ALM Thesis Proposal

A model for rapid assessment and mapping of ecological criteria for informed land use in small island developing states

East Caicos, Turks and Caicos Islands as a Case Study

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Abstract

Small-island developing states (SIDS) contain some of the most biodiverse ecosystems on earth (Churchyard et al., 2014), yet these countries suffer from pandemic sustainable policy failure (Mycoo, 2006), leading to significant losses in ecological assets and ecosystem services (Albuquerque & McElroy, 1992; McElroy, 2003). Many sustainability issues in SIDS arise from poor development practices due to a lack of economic and human resources to inform sustainable land use planning (Anonymous, 1994). The proposed thesis will address the sustainability problems experienced by SIDS by implementing a case study on the island of East Caicos, an uninhabited island in the Turks and Caicos Islands (TCI) that is currently slated for the development of a transhipping and cruise ship terminal. East Caicos is characterized by the presence of endemic and endangered species populations and critical habitats, such as mangrove forests, seagrass beds and coral reefs, yet no comprehensive environmental evaluation has ever been conducted and no sustainable land use plan exists for the island. To address these limitations, a multi-criteria evaluation model, that combines remote sensing, rapid ecological assessment and GIS mapping and data analysis, will be developed. Procedures for rapid assessment, classification and determination of evaluation criteria will be based on Nature Conservancy and European Union methods and will be standardized for ease of implementation and suitability for SIDS. Presence/absence of evaluation criteria, recorded during field studies, will provide objective data for the development of a GIS dataset and map of ecological characteristics. Resultant graphic imagery of ecological "hot spots" will be readily understandable to disparate interest groups and decision-makers.

The developed evaluation model can be applied to any land area and will be designed to employ readily available open-access software and imagery, thus being particularly relevant to the needs and resource limitations of SIDS. A final analysis will examine results to make recommendations for sustainable land use planning and development policy, to identify priority areas for conservation and to delineate areas for further analysis.

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"There are some things that sometimes we may have to sacrifice. It [East Caicos] is an area we can use to boost our economy, to boost our development" - Premier of the Turks and Caicos Islands Doctor Honourable Rufus Ewing, as quoted in the BBC Radio Series 'Costing the Earth' (Cross, 2014).

Introduction

Significance of the Research Problem

Small-island developing states (SIDS) struggle to foster economic development while simultaneously sustainably managing ecological assets. SIDS share many commonalities, including vulnerability to natural disasters, small economic and natural resource bases, limited land areas and scarce access to expertise to inform sustainable development decisions (Albuquerque, McElroy, & McElroy, 1992; Anonymous, 1994; Beukering, Brander, Tomkins, & McKenzie, 2007; Kaffashi & Yavari, 2011). SIDS are also typically areas of high biodiversity. For example, the United Kingdom's Overseas Territories (UKOTs), comprising 14 SIDS, contain an estimated 94 percent of the unique or endemic British species (Churchyard et al., 2014). The Caribbean region has been repeatedly cited as a biodiversity hotspot, defined as being an area with a high proportion of endemism and at risk (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). Because of their ecological values, great gains can be made by addressing the conservation vulnerabilities of SIDS. An easy-to-implement model, which uses rapid field assessment and GIS technology to graphically illustrate ecological assets, would assist SIDS in fostering sustainable use of ecological assets, based on informed land use.

The proposed research seeks to develop support for solutions to the sustainability problems associated with SIDS and will develop a decision tool to address the conservation needs of SIDS. A multi-criteria evaluation model will be designed to provide a graphic illustration of ecological assets

and inform sustainable land use. A case study to test the model will be implemented at East Caicos in the Turks and Caicos Islands.

Background

Sustainable Development in SIDS

In the time period following World War II, at least 80 SIDS achieved political autonomy. Traditionally characterized by subsistence agriculture and fisheries, many tropical islands have transitioned to economies based on tourism and government employment. With few viable alternatives, tourism development has allowed many SIDS to realize sustained economic growth by banking on the relatively intact ecosystems and cultures that have been preserved by previous subsistence lifestyles. While tourism has been associated with environmental impact, social problems and boom-bust economic cycles, the potential for sustainability in this industry remains feasible when coupled with appropriate and informed development planning (Albuquerque & McElroy, 1992).

In 1994, the Convention on Sustainable Development in Small Island Developing States recognized the needs of SIDS for sustainable planning initiatives, with a focus on the development of human resources and sustainable land use management (Anonymous, 1994); however, in the past 20 years, little progress has been made in this regard. With few other natural resources to exploit, tourism development practices have resulted in substantial degradation of environmental assets. In 2006, an analysis of tourism development in the Caribbean concluded that while the Caribbean is the most tourism-dependent region of the world, with tourism accounting for as much as 70 percent of GDP in many Caribbean countries, the region suffers from pandemic "sustainable tourism policy failure" (Mycoo, 2006, p. 506). In particular, the study cited failures of public planning policy and, where appropriate policy exists, inadequate implementation. A 2003 study reviewed the impact of tourism development on 51 islands and found that the vast majority of tourism development was unplanned and intrusive and had resulted in deforestation, erosion, pollution and reef damage. In

2003, at least 30 percent of Caribbean coral reefs were at high risk from impacts due to cruise ship development and pollutants (McElroy, 2003).

Many of the conservation losses in SIDS result from a lack of Informed land use planning, due to the fact that countries lack the human and economic resources to conduct the necessary research required to develop and implement such policies. Ideally, land use management would be based on a model of sustainable use and conservation of important ecological and cultural assets, including biodiversity, ecosystem services, cultural and traditional use and other important aspects. Traditionally, however, data to identify and quantify the above variables has been costly to accumulate and when it exists, difficult to access and use by decision-makers. Such a model has been devised by the Nature Conservancy (TNC), which has developed a seven-step process for conservation planning that seeks to establish a standardized method for ecosystem evaluation and conservation planning (C. Groves et al., 2000). The TNC steps are:

1. *To identify conservation targets* – including communities and ecosystems, abiotic and species targets,
2. *To collect information and identify information gaps* – via review of information sources, rapid ecological assessment, biological inventories and expert input,
3. *To establish conservation goals* – Including representativeness and quality, distribution of targets and establishment of realistic goals,
4. *To assess existing conservation areas* – via gap analysis,
5. *To evaluate ability of conservation targets to persist* – using size, condition and landscape contexts and GIS-based suitability indices,
6. *To assemble a portfolio of conservation areas* – Using site selection and algorithms as a tool and designing networks of conservation areas using biogeographic principles, and
7. *To identify priority conservation areas* – Using criteria of existing protection, conservation value, threat, feasibility and leverage (C. R. Groves et al., 2002).

The TNC steps provide a useful framework for targeted goals; however, simplified and inexpensive methods will be required if SIDS are to be able to implement them.

