CONSERVATION STATUS AND POTENTIAL OF WEST INDIAN ENDEMIC BIRD SPECIES IN A RAPIDLY SUBURBANIZING LANDSCAPE, MIDDLE CAICOS, TURKS & CAICOS ISLANDS.

By

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To the memory of Earl Franklin Reitz,
scientist, artist, historian

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Abstract of Dissertation Presented to the Graduate School
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CONSERVATION STATUS AND POTENTIAL OF WEST INDIAN ENDEMIC BIRD SPECIES IN A RAPIDLY SUBURBANIZING LANDSCAPE, MIDDLE CAICOS, TURKS & CAICOS ISLANDS

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Endemic bird species on tropical islands are a global conservation priority, and because they are often affiliated with native habitats these species can also be indicators for monitoring the effects of increasing residential land-use. The landscape on Middle Caicos, Turks and Caicos Islands (TCI) has been relatively stable for the last century, but the policy goals of the TCI government, based largely on high-end tourism, have placed Middle Caicos under immediate pressure for a major increase in its suburban area at the expense of native dry forest. Since this tourism sector is very sensitive to the appearance of environmental degradation, conservation activities based on endemic bird species may fulfill both economic and environmental policy agendas.

In April and May 2006, I surveyed the landbirds and vegetation composition and structure at 152 sites in upland Middle Caicos. The Gray Kingbird, Common Ground Dove, and Northern Mockingbird were significantly affiliated with suburban points and the Bahama Mockingbird, Thick-billed Vireo, and Bananaquit with native dry forest habitat. A categorical and regression tree analysis (CART) found that the Bahama Mockingbird is the only commonly occurring species whose presence is related strongly to distance from town. The CART demonstrated that

Bahama Mockingbirds tend to occur within a threshold of > 273 m from town. I also analyzed satellite remote sensing imagery using a land-cover change trajectory to assess different rates of suburban land-cover change occurring on various islands of the TCI from 1986-2001. I combined this analysis with territory mapping to evaluate the number of potential Bahama Mockingbird territories remaining under alternative land-use policies and applied a population viability analysis to assess the sustainability of these populations. During this time period, suburbanized land-cover increased by a factor of 1.45 on Middle Caicos and 3.45 on Providenciales. After 100 years, if development occurs at the Middle Caicos rate of suburbanization, the population has zero risk of island-wide extinction. Under the Providenciales rate of suburbanization, the population has a 100% risk of island-wide extinction and a mean time to extinction of 37 years.

Endemic bird species conservation in the TCI can be used to achieve both environmental and economic policy goals because birdwatching can be readily integrated into the high-end tourism sector and a species such as the Bahama Mockingbird is an excellent candidate around which to design conservation monitoring programs. While increasing tourism around endemic bird species would require a well-maintained trail system and additional luxury accommodations, both of which would generate more habitat loss, conservation of Bahama Mockingbird habitat would tend to increase environmental services beneficial to the tourism industry. Easy to identify and strongly affiliated with native forest habitat, the Bahama Mockingbird could be the centerpiece of a low-cost program to monitor population trends and to assess the impact of increased suburban land-use. Annual monitoring of the Bahama Mockingbird could assist in striking a balance between tourism-related development and ensuring a high quality environment.

CHAPTER 1
INTRODUCTION

Conservation Priority Setting and Endemic Island Species

Conservation projects may be established to protect environmental services needed by humans, such as water sources, renewable natural resources including forests, and landscapes that are valued for aesthetic, cultural, or religious reasons (Balmford et al. 2002, Wunder 2007). Conservation projects may be driven by political reasons, such as popular sympathy for a charismatic species (Andelman and Fagan 2000). A government may want to be perceived as addressing a social issue, such as uncontrolled suburban or industrial growth (Newburn et al. 2005). Priorities are also often set by donor- or funding-driven notions of conservation importance (Cleary 2006). These projects are frequently based in ecology: the decline in the population of a locally or nationally valued species (e.g., the Snail Kite), the loss of habitat- and regional-diversity due to anthropogenic changes (e.g., expanding agriculture areas), or obvious changes in ecosystem function following a human intervention (e.g., after a dam installation) (Martin et al. 2006, Butler et al. 2007, Poff et al. 2007).

The methods employed in these conservation projects are not equally cost-effective, and their efficiency may depend on local circumstances, including accessibility and heterogeneity of habitat or ease of observing different species and taxa (Franco et al. 2007). Conservation funds are limited and do not adequately address global needs (Halpern et al. 2006). It is, therefore, critical to consider both cost and the vulnerability of a species or ecosystem when prioritizing the allocation of limited conservation funds (Newburn et al. 2005). Most international conservation agencies have developed criteria for allocating these limited resources.

The activities of conservation organizations tend to prioritize irreplaceability, as measured by endemism or rarity, and vulnerability, particularly as determined by anthropogenic threat

(Brooks et al. 2006). The public is more willing to pay for the conservation of endemic species if they are at higher risk of extinction (Isik 2006, Wilson and Tisdell 2007). Islands tend to have high diversity and endemism, and anthropogenic threat, making them a prime target for conservation activities (Witt and Maliakal-Witt 2007). Species of birds on islands, for example, are approximately 40 times more likely to be extirpated than continental counterparts (Trevino et al. 2007). A combination of high avian endemism and risk of anthropogenic habitat loss places oceanic islands in the Caribbean, such as the Turks and Caicos Islands (TCI), in a position of conservation priority (Brooks et al. 2002, Myers et al. 2000).

Because of the variety of drivers for conservation projects, it is important to evaluate both the most effective scientific methods and the context of international, regional, and local stakeholder needs and desires for a conservation project to be successful. In this chapter, I describe the ecological methods I used to assess the conservation status of the endemic bird community in the TCI. I then outline the different groups of stakeholders related to this conservation problem and how their stated goals and activities provide the context for my research.

A "Hybrid" Approach to Selecting Species for Conservation Assessment and Monitoring

For parsimony and cost-efficiency, conservation decisions are often made on the basis of a single species of concern. Single-species studies provide robust information for conservation decision-making even in the face of an uncertain future (Nicholson and Possingham 2007). A single common species often can predict the occurrence of a rare species more reliably than habitat types or biophysical indicators, in part because of the ease and reliability of monitoring a single common species (Kintsch and Urban 2002). For instance, the Marbled Murrelet became an effective indicator species for old growth forest in southern Alaska when the initial species of concern, several species of goshawk, proved logistically impossible to monitor effectively

(Hanley et al. 2005). Good single-species indicators also often have a strong natural history affiliation with intact ecosystems, making them representative of disturbance impact in addition to a taxonomic community (Pearman et al. 2006). The effectiveness of a single-species conservation indicator often depends on the criteria for which it was selected.

Approaches that link single-species to their community context are often used by groups with conservation mandates to monitor and assess the persistence of biodiversity in areas under anthropogenic threat. The “focal” species approach concentrates on one or more species that may be particularly sensitive to limited ecosystem qualities or processes (e.g., habitat area, resource availability, fire) that place a group of species at risk of extirpation (Lambeck 1997). For example, the distribution and speciation of different warbler finches on the Galapagos Islands is most readily explained by the distribution of microhabitats across the islands, making each species representative of a different habitat type (Tonnis et al. 2005). If the correlations are established carefully, these indicators also often yield better results than using community-based indices such as diversity and dissimilarity as a basis for conservation. This is because such indices are often calculated and presented without regard to qualitative information about the species in the index, providing the false impression of objective values that can be compared easily across disparate ecosystems (Orme et al. 2005). One challenge to this approach is that it is critical to establish a strong link between species occurrence and particular processes, and selecting a species on the basis of other criteria (e.g., charisma or popular appeal, classification as an endangered species, institutional tradition) may yield questionable management results (Landres et al. 1988, Lindenmayer et al. 2002).

A “hybrid” approach can be used to select an indicator species by examining the occurrence of several individual species in the context of their communities. Done effectively, this allows selection of suitable candidates for conservation monitoring and assessment (Olden et al. 2006). The term “hybrid” refers to using a combination of community and single-species-based methodology. One advantage to this “hybrid” approach is that collecting general information on a broad group of species allows for objective selection of a particular species for more detailed observation (Lindenmayer et al. 2007). For instance, after mist-netting 159 bird species in Ecuador’s Machalilla National Park, researchers were able to identify three species of antbird whose high visibility and affiliation with rare species would make them excellent indicator species for mature forest habitat (Becker and Agreda 2005). When representative species in groups as diverse as birds and butterflies are selected based on such *a priori* data, they are much more effective indicator species (Fleishman et al. 2005). This “hybrid” approach is a cost-effective way to place the detailed study of a single-species into a broader community context.

In my research, I applied this “hybrid” approach to assessing the status of landbird conservation on Middle Caicos, Turks and Caicos Islands, with special emphasis on endemic species. I first evaluated the landbird community and compared the responses of endemic species to anthropogenic threats. These results led me to select one species, the Bahama Mockingbird *Mimus gundlachii*, which appeared to exhibit a representative response to changes in ecosystem resulting from human activities. I chose the landbird community on Middle Caicos to apply this “hybrid approach” because it is part of a biodiversity hotspot (Myers et al. 2000) and an Important Bird Area (BirdLife International 2004), containing high avian endemism and anthropogenic threat to the persistence of these species. In addition, the landbird community has not been formally studied and such information would be useful to terrestrial conservation efforts in this region (Sanders 2006).

Stakeholders in the Potential for Endemic Landbird Conservation on Middle Caicos, Turks & Caicos Islands

Scientific observations inform stakeholder groups who make policy decisions governing environmental management. Because many of these decisions are value-laden, it is important to understand the socio-political context in which an ecological study is carried out to ensure that data collection focuses on areas where the results can be applied to policy (Reagan 2006). No prescriptive approach exists that will guarantee the involvement and satisfaction of all members in a group of diverse stakeholders (Stringer et al. 2006). In addition, a disadvantage of developing policy alternatives strictly on stakeholder involvement is that most groups tend to be more comfortable with hypothetical scenarios that closely resemble the *status quo*, which may inhibit the introduction of innovative ideas (Baker et al. 2004). Nonetheless, these groups represent the context into which conservation policy is applied. In this section, I describe the stakeholders on Middle Caicos and explain how a better understanding of the status and conservation of the endemic bird community may further stated environmental management goals in this region.

Stakeholders on an International Scope

The Turks and Caicos Islands (TCI) are geologically the southern extent of the Bahamian Archipelago, but form an independent political unit (Figure 1-1). The TCI is one of 13 quasi-autonomous United Kingdom (UK) overseas territories, for which the "somewhat distant administration by the UK of her overseas territories has led, in many cases, to a *laissez faire* approach to environment and conservation" (Oldfield and Sheppard 1997). In part to remedy this deficiency, the UK Overseas Territory Conservation Forum (UKOTCF) was created as a body for liaison between the UK and territory governments and to provide publicity and fundraising assistance to burgeoning conservation organizations in the territories (UKOTCF 2003). In the

TCI, the UKOTCF has provided training and support for the Turks and Caicos National Trust and raised the international profile of the environmental conservation needs of these territories. The UKOTCF has supported the development of a management plan for the TCI Ramsar Site (encompassing the wetlands of North, Middle, and East Caicos), and has also fostered a scientific relationship for monitoring environmental and cultural sites with Royal Botanical Gardens (Kew, UK), Institute for Regional Conservation (Florida, USA), Carnegie Museum, and the Florida Museum of Natural History. These relationships generally support the conservation goals instituted by the government and non-governmental organizations in the TCI.

The TCI forms an important part of the international vacation and cruise industry in the Caribbean region. The most expensive island group in the insular Caribbean (McElroy 2006), the tourism sector grew in value by almost 20% in 2006 (CDB 2007). The May 2007 meeting of the Caribbean Development Bank (CDB) concluded that, in the case of the TCI:

> The focus is on the up-market end of the tourism industry, high-income visitors are more likely to demand value for money and will react faster to perceptions of environmental degradation. The natural environment which serves as the main attraction to visitors and the source of income requires effective and sustainable management (CDB 2007)

At the same time, a United Nations Human Development (UNDP) report comments that, “the infrastructure development undertaken to accommodate tourism [in the TCI] has placed a tremendous strain on the fragile natural environment” (UNDP 2005). This luxury-based economy is highly sensitive to international perceptions and presents a dichotomy of both requiring and destroying the marine and terrestrial ecosystems. The situation suggests that there is motivation for a group of international stakeholders to support environmental conservation efforts that will ensure the national slogan of the TCI, “Beautiful by nature,” retains an irony-free meaning. Many of the stated national goals for the environment discussed in the following section probably reflect, in part, the interests of these international groups.

Stakeholders on the National (TCI) Level

The national government body responsible for environment and conservation is the Department of Environmental and Coastal Resources (DECR), which is part of the Ministry of Natural Resources. The DECR works in tandem with the Turks and Caicos National Trust (TCINT), a non-profit entity chartered by UK and TCI governments that resembles similar trusts in other present and former UK territories. These organizations are partially funded by a 1% conservation tax that is added to the tourism tax on meals and lodging (Sanders 2006). Both organizations would likely be involved in carrying out the countrywide goal laid out in the National Development Vision by the Ministry of Finance, Health, and Insurance (MFHI), to "undertake a comprehensive terrestrial exercise to identify and map ecologically and scientifically important species and inform national and island land use zoning plans… [using the] relative abundance and distribution of selected indicator species" (MFHI 2006).

One of the primary responsibilities of these organizations is to maintain protected areas, which has become a challenge because of the "pressure by developers to extend development into protected areas with resultant encroachment on some protected areas [*sic*]" (MFHI 2006). This is further complicated by much undeveloped land in the TCI being UK Crown Land, which does not recognize TCI protected areas (MFHI 2006). This lack of clear tenure presents an additional difficulty to implementing conservation activities. In Middle Caicos, for example, the Royal Society for the Protection of Birds and BirdLife International recommend that a large tract of native dry forest between Bambarra and Lorimers settlements (Figure 1-2) be declared an Important Bird Area and protected, yet acknowledges the challenge of trying to establish effective protection of not just private, but Crown ownership (Sanders 2006). Scientific studies assessing the importance of this area may be instrumental in superseding these challenges.

Middle Caicos Island-level Stakeholders

Land ownership and development by foreigners have a mixed history of cooperation and contention in Middle Caicos. This island has a tightly organized community group of approximately 350 permanent residents that has, to date, largely curbed the uncontrolled development that has taken place on the nearby island of Providenciales (Pienkowski 2002). Other community stakeholders include taxi drivers/tour guides, boat drivers offering deep-sea fishing and visits to a Magnificent Frigatebird colony, and several small dry goods stores on the island, which are locally owned and operated (Arthur 2005). Limited transportation (air and land), housing, health care, water treatment, and waste disposal systems are constraints to present development.

A small (11 room) resort, Blue Horizon, has been operating west of Conch Bar by resident foreigners since the mid-1990's and is presently expanding to include private developments. The resort has aided the ferrying of petrol and building supplies from Providenciales, a role that will likely be changed when a proposed causeway linking Providenciales, North Caicos and Middle Caicos is completed (MFHI 2006). Another foreign investor operates an internet-based sale of homes and properties near Bambarra. Although details are unavailable, the TCI government has also announced a contract for a <400 ha resort complex on Middle Caicos, to include golf courses, 300 hotel rooms, shopping, and a marina (MFHI 2006).

Among the broad strategies outlined in the strategic vision for Middle Caicos is to "establish a pro-active and aggressive programme of monitoring and regulating the island's environment" (MFHI 2006). As part of achieving this goal, the TCI National Trust maintains a half-time conservation officer on the island who is largely responsible for keeping trails open through the native dry forest areas to provide access for tourists and scientists. In cooperation with the UKOTCF, the TCI National Trust has just opened an Eco Centre in Bambarra, which focuses on educational displays and may provide a home-base for further ecological field studies (Pienkowski and Pienkowski 2007).

Monitoring and Assessing the Endemic Bird Community on Middle Caicos

The economic development of the TCI, including Middle Caicos, depends on the intact natural dry forest ecosystem as an aesthetic commodity (CDB 2007), and also for its ecosystem services, such as protecting the meager freshwater supply (Sealy 1994). Environmental conservation and monitoring programs of the terrestrial ecosystem using indicator species are stated priorities of the TCI government (MFHI 2006). The native dry forest on Middle Caicos has already been identified by international conservation organizations as an Important Bird Area, home to critical breeding grounds for several endemic bird species (Sanders 2006). Endemic species tend to be representative of intact habitats, and endemic birds on tropical islands are among the species at a highest risk of extirpation in biodiversity hotspots (Pearman et al. 2006, Steadman 2006). These factors suggest that further study of the endemic bird community in Middle Caicos may identify species representative of intact native dry forest habitat that would be good candidates for monitoring.

Research Design and Dissertation Objectives

My dissertation objective is to assess the conservation potential of a little-studied group of endemic landbirds inhabiting an ecosystem under imminent anthropogenic threat, the native dry forest of Middle Caicos. In the present chapter (Chapter 1 of this work), I depict the justification for my study in terms of international approaches to, and priorities for, environmental conservation. I also describe the stakeholders involved in activities which influence and are influenced by environmental conservation in the TCI. Based on stakeholder needs and gaps in and scientific research, I conclude that assessing the ecology and conservation potential of the endemic landbird community on Middle Caicos, TCI would provide valuable information that could be readily applied to stated ecological and economic policy goals of the island, country, and region.

In Chapter 2, I examine the potential effects of converting native forest to suburban habitat, and identify possible indicator species for monitoring the effects of these changes on Middle Caicos. To address these issues, I observed all landbird species at 152 sampling points located on transects radiating away from each of three settlements on Middle Caicos. Using this data, I examined how the bird community composition on Middle Caicos differs between suburban and native forest habitat. I then explored which factors of the bird community, vegetation composition and structure, and spatial gradients are most strongly correlated with the presence of individual species. These results led me to identify the Bahama Mockingbird *Mimus gundlachii* as best species for ecological monitoring of the effects of suburbanization on Middle Caicos.

In Chapter 3, I examine the possible effects that alternative policy scenarios may have on the population of Bahama Mockingbirds in Middle Caicos. The growth of suburban land-cover on Middle Caicos has remained quite low over the past century, but government policies appear to favor increasing the rate of suburban growth to that of nearby Providenciales (MFHI 2006). The objectives of my research presented in this chapter are to examine trends in land-cover change on Middle Caicos and Providenciales, and estimate breeding territory size of the Bahama Mockingbird on Middle Caicos. I then conduct an assessment of the Bahama Mockingbird population's sustainability under alternative land-use change policies, comparing the effects of suburbanization occurring at the Middle Caicos and the Providenciales rates of land-cover change. To carry out these objectives, I used a combination of satellite remote sensing analysis and modeling, avian census data from Middle Caicos, and a population viability analysis.

