URBAN LAKES AND WATERBIRDS: EFFECTS OF DEVELOPMENT ON DISTRIBUTION AND BEHAVIOR

By

ASHLEY H. TRAUT

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To Kate,
for your immeasurable patience, support, and love.
You inspire me beyond words.

And to the birds,
who fill my dreams with hope.

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By

Ashley H. Traut

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Chair: Mark E. Hostetler
Department: Wildlife Ecology and Conservation

I studied waterbird distribution and behavior in the breeding and non-breeding seasons on four partially developed urban lakes in central Florida. I examined waterbird distributional and behavioral associations with developed and undeveloped shorelines, as well as distributional associations with specific elements of the littoral and onshore habitat in the urban environment. By understanding how waterbirds respond to development, and by identifying habitat elements that influence their movements and behaviors, we can provide more ecologically sound development and management practices for urban aquatic environments.

A total of 38 waterbird species were observed on the four lakes over both seasons. Wading bird, marsh bird, and duck abundance was significantly greater along developed shoreline in both seasons on all lakes. Diving bird abundance was significantly greater along developed shoreline in the winter. Species richness was not associated with shoreline development. Species evenness was greater along undeveloped shoreline in the summer and developed shoreline in the winter.

Tall emergent vegetation, open shore, lawn, and canopy appeared to be the primary habitat elements determining waterbird presence. All waterbirds were negatively associated with tall emergent vegetation on two or more lakes over both seasons, whereas wading birds, marsh birds, and ducks were positively associated with open shore in the summer, and wading birds, marsh birds, and diving birds were positively associated with lawn and canopy in the winter.

Summer behavioral observations revealed that wading birds foraged significantly more along developed shoreline, and that ducks rested and tended young significantly more along developed shoreline. Winter observations revealed that marsh birds foraged significantly more along undeveloped shoreline and displayed active/swimming behavior significantly more along developed shoreline.

Summer ducks and winter wading birds showed significantly greater alert/flee behavior along undeveloped shoreline. Ducks showed significantly greater alert/flee behavior than other guilds. Overall, alert/flee behavior was seen 1.6 times more often in the winter. Winter migrants did not show greater alert/flee behavior than resident birds.

Results show that a wide range of waterbirds can use urban lakes during the breeding and non-breeding seasons. Further, developed shoreline appears to be favored by many species for a variety of behaviors. However, dense stands of tall emergent vegetation along undeveloped shoreline may deter birds from using this shoreline. Greater alert/flee behavior along undeveloped shorelines may warrant the use of buffer zones to protect birds using these shorelines from undue human disturbance.

CHAPTER 1
INTRODUCTION

Background

Urbanization and Avian Ecology

Between 1900 and 1987 the proportion of the world's human population living in cities rose from 14 to 50 percent (United Nations 1987). By 2050 the world's urban population is predicted to equal 6.5 billion, equivalent to today's entire global population (United Nations 1996). Though the majority of urbanization will occur in developing countries, seventy-eight percent of United States residents already reside in urban environments (Adams 1994). Strohm (1974) estimated that this process of urbanization meant the paving, building over, or drowning of over 400,000 hectares of natural habitat a year. Today, urbanization is the second most frequently cited cause of species endangerment in the United States (Czech & Krausman 1997). With this understanding comes the need for a comprehensive understanding of the ecology of urban systems and how best to manage them both for the needs of humans and for wildlife. To date, however, there is a relative scarcity of such knowledge, with many questions still unanswered about the effects of urbanization on everything from ecosystems to individual species (Cairns 1988, Niemela 1999). As a result, most urban planning and management remains focused on the impacts of urbanization on human society rather than on the issues of biodiversity (Marzluff et al. 2001).

Urban ecosystems as a whole can be viewed as highly fragmented, heterogeneous landscapes dominated by buildings, roads, and pavement, and often lacking in substantial vegetation cover (Jokimaki 1999). The remaining vegetation composition is often greatly altered, consisting of a few favored natives and numerous exotic species (DeGraaf 1986). Further, the fragments of natural vegetation that are left relatively intact may be too small or isolated to support a healthy wildlife community (Savard et al. 2000). Urban habitats are also characterized by high levels of human-associated disturbance, such as traffic, construction, and recreation (Jokimaki 1999). These changes in structure and function can lead to a greatly modified wildlife assemblage consisting of habitat generalists, human-commensal species, and exotic species. Wildlife diversity in urban environments ultimately depends on how humans design and manage urban habitats.

Many urban wildlife studies to date have focused on avian responses to development. Birds are often selected for study due to their diurnal activity patterns and relative ease of identification both by song and sight (DeGraaf & Wentworth 1981). They are also regarded as excellent indicators of stresses in an environment due to their sensitivity to change in habitat structure and composition (Savard & Falls 1982, Clergeau et al. 1998). The presence or absence of various avian species within urban areas is often associated with changes in habitat structure.

Results from several studies have shown that with increased urbanization there is a shift in avian species composition, often accompanied with a decrease in bird species richness and diversity, and an increase in total bird density as a few human-commensal, often non-native species, such as the House Sparrow (*Passer domesticus*) and European Starling (*Sturnus vulgaris*) become very common (see Blair 1996 and Savard et al. 2000 for reviews). Decreased habitat availability, vegetative complexity, and food supply, and increased habitat fragmentation, competition, and human disturbance are examples of some of the mechanisms that have been identified as contributing to decreases in richness and evenness in urban bird communities (Marzluff 2001). Conversely, factors such as supplemental feeding, reduced predation, and reduced human persecution have benefited certain species in urban environments (Marzluff 2001). Species composition and richness have also varied in relation to the city and the locality within a city in which studies were conducted, with some areas showing considerable diversity, depending on local environmental conditions (Tilghman 1987, Blair 1996, Hostetler 1999, Hostetler & Holling 2000). The design and management of an area can have an appreciable effect on the distribution of birds across an urban environment.

Urban Lakes

The vast majority of urban bird studies have focused on passerine bird species in terrestrial habitats. Studies examining waterbirds have generally focused on marsh systems in non-urban environments, with relatively little attention being devoted to lacustrine habitats (but see Parris & Grau 1978, Whitfield & Cyrus 1978, Johnson & Montalbano 1984, Zaffke 1984, Pyrovetsi & Crivelli 1988, Edelson 1990, Hoyer & Canfield 1990, 1994). Virtually no studies have been conducted in the United States that have directly quantified waterbird responses to lakefront urbanization.

Urbanized lakes often undergo similar patterns of habitat alteration as terrestrial habitats. Habitat complexity is often greatly reduced as both onshore and littoral vegetation are reduced, replaced, or removed. The clearing of these habitats by property owners is a common practice in order to improve lake views and recreational pursuits such as swimming, boating, and fishing (Guillory et al. 1979, Frayer & Hefner 1991, Bryan & Scarnecchia 1992). Such modifications are usually made without considering the potential effects on local wildlife.

With the continued loss of wetland habitat throughout the United States (Mitsch & Gosselink 1993), the importance of lacustrine habitat to waterbirds may be increasing. Florida, home to some of the largest waterbird populations in the United States, has lost almost 50% of its wetlands over the past 200 years (Dahl 1990). Much of this loss can be attributed to urbanization, as seen in the fact that more than 84% of the state's 16 million residents currently live in urban areas (Morris & Morris 1995). With an estimated 7,783 lakes providing potential waterbird habitat, and at the same time facing significant development pressures, Florida offers optimal conditions for studying the effects of urbanization on waterbirds and developing better management policies for urban lakes.

In this project, I explored how waterbirds responded to shoreline habitat changes caused by human encroachment on urban lakes. In it, I examined both indirect and direct responses in waterbirds during the breeding and non-breeding seasons. In Chapter 2, I examine indirect responses measured by the presence or absence of birds along developed shoreline and in other specific habitat variables. It addresses the following research questions:

1. What is the composition of waterbirds found on Central Florida's urban lakes during the breeding and non-breeding seasons?
2. Are waterbird abundance, community composition, and species richness significantly different between developed and undeveloped shorelines?
3. Which onshore and littoral habitat elements are most closely associated with the presence or absence of various waterbird guilds?

In Chapter 3, I examine direct responses of waterbirds to development and human disturbance by measuring changes in waterbird behavior. Chapter 3 addresses the following research questions:

1. Are primary waterbird behaviors significantly different between developed and undeveloped shoreline?

2. Which waterbird guilds appear most sensitive to human disturbance?

Study Area

I conducted field research on four urban lakes within the Peace River drainage basin in and around the city of Winter Haven in Polk County, Florida (Figure 1-1). Polk County ranks fourth in lake abundance among all Florida counties, with 550 lakes within its borders (Edmiston & Myers 1983). Lakes Buckeye (28° 2' 24" N, 81° 42' 20" W), Conine (28° 3' 22" N, 81° 43' 29" W), Deer (28° 1' 32" N, 81° 45' 46" W), and Jessie (28° 3' 27" N, 81° 45' 48" W) are moderately developed lakes located along the edges of Winter Haven's urban area. They were selected for study because each lake still had significant portions of undeveloped shoreline. Polk County Environmental Services classifies these lakes as mesotrophic or eutrophic, meaning they carry moderate to high nutrient loads based on chlorophyll, nitrogen, and phosphorus concentrations (Polk County 1999). Each lake meets Florida Class III criteria for surface water quality, designated for the propagation and maintenance of healthy, well-balanced fish and wildlife populations (Polk County 1999).

Lake Buckeye was the smallest lake (29 ha) with the least developed shoreline (59%) (Figure 1-2). The majority of its undeveloped shoreline was located along the NE side of the lake and consisted of bottomland hardwoods (Florida DOT 1999). Lake Deer (47 ha) had the greatest amount of developed shoreline at 79%. Undeveloped shoreline, consisting of hardwood/conifer mix (Florida DOT 1999), was found in one contiguous stand along the SW corner of the lake. Lake Jessie (75 ha) was 69% developed with hardwood/conifer mix found along the northern shore and bottomland hardwoods dominating most of the eastern shore (Florida DOT 1999). Lake Conine was the largest lake at 96 ha and was developed along 61% of its shoreline. Three undeveloped areas, consisting of hardwood/conifer mix, wetland forest, and bottomland hardwood, were evenly spaced around the lake (Florida DOT 1999).

Undeveloped habitats on each lake were mostly discrete forest fragments less than 20 ha in size, and surrounded by development on all sides. Urbanization consisted primarily of single-family homes, with several apartment complexes located on lakes Buckeye and Deer, and a mobile-home park and private airport located on the north side of Lake Jessie. Much of the east side of Lake Conine and the southeast corner of Lake Buckeye were within 30 m of moderately to heavily traveled roads. All lakes had shallow sloping littoral shelves (Florida LAKEWATCH 2000) with moderately diverse littoral plant communities. The vast majority of residential properties had a dock and boathouse on the water. All lakes had public access boat ramps.

Lake littoral zones were markedly different along the developed and undeveloped shorelines. Undeveloped zones were often characterized by continuous dense stands of cattail (*Typha spp.*). Lake Jessie was the one exception to this, with much of its east side having sparse cattail mixed with a variety of lower emergents such as para grass (*Urochloa mutica*), torpedo grass (*Panicum repens*), and maidencane (*Panicum hemitomon*). Littoral zones along developed shorelines had a much patchier aquatic plant distribution with considerably more open water and far less cattail. Heavily developed shorelines were devoid of all aquatic vegetation. Less developed properties and areas between properties were characterized by a diverse community of low and tall emergent macrophyte species. Lake Deer was notable for its near continuous emergent zone around both the undeveloped and developed shores, and its dense floating-leafed macrophyte coverage (*Nymphea spp.*) around more than 80% of the lake perimeter.

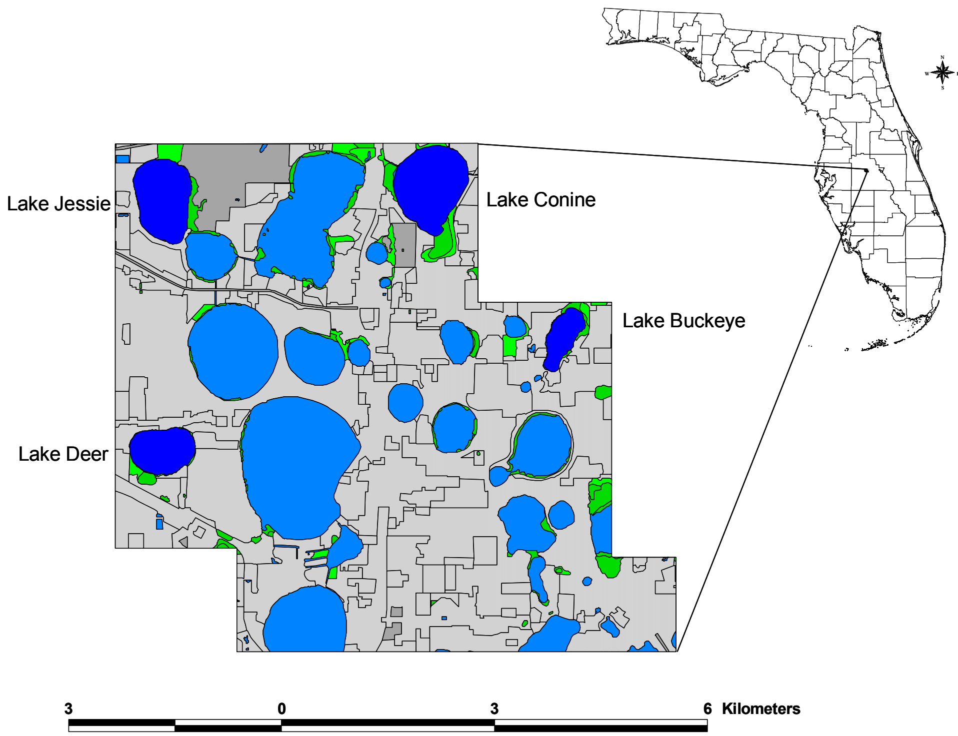

Figure 1-1. Map of study lakes within Winter Haven urban area, Polk County, FL. Developed areas are in grey. Undeveloped areas are in green. Study lakes are in dark blue.

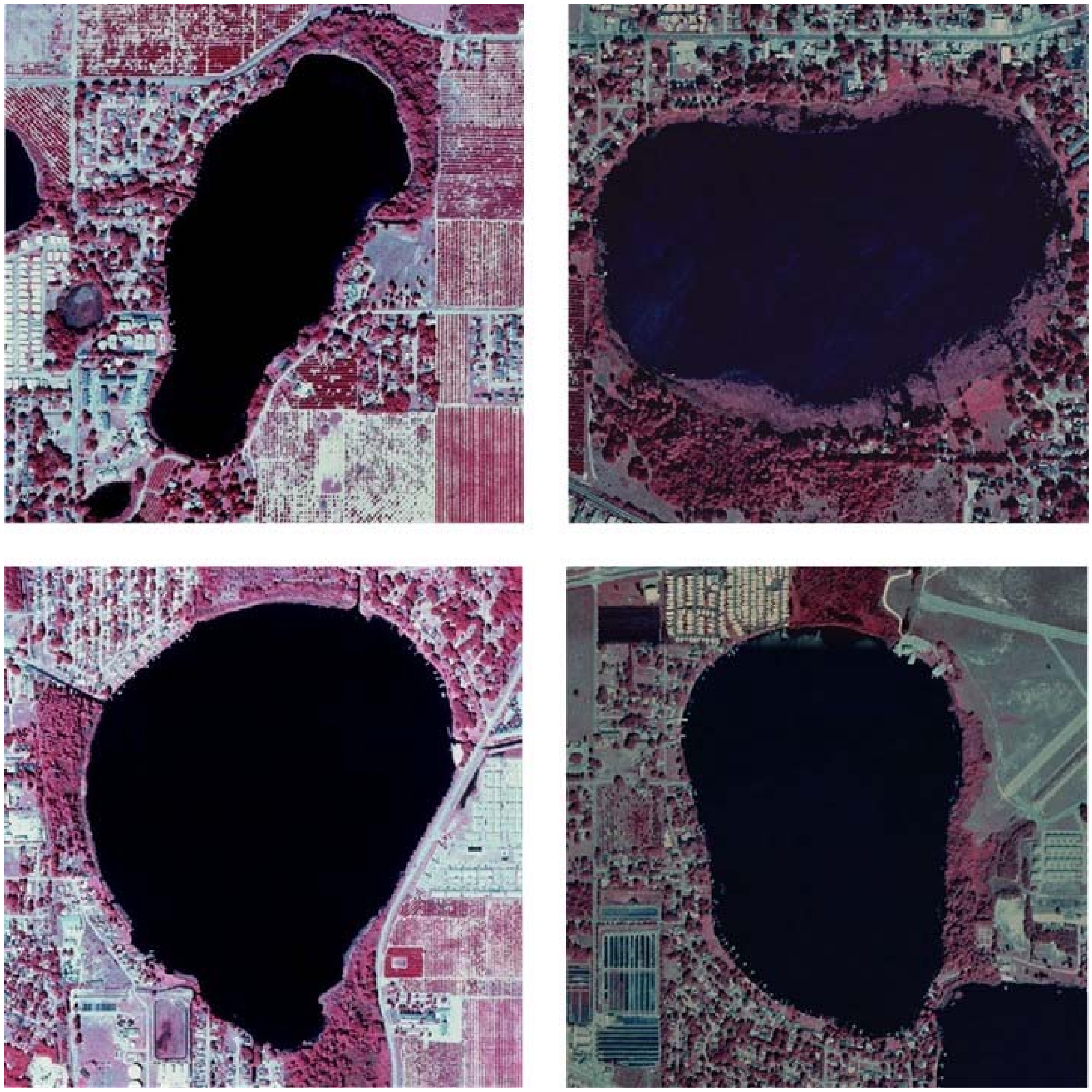

Figure 1-2. Aerial images of Winter Haven study lakes. Clockwise from upper left are Lakes Buckeye, Deer, Jessie, and Conine.