GIS and Environmental Assessment in SIDS

Global information system (GIS) technology has revolutionized environmental survey and evaluation processes (Almeida et al., 2014; Joerin, Thériault, & Musy, 2001); however, the use of GIS

modeling in environmental applications can be costly and requires a level of expertise that is often not available to SIDS. Consequently, GIS environmental research has had limited application in SIDS. Where it has been implemented, results are often incomplete and/or unusable by decision makers. For example, a 2014 habitat mapping of Anguilla was conducted by a private company, Environmental Systems Inc, and supported by the U.K. government and the Universities of Newcastle and Aberystwyth. The project mapped habitats and ecosystem services, relying heavily on remote sensing, with a technology known as Earth Observation. Ground-truthing was limited and resulted in a highly generalized assessment. The work was also facilitated by the use of costly WorldView-2 satellite imagery (Medcalf, Bell, Cameron, & Pike, 2014). Given the cost constraints and expertise involved with the assessment, such a method difficult to reproduce within the budgetary and human resource constraints of other United Kingdom Overseas Territories (UKOTs), without outside funding and assistance. Furthermore, the project was targeted towards valuation of environmental services only and did not take into account ecological criteria, such as endangered species populations, endemic species, critical habitats or other conservation values. Nevertheless, the Anguilla project provided valuable local training, and the evaluation model developed provides an effective framework upon which to build other, less-resource-intensive methods.

The proposed research will address the above limitations by developing an easy-to-use and inexpensive model that will incorporate a standardized method for rapid field assessment of terrestrial, wetland and marine habitats. Data gleaned will be used to develop a GIS digital database that records, maps and highlights ecological assets in relation to the subject landscape. Open-access GIS software (QGIS) and imagery (Google Earth and Landsat) will enhance accessibility by resource-limited users. The end product will be a GIS dataset that can be incorporated into national databases. Such a dataset has myriad applications and can be used to:

- Identify priority areas of high ecological value for conservation purposes,
- Develop a sustainable development plan,
- Identify critical areas and populations that merit further scientific research, and
- Inform other conservation priorities

In order to test the model, a case study will focus on the island of East Caicos in the Turks and Caicos Islands. East Caicos is an uninhabited island of approximately 47 square kilometers. As such, it is the largest uninhabited island in the Caribbean. The application of proposed model will demonstrate its practicality and ease of implementation in scenarios where resources are limited and physical planning lacks informed environmental input.

Below is a Google Earth image of the Turks and Caicos Islands. East Caicos is located in the northeastern portion of the larger Caicos Bank.

Figure 1 - Google Earth Image of the Turks and Caicos Islands

The Turks and Caicos as a Case Study

Turks and Caicos Islands (TCI) have experienced accelerated development within the past three decades, with associated environmental impacts (Anonymous, 2014; Cangialosi, 2011; Carleton & Lawrence, 2005; Pardee, 2014). In a 1971 assessment, visiting scientists described the natural environment "…as close to the natural state as is likely to be the case for any similar islands within the American tropics due to relatively light utilization by man" (Ray & Sprunt, 1971, p. 6). Ray and Sprunt also forewarned:

"Their [the islands'] value lies in their still retained beauty and relative remoteness. Their ecology and small size makes mandatory that development not violate ecological integrity or natural beauty. Their remoteness makes mandatory that they not imitate or compete with the massive developmental schemes in the more accessible Western Hemisphere tropics. In short, these islands are a special case. They deserve to be treated in a very special way" (Ray & Sprunt, 1971, p. 20).

Unfortunately, development in TCI did not take place in a special way. Development interests began flocking in large numbers to TCI shortly after Ray and Sprunt's assessment. Pristine dwarf forests and coastal habitats have been clear-cut for hotel development and infrastructure, and living and diverse coral reefs have been dredged to create marinas and a cruise ship terminal (Goreau et al., 2007; Johnson, 2002). Uncontrolled and illegal development and a rapid increase in population drives squatting and urban sprawl into undeveloped lands. No sustainable development plan for the country currently exists; therefore, development has largely been driven by investment interests, rather than by informed planning. The elected government has now indicated that it intends to seek investment to develop a transshipping and cruise ship terminal on East Caicos. Transshipping and cruise ship terminal development will require extensive dredging through coral reefs and other marine habitats and significant land clearance for infrastructural development.

East Caicos is characterized by populations of endangered and endemic species populations, coral reef ecosystems and critical habitats, such as spawning areas, nesting sites, seagrass beds and mangrove forests (Buden, 1975, 1986; Buden & Felder, 1977; Goreau et al., 2007; Hilton, Cleeves, Murray, Hughes, & Williams, 2000a; Presley & Willig, 2008; Wood, Brunnick, Harzen, Weinberg, & Kissinger, 2010).

Ecological Assets

Due to the intact nature of existing ecosystems, East Caicos lends itself well to the proposed case study. Quantitative data on the ecological variables of East Caicos are limited; however, the data that exist suggest the island possesses significant high conservation values. A 2002 Darwin Initiative project developed a biodiversity management plan for the North, Middle and East Caicos Ramsar Site (Pienkowski, 2002). The report recommended that the entire island of East Caicos be set

aside for conservation; however, no quantitative data is provided in the report to support this recommendation. Furthermore, most of the field studies associated with that project took place on the inhabited islands of North and Middle Caicos. The Ramsar site on East Caicos represents approximately one-fourth of the total land area of the island. The remaining areas of East Caicos were not intensively studied as part of the Darwin project.

A follow-up investigation to the Darwin Initiative Project explored cave ecosystems on East Caicos. East Caicos caves possess features of geological, ecological and historic interest. Bat populations of *Macrotus waterhousii* and *Erophylla sezekorni* were confirmed and evidence of *Brachyphylla spp.* and *Monophyllus spp.* was also present (Hutson, McCarthy, & Hart, 2005). In addition cave petroglyphs that date back to Lucayan Indian habitation at approximately 900-1200 C.E. have also been identified (Booy, 1912; Hutson et al., 2005; Pateman, 2013). The caves of East Caicos are currently not protected.

Bird populations on East Caicos are also only qualitatively described. A 2000 study of wetland habitats in TCI recorded a small population of piping plover (*Charadrius melodus)*, listed by the IUCN as a Near Threatened species (Hilton, Cleeves, Murray, Hughes, & Williams, 2000b). Population sizes were not measured or estimated. A survey in February and March of 1999 sought to make a preliminary assessment of the abundance and distribution of IUCN Vulnerable West Indian whistling duck (*Dendrocygna arborea)*, and identified only 5 animals (Hilton et al., 2000a); however subsequent reports from recreational users suggest higher numbers. Actual population sizes of these listed species and identification of the habitats being used have yet to be confirmed.