The conclusion and synthesis section of my dissertation is contained in chapter four, where I present an overview of my research. I discuss the statistical findings of my analyses, addressing research objectives from Chapters 2 and 3. I then discuss the general conclusions synthesized from my results and the implications for conservation in Middle Caicos and the region. In conclusion, I discuss opportunities for future research on Middle Caicos with the Bahama Mockingbird and other bird species.

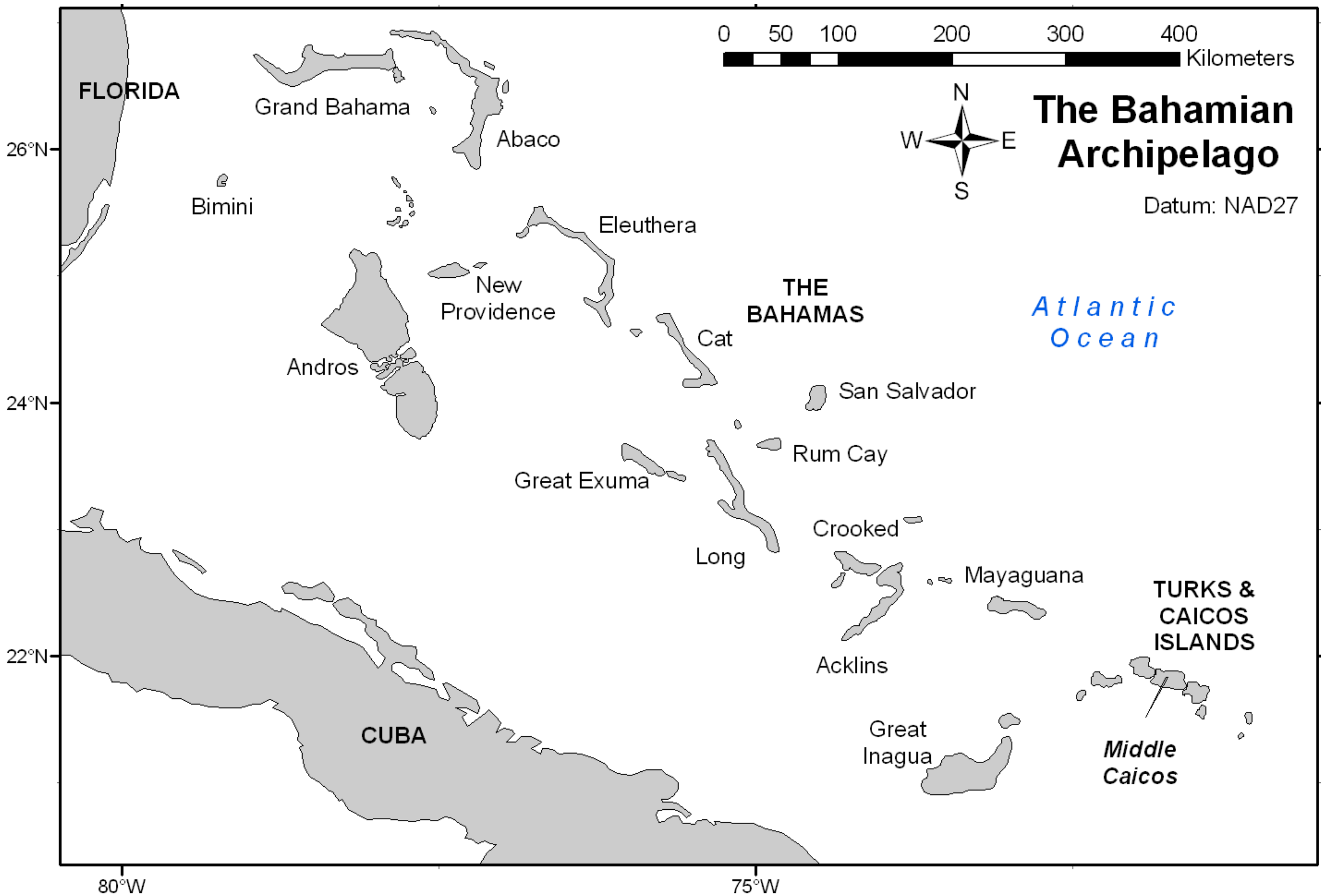

Figure 1-1. The Turks and Caicos Islands within the Bahamian Archipelago, with Middle Caicos highlighted in italics.

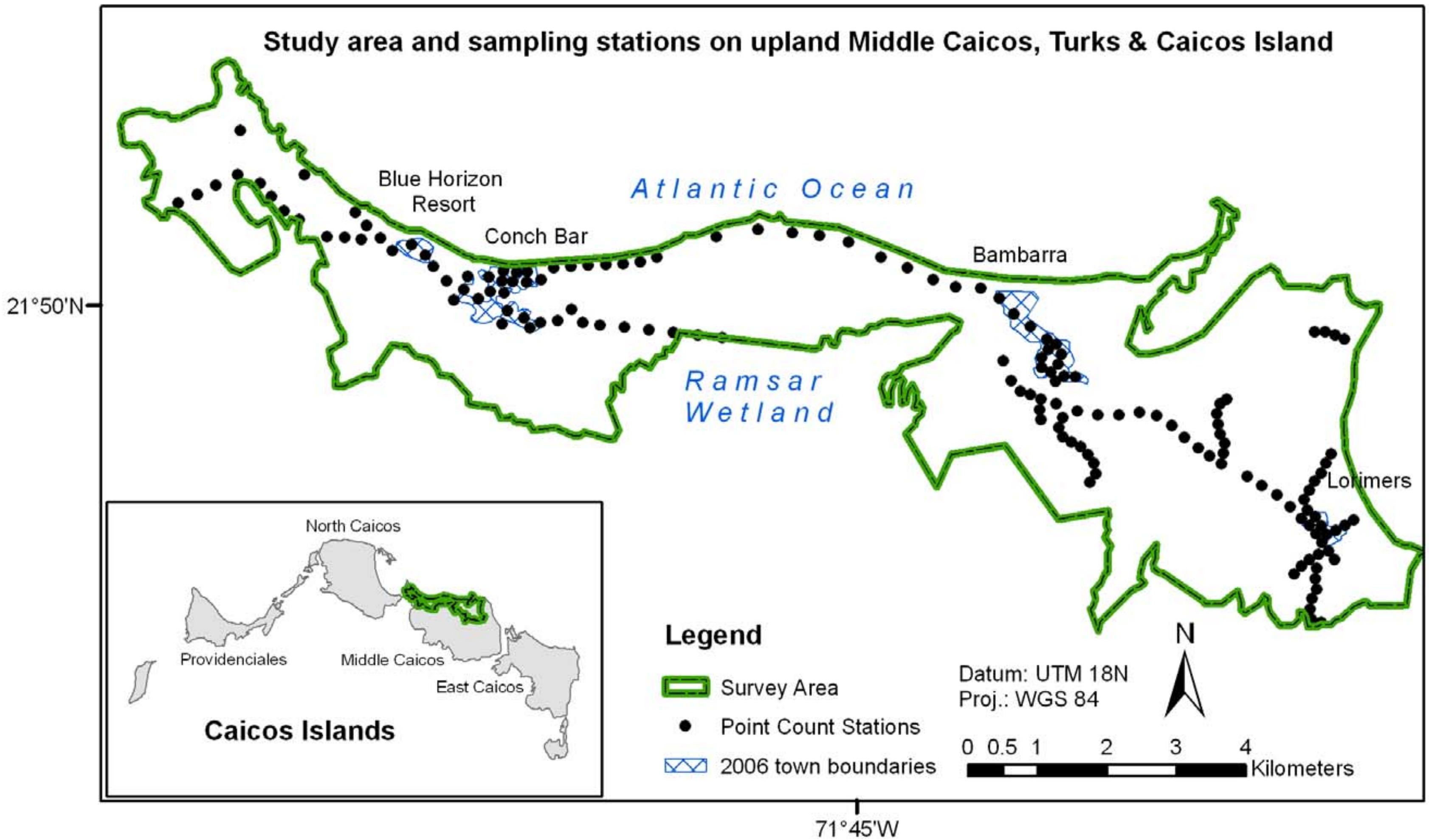

Figure 1-2. The geographic context of my study area and sampling stations within the Caicos Island bank.

CHAPTER 2
CONSERVATION POTENTIAL OF WEST INDIAN ENDEMIC BIRDS ON MIDDLE CAICOS, TURKS & CAICOS ISLANDS

Introduction

Indigenous birds on tropical islands are among the species most susceptible to human-induced extinction (Steadman 2006). Anthropogenic habitat loss and degradation, hunting, competition with and predation by exotic species, natural disasters (e.g., hurricanes, volcanoes, drought), and diseases are the primary threats to the persistence of these species (Arendt 1991, Milberg and Tyrberg 1993, Steadman 1995, Brooks et al. 2002). As habitat is converted to residential use, suburban-adapted species proliferate, forming a locally diverse, but regionally homogenous group of species often at the expense indigenous flora and fauna (Clergeau et al. 2006, McKinney 2006). Suburban growth is affecting habitat and extirpating native species in areas once considered too remote for the impacts associated with large-scale urbanization (Miller and Hobbs 2002, Radeloff et al. 2005). Understanding the ecological mechanisms through which suburbanization affects indigenous, especially endemic, species is critical to their conservation (Myers et al. 2000). In my research, I examine the potential effects that suburbanization may have on the distribution of endemic landbird species on Middle Caicos, Turks and Caicos Island (TCI). Several of these species of conservation concern are confined to the native tropical dry forest habitat that is dwindling in the TCI and throughout the Caribbean (Roth 1999, Strong and Sherry 2001, Sanchez-Azofeifa et al. 2005).

The theoretical framework for my research is niche theory, which states that species respond to environmental gradients and there is an optimum place along these gradients at which these species thrive (Grinnell 1922, Hutchinson 1957). In this investigation, I use a comparative observational study of the landbird community and biological, physical, and spatial factors that might influence the realized niche of each species to build a case of strong inference for the conservation status and management potential of these species (James and McCulloch 1995).

The overall objective of this study is to examine the potential effects of converting native forest to suburban habitat, and to identify potential indicator species for monitoring the effects of these changes on Middle Caicos. To address these issues, I first examined how the bird community composition on Middle Caicos differs between suburban and native forest habitat. I then explored which factors of the bird community, vegetation composition and structure, and spatial gradients are most strongly correlated with the presence of individual species. I then used these results to identify the best species for ecological monitoring of the affects of suburbanization on Middle Caicos.

Study Area

Environmental Characteristics of the Caicos Islands

The TCI are located at the southeast end of the Bahamian Archipelago (Figure 1-1). The climate of the Caicos Islands is arid, receiving an average of 1000 mm of rain annually with May being the wettest month (Pienkowski 2002). The bedrock of the TCI is oolitic limestone rising to peak elevations of 38 m above sea level on ridges parallel to the northern coasts on larger islands (GUK 1984, Carew and Mylroie 1997). There is no surface freshwater; access to the freshwater lens is gained through breaks in the limestone substrate (Sealy 1994). Upland tropical dry forest habitat is found in an area bounded on the north-northeastern side of the Caicos Islands by a strip of sandy beaches and to the south by estuarine wetlands protected by the international Ramsar Convention (Ramsar 2007). The habitat types within the upland terrain of the Caicos Islands have not been classified in detail, although such a process would assist with conservation planning (Pienkowski 2002).

Characteristics of the Caicos Island Bird Community

The landbird community of Middle Caicos consists of 22 species (Buden 1987, White 1998), 19 of which were recorded during this survey (Table 2-1). The other three (Barn Owl *Tyto alba*, Antillean Nighthawk *Chordeiles gundlachii*, and American Kestrel *Falco sparverius*) also were observed, but not during periods of data collection. The bird community includes six species that are endemic to the West Indies (White-crowned Pigeon *Columba leucocephala*, Bahama Woodstar *Calliphlox evelynae*, Cuban Crow *Corvus nasicus*, Bahama Mockingbird *Mimus gundlachii*, Western Spindalis *Spindalis zena*, and Black-faced Grassquit *Tiaris bicolor*); two that are Caicos Islands endemic subspecies (Thick-billed Vireo *Vireo crassirostris stalagmium* and Greater Antillean Bullfinch *Loxigilla violacea ofella*, found only on Middle and East Caicos).

This low number of species and proportionally high number of endemics are typical of oceanic islands, and has been described as a result of physical limitations (island size and isolation, MacArthur and Wilson 1967) or resource limitations (Lack 1976). Steadman (2006) has also demonstrated through exploration of the fossil bird community that tropical Pacific islands, before human arrival, hosted a much richer community than predicted by currently accepted models. Human arrival likely reduces the bird community diversity on islands through hunting, habitat alteration, and introduced predators, diseases and competitors (Steadman 1995). Steadman (2007) has identified the fossilized bones of at least 19 species of landbirds from ca. 1000 years ago that do not occur on Middle Caicos today, indicating that the present Middle Caicos bird community is depauperate compared to the community that existed before human arrival.

Regional Plant Community Characteristics

Native forest on the Turks and Caicos is biophysically similar to that of the southern Bahamas, which contains approximately 40 tree species with a canopy rarely higher than 3 m (Murphy et al. 2004). I recorded 37 common plant species in upland Middle Caicos during this study (Table 2-2). The native forest of each island of the Bahamian Archipelago (comprising The Bahamas and the TCI) has a somewhat different species composition, but that of the xeric southern islands tends to be more similar among islands than in the wetter, northern Bahamas (Smith and Vankat 1992). In the southern Bahamas and the TCI, this habitat is often located on higher ridges (Sykes and Clench 1998). Ornamental and often non-native species are associated with towns (Sykes and Clench 1998). Agriculture species, such as corn, sugar cane, papaya and other fruits, dominate active or recently abandoned agriculture plots; called "banana hole" farming, these plots are very small-scale and much less prevalent in the dry islands of the TCI than on islands to the north (Sealy 1994, MFHI 2006).

Residential development in the Bahamian Archipelago is expected to have a profound affect on the vegetation composition and structure of native forest habitats (Correll 1979, Smith and Vankat 1992). This development can happen very rapidly on a local scale in the Caribbean, such as the Hellshire Hills zone of dry limestone forest on Jamaica, which experiences a 7% annual loss of native tropical dry forest from to anthropogenic pressures (Tole 2002). A similar rate of development is predicted to occur in the near future for Middle Caicos (MFHI 2006).

Social Characteristics and the Future of Land-cover Change on Middle Caicos

The first Amerindian settlements occurred in the Turks and Caicos Islands around 800 A.D. and remained until European contact (O'Day 2002, Carlson and Keegan 2004). The islands were repopulated by Tory loyalists who left the United States in the late eighteenth century to establish salt pans and limited sugar-cane and sisal plantations (Craton and Saunders 1992). The descendents of their African slaves make up much of the present population of the TCI (Craton and Saunders 1992). Middle Caicos, the largest in the Caicos Island group (287.58 km^2, Buden 1987), has experienced very low levels of land-use change over the last century. The human population has varied from 300 to 700 persons since the early twentieth century (GPO 1912, 1922, JTC 1960, GSU 1989, DEPS 2001). In contrast, the human population on Providenciales, a nearby and physiographically similar island, has increased from less than 1000 to more than 13,000 permanent residents during the last 25 years (GSU 1989, DEPS 2001). This relative stability means that Middle Caicos provides a baseline for the relationship between biological, physical, and spatial factors and the West Indian endemic bird community of the TCI. In 2006, the TCI government signed a contract with an unnamed developer to allow a >400 ha luxury resort complex to be built on Middle Caicos, including hotel and townhouse residences, a golf course, marina, and commercial and civic center (MFHI 2006). Altering >10% of the upland habitat is likely to have a major influence the native plant and animal populations on this island and possibly heighten the risk of extirpation of some indigenous bird species.

Methods

Avian Community Data Collection

I carried out all observations of the landbird and plant communities on Middle Caicos during the primary breeding season, February – June 2005 and 2006, when birds were most likely to be vocalizing on territory (Brewer 2001). In April and May 2006, I collected data at 152 sampling stations, the locations of which were constrained by my research permit to existing roads and footpaths. To test the effects of proximity to settlements, I placed stations systematically 150 m apart in towns and along roads and trails radiating in transects away from town, increasing the distance to 300 m apart after 2 km from town to maximize coverage of the island (Appendix A). Towns were defined by walking the existing town boundaries with a GPS receiver in 2006. I estimated the distance to individual landbirds detected at each station over a 10 minute period (Buckland et al. 2001). Point counts occurred from sunrise to 10:00 am on days without rain or winds exceeding 13 km/hr. Each point was sampled once. The radius of detection was truncated at 50 m to ensure independence between stations (Ralph et al. 1993).

Vegetation Composition and Structure Assessment

Dominant woody plant species and habitat structure are two important factors that distinguish among different natural and human-altered areas within West Indian tropical dry forest. This has been supported by studies in such habitat in The Bahamas, TCI, Cuba, Jamaica, Puerto Rico, St. John, and the Dominican Republic (Wunderle and Waide 1993, Sykes and Clench 1998, Latta and Brown 1999, Currie et al. 2005a, 2005b). With the identification assistance of a botanist from the TCI National Trust, I recorded the presence/absence of the 37 common plant species within a 50 m radius of each sampling station, as well as the average canopy height, maximum emergent height, and percent canopy and ground cover (Patton 1987). I divided each sampling station into compass quadrants and used a 6 m extendible fiberglass height pole to estimate canopy height. The largest difference between the height of an emergent and the height of the canopy surrounding it was used as the maximum emergent height for each site. I then visually categorized each quadrant into percentage of canopy and rocky ground cover: 0, no cover; 1, >0 and <30%; 2, >30 and <60%; 3, >60 and <90%; and 4, >90% cover (Elzinga et al. 2001). The vegetation in the TCI and southern Bahamas consists of dense, thorny shrubs and low trees, which makes point and line transect sampling infeasible because of the strong bias associated with stretching out tapes and placing point measures (Elzinga et al. 2001). The unequal classification measures are most effective for monitoring cover in dense shrub and shrubby tree habitat because observer error tends to be lower in the high and low ends of the range and higher in the middle range (Floyd and Anderson 1987). Values among quadrants were averaged to give a single value for each site.

Spatial Distribution of Bird Species

To analyze the spatial distribution of bird species and other environmental factors on Middle Caicos, I procured three orthorectified and georeferenced Landsat TM and ETM+ satellite images of the TCI from the University of Maryland's Global Landcover Facility. The orthorectification process corrects the two-dimensional images for the curvature of the earth. All images were georeferenced to the Universal Transverse Mercator (UTM) North 18 projection system and the World Geodetic System (WGS) 84 datum. Dates of the images are 11 January 1986, 20 September 1999, and 14 December 2001. I layer-stacked the individual band files from the separate images using Imagine 9.0, creating three files with seven distinct bands in 30 x 30 m spatial resolution (plus one panchromatic band with a 15 x 15 m spatial resolution in the 2001 image).