During this study lake levels were unusually low (.5 – 1 m below normal) due to a severe drought. Water levels in the summer of 2001 reached record lows on all of the lakes, exposing much of the emergent zone substrate, creating numerous open mudflats along unvegetated shoreline, and creating a 50 m peninsula along the southern shore of Lake Conine and a small mudflat island off the southern shore of Lake Deer.

CHAPTER 2
WATERBIRD DISTRIBUTION, SHORELINE DEVELOPMENT, AND HABITAT STRUCTURE

Introduction

The importance of habitat structure in determining avian species composition in terrestrial systems has been well established (MacArthur & MacArthur 1961, MacArthur & Wilson 1967, Karr & Roth, 1971, Roth 1976). Though many factors have been proposed to explain avifaunal shifts in urban environments (Marzluff 2001), changes in habitat structure and composition are considered some of the primary mechanisms. Decreases in avian species richness and evenness in urban areas have been correlated with decreases in total woody vegetation volume, spatial heterogeneity, vertical structure, and plant species diversity (Lancaster & Rees 1979, DeGraaf 1986, Tilghman 1987, Marzluff & Sallabanks 1998), and increases in habitat fragmentation, habitat edge, and exotic vegetation (Soulé et al. 1988, Marzluff 2001). Avian species diversity has been found to be negatively correlated with elements of the built up environment, such as housing density (Lancaster & Rees 1979, Blair 2001).

The mechanisms that determine avian species distribution in aquatic systems have also received considerable attention. Broad-scale factors such as geography and climate have been shown to determine waterbird breeding and winter ranges (Weller 1999, Elphick et al. 2001). On a local scale, mechanisms such as species morphology, lake area, water depth, trophic status, and predator and prey densities have all been shown to influence the distribution of waterbird communities (Weller & Spatcher 1965, Jenni

1969, Brown & Dinsmore 1986, Picman et al. 1993, Hoyer & Canfield 1994, Weller 1999).

As in terrestrial systems, habitat structure may be one of the most important factors in determining avian community composition in aquatic systems, including physical components like water column depth, wetland substrate, shoreline, and vegetation strata (Weller 1999). Specific habitat associations are well documented for a variety of waterbirds. For example, grebes (Podicipedidae) prefer relatively shallow, well-vegetated wetlands (Weller 1999, Elphick et al. 2001). Other divers, such as the cormorants (Phalacrocoracidae) and anhingas (Anhingidae), require shrubs, trees, or snags near the water on which to loaf and nest (Hatch & Weseloh 1999, Frederick & Siegel-Causey 2000). Many large and mid-sized wading birds are known to prefer shallow, relatively open areas for foraging (Hancock & Kushlan 1984). Marsh birds such as rails and gallinules (Rallidae) require dense emergent or floating vegetation for nesting and foraging, while coots commonly use more open water habitat (Melvin & Gibbs 1996, Weller 1999, West & Hess 2002).

In urban areas, development and the alteration of both aquatic and terrestrial habitat structure may be the most important factors in determining the composition and distribution of waterbird communities. However, few studies have looked at the effects of lake-habitat structure on urban bird populations. In general, the majority of research on urban aquatic environments in the United States has focused on the effects of recreation on avian abundance, distribution, and breeding success (Hockin et al. 1992, Knight & Gutzwiller 1995). In general, these studies have found lower abundance, reduced use of sites, and lower breeding success in areas with significant recreation (see

Hockin et al. 1992 for review). Studies in Europe and Canada have examined the effects of shoreline cottages on diving birds (Lehtonen 1970, Bundy 1979, Andersson et al. 1980, Heimberger et al. 1983), finding reduced reproductive success and lake utilization in areas with cottages. These studies focused on a single species and did not attempt to quantify the role of habitat structure. The aim of this study was to directly examine the effects of development in urban lake environments by answering the following questions:

1. What is the composition of waterbirds found on Central Florida's urban lakes during the breeding and non-breeding seasons?
2. Are waterbird abundance, community composition, and species richness different between developed and undeveloped shoreline?
3. Which onshore and littoral habitat elements are most closely associated with the presence or absence of various waterbird guilds?

Question 1 addresses the general lack of knowledge about avian species composition on urban lakes by looking for species or groups of birds that are noticeably absent, exploring seasonal fluctuations, and comparing community composition with previous lake studies conducted in the Central Florida region (Hoyer & Canfield 1990, 1994, Roth in press). Questions 2 and 3 examine the impact of developed shoreline on the composition and distribution of waterbirds and explore the role of specific habitat elements in determining distribution patterns.

Methods

Bird Surveys

Waterbird surveys were conducted from June 7 – August 1 of 2001 and December 8 – February 6 of 2001/2002. For this study the term 'waterbird' referred to species in the orders Gaviiformes, Podicipediformes, Pelecaniformes, Ciconiiformes, Anseriformes, Falconiformes, Gruiformes, Charadriiformes, or Coraciiformes observed on or feeding from lacustrine habitats. Each of the four lakes were surveyed a total of eight times each season by driving at minimum-wake speed around the lakes (20 – 30 m from shore) in a small motorized canoe. Both the order of lakes surveyed and the direction of travel were alternated for each day of surveying in order to account for any time-related bird movements around the lakes. Surveys were conducted within the first five hours after sunrise on mornings with little to no rain and winds less than 24 km/hr.

Birds were identified by sight using 8x42 binoculars. Shoreline development and associated vegetation structure were recorded for each bird once it was identified (see description below). The location of each bird was also recorded on a 1999 aerial photograph of each lake obtained from the Florida Department of Environmental Protection (DEP) at their Land Boundary Information Systems (LABINS) website (www.labins.org).

In order to minimize count error along undeveloped shoreline, where dense tall-emergent vegetation was often encountered in the littoral zone, I drove the survey boat directly into the vegetation to flush hidden birds. This procedure was repeated every 30 – 50 m in areas of continuous vegetation. On alternate insertions, I shut off the motor and listened for calling birds for approximately two minutes.

Birds that flushed from any location and landed ahead of the boat were recorded only in their original location. Birds whose origin and destination were not observed or which were observed greater than 30 m offshore or 10 m onshore were recorded for analysis of overall bird composition on a given lake, but were not included in either shoreline development or habitat analyses.

Categorization of Shoreline Development

Each lake in the study had a mixture of developed and undeveloped shoreline. Lake shoreline was categorized as either developed or undeveloped based on DEP land cover classifications for each lake. Classifications were modified during preliminary surveys by basing categorizations only on the land cover within the first 20 m of shoreline extending away from the water on each lake. For the purposes of this study, developed shoreline referred to any continuous stretch of shoreline greater than 100 m, parallel to the edge of the lake, that had a minimum of 50% long-term habitat alteration, defined as cleared land, lawns, landscaping, buildings, and roads. Undeveloped shoreline was defined as any continuous stretch of shoreline greater than 100 m, parallel to the edge of the lake, with greater than 50% intact natural habitat, and little to no sign of regular human use. Developed and undeveloped areas were separated by a buffer of 40 m to eliminate the potential effects of converging habitats. Birds recorded in these border areas were not included in either shoreline development or habitat analyses.

Categorization of Habitat Structure

Upon sighting each bird I recorded several different habitat elements within the littoral zone and immediate onshore zone, as well as the type of substrate that each bird was sighted on. Visual estimates were made for littoral and onshore habitat elements found in 5x20 m rectangular bands around and adjacent to each bird. The 20-meter side of the band was parallel to the shoreline. Coverage of each of eight habitat elements was classified as one of five densities: 0-5%, 6-25%, 26-50%, 51-75%, or 76-100%. This was done in order to see if minimum or maximum thresholds existed at which birds selected or avoided each habitat element.

Littoral habitat

Three categories were created for littoral zone habitat: low emergent vegetation (< 1 m tall), tall emergent vegetation (> 1 m tall), and floating-leafed vegetation. For birds sighted onshore (within 10 m of the water) or less than 5 m offshore, I recorded the first 5 m of aquatic vegetation extending out from the shoreline and within 10 m of either side of the bird. For birds located greater than 5 m from shore, the 5x20 m band was centered around each bird. Since the drought caused extremely low water stages during this study, I determined the upland edge of the littoral zone by the edge of herbaceous emergent vegetation, rather than the presence of standing water. In several undeveloped areas on lakes Buckeye and Conine, backmarshes of fallen cattail and vines had developed behind dense stands of cattail, completely covering the shallows. In such cases, where the water was completely covered by vegetation and was too shallow for any diving birds to use, I considered the area onshore habitat.

Onshore habitat

Five categories were created for shoreline habitat: open shore (moist soil or sand), lawn (any maintained grassy area), understory (< .5 m tall), shrub (.5-3 m tall), and canopy (> 3 m tall). Immediate onshore habitat was recorded for any bird in the water within 20 m of shore and any bird onshore within 10 m of the water. For birds located in the water, I made a trajectory (perpendicular to the shoreline) from where the bird was sighted to a point on shore. For these birds and birds located onshore less than 5 m from the water, I recorded onshore habitat within a 5x20 m band placed 10 m on either side of the trajectory line or bird and extending 5 m inland from the water's edge. For birds located greater than 5 m from the water, the onshore band was centered on the bird.

Substrate

Substrate was defined as the human structure (e.g. pier, boat, etc.) or habitat element (e.g. cattail, shallows, lawn, etc.) on or nearest to which each bird was found. For example, if a bird was observed foraging in a pocket of unvegetated shallow water in a 5x20 m area that was dominated by tall emergent vegetation, the bird's substrate was recorded as shallow water.

Analyses

Waterbirds were grouped into guilds for certain analyses. Guilds were based on foraging behavior and habitat use, and included wading birds (Ardeidae, Threskiornithidae, Ciconiidae, Recurvirostridae), marsh birds (Rallidae), surface and aerial diving birds (Podicipedidae, Phalacrocoracidae, Anhingidae, Accipitridae, Laridae), and ducks (Anatidae). Analyses were only conducted for a given guild or species where 10 or more birds ($n \geq 10$) were observed within that guild or species over a season.

Summer and Winter Comparisons

Species counts from all lakes were summed for each season to examine overall waterbird community composition. Species richness and guild abundance on each of the lakes were calculated for each survey day and then averaged across all days and lakes each season (8 surveys per season) to determine the mean number of species and individuals observed.

The percent similarity measure (Brower et al. 1990) was used to compare avian community composition between seasons in order to determine whether differences in seasonal avian distribution patterns could be explained by differences in community composition.

The Jacaard index of community similarity (Brower et al. 1990) was used to compare community composition with that of two previous urban lake studies in Central Florida. Hoyer & Canfield (1994) examined 33 lakes, both developed and undeveloped in the north central and central regions of Florida. Roth (in press) examined six urban lakes in the Winter Haven area in 1991.

Waterbird Habitat Use

I tested for waterbird associations with developed and undeveloped shoreline and with littoral and onshore habitat elements using Chi-square goodness-of-fit tests ($\alpha = 0.05$, df = 1).

Developed versus undeveloped shoreline

Overall abundance, guild abundance, species abundance, species richness, and species evenness were compared between areas of developed and undeveloped shoreline. Expected values were based on the proportions of developed and undeveloped shoreline. For example, if 100 wading birds were observed on a lake and 70% of the shoreline was developed, then, assuming a random distribution of birds, expected values would be 70 birds along developed shoreline and 30 along undeveloped shoreline.

Overall abundance, species richness, and species evenness were compared between developed and undeveloped shorelines on a lake-by-lake basis. Each lake was analyzed separately to allow for the possibility of intra-lake variability. Guild abundance and species abundance were calculated with all lakes combined based on the results of overall abundance. Evenness was calculated using Simpson's measure of evenness (Krebs 1998).

Littoral and onshore habitat associations

I tested for waterbird associations with littoral and onshore habitat elements by comparing guild abundance in the presence and absence of each of the habitat elements on each lake. For each sighting, a habitat element was considered absent if it was recorded as occurring in 0-5% of the 5x20 m band around a bird. A habitat element was considered present if it was recorded as occurring in greater than five percent of the 5x20 m band around a bird.

Expected values were based on the percent lake coverage of each habitat element around the perimeter each lake. Habitat measures were taken during the winter 2001/2002 field season. Habitat coverage did not noticeably change between seasons except for open shoreline, which dramatically decreased from summer to winter due to rising water with the onset of fall rains. The amount of open shoreline was therefore calculated separately for each season. Habitat elements were assessed for presence/absence along the perimeter of each lake. Each littoral and shoreline habitat element was recorded as present if there was greater than 5% coverage within the first 10 m offshore or onshore, respectively. Measurements were then entered into ArcView 3.2 (ESRI 1999) to determine the exact percentage of the lakes that was covered by each habitat type. Any habitat type on a lake that occurred in less than 5% of the total littoral or shoreline zone was considered functionally absent and excluded from analysis.

Determining overall significance

Where analyses were conducted on a lake-by-lake basis, results were considered to have overall significance where significant same-direction associations ($p \leq 0.05$) were observed on at least three lakes without a significant contradictory finding on the fourth lake. In cases where habitat elements were only present on two lakes, results were considered to have overall significance where significant same direction associations ($p \leq 0.05$) were observed on both lakes. In cases where results were not significant but suggestive of an overall pattern on three or more lakes ($p \leq 0.2$ for each lake), without a contradictory finding on the fourth lake, probabilities (for lakes indicating a pattern) were combined for meta-analysis (Fisher 1958) to test for overall significance.

Habitat elements that were found to be significant were examined across the five different habitat coverage densities to see if minimum or maximum thresholds existed at which birds selected or avoided each habitat type.

Independence of significant habitat elements

My analyses for habitat association were univariate in nature, and therefore it was difficult to detect whether birds were responding to individual habitat elements, or to combinations of habitat elements. I looked for evidence of this preference for co-occurring habitat elements by comparing the proportion of birds that were significantly associated with two or more elements, with an estimate of the actual proportion of co-occurrence of those habitats on the lake. I first determined how often birds within a guild were sighted in significant positive association with two or more elements. I then used the aerial photographs and habitat estimates taken during the winter to estimate the degree of overlap among elements of interest (to nearest 1%). Since exact estimates could not be determined due to the resolution of the photographs, statistical analyses were not employed. I concluded that a guild may have been responding to a combination of habitat elements if the difference between percent actual overlap of habitats and percent of birds sighted where habitats overlapped was 50% or more. For example, if lawn and open shore habitats spatially overlapped 10% of the time, but 80% of wading birds observed were in areas where both elements were present, then I concluded that the guild was responding to the combination of these elements. Cross tabulations could not be used for negatively significant habitat elements since, by definition, birds were found in areas where these elements were absent. Independence of negative habitat elements was therefore estimated by looking only at the degree of actual spatial overlap around the lake.

Results

Avian Community Composition

A total of 38 waterbird species were observed over the course of this study, including nine species listed as endangered, threatened, or of special concern in the state of Florida (Appendix A). Thirty-five species were observed on more than 10% of the surveys.

When overall community composition on these lakes was compared with the two previous studies of Central Florida lakes, species similarity (Jacaard index) was 0.76 and 0.7. A similarity index of 1.0 in either case would indicate that all species were found in both studies.

A total of 33 waterbird species were observed during the summer 2001 season. An average of 13.6 species and 104.1 birds were observed per lake each day. Standard deviations between lakes varied widely over both seasons. Wading birds were the most common guild in terms of species richness, making up 45% of all species observed. Ducks showed the greatest abundance, making up 39% of all birds observed. Wood Ducks (*Aix sponsa*) accounted for 96% of all ducks.

Thirty-two species were observed during the winter 2001/2002 season. An average of 14.8 species and 114.4 birds were observed per lake each day. Wading birds continued to show the greatest species richness, making up 41% of all species. Several large flocks of migrant Double-crested Cormorants (*Phalacrocorax auritus*) accounted for diving birds showing the greatest winter abundance, making up 34% of all birds observed.

Species composition between seasons was moderately similar (0.54, percent similarity measure), with the variation explained by the arrival of 10 winter migrant species (i.e., birds observed in significantly greater numbers in winter than in summer in central Florida) (Appendix A). Six of these species were diving birds.

Shoreline Development and Habitat Coverage

Table 2.1 gives a breakdown of the percent coverage of developed and undeveloped shorelines and habitat elements on each lake. Due to the overlap between most habitat elements, total percentages on any lake were greater than 100%. Understory, shrub, and canopy in particular had near 100% overlap along undeveloped shoreline.

Littoral zones along developed shorelines were characterized by a very patchy habitat structure, with distinct clumps of low and tall emergent vegetation and large areas devoid of aquatic vegetation. Onshore habitat in developed areas was characterized by significant lawn coverage with very sparse, intermittent understory and shrub layers. Across all lakes, 90% of open shore habitat was found along developed shoreline. This habitat was typically found in conjunction with lawn habitat where onshore and littoral vegetation had been cleared.