A 2006 study assessed coral reef health throughout the Turks and Caicos Islands (Goreau et al., 2007), including East Caicos. The study incorporated extensive, rather than intensive assessment. This method involved incorporating trained divers swimming over large areas of reef to determine large-scale spatial patterns, rather than quantitative measurement (Goreau et al., 2007, p. 26). The study also generalized findings across locations throughout TCI, and East Caicos data from the study

were not specified. The characteristics of the reefs off East Caicos are therefore currently unknown. Given that these areas are at high risk and will necessarily be destroyed if transhipping and cruise ship terminal development takes place, an accounting of the conservation values of these coral reefs is imperative.

Other marine ecological assets include green, hawksbill and loggerhead turtles *(Chelonis mydas, Eretmochelys imbricata and Caretta caretta*), which are known to nest on TCI beaches. All species are listed under the IUCN Red List as Endangered or Critically Endangered. In 2009, a survey of known sea turtle nesting sites was conducted (Peter B Richardson et al., 2009); however, "because of the remote nature of many of the cays and limited resources available for the study, surveys for nesting activity were infrequent and opportunistic (Peter B Richardson et al., 2009, p. 194)." Three suspected nesting sites on East Caicos were identified, via aerial surveys, a review of published literature and interviews, on the northern and eastern beaches of East Caicos. Satellite tagging of an adult female hawksbill turtle has subsequently revealed several nesting episodes (see http://www.seaturtle.org/tracking/?project_id=398). To date, no comprehensive survey of turtle nesting sites and activities on East Caicos has been undertaken, but it is believed that the island serves as an important remnant rookery (Peter B. Richardson et al., 2009, p. 204).

In 2010, a terrestrial habitat mapping and classification project identified 32 terrestrial and wetland communities and 41 floral species, two reptile species, five mammal species and one invertebrate species of interest, including rare, threatened, endangered or endemic species (Wood et al., 2010). The habitat mapping and classification project conducted only limited, non-quantitative field studies. A majority of habitat identification was conducted via remote sensing, and habitats were therefore only classified to a class, sub-class, formation and group level (Cowardin, Carter, Golet, & LaRoe, 1979; Grossman & Conservancy, 1998). Floral alliances and associations were not classified or mapped, and ecological assets were not quantitatively measured.

Finally, a search for available data for East Caicos was conducted using the Global Biodiversity Information Facility (GBIF, www.gbif.org). The search returned results for only one floral species (*Lipidium filcaule,* a TCI endemic floral species*)* recorded on East Caicos as depicted in the graphic illustration of available GBIF data below:

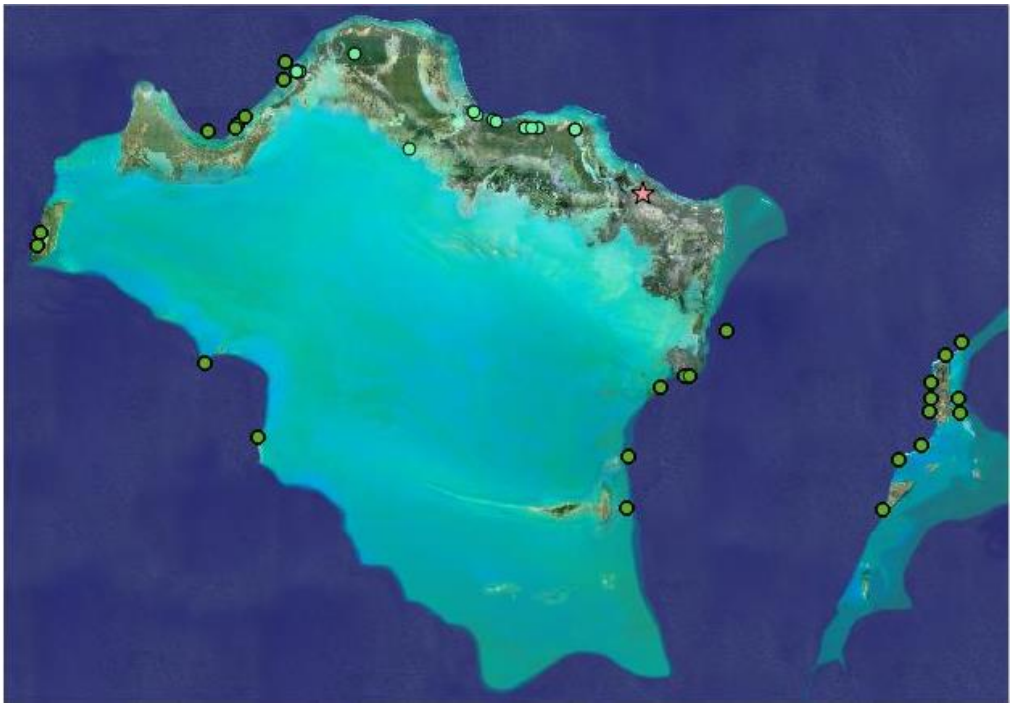

Figure 2 - Map of the Turks and Caicos Islands illustrating data available online through the GBIF database

This accumulated research has clearly identified ecological values of significance and provides justification and rationale for more in-depth assessment to guide sustainable development on East Caicos.

Research Hypothesis and Specific Aims

The goals of my proposed research are indicated in the following hypothesis:

The development of a rapid assessment and GIS mapping model for graphically illustrating ecological values, using East Caicos as a case study, will provide a valuable decision tool for informed land use planning and conservation management in small-island developing states.

The proposed project will:

1. Develop an approach for classifying and ranking ecological variables that is objective and easy to use,
2. Based on the above approach, determine evaluation criteria based on accepted practices,
3. Develop a multi-criteria evaluation model incorporating criteria identified above,
4. Develop a known inventory of ecological assets on East Caicos, including a baseline habitat map, comprised of GIS layers for vegetation cover, topography, soils and watersheds.
5. Develop a standardized method for rapid environmental assessment of terrestrial, wetland and marine ecosystems,
6. Conduct field studies and input field data into a GIS dataset model that graphically illustrates the locations of observed ecological assets of East Caicos and uses remote sensing to develop extended polygons of evaluation criteria, and
7. Analyse and discuss results, including recommendations for land use, conservation areas and further study.

Research Methods

Summary of Research Design

Evaluation of ecological variables is inherently fraught with subjectivity (Smith & Theberge, 1987). A credible model that will gain acceptance by broad interest groups must therefore devise methods that will be viewed across disparate interests as objective. A simple, empirical method involves presence/absence analyses. Presence/absence criteria are by their nature objective. Either a variable exists or it does not. By incorporating rapid assessment for the presence/absence of pre-determined ecological criteria, a simple and objective map of ecological significance can be developed using GIS mapping technology. Due to its simplicity and graphic representation, the tool will be broadly accessible across a wide range of decision-making disciplines, including those without scientific backgrounds.

