Marine Reserve
	Cat Island	None
	Long Island	None
	Crooked Island and Acklins	None
	Caicos Bank	Princess Alexandria National ParkWest Caicos National Park
Sheltered Banks with island chains and cays	Exuma Cays	Exuma Cays Land and Sea Park The Retreat Bonefish Pond National Park Moriah Harbour Cay Park The Primeval Forest Harold and Wilson Ponds Proposed Great Exuma Marine Reserve
	Berry Islands	Proposed Berry Island Marine Reserve
Island-Occupied Banks	Great Inagua	Inagua National Park Union Creek Reserve
	Little Inagua	Little Inagua National Park
	Mayaguana/Samana	None
	Rum Cay	None
	San Salvador	None
	Conception island	Conception Island National Park
Fully Exposed Banks	Cay Sal	None
	Southern Great Bahama Banks	None
	Plana Cays	None
	Mira Por Vos Cays	None
	Hogsty Reef	None
	Brown Bank	None
	Turks Islands	None
	Silver Banks	Humpback Whale Sanctuary
Anomalous Bank	Western Little Bahama Bank	Lucayan National Park Petersen Cay National Park Rand Nature Centre

Appendix

Bibliography Information

In the process of completing this project the Ecoregional Planning team has compiled a database consisting of over 7,200 references that address either the conservation targets (in the Bahamas and elsewhere) or the bank systems of the Bahamian archipelago. These references exist in a variety of formats, including journal articles, technical reports, books, book chapters, and websites. All relevant sources used in the development of this project have been entered into a ProCite database. To improve the convenience and utility of such a large database, each source has been sorted by two methods: 1) by geographic location(s) and 2) by conservation target(s) addressed (when applicable). Because some sources covered multiple categories, some broader categories were created as well. Examples of these broader categories are "entire archipelago" for geographic locations and 'all marine targets' for conservation targets. This sorting system allows a user to more efficiently identify those sources that pertain to a particular target or area of interest. The following tables show the number of references for each category that have been collected and entered into the database.

References available for Conservation Targets

Target	Number of References
Acroporid Corals	63
Beach Strand	12
Dry Evergreen Formation	21
Green Turtle	93
Hawksbill Turtle	88
Nassau Grouper	30
Pine Rockland	56
Queen Conch	117
Rock Iguanas	44
Shearwaters	8
Spiny Lobster	30
Spotted Dolphin	97
West Indian Flamingo	20
Wetlands	102
White Crowned Pigeon	14
All Community Targets	1
All Marine Targets	2
All Targets	2

References available for Geographic Locations

Geographic Location	Number of References
Abaco	148
Acklins/Crooked	23
Andros/Bimini	593
Berry Islands	15
Caicos Bank	281
Cat Island	32
Cay Sal Bank	20
Eleuthera	86
Exumas/New Providence	493
Grand Bahama Island	140
Grand Turk Bank	149
Inaguas	75
Long Island	18
Mayaguana/Flat/Plana/Samana	22
Mouchoir/Navidad/Silver Banks	10
Ragged Islands/Hogsty	44
San Salvador/Rum Cay	530
Entire Archipelago	1,880
Non-Caribbean	396
Other Caribbean	323
Unknown	173