Undeveloped shorelines, on the other hand, were much more homogeneous. Tall emergent vegetation dominated much of the littoral zones. Cattail (*Typha sp*.) was the dominant emergent vegetation and was present along 89% of undeveloped shoreline, with almost 70% of it found in dense, continuous stands. Open shore, or exposed shoreline in general was therefore rarely available. Onshore habitat consisted of relatively continuous low to moderate understory, and moderate to dense shrub and canopy.

Tall emergent vegetation was the dominant littoral zone habitat element on three of the four lakes, being present in 47-76% of total littoral zone area. Lake Deer showed considerable tall emergent coverage, at 68%, but was also dominated by floating-leafed vegetation, which was found in 83% of the total littoral zone area. Floating-leafed vegetation was considered functionally absent on Lakes Conine and Jessie since each lake had less than 5% coverage.

None of the shoreline habitat elements clearly dominated the overall shoreline habitat structure. Open shore significantly declined between seasons, dropping from 29% to 7% of available onshore area from summer to winter. On Lake Buckeye and Deer, open shore coverage dropped below 5% in the winter and therefore was considered functionally absent on those lakes.

Developed Versus Undeveloped Shoreline Use

During both seasons a strong association was observed between shoreline development and bird abundance, with more birds found along developed shore on all four lakes (Table 2-2). Wading birds, marsh birds, and ducks showed this positive association over both seasons (all tests: $\chi^2 \geq 39.09$, $p \leq 0.0001$). Diving birds showed this positive association only in the winter (all tests: $\chi^2 \geq 3.87$, $p \leq 0.05$). Only one lake, Lake Deer in the summer, showed an association between species richness and shoreline development. In this case, significantly more species than expected were found along undeveloped shoreline ($\chi^2 = 7.01$, $p = 0.008$). Since no other lakes in either season showed this pattern, an overall association between species richness and shoreline development was not established. Temporal and spatial patterns of evenness varied considerably among lakes. Undeveloped shoreline had greater species evenness than developed shoreline on all four lakes in the summer. Evenness indices for developed shoreline in the summer ranged from 0.15 – 0.38, and for undeveloped shoreline ranged from 0.27 – 0.68. The opposite pattern was observed in the winter, with three of the lakes having greater species evenness along developed shoreline. Evenness for developed shoreline ranged from 0.62 – 0.95, and for undeveloped shoreline from 0.51 – 0.73. In all cases, an evenness index of 1.0 would mean that all species were comprised of an equal number of individuals.

Table 2-1. Total shoreline development and habitat coverage of all habitat elements. Shoreline development measures were based on first 20 m of shoreline surrounding each lake. Habitat coverage was based on 5 m deep perimeter bands for littoral and shoreline zone habitats.

	Buckeye		**Conine**		**Deer**		**Jessie**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Development								
Developed	2.62	59	4.32	61	4.14	79	4.51	69
Undeveloped	1.83	41	2.74	39	1.09	21	2.09	31
Onshore Habitat								
Canopy	0.59	48	0.17	9	0.51	38	0.54	31
Shrub	0.76	62	1.22	65	0.55	41	0.81	47
Understory	0.75	61	1.28	68	0.62	46	0.82	47
Lawn	0.52	42	0.29	15	0.80	59	0.82	47
Open Shore - summer	0.41	34	0.69	37	0.18	14	0.58	33
Open Shore - winter	0.03	2*	0.31	16	0.01	1*	0.16	9
Littoral Habitat								
Floating Leaf	0.44	37	0.01	1*	1.06	83	0.05	3*
Tall Emergent	0.69	59	1.38	76	0.87	68	0.78	47
Low Emergent	0.06	5	0.28	16	0.55	43	0.77	46

* Below 5% considered absent

In terms of individual species abundance patterns, results for the summer season revealed that eight of 28 species (29%) observed using shoreline habitat showed a significant positive association with developed shore (all tests: $\chi^2 \geq 5$, $p \leq 0.03$). In the winter, 16 of 27 species (59%) showed a significant positive association with developed shore (all tests: $\chi^2 \geq 5.48$, $p \leq 0.02$); a significant increase over the summer season ($\chi^2 \geq 5.26$, $p \leq 0.02$). Winter migrants accounted for half of the species showing a positive association for developed shoreline in the winter.

Table 2-2. Overall waterbird abundance along developed and undeveloped shorelines on lakes Buckeye, Conine, Deer, and Jessie during summer 2001 and winter 2001/2002. All numbers represent the sum total from eight surveys conducted each season.

Lake	**Relative Abundance**			
	Summer		**Winter**	
	Developed	**Undeveloped**	**Developed**	**Undeveloped**
Buckeye	214*	66	195*	73
Conine	336*	133	522*	49
Deer	1209*	103	1254*	47
Jessie	693*	142	745*	103

*From Chi-square goodness-of-fit tests, significantly more birds than expected along indicated shoreline ($p < 0.0001$).

Year-round residents that showed a significant association with developed shoreline during both the summer and winter seasons included the Snowy Egret (*Egretta thula*), Tricolored Heron (*Egretta tricolor*), White Ibis (*Eudocimus albus*), Wood Duck, Common Moorhen (*Gallinula chloropus*), Purple Gallinule (*Porphyrula martinica*), and Killdeer (*Charadrius vociferous*) (Table 2-3). Winter migrants that showed a significant association with developed shoreline in the winter included the Double-crested Cormorant (*Phalacrocorax aulitus*), Ring-necked Duck (*Aythya collaris*), American Coot (*Fulica Americana*), Ring-billed Gull (*Larus delawarensis*), Belted Kingfisher (*Ceryle alcyon*), and Fish Crow (*Corvus ossifragus*).

Table 2-3. Species abundance along developed and undeveloped shorelines during summer 2001 and winter 2001/2002. Data from all lakes and survey dates are summed for each season.

Species	**Summer Abundance**		**Winter Abundance**	
	Developed	**Undeveloped**	**Developed**	**Undeveloped**
Diving Birds				
Pied-billed Grebe	1	1	20	3
D-C Cormorant	34	23	97*	9
Anhinga	145	76	97	82*
Osprey	11	9	9	9
Ring-billed Gull	n/a	n/a	18*	0
Belted Kingfisher	2	0	24*	1
Wading Birds				
Least Bittern	8	8	0	3
Great Blue Heron	106	50	61	32
Great Egret	43	20	41*	5
Snowy Egret[S]	45*	6	17*	0
Little Blue Heron[S]	11	3	18*	0
Tricolored Heron[S]	51*	6	44*	2
Cattle Egret	3	0	66*	0
Green Heron	61	32	11	6
B-C Night Heron	1	1	0	6
White Ibis[S]	160*	9	223*	0
Glossy Ibis	12	8	n/a	n/a
Wood Stork[E]	6	1	2	0
Limpkin[S]	8	1	2	0
Sandhill Crane[T]	8	0	2	0
Black-Necked Stilt	2	0	n/a	n/a
Ducks (wild)				
Wood Duck	1022*	89	384*	40
Mallard	56*	0	n/a	n/a
Blue-winged Teal	n/a	n/a	10	0
Ring-necked Duck	n/a	n/a	353*	0
Marsh Birds				
Rail	0	1	n/a	n/a
Sora	0	1	n/a	n/a
Purple Gallinule	127*	14	97*	5
Common Moorhen	464*	72	360*	74
American Coot	1	0	217*	0
Other				
Killdeer	13*	0	14*	0

[S] State listed as Species of Special Concern, [T] state listed as Threatened, [E] state and federally listed as Endangered.
*From Chi-square goodness-of-fit tests, significantly more birds than expected along indicated shoreline ($p < 0.05$).

Four species, the Rail (*Rallus sp*.), Sora (*Porzina carolina*), Least Bittern (*Ixobrychus exilis*), and Black-crowned Night Heron (*Nycticorax nycticorax*), were found exclusively along undeveloped shoreline during one or both seasons, but their numbers were too small to be analyzed. Only the Anhinga (*Anhinga anhinga*) showed a significant association with undeveloped shoreline, and only during the winter season ($\chi^2 = 12.71$, $p < 0.001$).

Substrate Use

Substrate analyses offered a fine-scale measure of habitat use by depicting the immediate habitat element or structure that each bird was using. The most commonly used substrates for each guild are reported here. Forty-nine percent of all marsh birds were found in either low-emergent or floating-leafed vegetation over both seasons. Fifty percent of wading birds were found either in the shallows or along open shore in the summer, whereas only 11% were found in these substrates in the winter, 35% were found on piers (vs. 9% in the summer), and 19% were found in low-emergent vegetation (vs. 3% in the summer). Forty-four percent of diving birds were found on piers and pylons over both seasons, while 34% were found in trees or on logs. This division was strongly related to shoreline development. Along the developed shoreline, 63% of diving birds were actually found on piers and pylons, whereas 83% of this guild was found in trees or on logs along undeveloped shoreline. Forty percent of all ducks were observed in floating-leafed vegetation over both seasons.

Littoral Zone Habitat Association

Table 2-4 summarizes the significant associations found between waterbird guilds and littoral zone habitat elements for summer and winter surveys.

Summer

Tall emergent. Summer analyses revealed that tall emergent vegetation was negatively associated with bird presence for marsh birds, wading birds, and ducks (all tests: $\chi^2 \geq 31.39$, $p \leq 0.0001$). Though not meeting the requirements for overall significance, diving birds may have also been negatively associated with this habitat element , showing a significant negative association on two lakes (both tests: $\chi^2 \geq 11.31$, $p \leq 0.001$). Species analyses revealed that the Least Bittern was the only species that was positively associated with tall emergent vegetation ($\chi^2 = 4.12$, $p = 0.04$). No other habitat element in either the littoral or shoreline zones showed such a broadly consistent pattern of association. Examination of overall bird presence across the five habitat densities showed that 81% of all birds using areas with tall emergent vegetation were found in areas with less than 50% coverage of this habitat element.

Floating leaf. Lakes Buckeye and Deer were the only lakes with enough floating-leaf coverage (>5%) to conduct habitat analyses for this element. A strong positive association was observed between ducks and floating-leafed vegetation on these lakes (both tests: $\chi^2 \geq 9.73$, $p \leq 0.002$). Ducks used this habitat at all coverage densities, but 40% were found in areas with greater than 75% floating-leaf coverage. Marsh birds, wading birds, and diving birds did not appear to respond to floating-leaf vegetation.

Low emergent. Results for low emergent vegetation were inconclusive for all waterbird guilds. Though individual lakes and guilds showed significant results, consistent patterns were never observed on more than two lakes.

Winter

Tall emergent. Winter analyses revealed a negative association between tall emergent vegetation and wading bird presence on all lakes (all tests: $\chi^2 \geq 8.61$, $p \leq$

0.003). Again, 81% of wading birds associating with tall emergent vegetation were found in areas with less than 50% coverage of this habitat element. Though not meeting the requirements for overall significance, marsh birds and diving birds may have also been negatively associated with this habitat, showing significant negative associations on two lakes each (all tests: $\chi^2 \geq 9.79$, $p \leq 0.002$). Separate species analysis showed that the Green Heron showed a positive association with tall emergent vegetation ($\chi^2 = 7.06$, $p = 0.008$).

Floating leaf. Ducks continued to show a positive association with floating-leafed vegetation in the winter on the two lakes with this habitat element (both tests: $\chi^2 \geq 14.08$, $p \leq 0.001$). Eighty percent of the ducks that associated with floating-leafed vegetation were found in areas of greater than 50% coverage. Both wading birds and diving birds were negatively associated with floating-leafed vegetation on the two lakes (all tests: $\chi^2 \geq 11.85$, $p \leq 0.001$). The avoidance threshold for these birds in this habitat appeared to be 50% coverage, with only 11% of the birds found in the greater coverage densities. Marsh birds were not associated with floating-leafed vegetation.

Low emergent. Wading bird presence was positively associated with the presence of low emergent vegetation on three of the four lakes (all tests: $\chi^2 \geq 15.91$, $p \leq 0.0001$). Of the waders associating with this habitat element, 40% were found in areas with less than 25% low emergent coverage. Marsh birds, diving birds, and ducks showed no consistent patterns of association with this habitat element.

Onshore Habitat Association

Table 2-5 summarizes the significant and marginally significant associations found between waterbirds guilds and onshore habitat elements.

Table 2-4. Waterbird guild associations with littoral habitat elements for summer 2001 (S), and winter 2001/2002 (W).

Guild	**Tall Emergents**		**Low Emergents**		**Floating-Leafed**	
	S	**W**	**S**	**W**	**S**	**W**
Marsh	--					
Waders	--	--		++		--
Divers						--
Ducks	--				++	++

-- significant negative association on at least three lakes ($p < 0.05$)
++ significant positive association on at least three lakes ($p < 0.05$)

Summer

Open shore. Open shore showed significant positive association on three of the four lakes with both ducks and marsh birds (all tests: $\chi^2 \geq 17.71$, $p \leq 0.0001$). Meta-analysis also showed a significant positive association between open shore and wading birds ($\chi^2 = 40.3$, $p < 0.0001$). Diving birds showed no consistent pattern of association with this element. As defined (moist soil or sand), open shore was rarely found extending beyond the first meter of shoreline. Coverage densities therefore rarely exceeded 0 – 25%, which precluded interpretation of threshold tolerances across the habitat density gradient. However, birds were found with this habitat at each of the coverage densities where they were available.

Lawn. Summer trends for lawn were inconsistent for all guilds but diving birds, which showed an overall significant pattern of negative association on three lakes (meta-analysis: $\chi^2 = 37.4$, $p < 0.0001$). Diving birds were found at equally low numbers across all coverage densities for this habitat element.

Understory, shrub, and canopy. Neither understory nor shrub habitat showed consistent patterns of association with any of the bird guilds during the summer season. Canopy habitat showed an overall significant pattern of positive association with diving birds on all lakes (meta-analysis: $\chi^2 = 44.5$, $p < 0.0001$). This association was relatively even across all canopy densities.

Winter

Open shore. Due to higher water levels in the winter, open shoreline was greatly reduced on all lakes compared to summer availability. Open shoreline became so limited on Lakes Buckeye and Deer (<5%) that these lakes were removed from analyses. Wading birds were positively associated with this habitat on the two remaining lakes (both tests: $\chi^2 \geq 4.21$, $p \leq 0.04$). Open shore never occurred on more than 25% of total onshore habitat in the winter, which prevented interpretation of threshold tolerances across the habitat density gradient. None of the other guilds showed a consistent preference for or against this habitat.

Lawn. Lawn showed a strong overall pattern of positive association with marsh birds, wading birds, and diving birds in the winter. Both marsh birds and wading birds showed significant positive associations (all tests: $\chi^2 \geq 18.4$, $p \leq 0.0001$) with this habitat. Diving birds showed a significantly positive association on two lakes and a positive trend on a third lake (meta-analysis: $\chi^2 = 35.51$, $p < 0.0001$). Fifty-eight percent of the birds associating with lawn habitat were found in areas of greater than 75% lawn coverage.

Understory. Understory showed a significantly positive association with diving birds (all tests: $\chi^2 \geq 4.69$, $p \leq 0.03$), and an overall pattern of significant positive association with marsh birds (meta-analysis: $\chi^2 = 17.98$, $p < 0.01$). No minimum or maximum habitat density thresholds were apparent.

Shrub. Shrub was negatively associated with wading birds, which significantly avoided this kind of onshore habitat on three lakes (all tests: $\chi^2 \geq 6.28$, $p \leq 0.012$). An avoidance threshold was not apparent, with birds found at equally low numbers across all levels of shrub coverage.

Canopy. Marsh birds and diving birds showed a significant positive association with canopy coverage (all tests: $\chi^2 \geq 7.77$, $p \leq 0.005$). Wading birds showed a significant positive association on two lakes and a positive trend on a third lake (meta-analysis: $\chi^2 \geq 42.05$, $p \leq 0.0001$). No minimum or maximum habitat density thresholds were apparent, with all guilds found in all levels of canopy coverage.

Table 2-5. Waterbird associations with onshore habitat elements by guild for summer 2001 (S), and winter 2001/2002 (W).

Guild	Open Shore		Lawn		Understory		Shrub		Canopy	
	S	W	S	W	S	W	S	W	S	W
Marsh	++			++		+				++
Waders	+	++		++				--		+
Divers			-	+		++			+	++
Ducks	++									

++/-- indicates significant positive/negative associations on at least three lakes ($p \leq 0.05$).
+/– indicates significant overall positive/negative association ($p \leq 0.05$) based on meta-analysis of trends ($p \leq 0.2$) on at least three lakes.

Independence of Significant Habitat Elements

Summer

Ducks showed a significant positive association with both floating-leafed vegetation and open shore in the summer. Looking only at the portions of the lakes covered with one or both of these habitat elements, floating-leafed vegetation overlapped with open shore 12% of the time. Twenty-five percent of all ducks sighted in these areas were found where these habitats overlapped. Thus, it did not appear that ducks were strongly responding to the combination of these elements. No other guilds showed multiple significant habitat associations in the summer.