An effective method should account for conservation values, as well as ecosystem services, in order to fully depict ecological assets. The proposed project will develop an inventory of accepted ecological criteria and a list of known variables for the island of East Caicos. Criteria and variables will be loaded into drop-down menu files to be used in a handheld GIS mobile device during field studies. Every time a feature of interest is observed in the field, it will be recorded as present. Known assets and their locations on East Caicos can then be mapped with QGIS to create a map of ecological "hot spots". Remote sensing will then be employed to enlarge survey points to remotely discernible

similar groupings. A GIS dataset will be the final product and can be uploaded into a national GIS database for inclusion in decision-making processes. The model can be easily adapted for any study area, and can also be used to inform land use and conservation priorities, to identify areas for further research and for other applications.

Methods

Develop an approach for classifying ecological variables that is objective and easy to use

A standardized approach for SIDS for classifying and determining the significance ecological variables must be easy-to-use, inexpensive to implement, objective and easy-to-interpret by decision makers with disparate disciplinary backgrounds and levels of skill. These objectives are complicated by the fact that methods for valuing or weighing the significance of ecological variables are the subject of some disagreement and are considered inherently subjective (C. R. Groves et al., 2002; Smith & Theberge, 1987). Smith and Theberge suggest that in order to evaluate ecological values, criteria for assessment must first be defined, measured and ranked (Smith & Theberge, 1987). This method is in keeping with the TNC seven-step process for conservation planning (refer back to the Background section), which establishes a standardized framework for ecosystem evaluation and conservation planning (C. Groves et al., 2000). Subjectivity problems are reduced by restricting evaluation criteria to presence/absence assessments, which are fundamentally objective. Subjectivity in ranking analysis is reduced by restricting interpretation to known variables only. The proposed approach therefore defines ecological criteria, measures criteria, based on presence/absence as observed during field studies, and maps values to visually illustrate ecological significance or rank without subjective interpretation.

In order to identify conservation targets, communities, species and abiotic factors of conservation interest must first be identified and classified. On a community level, classification methods will be derived from a review of several standardized and accepted classification systems. Classification methods for marine habitats will be based on the work of Mumby & Harborne (Mumby

& Harborne, 1999). Classification of wetland habitats will be based on Cowardin et al (Cowardin et al., 1979) and the derivation of that method adapted for the conditions of TCI (Wood & Brunnick, 2010). Terrestrial classification will be based on the Nature Conservancy method (Grossman & Conservancy, 1998) and the derivation of that method adapted for TCI (Wood & Brunnick, 2010). Species will be identified using accepted taxonomy and standardized texts (Correll & Correll, 1982; Raffaele, 2003; Reynolds, Hailey, Wilson, & Horrocks, 2011).

Abiotic factors are now recognized as also contributing to a region's biodiversity (C. Groves, 2003). In TCI, abiotic features such as caves, blue holes and other topographical relief, substrate, wind exposure, salinity level (for aquatic habitats) and other factors will be assessed within the confines of the model criteria as described below.

Determination of model criteria based on ecological significance

In order to ensure scientific validity, the set of ecologically significant criteria will be developed based on a composite of accepted standards throughout environmental fields (Boyd & Banzhaf, 2007; Fisher & Kerry Turner, 2008; Koschke, Fürst, Frank, & Makeschin, 2012; Moberg & Folke, 1999; Root, Akçakaya, & Ginzburg, 2003). Evaluation criteria are divided into three main categories, including species, habitats and ecosystem services. On a species level, criteria are selected based on the uniformity of scientific opinion regarding significance, and include endemism, extinction risk, rarity and other conservation considerations, such as range-restriction and/or other ecological variables that may become evident during field studies.

Habitat criteria include rarity, biodiversity and critical habitats for spawning, nesting and other variables that may become apparent during field studies. Parameters for selection for biodiversity criteria are to be determined based on relative values determined by plot samples.

Criteria for ecosystem services are based on the European Environment Agency's Common International Classification of Ecosystem Services (CICES), which includes a total of six "sections" of

ecosystem services (Agency, 2013). Each section is sub-divided into "divisions" and "groups". CICES classifications appropriate to East Caicos are outlined in the following table:

Table 1 - CICES Classification of Ecosystem Services

Section	***Division***	***Group***
Provisioning	Nutrition	Biomass
		Water
	Materials	Biomass
		Water
	Energy	Biomass Energy Materials
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota
		Mediation by ecosystems
	Mediation of flows	Liquid flows
	Mediation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection
		Water conditions
		Soil formation and composition
		Water conditions
		Atmospheric composition and climate regulation
Cultural	Physical and intellectual interactions with ecosystems and land/seascapes	Physical and experiential interaction
		Intellectual and representational interactions
	Spiritual, symbolic and other interactions with ecosystems and land/seascapes	Other cultural outputs
Abiotic Provisioning	Nutritional abiotic substances	Mineral
		Non-mineral
	Abiotic materials	Non-metallic
	Energy	Renewable abiotic energy sources (e.g. wind, solar)
Regulation & Maintenance by natural physical structures and processes	Mediation of waste, toxics and other nuisances	By natural chemical and physical processes (e.g. atmospheric dispersion and dilution, absorption and sequestration of waters in sediments, screening by natural physical structures)
	Mediation of flows by natural abiotic structures	By solid, liquid and gaseous flows (e.g. protection by mudflats, reef structures, etc.
	Maintenance of physical, chemical, abiotic conditions	By natural chemical and physical processes
Cultural settings dependent on abiotic structures	Physical and intellectual interactions with land/seascapes (physical)	By physical and experiential interactions and representational interactions (e.g. caves)
	Spiritual, symbolic and other interactions with land/seascapes	By type (e.g. Flamingo Hill is the highest elevation in TCI)

Developing an objective model and inventory based on presence/absence

Understanding species distributions is critical to conservation planning, as the knowledge of where species and species compositions of interest are present is a key requirement for informed management. At a basic level, determining the presence or absence of a species, habitats and ecosystem services at a particular geographical location can be a simple, objective means of determining several environmental parameters, including the identification of habitats of high value (Brotons, Thuiller, Araújo, & Hirzel, 2004; MacKenzie & Vojta, 2005). Presence-absence methods are therefore widely accepted and applied to a range of environmental management objectives.