In ArcGIS 9.1, I georectified a high quality aerial photograph of Middle Caicos supplied by the TCI Department of Environment and Coastal Resources (2005). Using >30 ground control points based on stable landscape features such as intersections, old buildings, and the airstrip, I achieved a root mean squared error value of < 1.0 m (Jensen 2000). From this image I created a shapefile of the study area, bounded to the south by the Ramsar wetland boundary (included on the aerial photos), and on all other sides by the ocean and wetlands separating this island from North Caicos to the west and East Caicos to the east. I also created a shapefile of each of the three townships based on this image, ground-truthing the suburban extent during my reconnaissance visit in 2005 and field work in 2006 (Figure 1-2). Rasters of distance from town (a polygon shape created by walking town boundaries with a GPS in 2006) were created in ArcGIS 9.1 spatial analyst extension, measuring the minimum Euclidean distance from town.

Each sampling station was located using a ground positioning satellite (GPS) receiver, and I imported these data directly into ArcGIS 9.1 as X/Y coordinates for spatial analyses.

Statistical Analysis

Landbird affiliation with suburban/ non-suburban areas

To assess the difference in the landbird community in suburban and native forest habitat, I separated the points into those located inside town boundaries (22 points) and those points not in town (130 points). I used the Spearman rank order correlation to compare the occurrence of each species in both habitat categories since both factors were not continuous (Cohen et al. 2003). I limited these calculations to species that were present at a minimum of eight points to ensure that the correlation would converge. These calculations were carried out in the program R, version 2.1.3 (Venebles and Smith 2005). Statistical significance was determined using a Bonferroni adjustment for multiple comparisons (Krebs 1999).

Categorical and regression trees

I assessed the strength of association between the Middle Caicos bird community and biological, physical, and spatial variables likely to influence bird species distribution (Table 2-3), using a classification and regression tree (CART, Breiman et al. 1998, Low et al. 2006). CART analyses are able to accommodate predictor variables of different distributions, making them particularly useful for ecological field studies (De'ath and Fabricius 2000, O'Connor and Wagner 2004, Beissinger et al. 2006). I carried out this analysis in the program DTREG (Sherrod 2005).

A series of recursive methods, such as *v*- or *k-fold* cross-validation, boot-strapping, and multiple adaptive splines can be combined with CARTs to produce an average tree with a measure of variance (Cohen et al. 2003, Prasad et al. 2006). Of these options, cross-validation may be the only practical means of assessing classification tree results (De'ath and Frabricius

2000). Cross-validation takes randomly selected subsets of the original data (usually 10) and runs the CART analysis with sets of 90% of the data, comparing the expected values from resulting model to the observed values from the 10% withheld data points. In this way, cross-validation creates an error measurement for the CART, while still allowing all the data to be used in creating the final model. For cross-validation to function well, it requires at least 20 presences and absences in the data set (Braga-Neto and Dougherty 2004), limiting the bird species I could use to the Mourning Dove (present at 25 of 152 points), Gray Kingbird (46 points), Blue-gray Gnatcatcher (24 points), Bahama Mockingbird (38 points), and Greater Antillean Bullfinch (31 points).

I ran the CARTs in DTREG as classification trees since bird species presence/absence is categorical, and used the gini splitting method, which is recommended for classification trees. I did not "prune", or artificially curtail the tree size, but I required that each node have at least 20 observations (some combination of presence and absence) to be split, for the same reasons as explained above (Braga-Neto and Dougherty 2004). I selected a 10-fold cross-validation to calculate a model error rate and also permitted DTREG to report the misclassification rate of each node, or the percentage of points that do not fit the dominant leaning of the target variable at a given split (i.e., if 60% of points in a given node split have the target species present, the misclassification rate would be 40%).

***Post hoc* power analysis**

Based on the results of my research, I calculated the level of precision (one-half of confidence intervals) given by my sample size. Because I used presence/absence of landbird species, I selected the *a priori* power analysis equation:

$$n = \frac{(Z_\alpha)^2 (p)(q)}{d^2} \qquad \text{Equation 1}$$

where n is the sample size to be calculated, Z_α is the confidence level (I used $\alpha = 0.05$, $Z_\alpha = 1.96$). In this case, p is the proportion of the target species, $q = 1 - p$, and d is the half of the maximum acceptable confidence interval width (e.g., $d = 0.05$ gives a confidence interval of ± 5%) (Elzinga et al. 2001). For my *post hoc* analysis, I transformed this equation and used:

$$d = \sqrt{\frac{(Z_\alpha)^2 (p)(q)}{n}} \qquad \text{Equation 2}$$

In this case, I used the number of sampling stations (152) for n, calculated the proportion p based on field data from my study, and used the appropriate Z_α for $\alpha = 0.05$.

Results

Landbird Affiliation with Suburban/ Non-suburban Areas

Of the 14 species present at 8 or more of the total 152 sampling points (Figure 2-1), three (Gray Kingbird, Common Ground Dove, and Northern Mockingbird) were significantly affiliated with suburban points and three others (Bahama Mockingbird, Thick-billed Vireo, and Bananaquit) with native dry forest habitat. These affiliations were statistically significant using the Bonferrorni adjusted threshold for significance ($P < 0.0036$).

Categorical and Regression Trees

Of the five species I analyzed using CART, the Bahama Mockingbird is the only species with its first split related to distance from town (Figure 2-2). The CART demonstrated that Bahama Mockingbirds tend to occur at a threshold of > 273 m from town. The Gray Kingbird, in contrast, is first affiliated with the presence of Australian Pine, then tends to occur at a threshold of < 138 m from town (Figure 2-3). The Greater Antillean Bullfinch does not occur at points with ornamental plant species (Figure 2-4). It favors areas that are moderately rocky (categories

2 and 3), but occurs at two points that are in areas with little rocky cover (category 1), which also have agricultural species present. The Blue-gray Gnatcatcher tends to occur in areas with canopy height > 2.5 m (Figure 2-5). Otherwise, it also occasionally was present in areas with moderately low rocky ground cover (category 2) where the Locust tree or shrub was present. Of the factors tested, the Mourning Dove was associated with other bird species (Figure 2-6), affiliated strongly with the Northern Mockingbird, to some degree with the Greater Antillean Bullfinch, and negatively with the Bananaquit. The Gray Kingbird had a cross-validation error rate of 7%, while the CARTs of the remaining species had cross-validation error rates that ranged from 12-13%.

Post hoc **Power Analysis**

I applied the *post hoc* power analysis to the Bahama Mockingbird because this species was both affiliated with non-suburban points in the correlation test and demonstrated a minimum distance from town in the CART analysis. Both of these results suggest that the Bahama Mockingbird may be an important target species for monitoring the affects of suburbanization on birdlife, which will be discussed further in the next section. The proportion of Bahama Mockingbird presence was 0.25 (present at 38 of 152 points). This means that the results demonstrate precision of ± 6.9% at $\alpha = 0.05$. While a precision of ± 5% would be preferred, these results are strong for a *post hoc* test, suggesting that the results for the Bahama Mockingbird are robust.

Discussion

Differences in Suburban and Non-suburban Bird Communities

Although maintaining certain habitat-related structures or plant species may aid the persistence of some bird species, the proximity or density of suburban area has been related to a decline in the populations of some plants and animals. Reduced abundance of grassland caused by suburban sprawl has been shown to create an extinction threshold for an endangered indigenous herbaceous plant in Sweden (Lennartsson 2002). Residential expansion affects the density of several hawk and falcon species in Colorado (Berry et al. 1998, Schmidt and Bock 2005). Distance between Whooper Swans and different levels of human activities, including towns and traffic, affects their persistence in a given area (Rees et al. 2005). Nested within the measurement of distance to town are changes in habitat composition and structure, noise and activity, local temperature and precipitation, and facilitation of competitive, urban adapted species (Shochat et al. 2006). Assessing the difference between the bird communities in suburban and native forest habitats helps to identify the species that are likely to decline with suburban expansion because of one or more of these ecological mechanisms. Recognizing species at higher risk provides guidance for further study and monitoring.

The results of my bird community analysis define two distinct sets of bird species associated with suburban and native dry forest. Suburban birds include the Gray Kingbird, Common Ground Dove, and Northern Mockingbird; native dry forest species consist of the Bahama Mockingbird, Thick-billed Vireo, and Bananaquit. All of the suburban birds are widespread in the western hemisphere and known to favor open areas for foraging, partially explaining their preference for open town habitat compared to the dense canopy of the native dry forest (Raffaele et al. 1998). The Northern Mockingbird may be a non-native invasive species, first appearing in the Bahamian Archipelago after European settlement (Brudenell-Bruce 1975). It is closely affiliated with urban or suburban habitat throughout its range, and its much higher fecundity than the congeneric native Bahama Mockingbird supports its status as an invader (Brewer 2002, MacDougall and Turkington 2005). Because the two species of mockingbirds did not co-occur and any given point, there may be some degree of congeneric competition, in addition to divergent habitat preferences.

Of the three native forest species, the Bahama Mockingbird and Thick-billed Vireo are West Indian endemics. Previous research has suggested that they might be closely affiliated to the xeric limestone forest. Thick-billed Vireos mist-netted on San Salvador were significantly heavier (more fit) in native forest than those netted in mangroves or disturbed areas (Murphy et al. 1998). Scientific observers have noted that even on islands where Bahama Mockingbirds are abundant, they tend to be absent in and near towns. Buden (1990, 1992) found this to be the case on Rum Cay and Long Island, as did White (1991) on San Salvador. Currie and colleagues (2005b) found decreasing abundance of Bahama Mockingbirds as canopy height decreased from mature native forest to recently abandoned plantations on Eleuthera. Aldridge (1984) found that, compared to Northern Mockingbirds, Bahama Mockingbirds tended to occupy higher canopy perches on Providenciales.

The Bahama Mockingbird's affiliation with native forest and congeneric replacement by the Northern Mockingbird in urban habitat suggests that as residential area increases, the population of Bahama Mockingbirds on Middle Caicos may be displaced. Indeed, fossil remnants of Bahama Mockingbirds from Puerto Rico and Barbuda indicate that this species was more widespread before modern settlement occurred (Olson 1985, Pregill et al. 1994). For these reasons, it may be a good species for monitoring the affects of suburbanization on the endemic bird community on Middle Caicos.

Biophysical and Spatial Factors Influencing Bird Species on Middle Caicos

Among the six species identified as suburban or native forest birds on Middle Caicos, only the Bahama Mockingbird and Gray Kingbird had appropriate sample sizes for more detailed examination with CART. Both of these species had distance from town as a factor for splitting nodes, with the Bahama Mockingbird preferring to be a minimum of 273 m from town and the Gray Kingbird tending to be present within 138 m or inside of town limits. These results concur with my earlier analysis of the bird community that labeled the Bahama Mockingbird as native forest species and the Gray Kingbird as a suburban species. Because they were the only species to have distance to town as a critical factor for occurrence, they may be excellent candidates for monitoring the affects of suburban expansion.

In addition to avoiding suburban areas, the Bahama Mockingbird also exhibited a negative correlation with the Buffalo Top Palm, suggesting that it may avoid areas of seasonally inundated wetlands and is limited to the upland terrain. The combination of the Bahama Mockingbird's reticence to live near human settlements and its preference for higher canopy native forest suggests that this species may be severely affected by the increased suburban development planned for Middle Caicos. Preservation of core areas of high canopy native forest, well removed from suburban areas, may be critical for the conservation of this West Indian endemic bird species with an already reduced range.

The other endemic bird species explored with a CART analysis was the Greater Antillean Bullfinch. Because it was correlated with an absence of ornamental plants, the bullfinch does not seem to have a strong an affiliation for disturbed sites. Indeed, the Greater Antillean Bullfinch was associated with mature rather than disturbed forest on Eleuthera (Currie et al. 2005b). On Middle Caicos, they tended to be found in moderately rocky ground, often corresponding with home garden plots. This affinity for the very small agricultural plots near houses may partially explain why the bullfinch does not appear to be affected by the distance from town. If future residential and commercial development on Middle Caicos changes emphasis from permanent residences with small home gardens to second homes and vacation properties that favor ornamental plantings over agricultural species, then the Greater Antillean Bullfinch may be more affected by development than this analysis initially suggests. Such a possibility merits monitoring.

In addition to the Gray Kingbird, two other widespread species were examined using the CART analysis, the Blue-gray Gnatcatcher and Mourning Dove. The Mourning Dove's co-occurrence with the Northern Mockingbird, a species classified as suburban in my community analysis, confirms that this dove is an urban species on Middle Caicos, as it is throughout its range. This is further supported by its negative correlation with the Bananaquit, a native forest species. Its affiliation with the Greater Antillean Bullfinch may be linked to the granivorous dove's ability to exploit food resources in home gardens with which the bullfinch is affiliated.

The results of the Blue-gray Gnatcatcher CART demonstrate its affinity for higher canopy forest, both through a correlation with canopy height over 2.5 m and affiliation with the Locust tree, one of the primary canopy species on Middle Caicos (Cutts 2004). Canopy height of native forest is often correlated with degrees of human disturbance, with higher canopy height being associated with lower anthropogenic effects (Toniato and Oliveira-Filho 2004). A study of the impacts of anthropogenic habitat alteration in comparable limestone forests in the Dominican Republic showed a significant difference in stand height between pre- and post-human disturbance sites (Roth 1999). Native forest on the Turks and Caicos is biophysically similar to that of the southern Bahamas where the canopy is rarely higher than 3-4 m (Murphy et al. 2004). Even in this small height range, canopy height is a good measure of forest maturity and habitat quality for indigenous birds on these islands (Currie et al. 2005b). In a study of Neotropical migrant birds comparing disturbed and undisturbed habitats on three Bahamian islands, among others in the Caribbean, Wunderle and Waide (1993) found that foliage height and density explained 73% of the variance in the winter avian community. For these reasons, the Blue-gray

Gnatcatcher's affinity for high canopy areas suggests that, like the Bahama Mockingbird, it may benefit from preservation of core areas of mature forest.

Of the birds highlighted as native forest species in my community analysis, the Bahama Mockingbird was the only one appropriate for further analysis with CART. The Thick-billed Vireo and Bananaquit were present at such high proportions of the total points (136 and 133 points out of 152, respectively) that their affiliations with specific biophysical factors could not be tested. The Bahama Mockingbird's sensitivity to a 273 m buffer around towns suggests that this species is an excellent candidate for determining the affects of suburbanization. A regional endemic, clearly associated with native upland forest, negatively correlated with suburban areas, and potentially displaced by its urban congener the Northern Mockingbird, the Bahama Mockingbird will become a species of particular conservation concern as Middle Caicos suburbanizes.

Synthesis

One of the greatest challenges in working with endemic species conservation is that each species may have a different reason that it is vulnerable to extirpation and extinction. In describing seven forms of rarity, Rabinowitz (1986) assigns species to categories of wide and narrow geographic range, broad and restricted habitat requirements, and somewhere large/ everywhere small local population size. In this paper, I defined endemic species as those with a narrow geographic range, limited to the West Indies. In relative terms within the set of eight endemic species, each has other limitations. Of the species that appear likely to be affected by increased anthropogenic disturbance, the Bahama Mockingbird and Thick-billed Vireo have restricted habitat requirements, but nevertheless are abundant on certain islands (e.g., Middle Caicos, San Salvador). The Western Spindalis, Cuban Crow, and White-crowned Pigeon, on the other hand, have broad habitat requirements but are relatively rare on Middle Caicos. In contrast, the Bahama Woodstar and Greater Antillean Bullfinch have broad habitat requirements and large populations, at least in some places. This suggests that a one-size-fits-all conservation program would not cover the needs of all of the endemic species.

Conservation organizations also have different criteria for prioritizing limited conservation funds to protect biodiversity, either by geographic area or species of conservation concern. Most conservation organizations focus on habitat loss for endemic species, and have a consensus that the Caribbean is an area of concern Brooks et al. (2006). The IUCN Red List, another important tool for prioritizing concern by species rather than area, is biased against species with little available biological information (Rodrigues et al. 2006), a category into which many endemic species fall (Myers et al. 2000). For this reason, it is likely that these species will be excluded from funding and policy decisions based on Red List status. Studies such as mine are important because they highlight conservation concerns of species that are not on the IUCN Red List but are part of biotic communities rich in endemic taxa that make up areas of threatened biodiversity worldwide.

Norris and Harper (2004) found that a key element to proactive conservation, which would prevent the extinction and extirpation of endemic bird species, is to identify those species limited to a single habitat type and focus conservation efforts on these species. The Bahama Mockingbird is strongly affiliated with native dry forest habitat, and further analysis showed that it is likely to be affected by increased residential and commercial land-cover. Based on Norris and Harper's criteria and the results of my study on Middle Caicos, the Bahama Mockingbird is of particular importance for further study.

McPherson and Jetz (2007) found that endemic bird species with limited ranges, but large populations in some places, such as the Bahama Mockingbird, are excellent candidates for predictive distribution models. This is because habitat and anthropogenic conditions tend to be more similar across their range than compared with widespread species. More detailed studies on breeding territory requirements for the Bahama Mockingbird, combined with an assessment of future land-cover change on Middle Caicos under alternative policy scenarios, would have strong predictive power for assessing the long-term viability of the Bahama Mockingbird population. Such a study might also suggest specific conservation activities to assess the risk and reduce the chances for extirpation of the Bahama Mockingbird from the TCI. Since it is representative of native forest habitat, such conservation activities would have positive implications for the many other species living in this threatened ecosystem.

Table 2-1. Resident landbirds observed on Middle Caicos, Turks and Caicos Islands recorded at point counts during May 2006.

Species	BirdLife International Conservation Status	Average individuals/ point
White-crowned Pigeon, *Columba leucocephala*	Endemic/Near Threatened	0.05
White-winged Dove, *Zenaida asiatica*	Least Concern	0.01
Zenaida Dove, *Zenaida aurita*	Least Concern	0.08
Mourning Dove, *Zenaida macroura*	Least Concern	0.22
Common Ground Dove, *Columbina passerina*	Least Concern	0.43
Mangrove Cuckoo, *Coccyzus minor*	Least Concern	0.03
Smooth-billed Ani, *Crotophaga ani*	Least Concern	0.12
Bahama Woodstar, *Calliphlox evelynae*	Endemic	0.09
Gray Kingbird, *Tyrannus dominicensis*	Least Concern	0.45
Cuban Crow, *Corvus nasicus*	Endemic	0.30
Blue-gray Gnatcatcher, *Polioptila caerulea*	Least Concern	0.25
Northern Mockingbird, *Mimus polyglottos*	Least Concern	0.06
Bahama Mockingbird, *Mimus gundlachii*	Endemic	0.34
Thick-billed Vireo, *Vireo crassirostris*	Endemic	2.28
Yellow Warbler, *Dendroica petechia*	Least Concern	0.05
Bananaquit, *Coereba flaveola*	Least Concern	1.89
Western Spindalis, *Spindalis zena*	Endemic	0.03
Black-faced Grassquit, *Tiaris bicolor*	Endemic	0.04
Greater Antillean Bullfinch, *Loxigilla violacea*	Endemic	0.30

Table 2-2. Dominant plants of upland Middle Caicos recorded in this study.