Winter

Marsh birds. Marsh birds showed a significant positive association with lawn, understory, and canopy in the winter. The most substantial differences between habitat availability and marsh bird distribution occurred in lawn/understory habitat and lawn/understory/canopy habitat. Lawn/understory habitat (without canopy) occurred on only 1% of the shoreline, while 12% of marsh birds were sighted in areas with both elements present. Similarly, lawn/understory/canopy habitat occurred on only 2% of significant habitat shoreline, while 25% of marsh birds were sighted with all three habitat elements present. Additionally, canopy habitat occurred in the presence of either lawn or understory along 98% of the shorelines having one or more of these elements. Thus, although there may be some selection of marsh birds for lawn/understory/canopy combinations, it could not be determined whether these combinations played a role in attracting marsh birds.

Wading birds. Wading birds showed a significant positive association with low emergent vegetation, open shore, and lawn in the winter. Overall, no combination of these habitat elements clearly attracted wading birds. The most substantial difference between overlapped habitat availability and wading bird distribution occurred in low emergent/lawn habitat, where 40% of wading birds were sighted in areas where both low emergents and lawn were present. Actual overlap of these two habitat elements was only 29%.

Wading birds showed a negative association with tall emergent vegetation, floating-leaf vegetation, and shrubs in the winter. Wading birds appeared to show the strongest negative association with tall emergent vegetation. Looking only at spatial distribution, tall emergent vegetation overlapped with at least one other element 83% of the time. Therefore it could not be determined whether wading birds were avoiding this habitat element alone or a combination of these elements.

Diving birds. Diving birds showed a significant positive association with understory and canopy in the winter. Fifty-seven percent of diving birds were sighted in areas where both habitat elements were present. Understory and canopy habitat overlapped along 26% of the shoreline. Thus, it could not be concluded that diving birds were selecting for the combination of these habitat elements.

Discussion

Seasonal Species Composition

Thirty-five species were observed using these lakes on a regular basis over one or both seasons, including nine state or federally listed species. In the summer, marsh birds, wading birds, and ducks were all observed breeding on these lakes, with numerous fledgling marsh birds and ducks observed (Chapt. 3). In the winter, almost one third of the species that used these lakes were winter migrants. Several of these species, like the Double-crested Cormorant, Ring-billed Gull, and Ring-necked Duck were observed in large foraging flocks using these lakes for brief periods. Other species, such as the Pied-billed Grebe, American Coot, and Belted Kingfisher established themselves more permanently on these lakes for the winter season. These findings confirm that urban lakes can sustain diverse waterbird communities during both the breeding and winter seasons, and apparently provide functional habitat for a variety of seasonal needs.

The similarity in community composition with Hoyer & Canfield's study (1994) and Roth's study (1991) indicates that urban lakes may not just have relatively stable avian communities from one season to the next, but also from year to year. This long-term stability may be the result of the dam-controlled water levels providing more stable environmental conditions than are found in many natural wetlands. If so, some waterbirds may learn to rely on urban lakes in times requiring stable water levels, such as the nesting season.

Shoreline Development

Wading bird, marsh bird, and duck abundance were significantly greater than expected along developed shoreline on all lakes during both the summer and winter seasons. While some birds may have been undercounted along undeveloped shoreline in areas of dense cattail, the degree of difference in the number of birds found along developed and undeveloped shorelines cannot be explained by this alone. In my repeated entries into cattail stands, I saw and heard almost no waterbirds using this habitat. Roth (in press) had similar results in a study of neighboring lakes. Further, many of the more conspicuous waterbirds, such as the large and mid-sized long-legged waders, are known to avoid areas of dense tall-emergent vegetation (Smith et al. 1995, Surdick 1998, Roth in press). That almost all of these species were found in significantly greater abundance along developed shoreline supports these results, and suggests that the prevalence of cattail along undeveloped shoreline may have been a primary factor in many birds selecting developed shoreline.

Knight and Cole (1995) stated that the four primary ways in which human activities can impact animals are through exploitation, pollution, disturbance, and habitat modification. Hunting is not allowed on these lakes, and, given the small size of the lakes', pollution effects are most likely evenly dispersed between developed and undeveloped shores. This leaves disturbance and habitat modification as the two primary activities affecting waterbird patterns. Human disturbance, in general, has been widely shown to be detrimental to birds and other wildlife (Hockin et al. 1992, Carney &

Sydeman 1999, but see Nisbet 2000). If human disturbance was the primary activity influencing the distribution of waterbirds around these lakes, then, given the fact that human activity was much greater in developed areas (Chapt. 3), fewer birds than expected should have been found along developed shorelines. That the exact opposite was found suggests that there are considerable benefits to the modified habitat found along developed portions of these lakes, and that under such circumstances many waterbird species will tolerate increased levels of human disturbance.

Tolerance of human disturbance, as indicated by a bird's presence along developed shorelines, may be a sign of habituation. Habituation has been defined as "the relatively persistent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement" (Hinde 1970). Other studies that have used similar presence/absence measures of habituation have had varying results. On separate refuge studies, Burger (1981) found that waterbirds were significantly less likely to be present when people were present at a site, whereas Klein at al. (1995) found that only half of the species in their study shifted away from areas of human disturbance as disturbance levels increased. Several authors though, have noted that it is common for waterbirds to habituate to moderate levels of disturbance in situations where people are regularly present but not causing any direct harm (Hockin et al. 1992, Weller 1999).

As mentioned above, the dense, cattail found along undeveloped shorelines appeared to be unattractive to many waterbirds. Such habitat conditions may have limited visibility, foraging opportunities, and escape routes, and increased vulnerability to predators. If this was the case, waterbirds may not have actually been showing a preference for developed habitat, but rather an avoidance of undeveloped habitat. When considering this option it is important to distinguish between undeveloped habitat and natural habitat. Though the undeveloped shorelines on these lakes had relatively undisturbed terrestrial vegetation structure, the deep, dense stands of cattail commonly dominating the littoral zones were most likely not part of the natural habitat originally found on these lakes. Rather, they were a result of the artificial eutrophication that has occurred on these lakes due to years of uncontrolled urban runoff (Gilbert 1987, Roth in press). Reestablishing a healthy, more diverse, and structurally heterogeneous aquatic plant community (i.e., “hemi-marsh”) along the undeveloped portions of these lakes might very well create a more favorable habitat than is currently available for the waterbirds on these lakes.

Previous urban studies based in terrestrial habitats have documented an overall increase in avian abundance as a select few human-commensal species prosper (Blair 1996, Savard et al. 2000). This same process appeared to occur on a seasonal basis on the urban lakes in this study, as seen in the summer by the lower species evenness along developed shorelines, and the fact that the overall preference for developed shoreline was explained by just eight species. Further, more secretive species such as rails and bitterns, often found in less disturbed wetland habitats, were rarely encountered on these lakes. The combined implications are that certain waterbird species are adaptable enough to benefit from aquatic urban habitats and may actively seek them out, as species like the House Sparrow (*Passer domesticus*) and European Starling (*Sturnus vulgaris*) do in terrestrial urban habitats. Species like the Great Blue Heron or Belted Kingfisher, both found in this study, are highly adaptable in terms of habitat and diet (Butler 1992, Weller 1999), and this may explain why they are found in urban aquatic habitats. Other species, such as the Anhinga or Black-crowned Night Heron, may be found in developed areas, but at lower numbers than in less disturbed habitats. And waterbirds such as rails or bitterns (found rarely in this study) may be entirely intolerant of development and/or disturbance and may avoid urban environments altogether when possible, even when portions of the environment are left undeveloped.

Dominant Habitat Elements

Tall emergent vegetation, open shore, lawn, and canopy were each associated with the distribution (presence/absence) of multiple guilds on these lakes, and were thus considered dominant habitat elements. Tall emergent vegetation had a negative overall association, whereas open shore, lawn, and canopy had positive overall associations.

Littoral habitat

Tall emergent vegetation. All guilds were negatively associated with tall emergent vegetation on at least 50% of the lakes over both seasons. No significant positive associations were observed within a guild on any lake. Previous studies have shown similar results, with a variety of waterbird species using dense tall-emergent monocultures far less than expected by chance (Weller & Spatcher 1965, Weller & Fredrickson 1974, Kaminski & Prince 1984, Collopy & Jelks 1989, Bildstein et al. 1994, Smith et al. 1995, Surdick 1998). The most substantial stands of tall emergent vegetation were located along undeveloped shoreline. Cattail was present along 89% of total undeveloped shoreline, with almost 70% of it found in dense, continuous stands. These stands were frequently found extending over 20 m from shore into water depths that were too great for even the tallest wading birds to use. In the summer, the larger stands of cattail became so dense that even smaller marsh birds and ducks had to struggle to penetrate the vegetation when attempting to flee.

Given its extensive coverage on many of the lakes, cattail overlapped other habitat elements quite frequently. In the case of wading birds, the only guild showing significant negative associations with multiple habitat elements, tall emergent vegetation (cattail) occurred in combination with other significant elements 83% of the time. Thus, it could not be conclusively determined whether birds were responding primarily to cattail or some combination of elements. However, given the abundance of previous research showing the avoidance of tall, dense, emergent vegetation by numerous waterbird species (see above), it seems likely that tall emergent vegetation, namely cattail, was indeed the dominant habitat element that birds were avoiding.

Cattail was most likely present on these lakes before they were developed, but at much lower densities (Gilbert 1987, Florida DEP 1983-1992). In this study both the Least Bittern (summer) and the Green Heron (winter) showed a positive association with tall emergent vegetation. Cattail, even at fairly high densities, is considered functional, even necessary habitat for a number of waterbirds; the Least Bittern, Rail, Sora, Black-crowned Night Heron, Common Moorhen, Purple Gallinule, Red-winged Blackbird (*Agelaius phoeniceus*) and Boat-tailed Grackle (*Quiscalus major*) (Terres 1991, Hoppe & Kennamer 1986, Davis 1993, Melvin & Gibbs 1996, Gibbs et al. 1992). Eliminating cattail from these lakes would therefore be detrimental to these species. However, limiting cattail coverage along undeveloped shoreline may allow for greater foraging and resting opportunities for a wider range of species.

Onshore habitat

Open shore. Open shore had a positive association with marsh birds, wading birds, and ducks during the summer. The creation of much of this habitat, defined as moist soil or sand, was a result of the extreme drought that Florida experienced in 2001.

Though ephemeral, open shore habitat appeared to serve as a valuable foraging area for these birds (pers. obs.). Dropping water levels exposed new foraging habitat that was not available during higher water conditions. As such, many dabbling and probing birds and small waders could take advantage of the shallow waters and exposed substrate. Of the eight species that were associated with developed shoreline in the summer, seven fit this description: Snowy Egret, Tricolored Heron, White Ibis, Wood duck, Mallard, Purple Gallinule, and Common Moorhen. All of these species are known to frequently forage in areas of relatively open shallow waters and sparse vegetation (Hancock & Kushlan 1984, Weller 1999). Given that only 10% of open shore was found along undeveloped shoreline, this habitat element may explain much of the overall preference for developed shoreline that was observed in the summer season.

Lawn. Lawn was positively correlated with marsh birds, wading birds, and diving birds during the winter. This habitat, an obvious indicator of development, by itself probably offered little functional value to most birds other than White Ibis, Cattle Egrets and Common moorhens, which frequented lawns for foraging. Substrate analysis showed that only five percent of all birds found along developed shoreline were directly found in lawns. Most birds were likely responding to other habitat elements of the developed shoreline located in the vicinity of lawns. For example, 40% of wading birds observed in areas where lawn was present were also found with low emergent vegetation. In general, areas with significant lawn coverage had reduced understory and shrub layers, and patchier emergent vegetation. Reduced onshore and littoral vegetation structure may have afforded birds better visibility and movement, allowing for easier detection and avoidance of predators or approaching humans. This idea is supported by previous studies that have suggested that many wading bird species are more vigilant and more easily disturbed in areas of dense vegetation (Smith et al. 1995, Safran et al. 2000). The patchier aquatic vegetation structure may have also provided better foraging habitat. Bildstein et al. (1994) found that patchy littoral vegetation structure allowed wading birds to feed in relatively open water while taking advantage of high fish densities in adjacent vegetated areas. Though no significant differences were observed in the proportion of birds foraging along developed and undeveloped shorelines (Chapt. 3), other measures, such as foraging times, prey selection, or strike/capture ratios, may have better shown the value of this habitat for foraging birds.

Other components of developed shoreline that were associated with lawns included human-made structures such as piers, pylons, and boats. Examination of the substrates on which birds were observed revealed that 25% of all birds using developed shoreline were found on such structures. Many species used these structures for resting, probably due to the unobstructed access to water and the ease of vigilance. Diving birds offer the strongest example in that 63% of all diving birds along developed shoreline were found on piers or pylons. Birds such as the Tricolored Heron, Snowy Egret, and particularly the Belted Kingfisher were observed actively foraging from these perches.

Canopy. Canopy was positively associated with marsh birds and wading birds in the winter and diving birds over both seasons. Though canopy was found in greater densities along undeveloped shorelines, it was also prevalent along developed shorelines, and therefore cannot be considered an indicator of undeveloped shoreline. It can be seen as an increase in structural habitat complexity, providing birds with an added vertical layer that they could use as a refuge from disturbance. Several species of wading birds were observed resting in canopy. Eighty-three percent of all diving birds resting along undeveloped shoreline were found resting in trees or on logs. Casual observation suggests that these individuals may have shown lower levels of alert/flee response than birds resting closer to the water. In addition, canopy may have provided shade refuge in the summer during the heat of the day, and thermal refuge in the winter, protecting birds from winter winds. In both seasons, it may have also provided sunny locations for basking birds. This is especially important to Anhingas, which rely on basking to dry their feathers and maintain body temperature (Frederick & Siegel-Causey 2000).

The association between marsh birds and canopy was most likely indirect. Besides canopy, marsh birds were also significantly associated with lawn and understory. Though marsh birds showed no clear association with any combination of these elements, the ecology of this guild suggests that understory may have been the primary habitat element determining their distribution. In general, many members of the rail family show a strong preference for relatively dense understory and generally weedy conditions (Terres 1991, Elphick et al 2001).

Guild Responses to Other Habitat Elements

Marsh birds

Marsh birds also showed a positive association with understory in the winter. As mentioned above, this finding was expected given the general ecology of this guild. However, though lawn, understory, and canopy overlapped along only 2% of total significant habitat shoreline, 25% of winter marsh birds were found in this area. Thus, though understory was most likely the dominant habitat element, it can not be ruled out that marsh birds were selecting for a combination of these elements.

Wading birds

Whereas wading birds were only associated with tall emergent vegetation and open shoreline in the summer, all habitat elements but understory were found to be significant in the winter. A positive association was observed with low emergents, lawn, and canopy, whereas a negative association was observed with floating-leafed vegetation and shrubs. Such variation between seasons suggests that wading bird habitat preferences may be more seasonally dependent than other waterbird guilds, and that other habitat elements, such as water depth, or groups of habitat elements, may be associated with this guild's within-lake habitat choices.

Summer results suggest that wading birds may have been primarily responding to a combination of water depth and vegetation structure. Water depth has been frequently cited as a significant factor determining the distribution of wading birds (Hancock & Kushlan 1984, Weller 1999, Bancroft et al. 2002). In the summer, this guild was found in greatest abundance in areas of open shore. Associated littoral zones in these areas were typically dominated by open water or sparse emergent vegetation. While all lakes had shallow water margins, the predominance of emergent vegetation often prevented waders access to these areas. The lack of emergent vegetation along open shore areas, when water levels dropped, allowed wading birds to utilize these shallower waters, providing optimal foraging conditions for many of these birds (Hancock & Kushlan 1984, Breininger & Smith 1990, Bildstein et al. 1994).

In the winter, in the absence of extreme drought conditions, shallow water areas became more limited. Wading birds, in turn, may have become more generalized in their habitat selection. Given that tall emergent vegetation continued to be used less than expected, and open shore, even at just 28% of summer availability, continued to be used more than expected, these habitats may have continued to be the primary elements to which wading birds were responding. However, the abundance of significant responses to other habitat elements suggests that this guild may have been responding to combinations rather than just individual habitat elements. One such example would be low emergent/lawn habitat. Though this habitat made up 29% of significant habitat shoreline, 40% of wading birds occurring with one or more significant habitat element were found in low emergent/lawn habitat.

Diving birds

Diving birds showed a negative association with lawn in the summer and a positive association with understory in the winter. The negative association with lawn in the summer is puzzling and cannot be readily explained by the ecology of these birds or by lawn's association with other habitat elements. The positive association with understory in the summer may be the result of diving birds selecting areas where understory and canopy overlapped. Understory/canopy habitat made up 26% of significant habitat shoreline, yet 57% of diving birds were found in this area of habitat overlap. Given the ecology of these birds and the results of this study showing diving birds frequently resting in the canopy, it seems likely that they were selecting either for canopy or canopy/understory, rather than just understory alone.

Ducks

Besides showing a negative association with tall emergent vegetation and a positive association with open shore in the summer, ducks showed a positive association only with floating-leafed vegetation during both seasons. Although only two lakes had enough floating-leaf habitat for analysis, both lakes showed strong associations ($p < 0.01$). On both lakes the primary floating-leafed species was spatterdock (*Nuphar* *luteum*), a type of water lily whose leaves stand above the water. Structurally acting as a low emergent species, and occurring at high densities, this species offered exceptional cover for waterfowl, particularly Wood Ducks. Tarver et al. (1978) also noted that Spatterdock seeds may be a valuable secondary food source for waterfowl in northern Florida. Floating-leafed vegetation overlapped with open shore along 12% of significant habitat shoreline, while 25% of ducks were found where these habitats overlapped. Though not conclusive, it could not be ruled out that ducks may have also been responding to this combination of habitat elements.