A key criticism of presence-absence methods is the likelihood of false negative reporting (Gu & Swihart, 2004). For example, a species may be recorded as absent, when it is actually present, but not observed. Multiple replicates during field studies of each habitat type will help to alleviate this type of sampling error to an extent. Furthermore, recent statistical methods allow for the acquisition of unbiased parameter estimates, which can be applied to field data to lend further rigor to results (Doubleday, Mackenzie, & Dalby, 2004). In the case of East Caicos, and in order to avoid subjectivity, evaluation criteria will be assessed based on presence/absence. Although this method may result in some false negatives, the resultant GIS map of ecological hot spots will be an accurate estimate of minimum values. The preliminary list of ecologically important assets will be divided into categories and sub-categories, based on evaluation criteria as outlined in the following table:

Table 2 - Categories for Multi-criteria Evaluation

Category	***Category Description***	***Sub-category***	***Sub-category Description***
I	Endemic Species	a	TCI Endemics
		b	Lucayan Archipelago Endemics
		c	Regional Endemics
II	Internationally Listed Species	a	IUCN Red List
		b	CITES
		c	SPAW Protocol
		d	Other Conservation Status
III	Rare Species	a	Locally Rare Species
		b	Regionally Rare Species
		c	Internationally Rare Species

IV	Other Species Conservation Considerations	a	Biome-restricted species
		b	Migratory Species
		c	Range-restricted Species
		d	Other Species of Interest
V	Critical habitats	a	Migratory Pathway or Stopover
		b	Spawning Area
		c	Nesting Site
		d	Other Critical Habitats
VI	Rare Habitats	a	Locally Rare Habitats
		b	Regionally Rare Habitats
		c	Other Rare Habitats
VII	Biodiversity	a	High biodiversity on a species level
		b	High biodiversity on a community level
VIII	Ecosystem Services (CICES)	a	Provisioning
		b	Regulation and Maintenance (biological)
		c	Cultural (biological)
		d	Abiotic Provisioning
		e	Regulation & Maintenance (physical)
		f	Cultural Settings (abiotic)
IX	Other Variables of Interest		

In order to develop an inventory of ecologically important assets on East Caicos, a desktop review of existing literature and data will provide a preliminary list of known ecologically significant species, habitats and services. The list of known habitats (higher-level classifications only) and species of interest is annexed as Appendix I. An additional list of possible ecological assets will also be developed, based on data from other areas in TCI for use in the field. Based on this collated data, a baseline habitat map will be developed, which merges GIS layers from existing topographical and geological surveys, habitat maps and previous studies. This map will be used to inform sampling locations and will be refined by ground-truthing.

Developing a standardized method for rapid environmental assessment of terrestrial, wetland and marine ecosystems

The Nature Conservancy has developed a method for rapid field assessment (*Nature in focus : rapid ecological assessment*, 2000). A method adapted from the Nature Conservancy model will be employed. The method is designed to be easy-to-implement with limited resources, in order to

address the needs and limitations of SIDS. As per Nature Conservancy guidelines, field studies will incorporate the following aspects:

1. Initial landscape characterization – remote sensing of aerial or satellite imagery to delineate discernable distinctions in landscape attributes. For terrestrial and wetland studies, this work has already been undertaken for the TCI habitat mapping and classification project (Wood et al., 2010), and the imagery developed with that project will be used for determining the logistics of the field sampling method. For marine habitats, Google Earth Pro or Landsat imagery will be used for this purpose. The below map is a jpeg image of the delineated habitats as remotely sensed for the above habitat mapping and classification project.

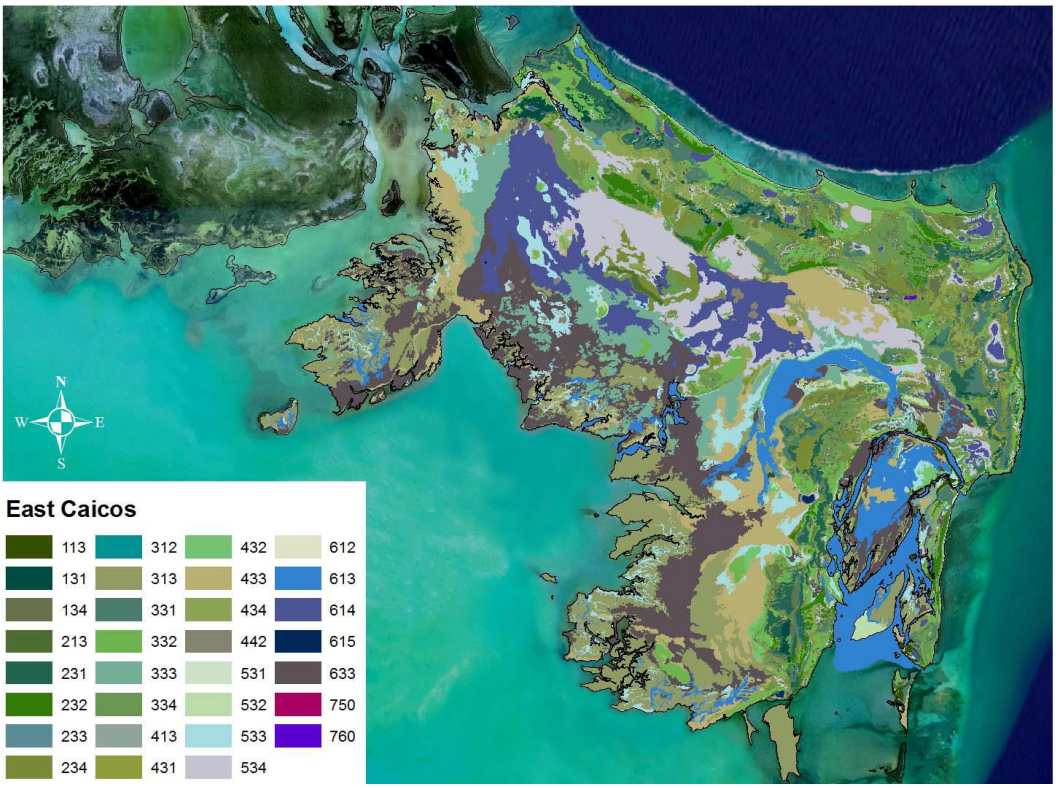

Figure 3 – Initial Landscape Attribution - East Caicos (Wood et al., 2010)

2. Field sampling – For terrestrial and wetland habitats, a series of transect lines will be pre-determined in order to sample every discernable habitat type at several locations throughout the island, with an objective of sampling at least one percent of each discernable

habitat. Marine transects will be organized around remotely discernable coral reefs, seagrass beds and other known features of interest. Sample points will be located within each discernable habitat type along transect lines and will be selected based on representativeness and known or suspected biological value. As the rapid assessment is intended to note presence/absence and community characteristics, the above method is preferable to random sampling, which may not take in all features of interest.

3. All coordinates for transects and pre-selected survey points will be loaded into a handheld GPS device to guide field studies.
4. For all survey points, all habitats (marine, wetland and terrestrial) will be classified to upper and lower hierarchy levels, in accordance with accepted methods (Cowardin et al., 1979; Grossman & Conservancy, 1998; Mumby & Harborne, 1999).
5. For terrestrial and wetland habitats, at each survey point, all species will be identified and counted within a 10 x 10 meter plot surrounding the survey point.
6. All birds, reptiles and other criteria observed along transect lines, either by voice or vision, will be counted and identified, using standardized texts (Raffaele, 2003). Additional species-level sampling for fauna may be undertaken if deemed necessary to assess ecological significance of a specific population. In particularly, sampling protocol will be designed to take in critical bird habitats, such as wetlands, ponds and tropical dry forests, during spring, summer and fall migration periods.
7. Marine habitats will be measured, using a combination of broad and medium-scale data collection methods (Hill & Wilkinson, 2004).
    a. Broad-scale assessment will be undertaken at all randomly selected sites and will include preliminary “manta tows” for preliminary assessment.
    b. Medium-scale assessment will be undertaken by incorporating belt transects at each preselected survey point, where applicable.

c. Belt transects will be similar in design to terrestrial transect lines and pre-determined to incorporate as many discernable habitats as possible. They will be 10 meters in width and of varying lengths.

d. A video record of the belt transect will be recorded for desktop analysis to determine all coral species present, percent coverage, fish and other species of interest, and presence/absence of coral disease and/or other aspects of interest.