Common Name	Scientific Name	Family
WOODY PLANT SPECIES		
Inaguan Palm	*Coccothrinax inaguensis*	ARECACEAE
Buffalo Top Palm	*Thrinax morrisii*	ARECACEAE
Sabal Palm	*Sabal palmetto*	ARECACEAE
Caribbean Pine	*Pinus caribaea* var. *bahamensis*	PINACEAE
*Casuarina	*Casuarina equisetifolia*	CASUARINACEAE
Poisonwood	*Metopium toxiferum*	ANACARDIACEAE
Black Mangrove	*Avicennia germinans*	AVICENNIACEAE
Five Fingers	*Tabebuia bahamensis*	BIGNONIACEAE
Yellow Trumpet Flower	*Tecoma stans*	BIGNONIACEAE
Strongback	*Bourreria ovata*	BORAGINACEAE
Gum Elemi (Gumbo Limbo)	*Bursera simaruba*	BURSERACEAE
Parrotwood	*Buxus bahamensis*	BUXACEAE
Wild Cherry	*Crossopetalum rhacoma*	CELASTRACEAE
Manchioneel	*Hippomane mancinella*	EUPHORBIACEAE
Sword Bush	*Phyllanthus epiphyllanthus*	EUPHORBIACEAE
Cinnecord	*Acacia choriophylla*	FABACEAE
Pork and Doughboy	*Acacia acuifera*	FABACEAE
*Cowbush	*Leucaena leucocephala*	FABACEAE
Locust (Wild Tamarind)	*Lysiloma latisiliquum*	FABACEAE
Bahama Haulback (Cat's Paw)	*Mimosa bahamensis*	FABACEAE
Cat's Claw	*Pithecellobium unguis-cati*	FABACEAE
Pigeon Berry	*Guapira discolor*	NYCTAGINACEAE
Beefwood	*Guapira obtusata*	NYCTAGINACEAE
Sea Grape	*Coccoloba uvifera*	POLYGONACEAE
Darling Plum	*Reynosia septentrionalis*	RHAMNACEAE
Black Torch	*Erithalis fruticosa*	RUBIACEAE
White Torch	*Amyris elemifera*	RUTACEAE
Wild Lime	*Zanthoxylum fagara*	RUTACEAE
Quicksilver	*Thouinia discolor*	SAPINDACEAE
Wild Dilly	*Manilkara bahamensis*	SAPOTACEAE
Screw Tree	*Helicteres jamaicensis*	STERCULIACEAE
Joewood	*Jacquinia keyensis*	THEOPHRASTACEAE
Lignumvitae	*Guaiacum sanctum*	ZYGOPHYLLACEAE
NON-WOODY PLANT SPECIES		
Graybeard Cactus	*Pilosocereus royenii*	CACTACEAE
Prickly Pear	*Opuntia* spp.	CACTACEAE
Wild Cotton	*Gossypium hirsutum*	MALVACEAE
*Wild Sisal	*Agave sisalana*	AGAVACEAE
*Agriculture species		
*Ornamental species		

Sources: Cutts (2004), identification assistance from Bryan Naqqi Manco, Turks and Caicos Islands National Trust. * Non-native species.

Table 2-3. Description of the variables used in the CART of the West Indian endemic and widespread birds on Middle Caicos. The type of factor is defined as (N) numeric or (C) categorical after De'ath and Fabricius (2000).

Variable	Type	Possible Values			
Presence of each of 19 bird species	C	0 absent, 1 present for all birds in Table 2-1			
Presence of each of 37 plant species	C	0 absent, 1 present for all plants in Table 2-2			
Canopy cover	C	0, 0%; 1, >0<30%; 2, >30<60%; 3, >60<90%; 4, >90%			
Rock ground cover	C	0, 0%; 1, >0<30%; 2, >30<60%; 3, >60<90%; 4, >90%			
		Maximum	Minimum	Mean	Standard Error
Distance from town (m)	N	4640.06	0.00	1164.05	89.77
Canopy height (m)	N	4.00	0.00	2.03	0.07
Maximum emergent height (m)	N	8.00	0.00	2.02	0.15

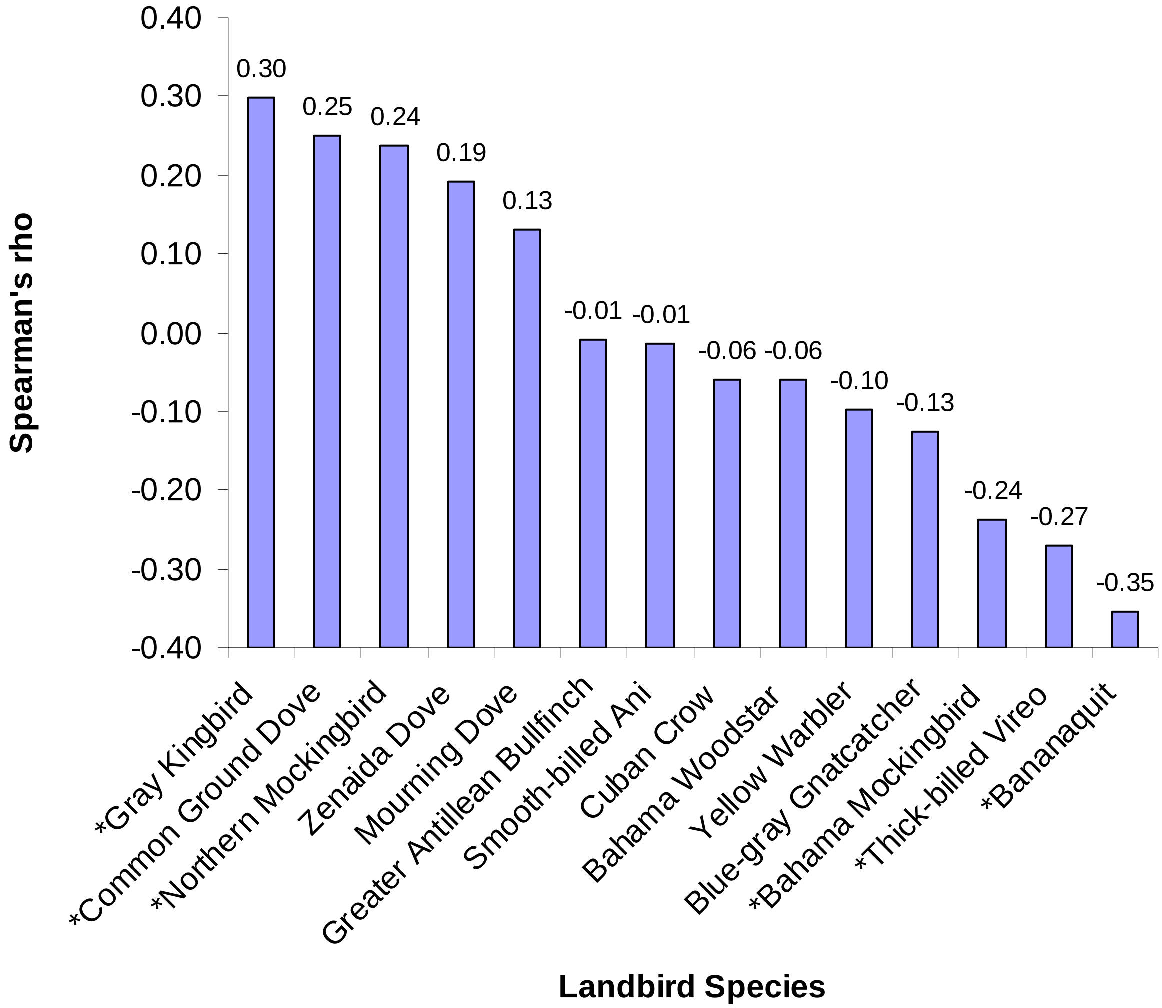

Figure 2-1. Spearman's rank correlation between the presence of each bird species at a given point and whether that point also occurred within a town. 22 sites out of 152 occurred within town limits, and bird in this analysis were present at a minimum of 8 sampling points. An asterisk (*) indicates that the relationship was significant using the Bonferroni adjustment for comparison of multiple species (14 species for $\alpha = 0.05$ giving a significance threshold of $P < 0.0036$).

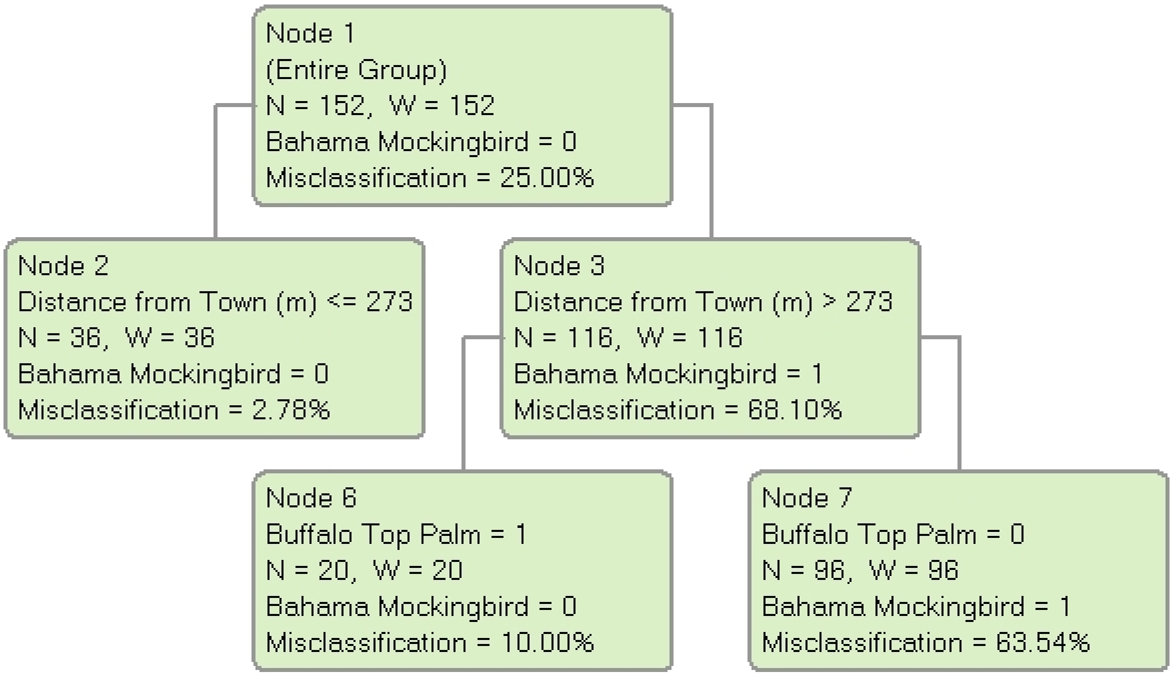

Figure 2-2. Categorical tree of Bahama Mockingbird occurrence on Middle Caicos, TCI. Minimum node size required for split = 20. Standard error of 10-fold cross-validation = 0.1211.

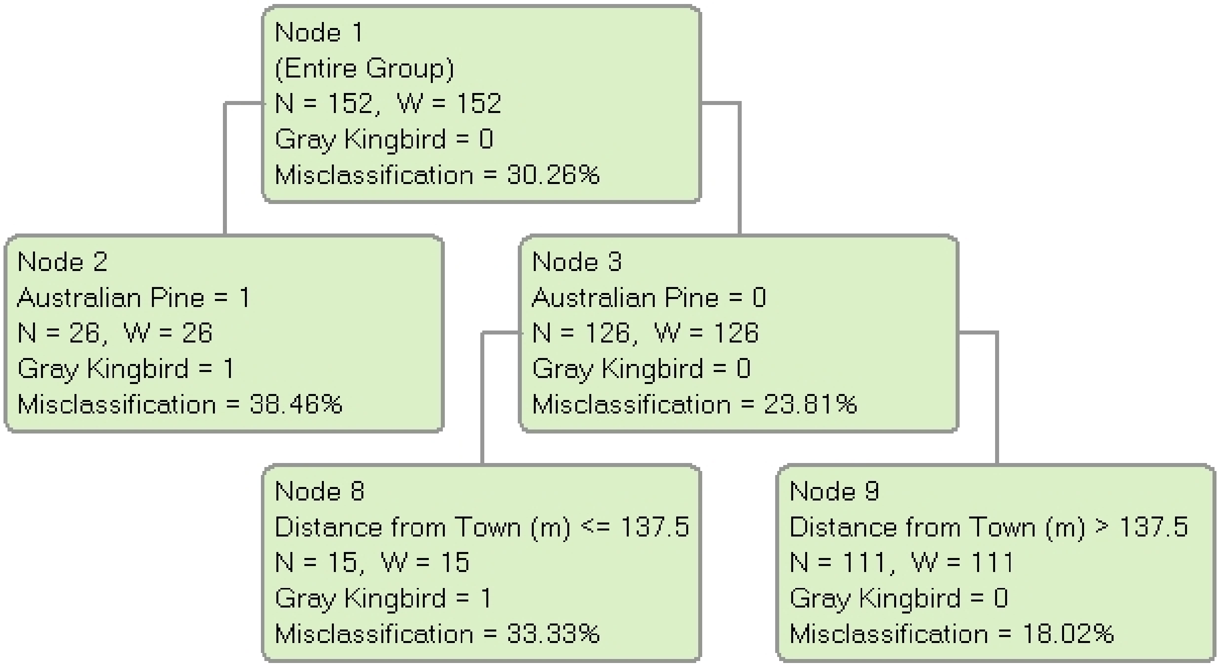

Figure 2-3. Categorical tree of Gray Kingbird occurrence on Middle Caicos, TCI. Minimum node size required for split = 20. Standard error of 10-fold cross-validation = 0.0787.

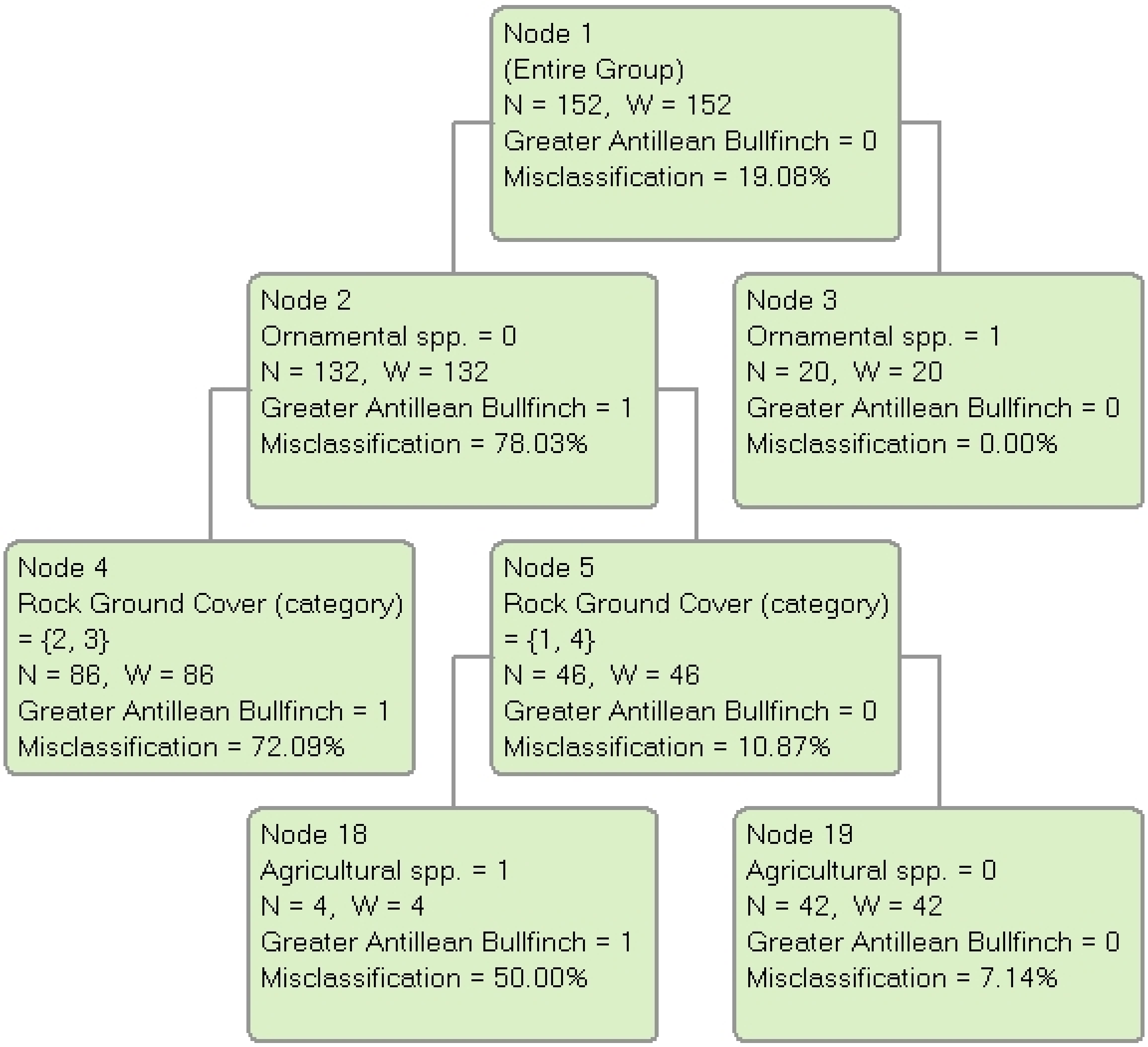

Figure 2-4. Categorical tree of Greater Antillean Bullfinch occurrence on Middle Caicos, TCI. Minimum node size required for split = 20. Standard error of 10-fold cross-validation = 0.1211.