Management and Future Research

More comprehensive and long-term research is strongly recommended for urban lake habitats. Further research needs to focus on whether these lakes are truly providing valuable habitat to these birds or whether they are actually acting as biological sinks. Though most birds in this study appeared to be healthy, and both marsh birds and ducks produced numerous young, the long-term effects of human impact, such as disturbance and pollution, need to be examined.

Developed shoreline around the lakes in this study clearly provided useable habitat for a variety of waterbird species, and may have actually been selected for by some species. However, the fact that over both seasons all guilds were negatively associated with tall emergent vegetation, which was predominantly found along undeveloped shoreline, suggests that it was avoidance of this habitat element that was responsible for the significantly greater proportion of birds along developed shoreline. In smaller, discrete stands, when interspersed with other plant species and patches of open water, cattail may provide habitat for a wider range of species. Weller (1999) has noted that a wide range of wetland birds prefer such “hemi-marsh” conditions. Such interspersion would increase structural habitat complexity and open up shallow areas closer to shore, creating preferred foraging habitat for many wading and dabbling birds. More detailed habitat studies should be conducted to determine optimal cattail densities for different avian species or guilds, and whether such management would be a feasible option. Currently, Florida's Bureau of Invasive Plant Management has no active management plans for this plant species.

Several onshore habitat elements were significantly associated with the distribution of waterbird guilds, indicating that terrestrial habitat may play a role in habitat selection for many of these birds. Specifically, open shore, lawn, and canopy appeared to be associated with multiple guilds. As shorelines continue to be developed, much of the natural habitat is being altered or removed both by developers and property owners. Florida Law (§369.20(7), Florida Statutes) states that "no person or public agency shall control, eradicate, remove, or otherwise alter any aquatic weeds or plants in waters of the state unless a permit for such activity has been issued by the department." There are currently no such laws protecting onshore habitat. Future studies should specifically test the degree of importance of terrestrial vegetation to waterbirds in order to determine whether this habitat needs greater protection.

Until further research is conducted, managers should consider the ecology of these birds when prioritizing habitats for protection. Since very few birds were observed nesting on these lakes (Chapt. 3), preliminary management should be based on the foraging and resting behavior of these birds. Wading birds, in general, prefer shallow, relatively open littoral zones. This study also showed potential associations with open shore and lawn. These conditions are currently often available along developed shorelines. The fact that many of the wading bird species using these lakes were found significantly more often along developed shorelines suggests that little further management may be required for this guild. Exceptions such as the Least Bittern and Green Heron should be noted though. These species often show a preference for dense, tall emergent vegetation, which was found in greater abundance along undeveloped shorelines. Management for these species should be focused there.

Marsh birds and ducks are often found in open water interspersed with mixed emergent and floating-leafed vegetation. In this study, both guilds may have selected for open shore in the summer, while marsh birds may have also been associated with lawn and understory in the winter. Many of these conditions are again being met along areas of developed shoreline, but in limited extent. Management should consider increasing low emergent and floating-leafed vegetation in developed areas lacking frequent boat traffic if increasing marsh bird and duck abundance is desired. Though nesting was not observed for these guilds, it should be noted that many marsh birds do require dense tall-emergent vegetation in the breeding season. Portions of this habitat should therefore be protected along undeveloped shoreline.

Many of the diving birds require larger areas of deeper open water for foraging, and canopy or other perching substrate for resting. Open water is currently managed for to promote lake use for fishing and other recreation. Common diving birds on these lakes, such as Anhingas and Double-crested Cormorants, often prefer resting areas immediately over the water. Developed shorelines, with their abundance of docks and boat houses, are thus well suited to these birds. However, diving birds were the one guild that did not have greater than expected numbers along developed shoreline. Management might therefore focus on protecting areas of undeveloped shoreline, as woody shoreline is more readily available there.

This project, being exploratory in nature, attempted to determine whether dominant habitat elements existed that independently explained waterbird distributions. Several elements, both aquatic and terrestrial, did indeed appear to be significantly more influential. Though tests for independence were inconclusive, many of the habitat elements selected in this study may have been correlated with one another, both spatially and perhaps functionally. Future studies would do well to examine waterbird/habitat associations at broader scales (e.g., Hostetler and Holling 2000) to investigate whether birds are responding to suites of habitat elements that comprise general macro-habitats around these lakes.

Duda (1987) found that 88% of Floridians enjoyed having birds near their homes and frequently engaged in activities to benefit them. Lake property owners should be informed of the abundance of waterbirds using the developed shorelines on their lakes. Many of these individuals might be very receptive to an education program on the value of shoreline habitat and the ways that homeowners can manage their property to meet their own needs as well as the needs of wildlife. Even with current conditions, many lakeshore residents are inadvertently creating habitat conditions favorable to many waterbirds by managing their properties for more heterogeneous littoral and onshore habitat in order to have direct lake access. State laws allow residents to clear up to 50%, or 50 ft (whichever is less) of the aquatic vegetation along their shoreline to allow for boating and other recreational access. With education, residents can learn to manage their own properties to benefit both themselves and wildlife, and may even be able to help managers improve waterbird habitat along undeveloped shorelines.

Soliciting public participation in future research, monitoring, and management efforts (i.e. citizen science) would also increase public awareness and generate a greater sense of stewardship on lands that may not have been previously thought to have much wildlife value. Citizen science can also generate valuable data sets supporting long-term monitoring efforts (Hoyer et al. 2001). The popularity of such public involvement is demonstrated by Florida LAKEWATCH, a lake-monitoring program that relies on a pool of over 1,800 trained volunteers to monitor water quality on approximately 1,200 lakes around the state. Beginning in 2001, Lakewatch incorporated aquatic-bird surveys into its monitoring program. This new wildlife component is being readily adopted by many of the volunteers and holds great promise for future research and management efforts on many of Florida's lakes.

CHAPTER 3
AVIAN BEHAVIORAL RESPONSES TO SHORELINE DEVELOPMENT

Introduction

The process of urbanization may affect birds both through changes in ecosystem processes, habitat structure, and food supply, and through changes in predation pressure, competition, and disease (Marzluff 1997). Avian responses can take two forms: changes in behavioral patterns, and changes in community composition. The majority of urban bird studies to date have examined the direct effects of development and habitat alteration on community composition by focusing on changes in avian abundance, species diversity, richness, and evenness (e.g. DeGraaf & Wentworth 1981, Tilghman 1987, Blair 1996, Clergeau et al. 1998, Jokimaki 1999, Rottenborn 1999). Very few studies have attempted to address how avian behavior is affected by development (As examples, see: Andersson et al. 1980, Galeotti et al. 1991, Gelbach 1994, Fernandez-Juricic et al. 2001).

Studies examining changes in avian behavioral patterns have focused primarily on the effects of human activity (e.g., Hockin et al. 1992, Knight & Gutzwiller 1995, Jozkowicz & Gorska-Klek 1996). Human disturbance has many negative impacts to wildlife and may ultimately reduce wildlife densities and diversity at both local and regional scales (Boyle & Samson 1985, Cole & Knight 1990). On the behavioral level, wildlife responses to disturbance may include attraction, avoidance, or habituation (Knight & Cole 1991). Attraction behavior, such as increased foraging and reduced wariness, can result from human actions like supplemental feeding (Knight & Temple 1995). Hunting typically results in avoidance behaviors such as increased wariness, altered foraging patterns, and reduced nest defense (Kenney & Knight 1992, Knight & Cole 1995). Increased flight times or increased aggression towards humans are other avoidance responses that may result from excessively close or frequent human disturbance (Knight & Temple 1986, Kahl 1991). Habituation, on the other hand, may occur in response to human disturbance when that disturbance is not associated with either a positive or negative reward (Eibl-Eibesfeldt 1970). In this case, wildlife species appear to show no signs of altered behavior in response to human presence.

A wide range of avoidance behaviors have been documented for waterbirds in response to recreationists or researchers in natural areas. Examples include reduced foraging and resting periods (Owens 1977, Kaiser & Fritzell 1984, Burger and Gochfeld 1991, Skagen et al. 1991), increased nest abandonment and egg loss (Kury & Gochfeld 1975, Tremblay & Ellison 1979, Titus & van Druff 1981), discouragement of late-nesting pairs from breeding (Ellison & Cleary 1978, Tremblay & Ellison 1979), and disruption of pair bonds (Tindle 1979) and parent-offspring bonds (Oldfield 1988). Other studies have shown that human disturbance can increase vigilance (Burger and Gochfeld 1991), flushing (Vos et al. 1985), flight times (Kahl 1991, Korschgen et al. 1985), and energy expenditure by birds and reduce their overall energy intake (Belanger & Bedard 1990).

Conversely, other studies have shown that in cases where humans are regularly present without posing an immediate threat of harm, waterbirds appear to habituate to some forms of disturbance (Hockin et al. 1992, Weller 1999). Some examples include New Zealand Dotterels (*Charadrius obscurus*) allowing closer human approach on high-use beaches (Lord et al. 2001); Great Crested Grebes (*Podiceps cristatus*) showing reduced flush distances in sites frequently visited by humans (Keller 1989); nesting

Ospreys (*Pandion haliaetus*) showing greater levels of habituation in areas of high human activity than in more remote sites (Swenson 1979, Poole 1981); Great Blue Herons (*Ardea herodias*) habituating to the activities of fishermen boating past a heronry (Vos et al. 1985); and Greylag Geese (*Anser anser*) habituating to people walking past as long as the people remained on paths (Kuhl 1979).

The objective of this portion of the study was to determine the effects of urbanized lakes on the behavioral patterns of waterbirds. The specific questions to be answered were as follows:

1. Are primary waterbird behaviors different between developed and undeveloped shoreline?
2. Which waterbirds appear most sensitive to human disturbance?

Question 1 addresses the general lack of knowledge about avian behavior on urban lakes. Many studies have compared waterbird behavior in areas of high human use with areas of low human use (e.g. Burger 1981, Keller 1989, Jozkowicz 1996), but have either been based in natural habitats such as refuges or areas where disturbed and undisturbed sites were well apart from one another.

Question 2 focuses specifically on avoidance behavior and sensitivity to human disturbance by examining which guilds appear most vulnerable to disturbance. Numerous studies have shown that sensitivity to human disturbance can vary considerably between species (e.g. Burger 1981, Bratton 1990, Klein 1993, Klein et al. 1995), with several studies showing greater sensitivity specifically in winter migrants (van der Zande et al. 1980, Klein et al. 1995). Both of these hypotheses are examined.

By understanding how waterbirds behave in urban settings and how sensitive they are to human disturbance, managers will be better equipped to balance the needs of humans and wildlife on urban lakes.

Methods

Behavioral surveys of waterbirds were conducted in the summer from June 7– August 1 of 2001 and in the winter from December 8– February 6 of 2001/2002. The term ‘waterbird’ referred to species in the orders Gaviiformes, Podicipediformes, Pelecaniformes, Ciconiiformes, Anseriformes, Falconiformes, Gruiformes, Charadriiformes, or Coraciiformes observed on or feeding from lacustrine habitats. Each of the four lakes were surveyed a total of eight times each season by driving at minimum-wake speed around the lake perimeters (20 – 30 m from shore) in a small motorized canoe. Both the order of lakes and the direction of travel were alternated for each day of surveying. Surveys were conducted within the first five hours after sunrise on mornings with little to no rain and winds less than 24 km/hr.

Lake shoreline was categorized as either developed or undeveloped based on DEP land cover classifications for each lake. Classifications were modified during preliminary surveys by basing the categorization only on the land cover within the first 20 m of shoreline extending away from the water on each lake. For the purposes of this study, developed shoreline referred to any continuous expanse of shoreline greater than 100 m, parallel to the edge of the lake, that had a minimum of 50% noticeable, long-term habitat alteration, defined as cleared land, lawns, landscaping, buildings, and roads. Undeveloped shoreline was defined as any continuous stretch of shoreline greater than 100 m, parallel to the edge of the lake, with greater than 50% intact natural habitat, and little to no sign of regular human use. Developed and undeveloped areas were separated by a buffer of 40 m to eliminate the potential effects of converging habitats. Birds recorded in these border areas were not included in analyses. In addition, behavioral analyses were not conducted on birds if their origin or destination were not observed, or if they were observed greater than 30 m offshore or 10 m onshore.

Upon sighting a bird along either developed or undeveloped shoreline, I recorded the first behavior that was observed. During preliminary surveys I found five primary behaviors: active/swimming, alert/fleeing, foraging, resting, and tending young. Active/swimming birds included those birds that were actively moving but not foraging or showing obvious signs of distress. Birds were classified as alert/fleeing if their attention appeared focused on the boat or another nearby disturbance, or if they vacated the location in which they were observed in response to the boat's approach. Foraging behavior was recorded for any bird monitoring the water, stalking, actively gleaning, or consuming prey. Birds were classified as tending young any time they were observed building or sitting on a nest, or in the presence of young, regardless of any other behaviors in which they may have been engaged. This behavior was only observed in the summer. Over the course of the two seasons, these five behaviors made up 89% of all recorded observations. Nine other behaviors were also recorded over the course of both seasons (e.g. aggression, calling, preening, etc.), but made up less than 12% of all observations. Because of the dominance of the five primary behaviors, I chose to restrict analyses to these behaviors only.

Disturbances other than the survey boat, such as anglers, jet skiers, water skiers, or people feeding birds, were also noted. In addition, several random resident contacts were made in order to estimate the use of the numerous Wood Duck (*Aix sponsa*) nest boxes observed on these lakes.

Analyses

Waterbirds were grouped into guilds for analyses. Guilds were based on foraging behavior and habitat use, and included wading birds (Ardeidae, Threskiornithidae, Ciconiidae, Recurvirostridae), marsh birds (Rallidae), surface and aerial diving birds (Podicipedidae, Phalacrocoracidae, Anhingidae, Accipitridae, Laridae), and ducks (Anatidae). Analyses were conducted for the four most commonly observed behaviors within each season. For a guild to be included in analyses for a given lake, at least 25 birds had to be observed for that lake during a season.

Shoreline Development

I examined the effect of shoreline development on guild behavior using contingency Chi-square tests ($\alpha = 0.05$, df = 1), by comparing the proportions of birds engaged in each behavior along developed and undeveloped shoreline. Expected proportions were based on the number of birds exhibiting a given behavior versus the number of birds exhibiting any other behavior, including the four focal behaviors observed each season and all other behaviors that were observed. Separate analyses were run for each lake on the four focal behaviors observed each season.

Disturbance Sensitivity

Measures of waterbird sensitivity to disturbance were based on alert/flee behavior. I tested whether the number of birds exhibiting alert/flee behavior differed significantly between seasons and between guilds. I used contingency Chi-square tests ($\alpha = 0.05$, df = 1) for comparisons between seasons, and 2x4 contingency Chi-square tests ($\alpha = 0.05$, df = 3) for comparisons between guilds. Expected proportions were based on the number of birds exhibiting alert/flee behavior versus the number of birds exhibiting any other behavior. Lakes were tested individually for both tests, with developed and undeveloped shorelines combined. Summer and winter data were combined for comparisons between guilds.

Using contingency Chi-square tests ($\alpha = 0.05$, df = 1), I also tested whether winter migrant species showed greater alert/flee behavior than resident species of the same guilds. Analyses were run on winter data for all lakes combined due to low numbers on individual lakes.

Determining Overall Significance

For all analyses conducted on a lake-by-lake basis, behavioral patterns were considered to have overall significance where significant same-direction associations ($p \leq 0.05$) were observed on at least three lakes without a significant contradictory finding on the fourth lake. In a season, if a guild was only observed with enough frequency for analysis on two lakes, then behavioral patterns were considered to have overall significance if both of the lakes had significant same-direction associations ($p \leq 0.05$). In cases where results were suggestive of an overall pattern on three or more lakes ($p \leq 0.2$ for each lake), but not necessarily significant, and a contradictory finding wasn't found on the fourth lake, probabilities (for lakes indicating a pattern) were then combined for meta-analysis (Fisher 1958). A two-tailed Fisher's exact test ($\alpha = 0.05$) was applied to all analyses where expected values dropped below five.

Results

Seasonal Behavioral Observations

In the summer, a total of 2817 behavioral observations were recorded for the four study guilds (Table 3-1). The four most common behaviors were alert/fleeing, foraging, resting, and tending young. Resting was the most commonly recorded behavior, accounting for 32% of all observations. Foraging birds accounted for 26% of behavioral observations, followed by alert/fleeing birds (18%), and birds tending young (10%). All other behaviors accounted for 14% of recorded observations.

In the winter, 2438 behavioral observations were recorded for the four focal guilds (Table 3-1). Alert/fleeing behavior was most commonly recorded, accounting for 33% of all observations. Resting behavior was observed in 26% of all birds, followed by foraging (23%), and active/swimming (12%).

Table 3-1. Percent of waterbird guilds engaged in focal behaviors during summer (S) 2001 and winter (W) 2001/2002.