8. Sampling methods for all transects will incorporate photographic documentation of all criteria, landscapes, species of interest, habitats and other features, where applicable.

9. Along each transect line, additional survey points may be implemented if evaluation criteria are observed.

10. For all data points, species density, relative density, dominance, relative dominance, frequency, relative frequency and importance values will be determined by the following formulas:

Density = Number of individuals/area sampled (per habitat type)

Relative density = (density for a species/total density for all species) x 100

Dominance = areal coverage values for a species/area sampled (per habitat type)

Relative dominance = (dominance for a species/total dominance for all species) x 100

Frequency = total number of plots in which a species occurs/total number of plots sampled

Relative frequency = (frequency value for a species/total of frequency values for all species) x 100

Importance value = relative density + relative dominance + relative frequency

a. Biodiversity values for each sample set will be determined using the Shannon Weaver Index, as described by the following formula:

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where H is the measured biodiversity and p_i is the proportion of species *i* relative to other species.

Field Logistics

In order to determine logistics and time required for field studies, a preliminary map of proposed transects (terrestrial) and polygons (marine) were identified, using Google Earth Pro satellite imagery (see below).

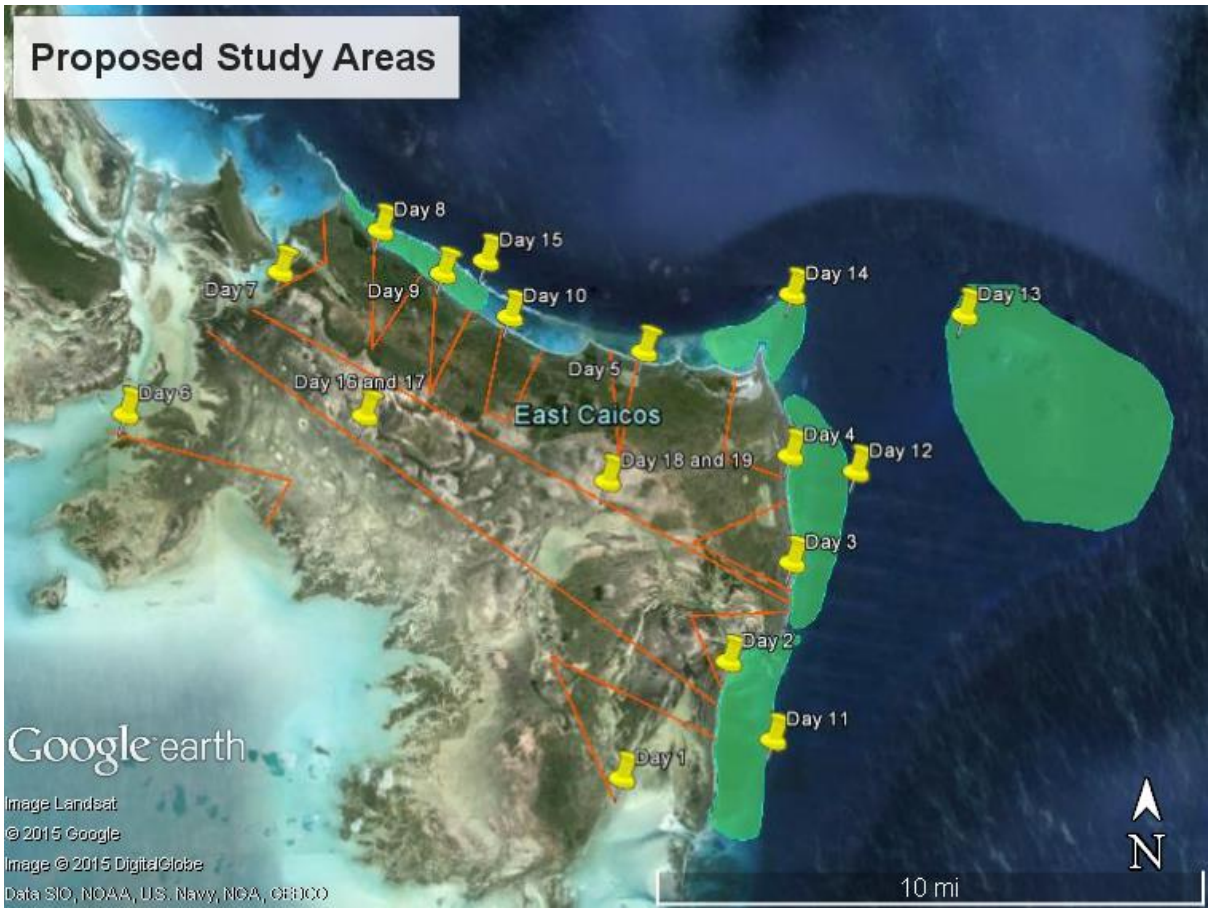

Figure 4 - Google Earth image of proposed study areas and work times

In the above figure, each pinned segment represents a day of field studies. For terrestrial and wetland habitats, each segment measures less than 10 kilometers in length. Marine areas vary in area and will be surveyed according to accessibility and the amount of area at each location that can be surveyed during three, one-tank dives per day.

The proposed field studies will take place for five days each in the months of February, March and May/June. Two days each of field studies will also take place in July and September, with additional days during these times as needed to follow up on incomplete works from previous months' work. The following list provides the details for each day of field studies.