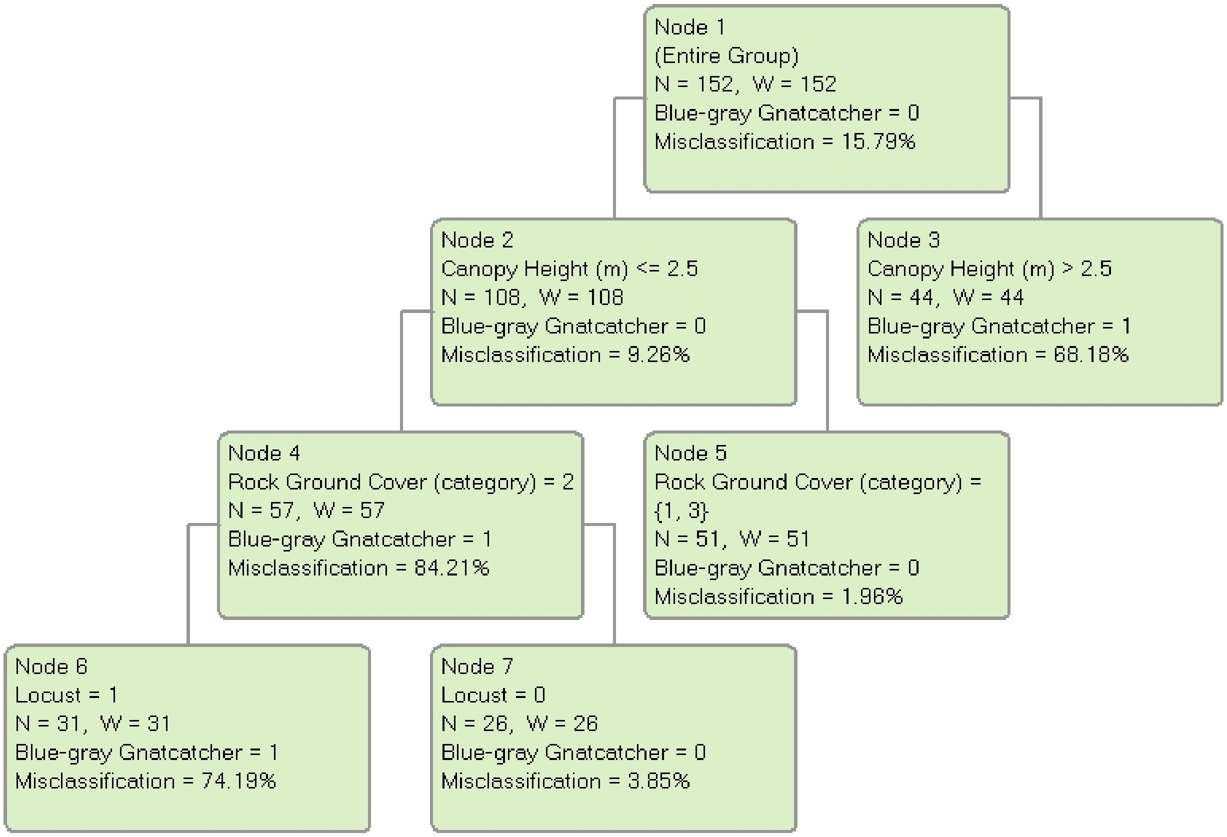

Figure 2-5. Categorical tree of Blue-gray Gnatcatcher occurrence on Middle Caicos, TCI. Minimum node size required for split = 20. Standard error of 10-fold cross-validation = 0.1294.

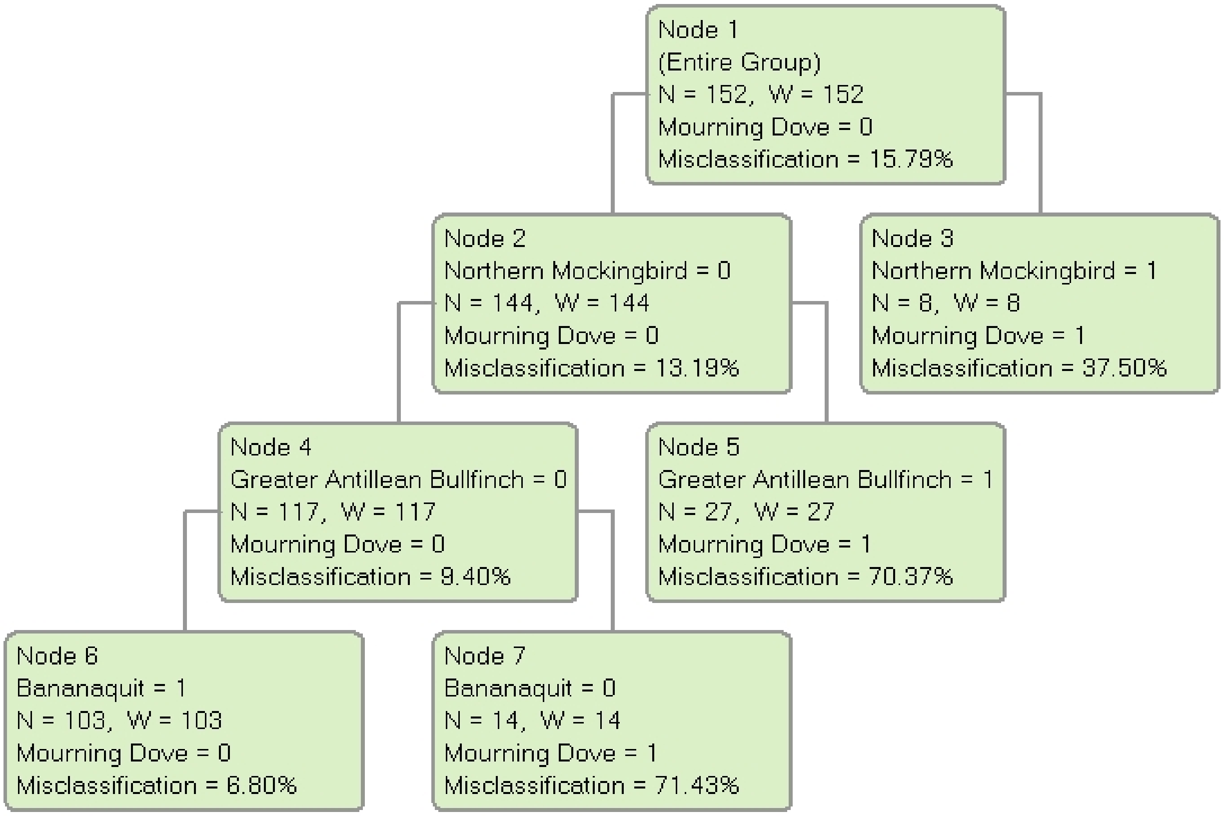

Figure 2-6. Categorical tree of Mourning Dove occurrence on Middle Caicos, TCI. Minimum node size required for split = 20. Standard error of 10-fold cross-validation = 0.1379.

CHAPTER 3
LAND-COVER CHANGE EFFECTS ON THE POPULATION VIABILITY OF THE BAHAMA MOCKINGBIRD IN NATIVE TROPICAL DRY FOREST HABITAT OF MIDDLE CAICOS, TURKS & CAICOS ISLANDS

Introduction

Indigenous bird species that are habitat specialists are susceptible to human-induced extirpation, particularly when their range is limited to tropical islands (Er et al. 2005, Steadman 2006). Extinction risk theory suggests that human activities (noise, hunting, and introduced predators) and habitat loss (decreased niche availability) are the two major anthropogenic causes of avian extinction and extirpation (Davis 2003). Birds that are habitat specialists are also placed at greater risk of extinction by anthropogenic habitat loss (Owens and Bennett 2000).

One of the challenges is that avian response to anthropogenic changes is often a threshold effect that is difficult to identify using traditional parametric techniques for occupancy-based data (Betts et al. 2007). In Chapter 2 (this volume), I use a non-parametric approach, the categorical and regression tree analysis (CART, De’ath and Fabricius 2000), to identify ecological factors related to habitat composition and structure that have a strong relationship to the presence of an indigenous bird species expected to be affected by anthropogenic habitat loss. In my analysis of the landbird community on Middle Caicos, Turks and Caicos Islands (TCI), I determined that the Bahama Mockingbird *Mimus gundlachii*, a native tropical dry forest habitat specialist, would face the greatest risk of extirpation if residential and commercial development increase (Chapter 2, this volume).

In this chapter, I examine the possible effects that alternative policy scenarios may have on the population of Bahama Mockingbirds in Middle Caicos. The growth of suburban land-cover on Middle Caicos has remained quite low over the past century (see Chapter 2, this volume), but government policies appear to favor increasing the rate of suburban growth to that of

Providenciales (MFHI 2006). The objectives of my research presented in this chapter are to examine trends in land-cover change on Middle Caicos and Providenciales, and estimate breeding territory size of the Bahama Mockingbird on Middle Caicos. I then conduct an assessment of the Bahama Mockingbird population's sustainability under alternative land-use change policies, comparing the effects of suburbanization occurring at the Middle Caicos and the Providenciales rates of land-cover change. To carry out these objectives, I used a combination of satellite remote sensing analysis and modeling, avian census data from Middle Caicos, and a population viability analysis.

Study Area and Species

Study Area

In Chapter 2 (this volume), I present an overview of my study area, Middle Caicos, Turks and Caicos Islands. This includes a summary of biophysical and geographic characteristics of these xeric islands located at the southeast end of the Bahamian Archipelago (consisting of The Bahamas and the TCI, Figure 1-1). In addition, I describe the native dry forest habitat consisting of approximately 37 plant species (Table 2-2), with which the Bahama Mockingbird is closely affiliated. I also discuss the history of land-use on Middle Caicos since Amerindian settlement around 800 A.D., and the prospects for land-use change that are presently proposed by the TCI government. In 2006, the TCI government signed a contract with an unnamed developer to allow a >400 ha luxury resort complex to be built, including hotel and townhouse residences, a golf course, marina, and commercial and civic center (MFHI 2006). Altering >10% of the upland habitat is likely to have a major influence on the native plant and animal populations on this island, including increasing the risk of extirpation of the Bahama Mockingbird.

The Bahama Mockingbird *Mimus gundlachii*

The Bahama Mockingbird is presently found nearly throughout The Bahamas and TCI, in an isolated area of xeric limestone forest in Jamaica, and on an unknown number of keys off the coast of Cuba (Raffaele et al. 1998). Fossils from Puerto Rico and Barbuda indicate that this species was once much more widespread (Olson 1985, Pregill et al. 1994). Pregill (1981) and Graves and Olson (1987) speculate that cooler, drier climates throughout the Caribbean during the Pleistocene permitted wider distribution of certain bird species adapted to drier habitats, such as the Burrowing Owl *Athene cunicularia*, Thick-knees *Burhinus* sp., Cuban Crow *Corvus nasicus*, and the Bahama Mockingbird.

Described as *Mimus bahamensis* based on a type specimen from the Exuma Cays, The Bahamas (Bryant 1859), *M. bahamensis*, *M. gundlachii* from Cuba and *M. hillii* from Jamaica were eventually merged as a single species (Gundlach 1893). Specimens of the Bahama Mockingbird were collected on most major islands of the Bahaman Archipelago during the late nineteenth and early twentieth century (Northrop 1891, Cory 1891, 1892, Bangs 1900, Bonhote 1903, Riley 1905). The mean body mass of nine Bahama Mockingbirds from Andros and Grand Bahama was 66.8 g with no significant difference between the sexes (Steadman et al. 1980). Mitochondrial DNA analysis shows that the Bahama Mockingbird has a greater genetic distance from the other Caribbean and North American mimids than the Northern Mockingbird *M. polyglottos*, Tropical Mockingbird *M. gilvus*, and Socorro Island Mockingbird *M. graysoni* have from each other (Arbogast et al. 2006).

The Bahama Mockingbird eats fruits, berries, arthropods, snails, and *Anolis* lizards (Brewer 2001). Of the plants that occur on Middle Caicos, Bahama Mockingbirds have been observed feeding directly on the fruits and flowers of *Guapira* sp., Cat's Claw *Pithecellobium unguis-cati*, Gumbo Limbo *Bursera simaruba*, Sisal *Agave sisalana*, and Bahama Swamp-bush

Pavonia bahamensis (Lack 1976, Aldridge 1984, Rathcke 2000). In 2005 and 2006, I observed Bahama Mockingbirds using Lignumvitae *Guaiacum sanctum*, Graybeard Cactus *Pilosocereus royenii*, Sea Grape *Coccoloba uvifera*, Beefwood *Guapira obtusata*, Five Fingers *Tabebuia bahamensis*, Bahama Haulback *Mimosa bahamensis*, and Locust or Wild Tamerind *Lysiloma latisiliquum* as singing perches, and eating fruits of the ornamental or wild Sapodilla *Manilkara* sp., Cowbush *Leucana leucocephala*, and Graybeard Cactus. Aldridge (1984) also observed Bahama Mockingbirds perching in *Acacia* sp. trees. Bahama Mockingbirds tend to avoid large open areas and usually are found in higher, more closed canopy forest (Currie et al. 2005b, Raffaele et al. 1998).

In mid-December, pairs of Bahama Mockingbirds establish territories that they maintain until the breeding season ends in late July (Riley 1905, Aldridge 1984). Males construct rough twig nests between 0.5 and 5 m high in densely foliated trees and shrubs where clutches of 1 to 3 eggs are laid in May and June (Buden 1987, 1992, Garrido and Kirkconnell 2000). On Middle Caicos, during both 2005 and 2006, local naturalist Cardinal Arthur reported seeing frequent Bahama Mockingbird nests in Parrotwood *Buxus bahamensis*. No instances of multiple broods have been recorded. Both males and females feed nestlings and fledglings through mid-July (Riley 1905). I observed breeding pairs feeding what appeared to be one-year-old birds on several occasions in May 2006. Nothing is known about juvenile dispersal (Buden 1992).

Methods

Remote Sensing Data Collection

To examine the change in land cover on Middle Caicos over a 15 year period, I procured two orthorectified and georeferenced Landsat TM and ETM+ satellite images of the TCI from the University of Maryland’s Global Landcover Facility. The orthorectification process corrects the two-dimensional images for the curvature of the earth. Both images were georeferenced to the Universal Transverse Mercator (UTM) North 18 projection system and the World Geodetic System (WGS) 84 datum. Dates of the images are 11 January 1986 and 14 December 2001. I layer-stacked bands 5, 4, and 3 for each year into two separate images in ENVI 4.3, creating two image files with 30 x 30 m spatial resolution (Figure 3-1). To correct for differences in atmospheric conditions between the two images, I used the darkbody correction in ENVI 4.3 (called the DOS [dark object subtraction] function). This function finds the darkest pixel in an image and assigns it a value of zero, subtracting the difference from the remaining pixels in the image. This is particularly effective in an image encompassing oceanic islands because very deep ocean tends to absorb all light, making it a good dark body for this method of atmospheric correction (Jensen 2000).

To identify features, including the Ramsar wetland boundary, I georectified a 2005 aerial photograph of Middle Caicos supplied by the TCI Department of Environment and Coastal Resources (DECR) and available only as a non-georeferenced PDF image, in ArcGIS 9.1 (DECR 2005). Using >30 ground control points based on stable landscape features such as intersections, old buildings, and the airstrip, I achieved an acceptable root mean squared error of <1.0 m (Jensen 2000). From this image I created a shapefile of the study area, bounded to the south by the Ramsar wetland boundary (included on the aerial photos), and on all other sides by the ocean and wetlands separating this island from North Caicos to the west and East Caicos to the east (Figure 3-1). I created a shapefile of each of the four residential areas by walking the boundaries with a handheld GPS unit during my 2006 fieldwork.

Bahama Mockingbird Presence

I carried out all observations of the Bahama Mockingbird on Middle Caicos during the primary breeding season, February – June 2005 and 2006, when birds were most likely to be vocalizing on territory (Brewer 2001). In April and May 2006, I collected data at 152 sampling stations, the locations of which were constrained by my research permit to existing roads and footpaths. Roads were single-lane with sand and residual asphalt substrates with light traffic (1-2 vehicles per hour). I placed stations systematically 150 m apart until reaching 2 km from town, after which they were located 300 m apart to maximize coverage of the island. I recorded the distance to each individual Bahama Mockingbird detected at each station over a 10 minute period (Buckland et al. 2001). Point counts occurred from sunrise to 10:00 am on days without rain or winds exceeding 13 km/hr. The radius of detection was truncated at 50 m to ensure independence between stations (Ralph et al. 1993).

Analyses

Land-cover change trajectory

To assess changes in land-cover, I compared band 3 from the two Landsat satellite images from the TCI (1986 and 2001) using band algebra in ENVI 4.3. I selected the difference between the band 3 reflectance in 1986 and 2001, because these wavelengths are absorbed by vegetation and are also typically associated with soil boundaries (Jensen 2000). In addition, high values of band 3 in both images visually correspond with paved roads and sand lots. The results of the band algebra analysis showed an increase in the mean (average change 150.92, standard deviation 115.76), which would generally suggest less vegetation area, since photosynthesizing vegetation absorbs more red light (Xu et al. 2003). However, this analysis is compromised by numerous shallow bodies of water, which also vary in their ability to absorb red light from band 3 (Palandro et al. 2004, Cho 2007). The brightness values of new roads in this change image ranged from 184-233, but these same values occurred at the edges of clouds and along the ocean where differences in the tide levels when the two images were taken probably accounts for the change in band 3 reflectance.

The image showing the difference between band 3 in 1986 and 2001 still visually highlighted areas where native forest had been replaced by paved and sand roads (Figure 3-1). To assess the change in area between old (pre-1986) and new (post-1986) development, I used the original dark body corrected band 3 images from 1986 and 2001, created polygons in ArcGIS 9.1 around developed areas, and extracted the area of each polygon using the Hawth's Spatial Ecology tools add-on to ArcGIS 9.1. I then divided the 2001 area by the 1986 area to calculate the rates of suburban growth on Middle Caicos during this 15 year period. For comparison, I repeated the same steps for Providenciales, a nearby biophysically similar island that has experienced a much higher rate of suburbanization since the mid-1980s than Middle Caicos. I then used these two rates of growth to project the future area on Middle Caicos that would contain suburban land cover, assuming that the island's residential growth policies followed either the *status quo* (Middle Caicos rate) or the precedent set by Providenciales (Providenciales rate).

Test for spatial autocorrelation

Primary data, such as species presence, may be the best way to predict where the species will occur because the distribution of many species is spatially autocorrelated, either because of autocorrelation in biophysical factors that determine habitat or because of the social structure of the species (Scott et al. 2002). To test the assumption of autocorrelation on the distribution of the Bahama Mockingbird on Middle Caicos, I randomly selected 10 training subsets (101 points each) in ArcGIS 9.1 to create a universal kriging surface based on spatial autocorrelation using the geospatial analyst extension, which I then validated with the remaining 51 test points. I calculated the area under the curve of receiver operating characteristic (ROC), which assesses whether there is a difference between the predicted and observed occurrence of Bahama Mockingbirds (Leathwick et al. 2005). I selected this goodness-of-fit test because of its ability to examine continuous predictor values against binomial observed values (Elith et al. 2006, Tuszynski 2006). ROC output varies between 0.5 and 1, with numbers closer to 1 indicating that the rate of correctly predicted positive results increases more rapidly than the rate of false positives.