Guild	**n**		**Alert/ Flee (%)**		**Forage (%)**		**Rest (%)**		**w/ Young (%)**	**Active/ Swim (%)**
	S	**W**	**S**	**W**	**S**	**W**	**S**	**W**	**S**	**W**
Waders	662	530	10	10	54	35	26	5	1	2
Marsh	673	723	5	19	46	46	6	5	23	26
Divers	299	361	11	23	2	68	83	68	0	6
Ducks	1183	671	31	67	4	2	38	8	9	9

n = total number of birds observed each season

Behavioral Associations with Shoreline Development

Alert/flee behavior

Alert/flee behavior showed an overall pattern of significant association with undeveloped shoreline for ducks in the summer (Table 3-2) and wading birds in the winter (Table 3-3). Across all lakes in the summer, 72% (n=89) of the ducks found along undeveloped shoreline displayed alert/flee behavior. On the two lakes where ducks were found with enough frequency for analysis, they displayed alert/flee behavior significantly more along undeveloped shoreline (both tests: $\chi^2 \geq 28.98$, $p < 0.0001$). Thirty-three percent of all wading birds found along undeveloped shoreline in the winter displayed alert/flee behavior (n=54). Wading birds displayed this behavior significantly more along undeveloped shoreline on three of the four lakes (all tests: $\chi^2 \geq 8.7$, $p \leq 0.012$).

Possible trends were observed in the summer for wading birds, marsh birds, and diving birds (Table 3-2). Both wading birds and marsh birds showed increased alert/flee behavior along undeveloped shoreline on two lakes (all tests: $\chi^2 \geq 2.74$, $p \leq 0.12$), whereas diving birds showed increased alert/flee behavior along developed shoreline on two lakes (both tests: $\chi^2 \geq 2.59$, $p \leq 0.14$).

Foraging behavior

Fifty-eight percent of the wading birds (n=512) observed along developed shoreline in the summer were engaged in foraging behavior (Table 3-2). Foraging wading birds showed a significant overall preference for developed shoreline on three lakes (meta-analysis: $\chi^2 = 27.07$, $p < 0.001$). The same preference was observed in the winter, but only on two lakes, and therefore lacked overall significance. Winter marsh birds displayed a significant overall preference for foraging along undeveloped shoreline on three lakes (meta-analysis: $\chi^2 = 13.78$, $p = 0.03$). Overall, 51% of wintering marsh birds (n=74) found along undeveloped shoreline were engaged in foraging behavior.

Resting behavior

In the summer, on the two lakes with sufficient duck numbers, ducks showed a significant preference for resting along developed shoreline (Table 3-2; both tests, $\chi^2 \geq 11.35$, $p < 0.001$). Overall, 40% of the ducks (n=1094) observed along developed shoreline were engaged in this behavior, versus just 4% along undeveloped shoreline. Though lacking overall significance, diving birds appeared to show a weak trend of resting in greater proportions along undeveloped shoreline in the summer ($\chi^2 \geq 2.59$, $p \leq 0.14$ on two lakes).

Tending young behavior

During the summer, 100% (n=111) of ducks tending young did so along developed shoreline (Table 3-2). On both lakes where ducks were observed with enough frequency for analysis ($n \geq 25$), they tended young significantly more along developed shoreline (both tests: $\chi^2 \geq 4.17$, $p \leq 0.04$). The only wading birds observed tending young were two pairs of Green Herons (*Butorides virescens*) on Lake Buckeye. No diving birds were observed tending young on any of the lakes.

Active/swim behavior

During the winter, a significant overall pattern of association was observed between active/swimming marsh birds and developed shoreline (Table 3-3). Twenty-eight percent (n=676) of the marsh birds found along developed shoreline were observed engaged in active/swim behavior, versus only 9% along undeveloped shoreline. This pattern was observed on all four lakes (meta-analysis: $\chi^2 = 27.98$, $p < 0.001$).

Human Activity

Though not quantified, the level of human activity on or immediately around all four lakes appeared relatively low during both seasons. Given that surveys were typically conducted during the week, and that the summer drought made lake access very difficult, the amount of activity that was observed was no doubt considerably lower than at peak times such as weekends during peak fishing season. High-intensity recreational activities such as water skiing or jet skiing were not observed. Though fishing from boats appeared to be the most common recreational activity, no more than four boats were ever encountered on a lake at one time. Anglers were typically found slowly trolling along undeveloped shoreline, fishing along edges of emergent or floating-leaf vegetation, and were rarely observed disturbing or displacing waterbirds. No land-based human activity was observed along undeveloped shorelines. Human activity along developed shorelines included feeding ducks and marsh birds, fishing and relaxing on piers, fishing from boats, lawn mowing, golf cart operation, construction, and small aircraft departure and arrival.

Several informal interviews with local residents who had Wood Duck nest boxes on their properties revealed that many of these boxes were used on a yearly basis, and frequently produced successful broods.

Table 3-2. Percent guild behavioral responses to developed (D) and undeveloped (U) shoreline for summer 2001. Results listed by lake.

Guild	**n**		**Alert/Flee**		**Forage**		**Rest**		**w/Young**	
	D	**U**	**% D**	**% U**	**% D**	**% U**	**% D**	**% U**	**% D**	**% U**
Waders										
Buckeye	52	29	23	14	29	41	31	41	12*	0
Conine	212	68	8	16*	71**	43	17	28*	-	-
Deer	141	17	6	18*	52*	29	27	29	-	-
Jessie	107	36	7	11	52*	39	33	28	-	-
Marsh										
Buckeye	137	21	4	33*	39	52	3	5	33**	0
Conine	48	28	6	11	50	61	19	21	-	-
Deer	283	22	2	23*	52*	36	4	5	23	14
Jessie	113	21	2	0	37	48	4	5	34	38
Divers										
Buckeye	21	6	38*	0	-	-	57	100*	-	-
Conine	50	38	12*	3	4	3	78	89*	-	-
Deer	61	11	3	0	-	-	93	91	-	-
Jessie	57	55	14	16	-	-	82	78	-	-
Ducks										
Buckeye	2	7	-	-	-	-	-	-	-	-
Conine	15	0	-	-	-	-	-	-	-	-
Deer	725	50	25	60**	3	0	43**	4	10**	0
Jessie	352	32	36	88**	5	0	36**	7	12**	0

n = total number of birds observed along developed and undeveloped shoreline. * Trend suggesting greater percentage of guild displayed behavior along indicated shoreline ($p \leq 0.2$). ** Significantly greater percentage of guild displayed behavior along indicated shoreline ($p < 0.05$). Dash indicates less than 25 birds observed on lake or no birds observed exhibiting behavior.

Table 3-3. Percent guild behavioral responses to developed (D) and undeveloped (U) shoreline for winter 2001/2002. Results listed by lake.

Guild	n		Alert/Flee		Forage		Rest		Active/Swim	
	D	U	% D	% U	% D	% U	% D	% U	% D	% U
Waders										
Buckeye	71	13	8	38**	61**	8	24	46*	6	8
Conine	133	14	9	36**	26	14	62*	36	1	7*
Deer	127	1	4	0	28	0	66	100	2	0
Jessie	152	26	7	31**	43**	19	47	50	1	0
Marsh										
Buckeye	57	19	25	32	25	42*	9	11	39*	16
Conine	78	20	13	25	33	50*	9	5	41*	20
Deer	442	24	19	42**	50	46	5	4	23**	0
Jessie	99	11	8	9	49	82**	3	9	34**	0
Divers										
Buckeye	52	32	17	22	-	-	75	72	8	3
Conine	58	13	19	23	3	0	71	69	5	8
Deer	56	3	43	67	-	-	41	33	16	0
Jessie	99	51	15	27*	3	0	77	73	4	0
Ducks										
Buckeye	5	9	100	56	-	-	-	-	0	44
Conine	25	2	0	100**	-	-	-	-	100**	0
Deer	629	19	66	68	2	0	8	0	7	0
Jessie	88	10	90	100	-	-	10	0	-	-

n = total number of birds observed along developed and undeveloped shoreline. * Trend suggesting greater percentage of guild displayed behavior along indicated shoreline ($p \leq 0.2$). ** Significantly greater percentage of guild displayed behavior along indicated shoreline ($p < 0.05$). Dash indicates less than 25 birds observed on lake or no birds observed exhibiting behavior.

Disturbance Sensitivity

Seasonal alert/flee comparisons

Guild analyses comparing alert/flee behavior between seasons showed a significant increase in alert/flee behavior in the winter for marsh birds and ducks (all tests: $\chi^2 \geq 6.2$, $p \leq 0.01$). Diving birds showed a similar trend, with birds on two lakes showing significantly greater alert/flee behavior in the winter (both tests: $\chi^2 \geq 4.73$, $p \leq 0.03$). The proportion of wading birds displaying alert/flee behavior did not change between seasons

($\chi^2 \geq 0.11$, $p \leq 0.74$). Across all guilds, alert/flee behavior was observed 1.6 times more often in the winter.

Inter-guild alert/flee comparisons

Ducks showed a significant pattern of greater alert/flee behavior than other guilds on three lakes (all tests: $\chi^2 \geq 61.2$, $p < 0.0001$). With all lakes combined, 32% (n=1183) of summer ducks (95% of which were Wood Ducks) displayed this behavior. Sixty-seven percent (n=787) of winter ducks displayed alert/flee behavior. Winter ducks included Wood Ducks, Blue-winged Teal (*Anas discors*), and Ring-necked Ducks (*Aythya collaris*). In both seasons, the next closest guild was diving birds, which displayed alert/flee behavior in 11% (n=299 for summer) and 25% (n=345 for winter) of all observations. Diving birds actually displayed alert/flee behavior considerably more than results indicate. However they appeared to tolerate a much closer approach distance than ducks before displaying alert/flee behavior (pers. obs.), and thus their first observed behavior was typically something other than the alert/flee response. Ducks on the other hand, tended to become alert or flee from the boat's approach even from substantial distances (> 50 m) (pers. obs.).

Migrant versus resident alert/flee comparisons

Six out of seven winter migrant species were either ducks or diving birds. Alert/flee behavior was compared between migrant and resident species of these guilds. Analyses for all lakes combined failed to show a significant difference for either guild (both tests: $\chi^2 \geq 0.13$, $p \leq 0.72$). Of note though was that only 1% of winter migrants were found using undeveloped shoreline.

Discussion

Avian Responses to Shoreline Development

Alert/flee behavior

Alert/fleeing behavior was observed significantly less along developed shoreline on the majority of lakes for summer ducks and winter wading birds. Though no other guilds showed overall significance, trends suggest that this pattern was the case for all guilds over both seasons (except summer divers). The findings suggest that many of the birds on these lakes showed localized habituation to human disturbance, tolerating such disturbance only along developed shoreline. Numerous other studies have noted patterns of apparent habituation in areas where waterbirds are regularly exposed to moderate or high levels of human activity. In her study of Great Crested Grebes (*Podiceps cristatus*), Keller (1989) found reduced flush distances for birds in sites frequently visited by humans. Lord et al. (2001) found that New Zealand Dotterels (*Charadrius obscurus*) nesting on high-use beaches allowed closer approach distances before flushing than birds nesting on remote beaches. Vos et al. (1985) found that Great Blue Herons were highly sensitive to disturbance early in the nesting season, but otherwise appeared to habituate to repeated non-threatening activities. And Burger and Galli (1987) found that the proportion of gulls fleeing when disturbed was greater in areas of infrequent disturbance than in heavily disturbed areas. However, the fact that summer diving birds showed a trend of greater alert/flee behavior along developed shoreline emphasizes that not all species may habituate.

In the previous studies mentioned above, disturbed and undisturbed sites were separate and unique. In this study disturbed and undisturbed sites were juxtaposed on the same lake for each of the four lakes sampled. The findings show that individual birds within a guild, ducks and waders in particular, may differentiate between disturbed and undisturbed sites even at a very localized scale. Even where undeveloped shoreline made up as little as 1/5 of the total habitat, such as on Lake Deer, wading birds (summer), ducks (summer), and marsh birds (both seasons) still showed greater sensitivity to disturbance in this habitat. This implies that undeveloped shoreline meets a behavioral need of at least some individuals, and may be seen as a localized refuge from disturbance. Results suggest that perhaps even small areas of undeveloped shoreline are important in order to minimize the stress to these birds.

It may be that some individuals that are less tolerant to disturbance only use undeveloped shoreline. Alternatively, those same individuals may utilize both undeveloped and developed shoreline. To determine this, individual behavioral observations were required, which were beyond the scope of this study.

Foraging and resting behavior

Wading birds selected developed shoreline for foraging in the summer. The removal of emergent and shoreline vegetation by property owners on these lakes most likely promoted foraging conditions favorable to these birds (Chapt. 2). Large expanses of relatively open shallow water were favored by stalking waders, such as herons and egrets, while open moist shoreline was utilized by probing birds, such as ibis. Both shallow open water and open shore were extremely limited along undeveloped shorelines (Chapt. 2). The greater overall significance observed in the summer was most likely linked to the extreme drought conditions during this study, which served to greatly increase the availability of this foraging habitat.

Marsh birds selected undeveloped shoreline for foraging in the winter. Rallids, in general, have strong seasonal shifts in diet, foraging primarily on animal matter in the summer and plant matter in the winter (Elphick et al. 2001). This shift in diet may have facilitated a winter shift to undeveloped shoreline, where greater densities of littoral vegetation were found (Chapt. 2).

Ducks showed a strong preference for resting along developed shoreline in the summer. This serves as another indication of this guild showing an increased tolerance for human disturbance along developed shoreline. That summer diving birds showed a trend in the opposite direction reiterates the idea that this guild, or least the year-round resident species in this guild, may not be as tolerant as other species.

Tending young behavior

During the summer, 93% of ducks that tended young did so along developed shoreline. This pattern suggests that either the value of developed shoreline habitat or the disadvantages of undeveloped shoreline habitat strongly outweighed the disadvantages of human disturbance. This was best exemplified by the Wood Duck. Despite being one of the most sensitive species in this study in terms of alert/fleeing behavior (see Disturbance Sensitivity below), Wood Ducks were reported to consistently use the next boxes located on numerous lakeshore properties. Wood Ducks are known to readily use artificial nest boxes often located in or around human-populated areas. Further, all Wood Ducks observed tending young in this study were found along developed shoreline.

Previous studies have shown that areas of developed lake shoreline have significantly lower fish species richness and total abundance than natural areas (Guillory et al. 1979, Bryan & Scarnecchia 1992). Other studies have shown the importance of dense stands of emergent vegetation as breeding areas and nurseries for fish and invertebrates (Wegener et al. 1973, Barnett & Schneider 1974). Given these findings and the fact that no significant differences were found in the amount of foraging observed along developed and undeveloped shorelines for either marsh birds or ducks (the two guilds observed with young), it seems unlikely that the greater abundance of birds tending young along developed shoreline can be explained by better foraging opportunities. However, on several occasions lake residents were observed putting out corn and bread for the birds. If this supplemental feeding occurred on a large enough scale, this could help explain the apparent preference for developed shoreline. In a review of urban bird studies over the past 100 years, Marzluff (2001) found 29 studies that linked supplemental feeding with increased bird densities in developed areas. Alternative possibilities that could explain this pattern include easier predator detection and reduced natural predators along developed shorelines.

The timing of this study did not coincide with the nesting season of most of these birds. Observed tending young behavior therefore consisted of interactions between parents and fledglings. Further research is needed to determine which habitats breeding birds use for nesting on these lakes. Several of the species in this study, including Common Moorhens, Purple Gallinules, Rails, Soras, Least Bitterns, and Green Herons, are either facultative or obligate emergent vegetation nesters (Terres 1991). Three of these species were found actively nesting in emergent habitat in a previous study of neighboring urban lakes (Roth, in press). Many wading birds as well as the Anhinga nest colonially in shrubs or trees close to waterbodies (Hancock & Kushlan 1984, Elphick et al. 2001). Considering that both emergent vegetation and woodlands were found in considerably greater abundance along undeveloped shorelines, and that many birds are least tolerant of disturbance at the beginning of the nesting season (Hockin et al. 1992), it seems likely that many of the birds in this study would have selected undeveloped shorelines for nesting.

With few exceptions, wading birds and diving birds did not appear to breed or raise young on these lakes. One possibility is that these guilds were so intolerant of human disturbance during the breeding season that they sought out altogether less disturbed habitats for nesting and rearing young. Miller (1943) suggested that distance from human activity was the most important factor in heron nest site selection. However, numerous studies have documented these guilds breeding in disturbed or developed areas (e.g. Robertson & Flood 1980, Titus & Van Druff 1981, Vos et al. 1985, Keller 1989). Further, in a similar study on neighboring developed lakes, Roth (in press) found heron rookeries along the edges of several of his lakes.

Another possible scenario is that wading and diving birds did not breed on these lakes due to the extreme drought. Several studies have shown that in cases of extreme water regimes, waterbird nesting has been delayed (Weller & Spatcher 1965, Custer et al. 1996), abandoned (Breeden & Breeden 1982), or moved to more favorable sites (Weller 1999). This is just speculation however, and there are a variety of other factors, such as the limited amount of undeveloped habitat, and the composition of this habitat, that may have been unfavorable to these birds.

Active/swimming behavior

Active/swimming behavior, examined only in the winter, was seen significantly more along developed shoreline in marsh birds. Active/swim behavior can be viewed as a low-distress behavior, as opposed to alert/flee, and as such may be another indication of habituation among these birds along developed shoreline. All three of the common marsh bird species observed, the Common Moorhen, Purple Gallinule, and American

Coot, are known to become relatively tame, and even quite bold in developed areas if left unmolested (Terres 1991, Elphick et al. 2001, West & Hess 2002).