February – Access via South Caicos
5 days of field studies (terrestrial and wetland)

Day 1 – boat drop-off – survey south-eastern wetland area – boat drop-off water and food at each campsite (camp overnight)
Day 2 – east coast south upland and wetland survey (camp overnight)
Day 3 – east coast middle upland and pond surveys (camp overnight)
Day 4 – east coast north and north coast east upland and pond surveys (camp overnight w/boat support)
Day 5 – north coast mid-east upland and pond surveys – boat pickup

Resources required:
Roundtrip airfare to South Caicos
Accommodation on South Caicos – 2 nights
Food and water
Boat support (2 full days)
Equipment
Field assistant

March – Access via Middle Caicos
5 days of field studies (terrestrial and wetland)

Day 6 – boat drop off and pickup - southwest coast wetland – boat drop-off water and food at each campsite (camp overnight)
Day 7 – boat drop off (night before) west and northwest coast terrestrial and wetland surveys (camp overnight)
Day 8 - northwest coast upland, wetland and ponds (camp overnight)
Day 9 – north mid-west coast upland and ponds (camp overnight)
Day 10 - north middle coast upland and ponds, boat pickup

Resources required:
Roundtrip ferry and ground transportation to Middle Caicos
Accommodation on Middle Caicos – 2 nights
Food and water
Boat support (1 full day and pick-up on day 10)
Equipment
Field assistant

May-June – Access via South Caicos and Middle Caicos
5 days of field studies (marine and bird)

Day 11 – Boat access via South Caicos – southeast polygon (return to South Caicos)

Day 12 – Boat access via South Caicos – northeast polygon (return to South Caicos)
Day 13 – Boat access via South Caicos – northeast bank polygon (return to South Caicos)
Day 14 – Boat access via South Caicos – northeast shoreline polygon (camp overnight for bird surveys - Audubon shearwater at Drum Point)
Day 15 – Boat access via Middle Caicos – northwest polygon (return to Middle Caicos)

Resources required:
One-way airfare to South Caicos
One-way ferry and ground transportation from Middle Caicos
Accommodation on South Caicos (4 nights)
Accommodation on Middle Caicos (1 night)
Boat support (5 full days)
Food and water
Dive tanks (3 per day per person)
Equipment
Field assistant (dive buddy)

July – Access via South Caicos or Middle Caicos
Field studies to fill in gaps from previous work (terrestrial, marine and wetland)

Day 16-17 - Trans-island wetland transect (boat drop-off and pickup)
Other days as needed

September/October – Access via South Caicos or Middle Caicos
Field studies to fill in gaps from previous work (terrestrial, marine and wetland)

Day 18-19 – Trans-island wetland and terrestrial transect (boat drop-off and pickup)
Other days as needed

Resources required
Airfare and/or ferry and ground transportation
Accommodation on South Caicos and/or Middle Caicos
Boat support
Food and water
Dive tanks (as needed)
Equipment
Field assistant

The Royal Society for the Protection of Birds (RSPB) has generously offered to provide the funding for logistical support for the research. Field assistants will be drawn from the TCI Department of Environment and Maritime Affairs (DEMA) and student interns from various academic institutions.

Input field data for ecologically important values into a GIS handheld device

Prior to the commencement of field studies, a drop-down menu will be developed that lists all known species, habitats and abiotic variables. These variables will be entered into a spreadsheet according to their criteria (e.g. endemic, protected, etc.). As these variables are noted in the field, they will be recorded into a hand-held Trimble GPS unit that will also record locations of each variable.

Conduct field studies and input data into GIS dataset to graphically illustrate the ecological values of East Caicos.

The proposed method for developing a GIS layer that graphically illustrates the ecological "hot spots" of East Caicos involves the integration of aerial imagery, input of field study data and remote sensing. An existing set of geo-rectified aerial raster images have already been attributed with upper-level habitat classifications (Wood et al., 2010). Field data will be uploaded into the imagery database and will receive color coding and attribution according to presence/absence of evaluation criteria.

The initial GIS layer will be the series of data points, with associated metadata. Once completed, the preliminary habitat classification layer will then be updated with all field data. Habitats will receive final, full classification, and remote sensing will be used to cross reference areas that are discernably similar with those that were ground-truthed. A final GIS database will be matched to Landsat imagery and will contain a comprehensive habitat map of terrestrial, wetland and marine habitats, including all evaluation criteria at each geographical location.

Analyze and discuss results

The resultant map will be analyzed based on identified evaluation criteria and appropriate land use management strategies will be discussed. Areas for further research will be identified, and recommendations for conservation approaches will be made. The results will also be presented to policy makers as a written report and through a seminar to present results and provide a forum for discussion and feedback.

Research Limitations

The proposed research is potentially limited by logistical, sampling and political considerations. East Caicos is a remote island, surrounded on the eastern and western boundaries by barrier reef and along the southern and western boundaries by shallow mudflats and estuaries. Consequently, access is somewhat physically restricted and can be treacherous under various climactic conditions. In order to address this limitation, field studies will be conducted throughout the year in order to take advantage of seasonal benefits. All marine studies will be conducted during the summer months in order to avoid winter oceanic swells, while terrestrial and wetland surveys will be conducted in spring and fall months to take advantage of lower temperatures, reduced mosquito populations and migratory bird schedules. When necessary, the island will be accessed via kayak to reduce coral reef and shallow water hazards.

Errors in sampling are also a possibility. Given that primary analyses will be dependent on presence/absence determination, false negatives may be reported, which could result in underestimating the ecological attributes of East Caicos. Multiple replicates in each habitat type will help to alleviate this limitation to some extent. Ultimately the final outcomes will be explained as a minimum baseline for ecological criteria, with the understanding that values in some areas are probably higher than reported.

Finally, the development of East Caicos is a politically controversial topic in TCI. After years of economic stagnation, the elected government is eager to demonstrate that development is taking place. They may therefore prefer to keep ecological variables of value unknown as they seek external investment for the proposed development. In order to address this potential limitation in a timely manner, I have already applied for a research permit, and I have been issued Conditions of Approval (CoA). The CoA appear to be reasonable, and one can infer that this indicates research permission will be granted. I am also seeking to address this potential limitation by offering incentives, such as training opportunities for government staff and community volunteers. The

application to conduct scientific research will also stress the value of the research to the land use planning process. All results and the final GIS database will be shared with government and relevant government bodies at no cost as a further incentive.

Tentative Schedule

The following table outlines the expected timeframe for research benchmarks:

Benchmark	***Expected Date of Delivery***
Target date for contacting prospective thesis director	7 February
Target date for appointment of thesis director	15 March 2015
Date for starting research	15 March 2015
First draft submitted to thesis director	1 November 2015
Target date for thesis draft discussion	December2015 – February 2016
Final draft submitted to thesis director and research advisor	1 March 2016
Binding of thesis	15 April 2016

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Appendix I – East Caicos species of interest and known habitats