Bahama Mockingbird territory size mapping

I calculated the territory size of the Bahama Mockingbird compared to the density of four pairs on a 10 ha plot observed by Aldrige (1984) in Providenciales. To do so, I used territory plot mapping, which identifies territories through clusters of unmarked birds observed on different days (Bibby 2000). On Middle Caicos, I walked transects in two areas, west of Lorimers settlement and south of Conch Bar settlement on five different days each, recording the position of every Bahama Mockingbird seen or heard. I assumed that each detection on a given day represented a different male singing on territory and I traced territories around clusters of observations from different days (Figure 3-2, Christman 1984, Bibby 2000). In ArcGIS 9.1, I extracted the areas of each of the 7 territories using Hawth's Spatial Ecology tools.

Population viability analysis

For an initial assessment of the potential sustainability of the Bahama Mockingbird populations that would remain on Middle Caicos under the two rates of suburbanization, I conducted a population viability analysis (PVA) in Vortex 9.71 (Miller and Lacy 2007). A PVA applies an iterative modeling process using parameters such as population size, sex ratio, fecundity, mortality, and expected changes in carrying capacity to evaluate the probability of a particular population going extinct. In this case, I assessed the probably of Bahama Mockingbird extirpation from Middle Caicos under alternative land-cover change policy options, suburban expansion continuing at the Middle Caicos rate or increasing to the Providenciales rate. Although a PVA typically requires exhaustive demographic field data that are not available for the Bahama

Mockingbird, a more general application of a PVA can to evaluate the effects of alternative management scenarios, giving results that are often extremely accurate (Brook et al. 2000, Ellner et al. 2002).

In Vortex 9.71, I compared the likelihood of Bahama Mockingbird persistence under Middle Caicos and Providenciales rates of suburbanization using initial population sizes generated from my land-cover change and territory size analyses. Each simulation was run for 1000 iterations and used the same demographic parameters. Only the annual change in carrying capacity, derived from the aforementioned analyses, differed. Lacking evidence to the contrary, I assumed that certain PVA conventions were correct: breeding pairs are monogamous, there is a 1:1 sex ratio, stable age distribution, breeding by 100% of adults, default value of 3.14 inbreeding effect, and no density dependent effects (Lindenmayer et al. 2000, Miller and Lacy 2007, Castellon and Sieving *in press*). I used the breeding ages of 2-9 years and adult survival rates (average for both sexes = 0.81, SD 0.16) of the Floreana Mockingbird *Nesomimus trifasciatus* on the Galapagos Islands (Grant et al. 2000). Results did not change when individual values for adult survival rate by sex were used. Rates for nest success and fledgling survival (0.5, SD 0.11) were taken from field studies of the tropical Chalk-browed Mockingbird *Mimus saturninus* (Rabuffetti and Reboreda 2007).

Results

Test for Spatial Autocorrelation

Ten training subsets (101 points each) were transformed into a universal kriging surface using the ArcGIS 9.1 geospatial analyst extension and then validated with the remaining 51 test points. The results of the 10 iterations returned an average receiver operating characteristic (ROC) of 0.55 (standard error 0.01), which is only slightly better than random. This suggests that spatial autocorrelation does not significantly influence Bahama Mockingbird occurrence in this dataset.

Territory Size Mapping

The mean territory size calculated by the territory mapping method (Figure 3-2) was 5.87 ha (standard error 1.48). This a little more than twice the only other estimate of average territory size, which is 2.5 ha approximated for four breeding pairs in a 10 ha parcel on pre-development Providenciales (Aldridge 1984).

Land-cover Change Trajectory

During this 15 year period, urbanized land-cover increased by a factor of 1.45 on Middle Caicos (from 98.8 ha in 1986 to 144.70 ha in 2001) and by a factor of 3.45 during the same time period on Providenciales. Using Hawth's Spatial Ecology tools in ArcGIS 9.1, I extracted the area of the upland terrain (north of the Ramsar wetlands boundary and otherwise constrained by the ocean, irrespective of suburban land-cover) on Middle Caicos to be 3990 ha. Based on rates of growth that I calculated, if development on Middle Caicos remains at the 1986-2001 rate, then this island would have >50% of its upland area (ca. 2000 ha) suburbanized within the next 100 years. If residential development began to take place at the Providenciales rate, the upland area of Middle Caicos would be >50% suburbanized in less than 25 years.

A semivariogram of the land-cover change in Middle Caicos demonstrated that urbanization was anisotropic, radiating from existing infrastructure rather than being evenly spaced throughout the island, which concurs with a bid-rent theoretical approach (Lamdin et al. 2001, Walker 2001, Geist and Lambin 2002). Using the buffer tool in ArcGIS 9.1, I grew areas from existing towns that corresponded to the total area of suburbanization expected in Middle Caicos in the year 2031 if the 1986-2001 Middle Caicos rate of growth is maintained or if it is increased to the rate of suburbanization of Providenciales (Figure 3-3). After creating shapefiles of the new areas, I added an optional 273 m buffer since that is the threshold for Bahama Mockingbird persistence determined by the CART analysis (Chapter 2, this volume). To determine the non-suburban area on Middle Caicos under alternative land-cover change rates, I subtracted the total predicted suburban area from the total upland area on Middle Caicos. I then made the same calculations using the 273 m buffer around suburban areas that the CART suggested the Bahama Mockingbird may require for persistence on Middle Caicos.

Using the average territory size of 5.87 ha, I estimate that Middle Caicos had 663 potential Bahama Mockingbird territories in 1986. If development continues as it has for the last century, ca. 628 potential territories could still remain in the year 2031. When considering a 273 m buffer effect outside of towns, the number of potential territories decreases to 560. If, however, the rate of suburban land-cover increases as it has in Providenciales, the number of potential Bahama Mockingbird territories in the year 2031 would be ca. 386. Taking the 273 m buffer effect into account, the number of potential Bahama Mockingbird territories in 2031 at the Providenciales rate would decrease to 290.

Population Viability Analysis

For the Middle Caicos rate of suburbanization scenario, starting population size and carrying capacity are both 628 and the annual decrease in carrying capacity is -0.35%. After 100 years, the population has zero risk of island-wide extinction and, therefore, a mean time to extinction of 0 ($r = 0.118$, SD 0.017). This means that the Bahama Mockingbird would be unlikely to be extirpated within the next century if suburbanization continued to increase at the Middle Caicos rate. In contrast, under the Providenciales rate of suburbanization scenario, starting population and carrying capacity were 386, and the annual decrease in carrying capacity would be -2.78%. After 100 years, the population has a 100% risk of island-wide extinction and a mean time to extinction of 37 years (r = 0.110, SD 0.042). This means that the Bahama Mockingbird would likely be extirpated within the next century.

Discussion

Potential Extirpation of the Bahama Mockingbird

For the last century, land-cover has been very stable on Middle Caicos, which has the largest land area (approximately 287.58 km^2) of any TCI island, and the smallest human population of the inhabited islands (Buden 1987, Pienkowski 2006). This is expected to change radically as the TCI government has signed a contract to permit a >400 ha luxury resort and commercial complex on this island (MFHI 2006). This project makes it more likely that development in Middle Caicos will follow a pattern similar to that of Providenciales, which would drastically decrease non-suburban areas in the next 25 years. My research demonstrates that if this pattern of suburbanization is implemented, the Bahama Mockingbird may be extirpated from Middle Caicos in the next century.

The percentage of urbanization across a landscape affects species as varied as hawks and falcons, fishes, and herbaceous plants (Berry et al. 1998, Gergel et al. 2002, Lennartsson 2002, Schmidt and Bock 2005). The possibility of Bahama Mockingbird extirpation within the next century assumes that suburban areas will spread according to bid-rent theory, clustered around existing infrastructure. Because the TCI economy is based on “high-end” or expensive, all-inclusive resort package tourism, development may occur sporadically in remote areas by investors willing to pay the cost of installing infrastructure (MFHI 2006). This could spawn further residential land-use around the new infrastructure, decreasing and fragmenting the total available natural habitat, a process that is well known to affect indigenous bird communities (Turner 1996, Sodhi et al. 2004). Careful planning and management of residential growth are critical for the persistence of the Bahama Mockingbird and other species dependent on native dry forest habitat.

The PVA of the Bahama Mockingbird's persistence on Middle Caicos under two land-cover change alternatives is limited to data from the literature on other tropical mockingbirds. Its applicability would be improved with detailed demographic information on the Bahama Mockingbird, which, although not published, may be available from other research institutions (R. Curry, *personal communication*). On the other hand, the over-riding factor in this PVA was the percentage annual decrease in carrying capacity of the island's native forest cover. This suggests that although detailed demographic studies are important to many aspects of conservation biology, fine-tuning particular mortality of fecundity parameters with decades of research may not matter if habitat conversion continues at rapid rates.

Persistence of Other Endemic Species

In contrast to the Bahama Mockingbird, which did not occur within any town boundaries (Figure 3-3), the Greater Antillean Bullfinch is present in many areas that are already suburbanized (Figure 3-4). The bullfinch provides an example of an indigenous bird species that is unlikely to be extirpated even if land-cover policies encourage increased urbanization. Its distribution pattern appears to be more similar to that of the urban-affiliated Northern Mockingbird (see Chapter 2, this volume) than the native Bahama Mockingbird. This supports the argument that classification as an endemic species is not enough to make a species a good indicator of habitat loss. It is critical to demonstrate a strong affiliation with native habitat or ecological processes.

Congeneric Competition between Bahama and Northern Mockingbirds

In addition to its strong affiliation with native habitat that will be lost as suburbanization increases on Middle Caicos, congeneric competition with the recently colonizing Northern

Mockingbird, known to thrive in suburban areas throughout its range (Raffaele et al. 1998, Brewer 2001), is another possible cause for the Bahama Mockingbird's failure to persist in suburbanized areas (Brudenell-Bruce 1975). On Middle Caicos, I did not find these two species occurring at the same point, although with only eight sites where the Northern Mockingbird was present (Figure 3-4), this pattern is far from definitive. Previous studies have noted that the Bahama Mockingbird does not persist in disturbed habitat within its range. When Providenciales resembled Middle Caicos more closely than its present residential and commercial land-cover mosaic, Bahama Mockingbirds were found only in thicker, higher native vegetation and not in grassy open areas (Aldridge 1984). On Grand Bahama, Northern Mockingbirds thrive in suburban areas where Bahama Mockingbirds are not seen (Emlen 1977). The relatively high abundance of the Northern Mockingbird on the now much more suburban Providenciales (White 1998) may support the idea that this species is a passenger on anthropogenic ecosystem change rather than being an aggressive competitor that excludes the Bahama Mockingbird (MacDougall and Turkington 2005).

Synthesis

Policies governing land-use change are certainly among the most important ecological drivers of long-term environmental trends in the 21st century (Novacek and Cleland 2001, Foley et al. 2005). While the basic biology of a species and its interactions with physical, chemical, and other biological elements in its environment should continue to be explored, anthropogenic influences, from direct habitat loss to global climate change, are likely to cause large-scale alterations in the distribution and relative abundance of species that will override the finer points of population management. Trends in "exurban" development (suburban growth into traditionally rural areas) frequently appear to affect bird community hotspots, and require aggressive growth management to limit their impact (Gude et al. 2007). As this suburbanization increases, specialist bird species are disproportionately extirpated, leaving an avifauna that may be locally rich but regionally homogenous (DeVictor et al. 2007). As the human population continues to grow exponentially, it is increasingly important that urban planners incorporate the distribution of natural resources and native habitat into long-range management plans, both for conservation of indigenous species and the practical effects of maintaining local hydrological, geological, and atmospheric conditions (Tarsitano 2006).

Urban planning that incorporates environmental concerns frequently runs afoul of multiple stakeholder needs (Wattage and Mardle 2005). Resort development, in particular, typically conflicts with the conservation of coastal resources and function (Jennings 2004). In the TCI, pressure from resort developers has resulted in encroachment into protected areas, partially due to suboptimal collaboration among enforcement agencies (MFHI 2006). This study recognizes the importance of incorporating species conservation into policies governing suburban expansion. Specific ways in which conservation of Bahama Mockingbirds could influence the urban planning include,

- Decreasing habitat fragmentation by permitting new development only in areas connected to present townships,
- Encouraging the persistence of native forest species through xeric landscaping requirements and protecting indigenous plants, and
- Educating tourists and domestic and foreign investors of the value of these indigenous species and the economic advantages of natural resource conservation, which they represent.

The TCI government plan appears open to incorporating resort development that encompasses the natural, if rugged, beauty of the native tropical dry forest (MFHI 2006). The TCI has the highest cost per tourist (just under US$2,000/trip) of the insular Caribbean, and its popularity has increased in recent years due to a combination of decreased tourism in Asia-Pacific island resorts after the 2001 bombings in tourist areas, and the great increase in new development infrastructure (McElroy 2006). This places the TCI in the position of exceptional prosperity, whereby concern for the environment begins to compete with basic economic needs (MFHI 2006).

My results suggest that the Bahama Mockingbird will not persist in areas of Middle Caicos that become suburbanized. Potential mitigation efforts should be carefully monitored for their effectiveness. At present, the TCI has fewer than 10 full-time employees devoted to terrestrial conservation and monitoring. Another potential monitoring option would be to organize groups of volunteers from the TCI community college campuses, high school environmental clubs, and perennial tourists and second home owners to engage in regular monitoring activities. Such citizen science has been successful at defining local population trends and often is equally or more successful than professional science programs at integrating the results into local policy decisions (Danielsen et al. 2005). The Bahama Mockingbird would be an excellent candidate for volunteer monitoring programs because it is highly visible, easily identified, and calls throughout the day. As this research has shown, its presence may be a positive indicator of undisturbed native forest on Middle Caicos. Citizen science could confirm that this pattern is consistent across the major islands of the TCI.

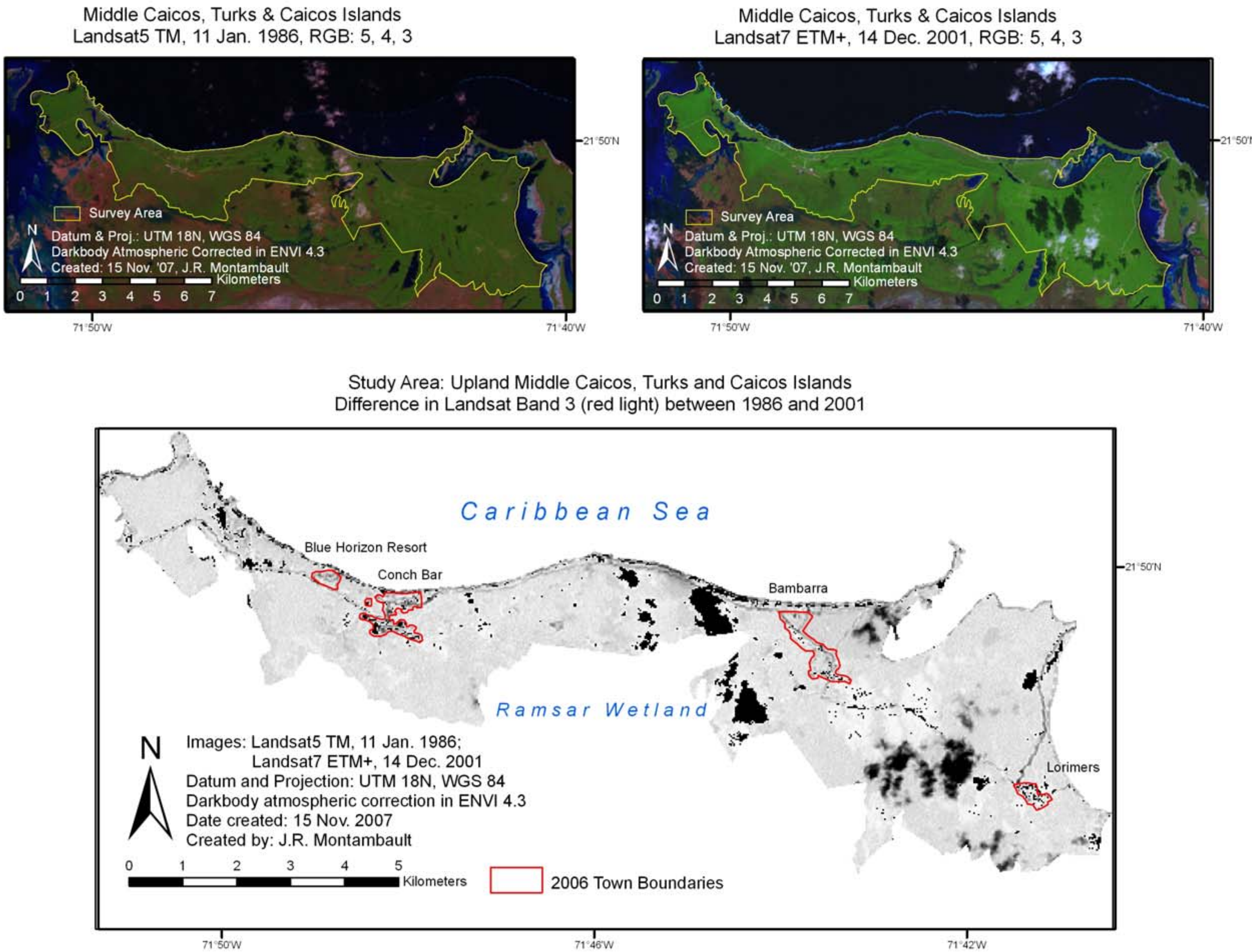

Figure 3-1. Satellite images of Middle Caicos from 1986 and 2001 and the difference in band 3 reflectance from the same years.