In some instances this perceived behavior may have actually been an effort to slowly move away from my boat. These cases may have represented a stage in a process of habituation, where the birds were not entirely tolerant of disturbance, but did not feel threatened enough to rapidly flee the area.

Disturbance Sensitivity

Seasonal alert/flee response

Results of this study revealed that waterbirds on these lakes displayed alert/flee behavior 1.6 times more often in the winter than in the summer. Though several studies have examined waterbird behavior across seasons (Burger 1981, Klein 1993, Klein et al. 1995), to my knowledge, no previous studies have attempted to quantify the degree of variation in sensitivity to disturbance between seasons. The significant increase in alert/flee behavior in marsh birds, diving birds, and ducks supports the idea that avian disturbance sensitivity has a strong seasonal component. In general, there is a significantly greater cost involved in failing to protect a nest and young during the breeding season than there is in failing to defend temporary foraging and loafing sites at other times of the year (Rodgers and Smith 1997). Thus, birds may be more likely to temporarily abandon a preferred foraging or resting location in the non-breeding season. However, an increase in alert/flee behavior is not necessarily an indication of increased sensitivity to disturbance. In attempting to raise and ensure the survival of young during the breeding season, birds must meet some of their greatest energy demands of the year. Such physical demands may be mirrored in the amount of stress these birds undergo. If breeding birds are facing at a minimum the same amount of stress that wintering birds are facing, one could conclude that they would be equally sensitive to disturbance. Since this sensitivity is not indicated through overt responses such as alert/flee behavior, these birds may be enduring high levels of physiologically manifested stress, such as increased heart rate, temperature, and blood sugar that could reduce their overall fitness (Gabrielsen & Smith 1995).

The alternative, that birds are more easily stressed in the non-breeding season, suggests that urban lakes may act as an energy drain for birds during this season. Even if waterbirds are normally easily stressed in the non-breeding season, due to forces such as a fluctuating food supply or simple “flightiness,” they are more likely to encounter disturbances in an urban environment that might trigger an alert/flee response. Such a response may incur numerous negative physiological responses, increase energy expenditures, reduce foraging times, and reduce overall fitness (Knight & Cole 1995).

Inter-guild alert/flee comparisons

Ducks showed significantly greater alert/flee behavior than other guilds in response to the approach of the survey boat. This reinforces the results of other studies that have documented a significant variation between waterbird species in sensitivity to human disturbance (Batten 1977, Burger 1981, Vaske et al. 1983, Klein 1993, Klein et al. 1995, Rodgers & Smith 1997, Rodgers & Schwikert 2002). Though Klein et al. (1995) found migratory dabbling ducks showed the most consistent patterns of avoidance of human visitors, no other studies have found this guild to be uniformly more sensitive to disturbance than other species. Wood Ducks comprised over 80% of all duck observations in this study. Previous studies have shown that this species will readily nest in urban environments (Hepp & Bellrose 1995). The heightened alert/flee behavior observed in these birds might represent an evolving process of habituation, where the birds originally adopted these human-dominated environments out of necessity, but are not yet entirely tolerant of the conditions. A similar process has been suggested for both the Common Loon (*Gavia immer*) and the Great Crested Grebe (Titus & Van Druff 1981, Keller 1989).

Migrant versus resident alert/flee response

The proportion of winter migrants that responded to human disturbance with alert/flee behavior was not significantly greater than that of resident species. This fails to confirm the results of van der Zande et al. (1980), Burger (1981), Burger and Gochfeld (1991), and Klein et al. (1995), which consistently showed migrant waterbirds displaying a greater sensitivity to human disturbance than resident birds. One possible explanation is that the winter migrants arriving on urban lakes came from summer breeding grounds that were also disturbed and thus they had already developed a tolerance. Previous studies (above) were conducted in more natural habitats. If the winter migrants arriving in those areas came from undisturbed breeding grounds, they may have not been habituated to human disturbance upon arrival. The previous studies also found increased disturbance sensitivity primarily in migrant waterfowl and shorebirds, whereas the majority of migrants in this study consisted of diving birds. Another explanation can be seen in studies that have shown distinct variation in sensitivity to disturbance between individuals of the same species (Klein 1993, Klein et al. 1995). If this were the case, less tolerant individuals would frequent less disturbed areas. In this study however, only 1% of migrant birds were found along undeveloped shoreline. It may be that only highly tolerant individuals (both migrants and residents) are attracted to urban lakes to begin with and that they are fairly habituated to humans.

Management and Future Research

Clearly there are a wide range of factors that are associated with the behavioral patterns of waterbirds in urban environments. Season, development and changes in habitat complexity, disturbance levels, and individual guild and species' tolerances are just a few examples. Managing for all of these variables is neither practical nor feasible for most local or state agencies. Nor would a litany of restrictions be acceptable to local residents. Though further research is needed on a greater number and variety of lakes before specific management recommendations should be made, several general recommendations are worth considering.

Waterbird behavior does appear to be associated with shoreline development, and undeveloped shoreline may serve as an important refuge for birds that are more sensitive to human disturbance or developed habitat. For example, significantly more wintering marsh birds were observed foraging on undeveloped shoreline. Further, some guilds had heightened alert/flee behavior on undeveloped shoreline, such as ducks (summer) and waders (winter), which may indicate that some portion of these populations consists of individuals that have not habituated to humans. The preservation of undeveloped shoreline, preferably in larger contiguous patches, should therefore be considered in future lake development plans.

Until more detailed habitat studies are conducted in urban aquatic environments, developers should use the general ecology of the waterbird guilds that they hope to attract as a guide for selecting areas of shoreline to preserve. Examples of foraging habitat include areas of shallow, relatively open littoral zones for wading birds, open water interspersed with mixed emergent and floating-leafed vegetation for ducks and marsh birds, and larger areas of deeper open water for diving birds. Examples of nesting and loafing habitat include shrubby or wooded shoreline for wading and diving birds, stands of dense tall-emergent vegetation for marsh birds, and areas of floating-leafed vegetation for ducks.

Likewise, residents wishing to increase waterbird biodiversity on urban lakes have many options available to them. Adding Wood Duck boxes on residential properties may increase nesting by this species along developed shorelines. Providing perching substrates separate from high human-use areas such as docks might reduce disturbance to resting diving birds and decrease unwanted fouling of docks. Ducks and marsh birds may also be encouraged to forage along developed shorelines by planting species of native emergent and floating-leafed vegetation typically found in their diet. Lists of such plants are often available through local birding groups, state wildlife agencies, or state extension offices. These resources may also be able provide residents with a better understanding of the general behavior of many of these species and how best to limit negative interactions.

There has been considerable research examining the potential use of buffer zones to protect waterbirds from undue disturbance (Rodgers & Smith 1995, 1997, Rodgers & Schwikert 2002). Buffer zones are impractical though along developed shorelines where residents require lake access and desire the freedom to engage in a variety of activities on their own property. If birds do indeed habituate at a local scale along developed shorelines, then buffer zones may only be required along undeveloped portions of shoreline. Given the overall elevated alert/flee behavior observed in the winter, buffers in the non-breeding season may be warranted. However, further research is needed to examine fluctuations in sensitivity to disturbance throughout the winter season. Further research is also needed to determine nesting areas around urban lakes and whether breeding season buffers are needed. Future studies should be conducted in years with less extreme water conditions and examine where exactly birds are nesting on these lakes and to what degree their tolerance of human disturbance fluctuates during the breeding season.

Further research on foraging and resting behaviors is needed for waterbirds in urban environments. Previous studies have suggested that sensitive species may find a lack of adequate foraging or loafing sites as their preferred habitats become developed and disturbances increase (Skagen et al. 1991, Pfister et al. 1992). This has been corroborated, at least in terms of foraging opportunities, by studies that have shown lower fish species richness and abundance along areas of developed lake shoreline (Guillory et al. 1979, Bryan & Scarnecchia 1992). Though I found no difference in the proportion of birds foraging along developed and undeveloped shorelines, other measures, such as foraging times, prey selection, or strike/capture ratios, may better show the value of this habitat for foraging birds, and should be examined in the future.

More comprehensive and long-term research is also strongly recommended for urban lake habitats. Much work has been devoted to passerines in terrestrial systems such as parks and the urban rural gradient (e.g. Blair 1996, Clergeau et al. 1998, Fernandez-Juricic 2001). Urban aquatic systems have received far less attention, and studies typically have been of relatively short duration; no more than a season or two. Repeated case studies are needed to determine whether these birds are indeed adapting to human-manipulated environments and whether such environments are acting as functional habitat or merely as sinks. The urban rural gradient also needs to be examined for lacustrine habitats, comparing waterbird behaviors across varying levels of shoreline development. Additionally, though Hoyer & Canfield (1990, 1994) showed that higher trophic state lakes are positively correlated with waterbird abundance, the popularity of oligotrophic lakes for development (Hoyer, pers. comm.) indicates that future studies should look at urban lakes covering a range of trophic states. Such studies would allow us to better understand the effects of residential development and thus better plan for limiting our impact in future growth.

In general, research with potential for direct application (e.g. urban studies), should be organized to be as approachable as possible to planners and managers. Research at the guild level can be much more readily applied to management efforts. While species-level studies are critical in determining birds that appear most vulnerable to development and disturbance, managing on a species by species basis requires tremendous effort and often has conflicting priorities. Research and management that focuses at the guild level, when based on sound science, should yield greater species richness and waterbird abundance with the least amount of management. Many waterbird behavioral studies have examined entire communities at the species level, occasionally grouping birds by size or seasonal distribution. Comparing ecological functional groups of any kind should be considered in future studies to allow for the results to be more easily applied to management efforts.

APPENDIX A
WINTER HAVEN WATERBIRD SURVEY DATA

Table A-1. Aquatic bird species observed on lakes Buckeye (B), Conine (C), Deer (D), and Jessie (J) in Winter Haven, Florida, summer 2001 and winter 2001/2002.

Species	Scientific Name	Res[1]	Lake							
			Buckeye		Conine		Deer		Jessie	
			S	W	S	W	S	W	S	W
Diving Birds										
Pied-billed Grebe	*Podilymbus podiceps*	W	5	19	8	8	15	10	8	8
Brown Pelican[S]	*Pelicanus occidentalis*	Y	0	0	1	0	0	0	0	0
D-C Cormorant	*Phalacrocorax autitus*	W	3	332	40	309	10	41	25	64
Anhinga	*Anhinga anhinga*	Y	29	68	54	26	77	37	99	68
Osprey	*Pandion haliaetus*	Y	7	11	34	21	11	3	30	14
Ring-billed Gull	*Larus delawarensis*	W	0	33	0	36	0	67	0	23
Caspian Tern	*Sterna caspia*	W	0	0	0	5	0	2	0	1
Forster's Tern	*Sterna fosteri*	W	0	4	0	0	0	0	0	0
Least Tern[T]	*Sterna antillarum*	S	1	0	0	0	0	0	14	0
Belted Kingfisher	*Ceryle alcyon*	W	0	4	0	15	0	7	2	10
Wading Birds										
Least Bittern	*Ixobrychus exilis*	S	9	0	1	3	6	0	3	0
Great Blue Heron	*Ardea herodias*	Y	13	24	67	42	33	7	52	39
Great Egret	*Ardea alba*	Y	4	11	26	11	22	18	21	14
Snowy Egret[S]	*Egretta thula*	Y	1	3	29	10	3	0	33	5
Little Blue Heron[S]	*Egretta caerulea*	Y	1	4	4	2	8	14	2	4
Tricolored Heron[S]	*Egretta tricolor*	Y	7	8	28	14	19	22	15	11
Cattle Egret	*Bubulcus ibis*	Y	1	1	0	6	0	31	5	35
Green Heron	*Butorides virescens*	Y	48	11	24	1	21	3	16	2
B-C Night Heron	*Nycticorax nycticorax*	Y	0	0	0	0	0	0	2	9
White Ibis[S]	*Eudocimus albus*	Y	7	35	112	69	60	91	23	144
Glossy Ibis	*Plegadis falcinellus*	S	0	0	31	0	0	0	0	0
Wood Stork[E]	*Mycteria americana*	Y	0	0	2	1	6	2	1	0
Limpkin[S]	*Aramus guarauna*	Y	4	3	0	0	4	0	1	0
Sandhill Crane[T]	*Grus canadensis*	Y	0	0	12	2	0	0	0	0
Black-Necked Stilt	*Himantopus mexicanus*	S	0	0	2	0	0	0	0	0
Ducks (wild)										
Wood Duck	*Aix sponsa*	Y	11	22	15	27	808	334	396	106
Mallard	*Anas platyrhnchos*	Y	0	0	6	2	0	0	50	0
Blue-winged Teal	*Anas discors*	W	0	5	0	0	0	5	0	0
Ring-necked Duck	*Aythya collaris*	W	0	0	0	0	0	357	0	0

Appendix A, continued.

Species	Scientific Name	Res[1]	Lake							
			Buckeye		Conine		Deer		Jessie	
			S	W	S	W	S	W	S	W
Marsh Birds										
Rail	*Rallus sp.*	Y	0	0	1	0	0	0	0	0
Sora	*Porzana carolina*	W	0	0	1	0	0	0	0	0
Purple Gallinule	*Porphyrula martinica*	Y	2	5	2	0	137	97	0	0
Common Moorhen	*Gallinula chloropus*	Y	171	81	83	73	177	206	153	94
American Coot	*Fulica americana*	W	0	0	0	26	1	169	0	22
Other										
Domestic Goose	*Anser domesticus*	Y	0	0	0	0	0	0	29	22
Domestic Duck	*Anas domesticus*	Y	5	7	6	4	0	0	31	17
Bald Eagle[T]	*Haliaeetus leucocephalus*	W	0	2	0	0	0	1	0	0
Killdeer	*Charadrius vociferous*	Y	0	0	12	5	0	0	2	11

[S] State listed as Species of Special Concern, [T] State listed as Threatened, [E] State and federally listed as Endangered. [1]Residence: S=summer resident, W=winter migrant, Y=year- round resident.

APPENDIX B
WINTER HAVEN WATERBIRD HABITAT DATA

Table B-1. Wading bird habitat associations, summer 2001. Expected values based on availability of habitat elements on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	9	4.13	4.87	0.027*	+
	Conine	40	39.22	0	1	
	Deer	73	59.78	4.73	0.03*	+
	Jessie	48	64.44	7.26	0.007*	+
Tall E	Buckeye	44	47.71	0.53	0.467	
	Conine	120	192.03	110.55	<0.0001*	-
	Deer	57	94.92	45.81	<0.0001*	-
	Jessie	32	65.99	31.94	<0.0001*	-
Floating	Buckeye	27	30.21	0.38	0.538	
	Conine	n/a	n/a	n/a	n/a	
	Deer	112	116.06	0.64	0.424	
	Jessie	n/a	n/a	n/a	n/a	
Shore	Buckeye	29	27.14	0.1	0.752	
	Conine	189	92.60	156.66	<0.0001*	+
	Deer	38	19.32	19.89	<0.0001*	+
	Jessie	55	46.81	1.82	0.177	
Lawn	Buckeye	28	33.86	1.46	0.227	
	Conine	69	37.90	29.09	<0.0001*	+
	Deer	76	75.78	0	1	
	Jessie	62	66.83	0.53		
Understory	Buckeye	35	46.89	7.08	0.008*	-
	Conine	135	153.45	6.48	0.01*	-
	Deer	87	57.91	25.94	<0.0001*	+
	Jessie	91	65.94	17.29	<0.0001*	+
Shrub	Buckeye	49	50.14	0.02	0.888	
	Conine	124	12.30	25.42	<0.0001*	+
	Deer	64	52.48	3.92	0.048*	+
	Jessie	64	65.99	0.06	0.806	
Canopy	Buckeye	53	38.80	9.29	0.002*	+
	Conine	37	22.68	9.25	0.002*	+
	Deer	32	48.26	8.25	0.004*	-
	Jessie	24	43.57	12.08	<0.001*	-

+/- Significant positive or negative association with habitat element.

Table B-2. Wading bird habitat associations, winter 2001/2002. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	46	4.90	354.84	<0.0001*	+
	Conine	84	23.87	176.28	<0.0001*	+
	Deer	52	55.08	0.21	0.647	
	Jessie	95	69.92	15.91	<0.0001*	+
Tall E	Buckeye	39	56.54	12.5	<0.001*	-
	Conine	68	116.89	83.11	<0.0001*	-
	Deer	36	87.46	92.21	<0.0001*	-
	Jessie	53	71.60	8.61	0.003*	-
Floating	Buckeye	19	35.81	11.85	<0.001*	-
	Conine	1	1.08	0	1	
	Deer	88	106.94	18.6	<0.0001*	-
	Jessie	1	2.91	0.69	0.406	
Shore	Buckeye	9	2.11	19.75	<0.0001*	+
	Conine	35	25.10	4.21	0.04*	+
	Deer	1	1.28	0	1	
	Jessie	39	14.38	44.64	<0.0001*	+
Lawn	Buckeye	73	40.13	44.88	<0.0001*	+
	Conine	73	23.25	122.84	<0.0001*	+
	Deer	116	75.78	51.04	<0.0001*	+
	Jessie	115	72.522	46.2	<0.0001*	+
Understory	Buckeye	61	58.46	0.18	0.671	
	Conine	93	104.10	3.33	0.068	
	Deer	80	58.37	14.06	<0.001*	+
	Jessie	58	72.06	4.82	0.028*	-
Shrub	Buckeye	47	59.42	6.28	0.012*	-
	Conine	49	99.79	72.01	<0.0001*	-
	Deer	49	52.48	0.29	0.59	
	Jessie	52	71.60	9.58	0.002*	-
Canopy	Buckeye	74	45.98	31.61	<0.0001*	+
	Conine	18	13.86	1.05	0.306	
	Deer	82	48.26	36.76	<0.0001*	+
	Jessie	58	47.28	3.2	0.074	

+/- Significant positive or negative association with habitat element.