Species of Interest East Caicos

Species	***Common Name***	***Comments****
Flora		
1 Acacia acuifera	*Pork and Doughboy*	Endemic B
2 Agave braceana	*Century Plant*	Endemic B
3 Agave inaguensis		Endemic B
4 Argythamnia argentea		Endemic TCI
5 Borreria bahamensis		Endemic B
6 Caesalpinia reticulata	*Brazileeta*	Endemic B
7 Catesbaea foliosa		Endemic B
8 Cephalocereus millspaughii	*Dildo Cactus*	Endemic C
9 Coccothrinax inaguensis	*Inagua Silver Palm*	Endemic B, IUCN
10 Cordia lucayana		Endemic B
11 Eleocharis bahamensis		Endemic B
12 Encyclia caicensis	*Caicos Islands Endemic Orchid*	Endemic TCI, CITES
13 Encyclia altissima	*Tall Orchid*	Endemic C, CITES
14 Encyclia inaguensis	*Inagua Orchid*	Endemic B, CITES
15 Encyclia rufa	*Spring Orchid*	Endemic C, CITES
16 Eragrostis bahamensis	*Bahama Lovegrass*	Endemic B
17 Ernodea serratifolia		Endemic B
18 Euphorbia inaguensis	*Wild Thyme*	Endemic B
19 Euphorbia gymnonota	*Milk Tree, False Frangipani*	Endemic B
20 Euphorbia lecheoides	*Pinweed Spurge*	Endemic B
21 Euphorbia vaginulata		Endemic B
22 Euphorbia lecheoides		Endemic B
23 Evolvulus squamosus	*Broom Bush*	Endemic B
24 Guaiacum officinale	*Lignum Vitae*	IUCN Vulnerable, only known TCI population
25 Guaiacum sanctum	*Lignum Vitae*	IUCN Vulnerable
26 Heliotropium nanum	*White Pussley, Low Ashy Heliotrope*	Doubtfully Endemic B
27 Hibiscus brittonianus	*Bahama Hibiscus*	Endemic B
28 Melocactus intortus	*Turk's Cap Cactus*	Endemic C,CITES,SPAW
29 Metastelma inaguense	*Inagua Metastelma*	Endemic B
30 Mimosa bahamensis	*Bahama Mimosa*	Endemic B
31 Opuntia (Consolea) nashii	*Nash's Tree Cactus*	Endemic B
32 Opuntia bahamana	*Bahama Prickly Pear*	Endemic B
33 Opuntia lucayana	*Turk's Island Prickly Pear*	Endemic TCI, only known TCI population
34 Pavonia bahamensis	*Bahama Swamp Bush*	Endemic B
35 Pedilanthus bahamensis	*Monkey Fiddle*	Endemic B
36 Stachytarpheta fruticosa	*Bahama Vervain*	Endemic B
37 Swietenia mahagoni	*Madeira, Mahogany*	IUCN Endangered
38 Thouinia discolor	*Naked-wood, Quick Silver, Hard Bark*	Endemic B
39 Vernonia bahamensis		Endemic B
40 Wedelia bahamensis	*Rong Bush, Bahama Wedelia*	Endemic B

41 Ziziphus taylori	*Jujube*	Endemic B
AVES	***Birds***	
1 Calliphlox evelynae	*Bahama Woodstar Hummingbird*	Endemic B, IUCN LC
2 Charadrius melodus	*Piping Plover*	IUCN Near Threatened
3 Chordeiles gundlachii	*Antillean Nighthawk*	Biome-restricted Species, IUCN LC
4 Columba leucocephala	*White-Crowned Pigeon*	Regionally Threatened
5 Corvus nasicus	*Cuban Crow*	Endemic C, IUCN LC
6 Dendrocygna arborea	*West Indian Whistling Duck*	IUCN Vulnerable
7 Dendroica kirtlandii	*Kirtland's Warbler*	IUCN Vulnerable
8 Egretta rufescens	*Reddish Egret*	Significant Population
9 Falco sparverius	*American Kestrel*	CITES
10 Loxigilla violacea ofella	*Greater Antillean Bullfinch*	Biome-restricted Species
11 Mimus gundlachii	*Bahama Mockingbird*	Range-restricted Species
12 Pandion haliaetus	*Osprey*	IUCN Near-threatened
13 Phaethon lepturus	*White-tailed Tropicbird*	Biome-restricted Species
14 Phoenicopterus ruber	*West Indian Flamingo*	CITES
15 Sterna hirundo	*Common Tern*	Significant Breeding Population
16 Tyto alba	*Barn Owl*	CITES
17 Vireo crassirostris stalagmium	*Thick-billed Vireo*	Range-restricted Species
Reptiles		
1 Anolis scriptus scriptus	*Bark Anole Lizard*	Endemic Sub-species
2 Leiocephalus psammodromus	*Curly-tail Lizard*	Endemic Species
Mammals		
1 Brachyphylla nana	Cuban Fruit-eating Bat	IUCN Near-threatened
2 Erophylla sezekorni	Buffy Flower Bat	Range-restricted Species
3 Lasiurus borealis	Red Bat	Biome-restricted Species, IUCN LC
4 Macrotus waterhousii	Waterhouse's Big Eared Bat	Biome-restricted Species, IUCN LC
5 Monophyllus redmani	Redman's Long-tongued Bat	Biome-restricted Species, IUCN LC
Invertebrates		
Barbouria cubensis	Pink Cave Shrimp	Endemic C

East Caicos Habitats

TCINVC	Habitat Description	%
113	Estuarine Evergreen Forest	0.48
131	Upland Mixed Evergreen/Drought Deciduous Forest	0.66
134	Palustrine Mixed Evergreen/Drought Deciduous Forest	1.97
213	Estuarine Evergreen Woodland	0.34
231	Upland Mixed Evergreen/Drought Deciduous Woodland	2.63
232	Coastal Mixed Evergreen/Drought Deciduous Woodland	1.82
233	Estuarine Mixed Evergreen/Drought Deciduous Woodland	0.09
234	Palustrine Mixed Evergreen/Drought Deciduous Woodland	4.12
312	Coastal Evergreen Shrubland	0.05
313	Estuarine Evergreen Shrubland	13.18
331	Upland Mixed Evergreen/Drought Deciduous Shrubland	3.44
332	Coastal Mixed Evergreen/Drought Deciduous Shrubland	5.05
333	Estuarine Mixed Evergreen/Drought Deciduous Shrubland	5.18
334	Palustrine Mixed Evergreen/Drought Deciduous Shrubland	5.85
413	Estuarine Evergreen Dwarf Shrubland	0.16
431	Upland Mixed Evergreen/Drought Deciduous Dwarf Shrubland	0.79
432	Coastal Mixed Evergreen/Drought Deciduous Dwarf Shrubland	1.37
433	Estuarine Mixed Evergreen/Drought Deciduous Dwarf Shrubland	8.24
434	Palustrine Mixed Evergreen/Drought Deciduous Dwarf Shrubland	3.91
442	Coastal Rock Dwarf Shrubland	0.7
531	Upland Mixed Graminoid/Forb Herbaceous	0.06
532	Coastal Mixed Graminoid/Forb Herbaceous	0.55
533	Estuarine Mixed Graminoid/Forb Herbaceous	4.46
534	Palustrine Mixed Graminoid/Forb Herbaceous	6.85
612	Coastal Nonvascular	0.2
613	Estuarine Nonvascular	7.92
614	Palustrine Nonvascular	6.94
615	Lacustrine Nonvascular	0.08
633	Estuarine Mixed Algal Nonvascular	12.86
750	Cave	0.00
760	Archaeological Artifact	0.05