A

B

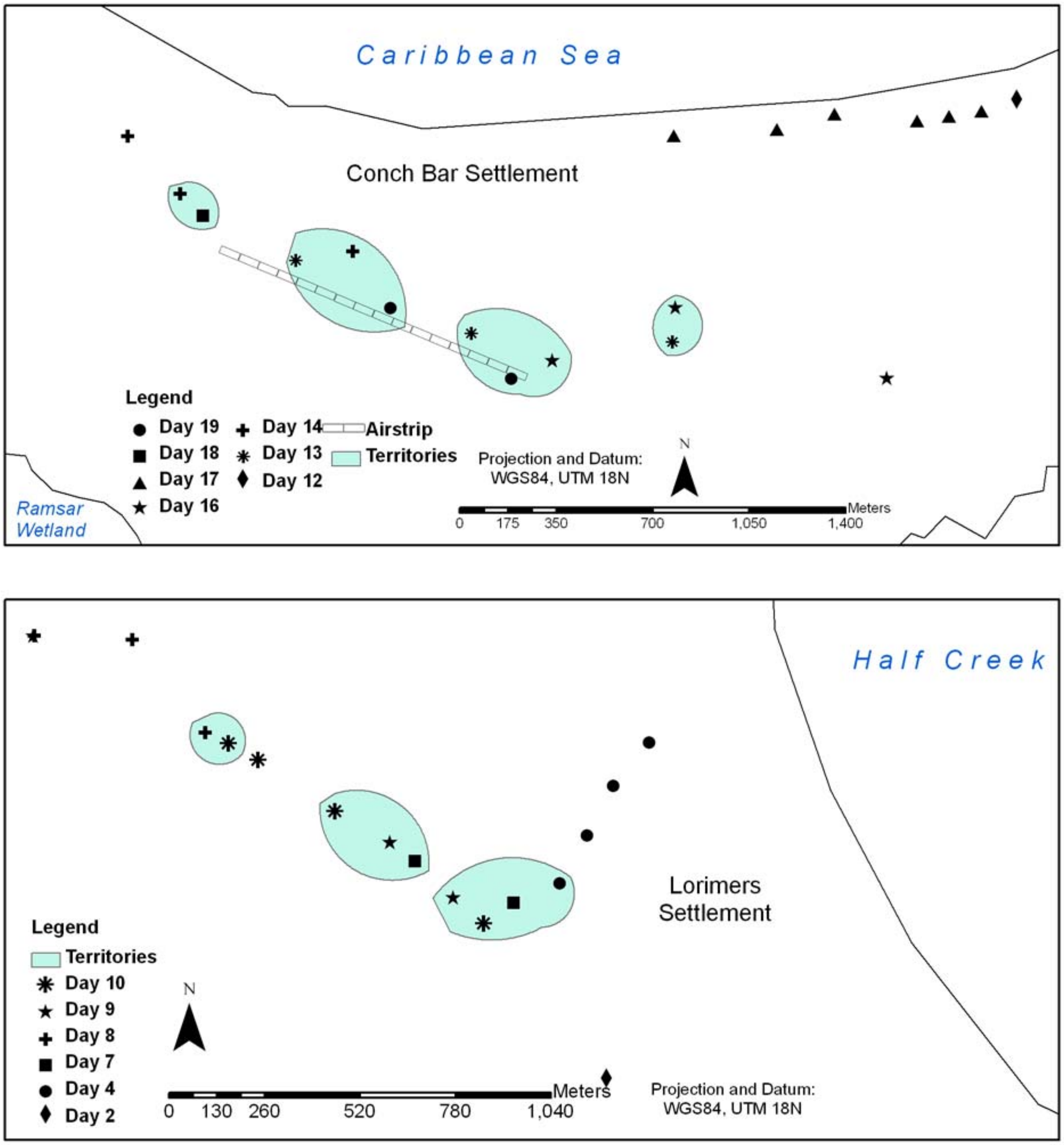

Figure 3-2. Mapping of Bahama Mockingbird territories near (A) Conch Bar and (B) Lorimers settlements on Middle Caicos. Each symbol represents the location of one or more Bahama Mockingbird on a given sampling day. Adjacent, identical symbols represent different birds.

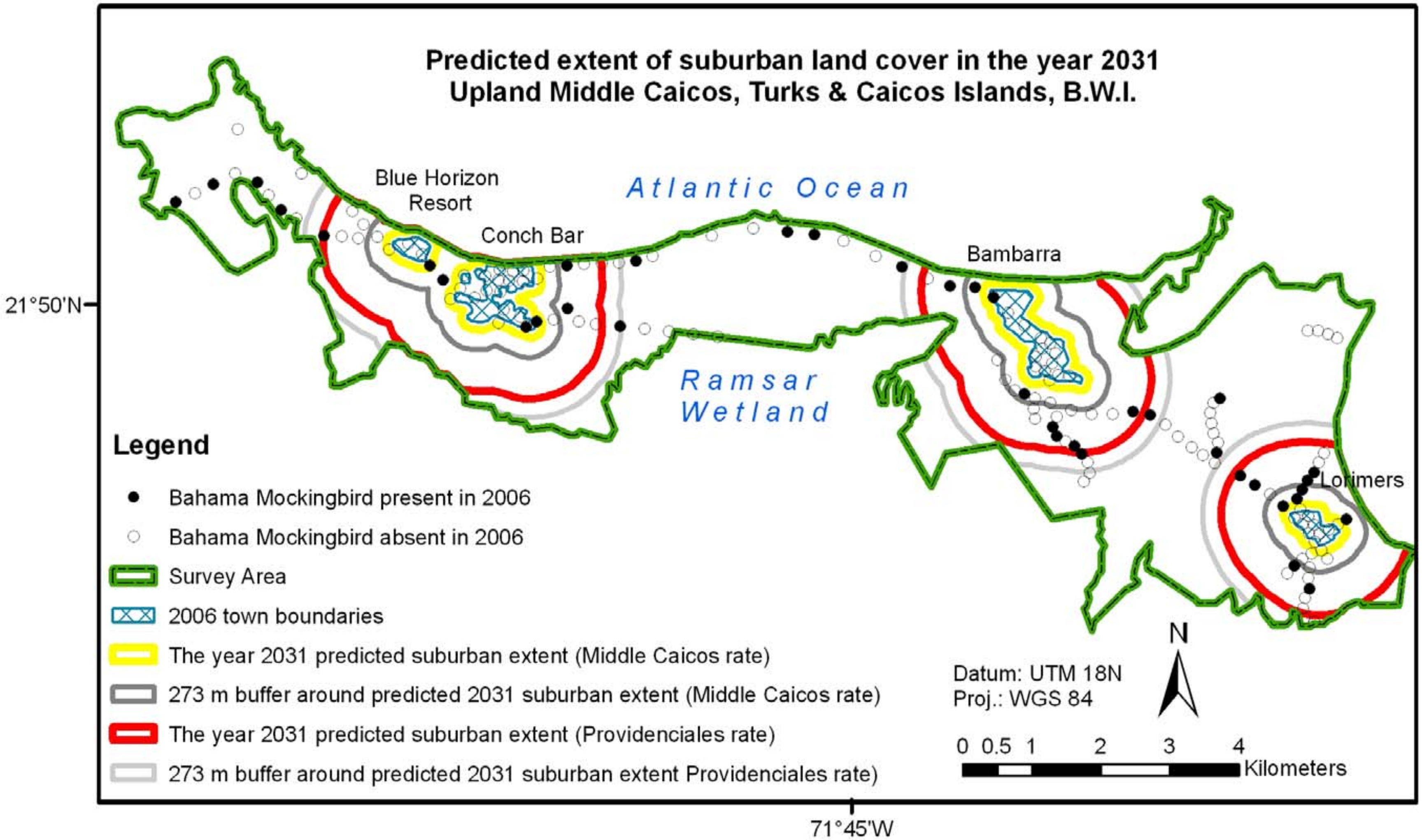

Figure 3-3. Predicted 2031 extent of suburban areas on Middle Caicos following the present growth rate on Middle Caicos and the growth rate from Providenciales. Sampling stations with presence and absence of Bahama Mockingbirds are highlighted.

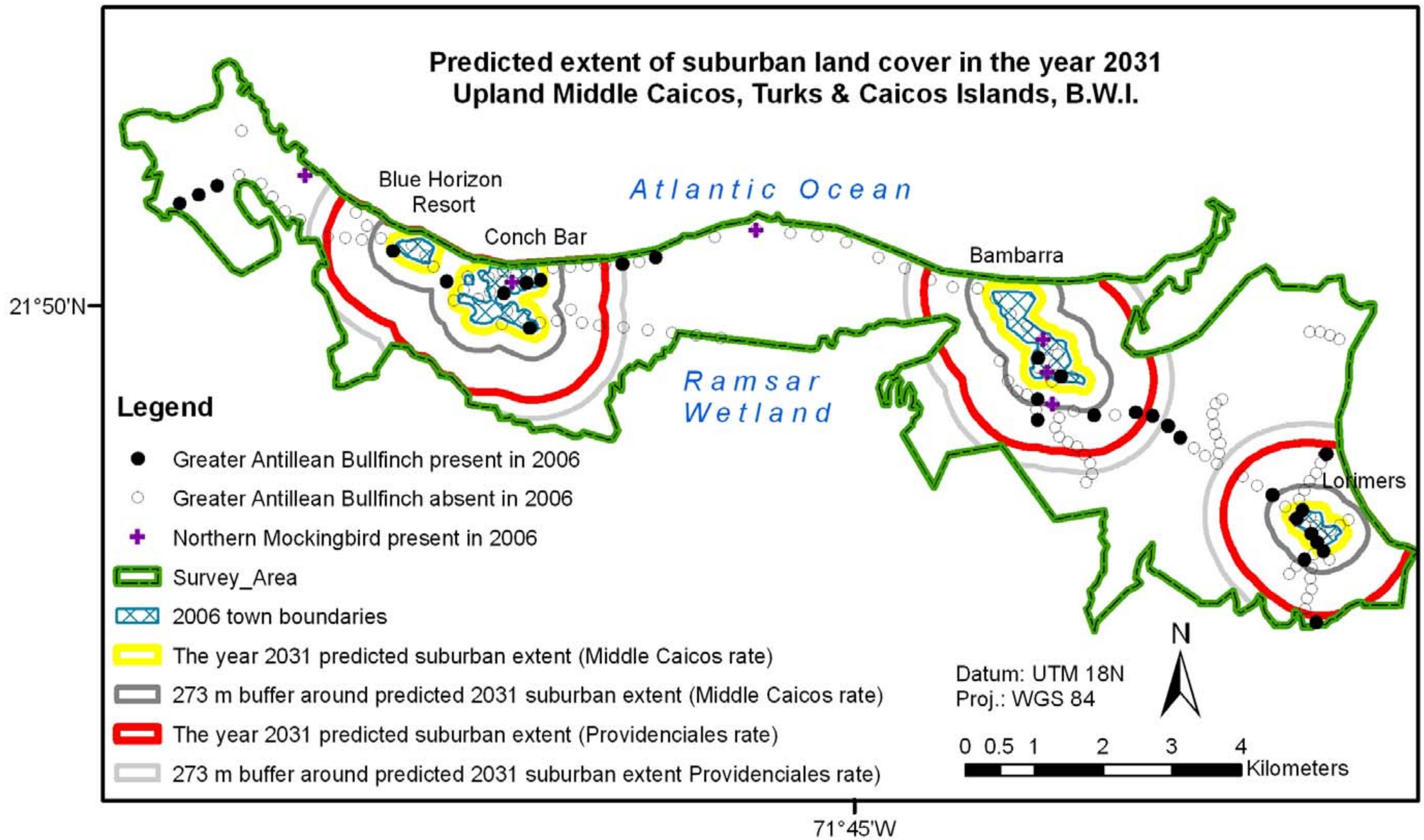

Figure 3-4. Predicted 2031 extent of suburban areas on Middle Caicos following Middle Caicos and Providenciales growth rates. Sampling stations with presence and absence of Greater Antillean Bullfinch and Northern Mockingbird are highlighted.

CHAPTER 4
CONCLUSIONS

My dissertation research examined of the status and conservation potential of the endemic bird community on Middle Caicos Island, Turks and Caicos Islands (TCI). The results of this investigation led me to conduct a more detailed analysis of the biological, environmental, and spatial characteristics that were strongly correlated with the occurrence of one species, the Bahama Mockingbird *Mimus gundlachii*. This further analysis included approximating trends in potential territories available to the Bahama Mockingbird on Middle Caicos in the future given expected changes in land-use, and a population viability analysis that assessed the sustainability of the Bahama Mockingbird population under different policy scenarios. In this concluding chapter, I review the justification and my research questions in the Research Overview section. I then summarize the results of my statistical analyses in the Findings section. The Conclusions and Conservation Implications section gives concise answers to the initial research questions and relates two major practical applications of my research to avian conservation issues on Middle Caicos. In the Suggestions for Future Research section, I outline specific opportunities for further study on the Bahama Mockingbird and other endemic birds on Middle Caicos.

Research Overview

Conservation projects worldwide must be prioritized because insufficient funding, human, and technical resources are dedicated to address the global problem of biodiversity loss (Brooks et al. 2006, Halpern et al. 2006). Endemic birds on oceanic islands are among the species given primary conservation concern because of their restricted ranges and vulnerability to extirpation by the high levels of anthropogenic habitat alteration on oceanic islands (Wilson and Tisdell 2007, Witt and Maliakal-Witt 2007). Conservation objectives may often be most efficiently achieved through monitoring a single species, but it is critical that this species be selected in the context of the avian community and its habitat (Fleishman et al. 2005, Lindenmayer et al. 2007). This is especially important for endemic birds on oceanic islands as their ecology tends to be poorly understood compared to that of widespread and continental species (Steadman 2006).

The goal of my research is to examine the endemic landbird community of Middle Caicos Island in the TCI to identify indicator species that would be appropriate for a long-term monitoring program of the native dry forest ecosystem. While this region has already been identified as a global conservation priority (Myers et al. 2000, BirdLife International 2004), there is little baseline ecological information for policy decision-making (Pienkowski 2002, Sanders 2006). The results of my research directly support stated policy goals of international, national, and local stakeholders who aim to conserve the natural terrestrial environment, upon which the continued development of the TCI's largest economic sector, high-end tourism, depends (UNDP 2005, MFHI 2006, CDB 2007).

To accomplish this objective, I collected data on bird and plant species and environmental characteristics at 152 sampling stations located on transects radiating away from centers of human settlements on Middle Caicos. I also used archival Landsat imagery and high quality aerial photos of this island to assess both present environmental characteristics and land-use change that has occurred since 1986. A two-step process was needed to select an indicator species from the bird community and assess its affiliation with native dry forest habitat and its efficacy for monitoring. First, I examined the shift in the Middle Caicos landbird community between sites located in town and in native dry forest habitat. I then used a categorical and regression tree (CART) analysis to examine which bird species are most sensitive to distance from town areas.

After the results of Chapter 2 identified the Bahama Mockingbird *Mimus gundlachii* as the endemic species most closely affiliated with native forest habitat and most likely to be affected by anthropogenic change, and, therefore the best indicator species, I examined the future of its population on Middle Caicos under alternative land-cover change options in Chapter 3. To do this, I used a land-cover change trajectory comparing TCI satellite images from 1986 and 2001 to calculate the rate of change on Middle Caicos and near-by Providenciales. I then used territory mapping to determine the average size of the Bahama Mockingbird's breeding territory on Middle Caicos. A population viability analysis then assessed the sustainability of the Bahama Mockingbird under low- and high-rates of land-cover change.

Findings

Of the 14 species present at 8 or more of the total 152 sampling points, the Gray Kingbird, Common Ground Dove, and Northern Mockingbird were significantly affiliated with suburban points and the Bahama Mockingbird, Thick-billed Vireo, and Bananaquit with native dry forest habitat. Of the five species with sufficient sample size to analyze using CART, the Bahama Mockingbird is the only species with its first split related to distance from town. The CART demonstrated that Bahama Mockingbirds tend to occur at a threshold of > 273 m from town.

During the 15 year period of 1986-2001, suburbanized land-cover increased by a factor of 1.45 on Middle Caicos and by a factor of 3.45 during the same time period on Providenciales. The mean territory size calculated by the territory mapping method was 5.87 ha. If development continues as it has for the last century, ca. 628 potential territories could still remain in the year 2031. If, however, the rate of suburban land-cover increases as it has in Providenciales, the number of potential Bahama Mockingbird territories in the year 2031 would be ca. 386. For the Middle Caicos rate of suburbanization scenario, the population has zero risk of island-wide extinction and, therefore, a mean time to extinction of 0. In contrast, under the Providenciales rate of suburbanization scenario, after 100 years, the population has a 100% risk of island-wide extinction and a mean time to extinction of 37 years.

Conclusions and Conservation Implications

The findings of my research demonstrate that two out of the three species strongly affiliated with native forest habitat are endemic (the Bahama Mockingbird and Thick-billed Vireo), while none of the three species associated with towns are endemic. This supports the concept that conserving native forest will also have a positive effect on the endemic bird community. It also suggests that endemic landbirds are better possible indicator species than non-endemics on Middle Caicos. The CART analysis confirmed that Bahama Mockingbirds exhibit a threshold effect, avoiding towns by over a quarter kilometer.

For the last century, land-cover has been very stable on Middle Caicos, which has the largest land area (approximately 287.58 km^2) of any TCI island, and the smallest human population of the inhabited islands (Buden 1987, Pienkowski 2006). This is expected to change radically as the TCI government has signed a contract to permit a >400 ha luxury resort and commercial complex on this island (MFHI 2006). This project makes it more likely that development in Middle Caicos will follow a pattern similar to that of Providenciales, and my research demonstrates that if this pattern of suburbanization is implemented, the Bahama Mockingbird may be extirpated from Middle Caicos in the next century. As an indicator species for the native dry forest, the Bahama Mockingbird’s extirpation suggest that the entire plant and animal community, as well as the ecosystem services associated with this habitat may also be at risk of disappearing during this time.

Another implication for conservation activities based on this study is that if management efforts increase populations of endemic bird species, this may also increase tourism based on birdwatching. Birdwatchers tend to be wealthier members of society who are also involved in environmental conservation activities (Sekercioglu 2002, USFWS 2002). This profile fits well with the high-end tourism sector that already thrives in the TCI. The willingness of such tourists to pay for goods and services increases as the likelihood of seeing a species of interest increases (Naidoo and Adamowicz 2005, Uyarra et al. 2005). Efforts to increase the population of endemic bird species on Middle Caicos may lead to continued augmentation of the tourism sector, and a corresponding increase in money spent locally on food, lodging, guide services, and souvenirs (Laiolo 2003). Such positive feedback into the economy would likely provide an incentive for the government to continue to promote endemic bird conservation. By focusing a sector of the tourism industry on these bird species, more care may be taken to ensure that any increase in activities related to tourism are not detrimental to the bird populations (Lailo et al. 2003, Bautista et al. 2004, Heil et al. 2007).

Suggestions for Future Research

My dissertation research on the conservation biology of the endemic bird community on Middle Caicos highlighted opportunities for further research. The results support implementing a monitoring program that uses the Bahama Mockingbird as an indicator species for native forest habitat. In addition, this study provides the groundwork for further investigation into the potential invasion of Middle Caicos by the Northern Mockingbird.

Monitoring programs are critical to implementing and evaluating conservation policy, and the long-term success of such programs depends on carefully chosen measurements that are cost-efficient for future replication (Lovett et al. 2007). Middle Caicos has specific logistical constraints for implementing a monitoring program, which include the presence of only a single half-time conservation officer, who would require at least basic equipment and training to carry out the monitoring, as well as few working vehicles and few decent trails that would serve the purposes of a volunteer monitoring group. One advantage of continuing point count censusing as a long-term monitoring program is that the results can be compared to the baseline data established in 2006. Point counts could be repeated either in exact locations of this study (Appendix A) or at set distances from different randomly selected points, recording the exact location with a GPS to determine distance from town and affiliation with different landscape properties (Levy and Lemeshow 1999). These long-term census data should be taken in tandem with basic information on precipitation and temperature, as well as the fruiting phenology of trees that are potential food resources for the Bahama Mockingbird (Chapman et al. 1994). These methods should be accessible to an organized group of trained volunteers with limited transportation, such as groups of students from the TCI Community College campuses on Grand Turk and Providenciales. Using volunteer groups to collect data would allow paid employees to focus on data analysis and strategic planning (Lovett et al. 2007). Trained volunteer groups could also confirm whether the Bahama Mockingbird patterns of occurrence I observed across Middle Caicos are consistent across other islands in the TCI.

The Bahama Mockingbird's disappearance from native habitat that will be lost as suburbanization increases on Middle Caicos may be excaserbated by congeneric competition with the recently colonizing Northern Mockingbird. The Northern Mockingbird is known to thrive in urban and suburban areas throughout its range (Raffaele et al. 1998, Brewer 2001, Hallett 2006). Competition with the Northern Mockingbird may be another possible cause for the Bahama Mockingbird's failure to persist in suburbanized areas (Brudenell-Bruce 1975). On the other hand, the Northern Mockingbird may simply be a passenger on anthropogenic ecosystem change (MacDougall and Turkington 2005). On Middle Caicos, I did not find these two species occurring at the same point, although with only eight sites where the Northern Mockingbird was present, this pattern is far from definitive. To test whether these two mimids failure to coexist is direct competition vs. habitat association, a quasi-experimental design could be set up to compare of the interaction of these two species across islands in the TCI that have different level of suburban land cover.

Synthesis

My research supports the concept that some species are intolerant of proximity to human settlement, even if patches of preferred habitat are available. On Middle Caicos, the Bahama Mockingbird is one such species. This mockingbird tends not inhabit areas near human settlements where other endemic birds, such as the Thick-billed Vireo and Greater Antillean Bullfinch are present. All three of these species are endemic and occur in the fossil record, suggesting that they are adapted to the native dry forest habitat and have survived initial human occupation of this island (Steadman 2007). The important difference in the present conservation potential of these species is how they may respond to rapid increases in suburbanization. My dissertation provides an example and some practical tools for identifying species and populations such as the Bahama Mockingbird on Middle Caicos that appear to be intolerant of land-use change, which may assist in averting further biodiversity loss across the globe.

APPENDIX
GEOREFERENCED POINTS SAMPLED

Point	UTM 18N Easting	Northing	Date and Time	Locale
1	842586	2413644	05-MAY-06 5:58:57AM	Lorimers, near Garnett Outten’s house
2	842675	2413522	05-MAY-06 6:24:59AM	Lorimers, toward Increase Plantation
3	842763	2413401	05-MAY-06 6:48:42AM	Lorimers, further toward Increase Plantation
4	842532	2413478	05-MAY-06 7:19:40AM	Lorimers, path to Big Well
5	842404	2413393	05-MAY-06 7:41:00AM	Lorimers, Big Well
6	842286	2413300	05-MAY-06 8:01:17AM	Lorimers, toward Charles Rigby Hole
7	842181	2413187	05-MAY-06 8:25:28AM	Lorimers, Charles Rigby Hole
8	842495	2413770	06-MAY-06 5:11:53AM	Lorimers, near dental clinic
9	842646	2413765	06-MAY-06 5:18:51AM	Lorimers, toward boat dock
10	842788	2413814	06-MAY-06 5:34:39AM	Lorimers, near old primary school
11	842914	2413893	06-MAY-06 5:50:48AM	Lorimers, further toward boat dock
12	843046	2413968	06-MAY-06 6:05:49AM	Lorimers, nearest boat dock
13	842403	2413891	06-MAY-06 6:40:24AM	Lorimers, near Alton Higgs’ house
14	842292	2413994	06-MAY-06 6:57:44AM	Lorimers, near Miss Mary’s house
15	842487	2414019	06-MAY-06 7:15:20AM	Lorimers, NW agriculture fields
16	842570	2413887	06-MAY-06 7:49:16AM	Lorimers, between fields and graveyard
17	842370	2414118	06-MAY-06 8:26:13AM	Lorimers, graveyard
18	842330	2414267	07-MAY-06 5:26:17AM	Road toward Haulover Plantation
19	842404	2414398	07-MAY-06 5:42:31AM	Road toward Haulover Plantation
20	842475	2414533	07-MAY-06 5:57:11AM	Road toward Haulover Plantation
21	842573	2414651	07-MAY-06 6:16:54AM	Road toward Haulover Plantation, old field road
22	842640	2414787	07-MAY-06 6:32:41AM	Road toward Haulover Plantation
23	842713	2414921	07-MAY-06 6:47:22AM	Road toward Haulover Plantation
24	842912	2416590	07-MAY-06 7:24:17AM	Haulover Plantation, entrance
25	842772	2416646	07-MAY-06 7:39:07AM	Haulover Plantation, trail
26	842629	2416690	07-MAY-06 7:50:39AM	Haulover Plantation, further on trail
27	842477	2416694	07-MAY-06 8:03:44AM	Haulover Plantation, great house ruins
28	838523	2415720	08-MAY-06 6:41:05AM	Bambarra, entrance to active agriculture trail off old King’s Highway before cell towers.
29	838507	2415569	08-MAY-06 7:00:06AM	Bambarra, further along agriculture trail
30	838527	2415417	08-MAY-06 7:20:20AM	Bambarra, further along agriculture trail
31	838378	2415779	08-MAY-06 9:01:53AM	Bambarra, toward cell towers
32	838231	2415831	08-MAY-06 9:12:43AM	Bambarra, at cell towers
33	838096	2415983	08-MAY-06 9:25:08AM	Bambarra, west past cell towers
34	837987	2416266	08-MAY-06 9:37:28AM	Bambarra, further west past cell towers
35	838672	2416108	09-MAY-06 6:59:34AM	Bambarra, church/ community center
36	838738	2415974	09-MAY-06 7:10:05AM	Bambarra, south down the hill out of town
37	838865	2416053	09-MAY-06 7:25:06AM	Bambarra, near Carlyn Forbes house
38	839026	2416039	09-MAY-06 7:45:00AM	Bambarra, near Miss Gertie’s house

Point	UTM 18N Easting	Northing	Date and Time	Locale
39	838536	2416172	09-MAY-06 8:07:28AM	Bambarra, near expanding construction
40	838536	2416321	09-MAY-06 8:25:11AM	Bambarra, old well
41	838635	2416437	09-MAY-06 8:43:35AM	Bambarra, agriculture fields
42	838616	2416588	09-MAY-06 8:57:42AM	Bambarra, gas station and restaurant
43	838744	2416507	09-MAY-06 9:10:12AM	Bambarra, returning toward center of town
44	838818	2416371	09-MAY-06 9:25:23AM	Bambarra, south returning toward church
45	838778	2416225	09-MAY-06 9:39:09AM	Bambarra, near Eco-Centre (old school)
46	841136	2414784	12-MAY-06 6:27:50AM	Garden Pond Trail, entrance near quarry
47	841164	2414932	12-MAY-06 6:44:22AM	Garden Pond Trail, toward Garden Pond
48	841184	2415080	12-MAY-06 7:00:20AM	Garden Pond Trail, dry pond bed
49	841110	2415206	12-MAY-06 7:29:23AM	Garden Pond Trail, at Garden Pond
50	841087	2415356	12-MAY-06 7:34:18AM	Garden Pond Trail, toward Nanny Pond
51	841070	2415505	12-MAY-06 7:54:41AM	Garden Pond Trail, toward Nanny Pond
52	841110	2415652	12-MAY-06 8:13:02AM	Garden Pond Trail, toward Nanny Pond
53	841206	2415716	12-MAY-06 8:29:30AM	Garden Pond Trail, Nanny Pond
54	840960	2414892	12-MAY-06 9:10:16AM	Garden Pond Trail, west on road toward Bambarra
55	840794	2415009	12-MAY-06 9:24:03AM	Garden Pond Trail, further west on road toward Bambarra
56	838845	2415450	13-MAY-06 6:48:05AM	Armstrong Pond Trail, entrance
57	838788	2415310	13-MAY-06 7:04:52AM	Armstrong Pond Trail, south on trail along field wall
58	838837	2415169	13-MAY-06 7:23:20AM	Armstrong Pond Trail, on crest of hill
59	838970	2415098	13-MAY-06 7:40:45AM	Armstrong Pond Trail, south on trail
60	839103	2415027	13-MAY-06 7:58:07AM	Armstrong Pond Trail, south on trail
61	839207	2414914	13-MAY-06 8:15:09AM	Armstrong Pond Trail, south on trail
62	839290	2414788	13-MAY-06 8:36:41AM	Armstrong Pond Trail, south on trail
63	839320	2414641	13-MAY-06 8:54:59AM	Armstrong Pond Trail, south on trail
64	839231	2414514	13-MAY-06 9:12:13AM	Armstrong Pond Trail, pond in view
65	842122	2414158	14-MAY-06 6:14:37AM	Lorimers-Bambarra Road, entrance to Lorimers settlement
66	841931	2414333	14-MAY-06 6:30:34AM	Lorimers-Bambarra Road, west toward Bambarra
67	841717	2414465	14-MAY-06 6:46:20AM	Lorimers-Bambarra Road, further west toward Bambarra
68	841507	2414605	14-MAY-06 7:02:40AM	Lorimers-Bambarra Road, further west toward Bambarra
69	840600	2415168	14-MAY-06 7:22:27AM	Lorimers-Bambarra Road, skips quarry and following two points, continues west toward Bambarra
70	840414	2415336	14-MAY-06 7:38:50AM	Lorimers-Bambarra Road, further west toward Bambarra
71	840199	2415475	14-MAY-06 8:00:15AM	Lorimers-Bambarra Road, further west toward Bambarra

	UTM 18N			
Point	Easting	Northing	Date and Time	Locale
72	839951	2415527	14-MAY-06 8:22:51AM	Lorimers-Bambarra Road, further west toward Bambarra
73	839652	2415487	14-MAY-06 8:38:36AM	Lorimers-Bambarra Road, further west toward Bambarra
74	839350	2415487	14-MAY-06 8:54:47AM	Lorimers-Bambarra Road, further west toward Bambarra
75	839056	2415546	14-MAY-06 9:11:26AM	Lorimers-Bambarra Road, further west toward Bambarra
76	838749	2415646	14-MAY-06 9:30:01AM	Lorimers-Bambarra Road, entrance to Armstrong Pond Trail
77	842504	2413269	15-MAY-06 6:47:30AM	Big Pond Trail, past Big Well
78	842491	2413116	15-MAY-06 7:03:01AM	Big Pond Trail, heading up hill
79	842507	2412965	15-MAY-06 7:19:06AM	Big Pond Trail, continuing uphill
80	842437	2412833	15-MAY-06 7:35:21AM	Big Pond Trail, approaching "peak" overlooking Haulover crossing
81	842413	2412685	15-MAY-06 7:53:13AM	Big Pond Trail, on old field road at peak
82	842433	2412534	15-MAY-06 8:11:16AM	Big Pond Trail, descending field road
83	842578	2412492	15-MAY-06 8:44:01AM	Big Pond Trail, overlooking Lomshor Pond
84	838372	2416766	16-MAY-06 6:56:08AM	Crossing Place Trail I, shores of Salt Pond
85	838130	2416952	16-MAY-06 7:10:50AM	Crossing Place Trail I, west leaving Bambarra, near dry pond
86	837921	2417174	16-MAY-06 7:25:14AM	Crossing Place Trail I, approaching beach road
87	837656	2417316	16-MAY-06 7:40:11AM	Crossing Place Trail I, entrance to new development
88	837300	2417339	16-MAY-06 7:57:25AM	Crossing Place Trail I, entrance to Dreamscape Villa
89	836966	2417448	16-MAY-06 8:14:57AM	Crossing Place Trail I, west toward Conch Bar
90	836602	2417618	16-MAY-06 8:31:16AM	Crossing Place Trail I, west toward Conch Bar
91	836219	2417767	16-MAY-06 8:49:41AM	Crossing Place Trail I, west toward Conch Bar
92	835753	2417988	16-MAY-06 9:07:09AM	Crossing Place Trail I, west toward Conch Bar
93	835326	2418086	16-MAY-06 9:24:54AM	Crossing Place Trail I, near fork for old beach road, property for sale by Prestigious Properties
94	830744	2417422	18-MAY-06 6:19:23AM	Conch Bar, 200m west of primary school
95	830553	2417485	18-MAY-06 6:32:43AM	Conch Bar, near Stacia Arthur's house
96	830574	2417277	18-MAY-06 6:46:18AM	Conch Bar, near policeman's house
97	830776	2417250	18-MAY-06 6:59:43AM	Conch Bar, cleared lot north of airport
98	830402	2417173	18-MAY-06 7:22:28AM	Conch Bar, west of town near trail to

	UTM 18N			
Point	Easting	Northing	Date and Time	Locale
				airstrip
99	830192	2417297	18-MAY-06 7:37:45AM	Conch Bar, approaching quarry road entrance
100	830249	2417489	18-MAY-06 7:52:29AM	Conch Bar, quarry
101	829948	2417424	18-MAY-06 8:10:56AM	Crossing Place Trail II, west toward Indian Cave
102	829758	2417634	18-MAY-06 8:27:55AM	Crossing Place Trail II, Indian Cave
103	829636	2417793	18-MAY-06 8:47:40AM	Crossing Place Trail II, west toward Blue Horizon Resort
104	829442	2417950	18-MAY-06 9:05:25AM	Crossing Place Trail II, west toward Blue Horizon Resort
105	829162	2417866	18-MAY-06 9:21:47AM	Crossing Place Trail II, entrance to Blue Horizon Resort
106	828989	2418048	19-MAY-06 6:30:12AM	Crossing Place Trail II, entrance to wetland
107	828786	2418232	19-MAY-06 6:45:14AM	Crossing Place Trail II, past wetland up dune toward beach
108	826968	2419602	19-MAY-06 7:42:28AM	Crossing Place Trail II, 250m from beach where trail diverges to blow hole
109	827890	2418959	19-MAY-06 8:30:44AM	Crossing Place Trail II, overlooking estuarine lakes
110	828632	2418423	19-MAY-06 9:04:33AM	Crossing Place Trail II, returning on beach trail
111	830827	2416999	20-MAY-06 6:06:19AM	Airport
112	831058	2416891	20-MAY-06 6:23:49AM	Old King's Highway, east from airport toward Pineyards
113	831301	2416821	20-MAY-06 6:38:54AM	Old King's Highway, Pineyards begin
114	831550	2416855	20-MAY-06 6:54:44AM	Old King's Highway, east toward National Park
115	831747	2417013	20-MAY-06 7:11:09AM	Old King's Highway, Conch Bar National Park entrance
116	831911	2416822	20-MAY-06 7:32:06AM	Old King's Highway, east toward cell towers
117	832160	2416785	20-MAY-06 7:46:42AM	Old King's Highway, east toward cell towers
118	832516	2416757	20-MAY-06 8:02:56AM	Old King's Highway, east toward cell towers
119	832865	2416720	20-MAY-06 8:21:53AM	Old King's Highway, east toward cell towers
120	833217	2416681	20-MAY-06 8:38:58AM	Old King's Highway, east toward cell towers
121	833572	2416639	20-MAY-06 8:54:33AM	Old King's Highway, east toward cell towers, borders on Ramsar site
122	833922	2416601	20-MAY-06 9:10:15AM	Old King's Highway, east toward cell towers, borders on Ramsar site

Point	UTM 18N Easting	Northing	Date and Time	Locale
123	831310	2417441	21-MAY-06 6:09:01AM	Crossing Place Trail I, near Village Pond
124	831491	2417615	21-MAY-06 6:26:55AM	Crossing Place Trail I, exit Conch Bar
125	831741	2417636	21-MAY-06 6:42:17AM	Crossing Place Trail I, near town dump
126	831990	2417655	21-MAY-06 7:02:27AM	Crossing Place Trail I, east toward Bambarra
127	832242	2417664	21-MAY-06 7:17:16AM	Crossing Place Trail I, east toward Bambarra
128	832493	2417672	21-MAY-06 7:34:45AM	Crossing Place Trail I, east toward Bambarra
129	832742	2417706	21-MAY-06 7:51:54AM	Crossing Place Trail I, east toward Bambarra
130	832985	2417767	21-MAY-06 8:10:52AM	Crossing Place Trail I, east toward Bambarra
131	834937	2418125	21-MAY-06 8:38:29AM	Crossing Place Trail I, just west of point 93
132	834437	2418171	21-MAY-06 8:58:46AM	Crossing Place Trail I, return west toward Conch Bar
133	833842	2418062	21-MAY-06 9:27:10AM	Crossing Place Trail I, return west toward Conch Bar
134	828717	2418030	22-MAY-06 6:22:32AM	Road to ferry dock, south of wetland from point 106/107
135	828474	2418054	22-MAY-06 6:37:35AM	Road to ferry dock, on overlook of estuary
136	828222	2418067	22-MAY-06 6:51:41AM	Road to ferry dock, east end of causeway
137	827812	2418309	22-MAY-06 7:12:13AM	Road to ferry dock, west end of causeway
138	827595	2418442	22-MAY-06 7:25:44AM	Road to ferry dock, west toward dock
139	827418	2418647	22-MAY-06 7:41:11AM	Road to ferry dock, west toward dock
140	827256	2418838	22-MAY-06 7:55:55AM	Road to ferry dock, west toward dock
141	826931	2418965	22-MAY-06 8:11:28AM	Road to ferry dock, near entrance to new National Trust trail
142	826614	2418813	22-MAY-06 8:28:46AM	Road to ferry dock, west toward dock
143	826343	2418680	22-MAY-06 8:44:31AM	Road to ferry dock, west toward dock
144	826068	2418554	22-MAY-06 8:59:47AM	Road to ferry dock, near ferry dock
145	830899	2417415	23-MAY-06 6:17:07AM	Conch Bar, primary school
146	831100	2417409	23-MAY-06 6:32:11AM	Conch Bar, near Village Pond
147	831105	2417563	23-MAY-06 6:45:11AM	Conch Bar, approaching Conch Bar exit
148	830960	2417552	23-MAY-06 7:00:26AM	Conch Bar, north of District Commissioner’s office
149	830762	2417572	23-MAY-06 7:17:13AM	Conch Bar, beach access trail from east Conch Bar
150	831152	2416752	23-MAY-06 7:56:32AM	Conch Bar, east end of airstrip
151	830747	2416810	23-MAY-06 8:26:00AM	Conch Bar, agriculture plot south of airstrip
152	830050	2417149	23-MAY-06 9:04:41AM	Conch Bar, west end of airstrip

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BIOGRAPHICAL SKETCH

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