Table B-3. Marsh birds habitat associations, summer 2001. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	19	7.85	15.21	<0.0001*	+
	Conine	10	9.46	0	1	
	Deer	76	126.39	34.36	<0.0001*	-
	Jessie	71	64.44	1.05	0.31	
Tall E	Buckeye	56	90.71	31.39	<0.0001*	-
	Conine	45	46.30	0.05	0.823	
	Deer	148	200.69	42.15	<0.0001*	-
	Jessie	30	65.99	35.88	<0.0001*	-
Floating	Buckeye	51	57.44	0.98	0.322	
	Conine	0	0.43	0	1	
	Deer	279	245.38	26.14	<0.0001*	-
	Jessie	4	2.68	0.25	0.617	
Shore	Buckeye	79	51.59	21.11	<0.0001*	+
	Conine	39	22.33	18.48	<0.0001*	+
	Deer	38	40.60	0.13	0.718	
	Jessie	71	46.81	17.71	<0.0001*	+
Lawn	Buckeye	100	64.37	32.94	<0.0001*	+
	Conine	7	9.21	0.38	0.538	
	Deer	84	148.59	67.75	<0.0001*	-
	Jessie	52	66.83	5.84	0.016*	-
Understory	Buckeye	70	91.35	12.17	<0.001*	-
	Conine	37	34.48	0.37	0.543	
	Deer	108	106.70	0.01	0.92	
	Jessie	114	66.41	63.12	<0.0001*	+
Shrub	Buckeye	52	95.33	50.5	<0.0001*	-
	Conine	41	39.53	0.06	0.806	
	Deer	183	102.91	104.33	<0.0001*	+
	Jessie	55	65.99	3.14	0.076	
Canopy	Buckeye	64	73.77	2.23	0.135	
	Conine	9	5.49	1.81	0.179	
	Deer	75	95.00	6.42	0.011*	-
	Jessie	31	43.57	4.84	0.028*	-

+/- Significant positive or negative association with habitat element.

Table B-4. Marsh bird habitat associations, winter 2001-2002. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	38	4.39	263.45	<0.0001*	+
	Conine	22	15.35	2.92	0.087	
	Deer	169	201.12	8.67	0.003*	-
	Jessie	87	50.73	46.46	<0.0001*	+
Tall E	Buckeye	47	50.65	0.48	0.488	
	Conine	70	75.14	1.19	0.275	
	Deer	169	319.34	218.35	<0.0001*	-
	Jessie	35	51.95	9.79	0.002*	-
Floating	Buckeye	26	32.08	1.55	0.213	
	Conine	0	0.69	0.05	0.823	
	Deer	406	390.46	3.39	0.066	
	Jessie	2	2.11	0	1	
Shore	Buckeye	10	1.85	32.39	<0.0001*	+
	Conine	9	16.14	3.26	0.071	
	Deer	0	3.19	2.29	0.13	
	Jessie	14	10.34	1.07	0.301	
Lawn	Buckeye	55	35.11	18.4	<0.0001*	+
	Conine	22	14.95	3.38	0.066	
	Deer	234	188.85	25.88	<0.0001*	+
	Jessie	88	52.14	45.59	<0.0001*	+
Understory	Buckeye	58	51.16	2.02	0.155	
	Conine	84	66.92	12.68	<0.001*	+
	Deer	243	145.46	118.99	<0.0001*	+
	Jessie	46	51.81	1.02	0.313	
Shrub	Buckeye	57	52.00	1.02	0.313	
	Conine	78	64.15	7.89	0.005*	+
	Deer	217	130.79	95.2	<0.0001*	+
	Jessie	35	51.48	9.32	0.002*	-
Canopy	Buckeye	66	40.24	30.44	<0.0001*	+
	Conine	8	8.91	0.02	0.888	
	Deer	198	120.26	79.62	<0.0001*	+
	Jessie	48	33.99	7.77	0.005*	+

+/- Significant positive or negative association with habitat element.

Table B-5. Diving bird habitat associations, summer 2001. Expected values based on availability of habitat element on each lake.

Habitat	**Lake**	**Observed**	**Expected**	χ^2	**p-value**	**+/-**
Low E	Buckeye	7	1.53	17.01	<0.0001*	+
	Conine	21	12.09	6.92	0.009*	+
	Deer	30	28.61	0.05	0.823	
	Jessie	42	51.64	2.98	0.084	
Tall E	Buckeye	17	17.67	0	1	
	Conine	46	59.20	11.31	<0.001*	-
	Deer	43	45.43	0.25	0.617	
	Jessie	24	52.88	28.63	<0.0001*	-
Floating	Buckeye	5	11.19	4.61	0.032*	-
	Conine	n/a	n/a	n/a	n/a	
	Deer	53	55.54	0.44	0.507	
	Jessie	n/a	n/a	n/a	n/a	
Shore	Buckeye	9	10.05	0.05	0.823	
	Conine	50	28.55	24.26	<0.0001*	+
	Deer	7	9.38	0.44	0.507	
	Jessie	27	37.52	4	0.046*	-
Lawn	Buckeye	7	12.54	3.48	0.062	
	Conine	14	11.78	0.29	0.59	
	Deer	22	36.11	12.57	<0.001*	-
	Jessie	24	53.56	29.98	<0.0001*	-
Understory	Buckeye	18	16.44	0.18	0.671	
	Conine	57	51.38	1.58	0.209	
	Deer	39	26.90	9.19	0.002*	+
	Jessie	86	53.22	37	<0.0001*	+
Shrub	Buckeye	21	18.57	0.53	0.467	
	Conine	47	50.54	0.52	0.471	
	Deer	44	25.83	20.49	<0.0001*	+
	Jessie	73	52.88	13.68	<0.001*	+
Canopy	Buckeye	26	14.37	16.55	<0.0001*	+
	Conine	19	7.02	20.63	<0.0001*	+
	Deer	29	22.62	2.45	0.118	
	Jessie	42	34.92	1.79	0.181	

+/- Significant positive or negative association with habitat element.

Table B-6. Diving bird habitat associations, winter 2001/2002. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	23	4.85	67.79	<0.0001*	+
	Conine	26	11.78	18.91	<0.0001*	+
	Deer	34	35.87	0.09	0.764	
	Jessie	65	61.24	0.32	0.572	
Tall E	Buckeye	51	55.96	0.86	0.354	
	Conine	32	57.68	45.62	<0.0001*	-
	Deer	34	56.95	27.49	<0.0001*	-
	Jessie	58	62.71	0.53	0.467	
Floating	Buckeye	7	35.44	35.12	<0.0001*	-
	Conine	4	0.76	9.98	0.002*	+
	Deer	49	69.64	34.05	<0.0001*	-
	Jessie	1	4.15	1.75	0.186	
Shore	Buckeye	0	2.00	1.16	0.281	
	Conine	21	12.23	6.69	0.01*	+
	Deer	0	0.75	0.08	0.777	
	Jessie	6	12.50	3.18	0.075	
Lawn	Buckeye	39	38.04	0.01	0.92	
	Conine	31	11.33	38.24	<0.0001*	+
	Deer	60	44.40	12.59	<0.001*	+
	Jessie	71	63.04	1.68	0.195	
Understory	Buckeye	66	55.42	4.69	0.03	+
	Conine	46	50.70	1.08	0.299	
	Deer	65	34.20	49.34	<0.0001*	+
	Jessie	104	62.65	50.38	<0.0001*	+
Shrub	Buckeye	62	56.33	1.24	0.265	
	Conine	29	48.60	21.33	<0.0001*	-
	Deer	57	30.75	36.54	<0.0001*	+
	Jessie	98	62.24	37.54	<0.0001*	+
Canopy	Buckeye	83	43.59	66.67	<0.0001*	+
	Conine	17	6.75	15.47	<0.0001*	+
	Deer	69	28.28	91.86	<0.0001*	+
	Jessie	64	41.10	17.67	<0.0001*	+

+/- Significant positive or negative association with habitat element.

Table B-7. Duck habitat associations, summer 2001. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	0	0.51	0	1	
	Conine	0	2.17	1.53	0.216	
	Deer	194	312.99	78.29	<0.0001*	-
	Jessie	71	176.40	114.88	<0.0001*	-
Tall E	Buckeye	3	5.89	2.36	0.124	
	Conine	0	10.63	40.04	<0.0001*	-
	Deer	235	496.97	427.24	<0.0001*	-
	Jessie	34	180.65	222.25	<0.0001*	-
Floating	Buckeye	9	3.73	9.73	0.002*	+
	Conine	n/a	n/a	n/a	n/a	
	Deer	713	607.66	105.79	<0.0001*	+
	Jessie	n/a	n/a	n/a	n/a	
Shore	Buckeye	2	3.35	0.33	0.566	
	Conine	14	5.12	21.59	<0.0001*	+
	Deer	246	100.80	241.53	<0.0001*	+
	Jessie	247	128.15	162.31	<0.0001*	+
Lawn	Buckeye	3	4.18	0.19	0.663	
	Conine	12	2.11	49.08	<0.0001*	+
	Deer	269	330.34	27.46	<0.0001*	-
	Jessie	206	182.96	5.28	0.022*	+
Understory	Buckeye	n/a	n/a	n/a	n/a	
	Conine	4	9.46	8.03	0.005*	-
	Deer	391	245.78	156.63	<0.0001*	+
	Jessie	297	181.81	136.78	<0.0001*	+
Shrub	Buckeye	6	6.19	0	1	
	Conine	1	0.69	17.95	<0.0001*	+
	Deer	325	228.78	12.17	<0.001*	+
	Jessie	104	180.65	60.34	<0.0001*	-
Canopy	Buckeye	5	5.75	0.02	0.888	
	Conine	0	1.26	0.51	0.475	
	Deer	131	210.37	47.46	<0.0001*	-
	Jessie	40	119.27	75.29	<0.0001*	-

+/- Significant positive or negative association with habitat element.

Table B-8. Duck habitat associations, winter 2001/2002. Expected values based on availability of habitat element on each lake.

Habitat	Lake	Observed	Expected	χ^2	p-value	+/-
Low E	Buckeye	0	1.38	0.59	0.442	
	Conine	2	4.19	0.8	0.371	
	Deer	62	277.12	290.09	<0.0001*	-
	Jessie	16	17.82	0.18	0.671	
Tall E	Buckeye	2	15.90	27.49	<0.0001*	-
	Conine	25	20.49	3.25	0.071	
	Deer	133	440.02	668.13	<0.0001*	-
	Jessie	23	18.25	1.86	0.173	
Floating	Buckeye	20	10.07	14.08	<0.001*	+
	Conine	2	0.19	9.15	0.002*	+
	Deer	580	538.02	18.7	<0.0001*	+
	Jessie	5	0.74	19.44	<0.0001*	+
Shore	Buckeye	7	0.37	96.21	<0.0001*	+
	Conine	0	4.40	4.13	0.042*	-
	Deer	0	2.20	1.32	0.251	
	Jessie	11	3.67	14.06	<0.001*	+
Lawn	Buckeye	7	7.52	0	1	
	Conine	25	4.08	120.51	<0.0001*	+
	Deer	148	130.24	5.61	0.018*	+
	Jessie	17	18.49	0.1	0.752	
Understory	Buckeye	11	10.96	0	1	
	Conine	27	18.25	11.51	<0.001*	+
	Deer	182	100.32	120.76	<0.0001*	-
	Jessie	24	18.37	2.71	0.1	
Shrub	Buckeye	11	11.14	0	1	
	Conine	2	17.50	13.16	<0.001*	-
	Deer	153	90.20	72.93	<0.0001*	+
	Jessie	22	18.25	1.09	0.296	
Canopy	Buckeye	18	8.62	17.54	<0.0001*	+
	Conine	2	2.43	0	1	
	Deer	179	82.94	176.73	<0.0001*	+
	Jessie	11	12.05	0.04	0.841	

+/- Significant positive or negative association with habitat element.

APPENDIX C
WINTER HAVEN WATERBIRD BEHAVIOR DATA

Table C-1. Data for summer guild behavior, listed by guild and lake. Results from contingency Chi-square based on the proportion of birds engaged in each focal behavior versus the proportion engaged in all other (Other) behaviors.

		Foraging				Resting				w/Young				Alert/Fleeing			
	D/U	**Forage**	**Other**	**χ^2**	**P-value**	**Rest**	**Other**	**χ^2**	**P-value**	**w/ Young**	**Other**	**χ^2**	**P-value**	**Alert/ Flee**	**Other**	**χ^2**	**P-value**
Waders																	
Buckeye	D	15	37			16	36			6	46			12	40		
	U	12	17	1.32	0.251	12	17	0.93	0.336	0	29	3.61	0.083[F]	4	25	1.01	0.314
Conine	D	151	61			37	175			n/a	n/a	n/a		17	195		
	U	29	39	18.32	<0.0001*	19	49	3.54	0.06	n/a	n/a	n/a	n/a	11	57	3.81	0.051
Deer	D	73	68			38	103			n/a	n/a	n/a		9	132		
	U	5	12	3.04	0.081	5	12	0.04	0.78[F]	n/a	n/a	n/a	n/a	3	14	2.74	0.123[F]
Jessie	D	56	51			35	72			n/a	n/a	n/a		8	99		
	U	14	22	1.95	0.163	10	26	0.3	0.581	n/a	n/a	n/a	n/a	4	32	0.46	0.497[F]
Marsh																	
Buckeye	D	54	83			4	133			45	92			6	131		
	U	11	10	1.26	0.261	1	20	0.20	0.653	0	21	9.65	0.002*	7	14	28.21	<0.001[F]*
Conine	D	24	24			9	39			n/a	n/a	n/a		3	45		
	U	17	11	0.82	0.366	6	22	0.08	0.777	n/a	n/a	n/a	n/a	3	25	0.49	0.664[F]
Deer	D	146	137			12	271			64	219			5	278		
	U	8	14	1.89	0.169	1	21	0.01	0.999[F]	3	19	0.96	0.429[F]	5	17	28.28	<0.001[F]*
Jessie	D	42	71			5	108			38	75			2	111		
	U	10	11	0.82	0.367	1	20	0.01	1[F]	8	13	0.16	0.692	0	20	0.36	0.999[F]

Summer guild behavior, continued.

	D/U	Foraging				Resting				w/Young				Alert/Fleeing			
	D/U	**Forage**	**Other**	**χ^2**	**P-value**	**Rest**	**Other**	**χ^2**	**P-value**	**w/ Young**	**Other**	**χ^2**	**P-value**	**Alert/ Flee**	**Other**	**χ^2**	**P-value**
Divers																	
Buckeye	D	n/a	n/a	n/a		12	9			n/a	n/a	n/a		8	13		
	U	n/a	n/a	n/a	n/a	6	0	3.86	0.136^F	n/a	n/a	n/a	n/a	0	6	3.25	0.136^F
Conine	D	2	48			39	11			n/a	n/a	n/a		6	44		
	U	1	37	0.12	1^F	34	4	2.1	0.156	n/a	n/a	n/a	n/a	1	37	2.59	0.135^F
Deer	D	n/a	n/a	n/a		57	4			n/a	n/a	n/a		2	59		
	U	n/a	n/a	n/a	n/a	10	1	0.09	0.575^F	n/a	n/a	n/a	n/a	0	11	0.37	1^F
Jessie	D	n/a	n/a	n/a		47	10			n/a	n/a	n/a		8	49		
	U	n/a	n/a	n/a	n/a	43	12	0.32	0.569	n/a	n/a	n/a	n/a	9	46	0.12	0.731
Ducks																	
Buckeye	D	n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a	
	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Conine	D	n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a	
	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Deer	D	23	702			315	410			70	655			181	544		
	U	0	50	1.64	0.39^F	2	48	30.11	<0.0001*	0	50	5.31	0.018^F*	30	20	28.98	<0.0001*
Jessie	D	18	334			125	227			41	311			125	227		
	U	0	32	1.72	0.383^F	2	30	11.35	<0.001*	0	32	4.17	0.036^F*	28	4	33.08	<0.0001*

D=Developed shoreline, U=Undeveloped shoreline

^{F}P-value based on Fisher's exact test.

Table C-2 Data for winter guild behavior, listed by guild and lake. Results from contingency Chi-square based on the proportion of birds engaged in each focal behavior versus the proportion engaged in all other (Other) behaviors.

		Foraging				**Resting**				**w/Young**				**Alert/Fleeing**			
	D/U	**Forage**	**Other**	χ^2	**P-value**	**Rest**	**Other**	χ^2	**P-value**	**w/ Young**	**Other**	χ^2	**P-value**	**Alert/ Flee**	**Other**	χ^2	**P-value**
Waders																	
Buckeye	D	43	28			17	54			6	65			4	67		
	U	1	12	12.31	<0.001*	6	7	2.73	0.172[F]	5	8	8.7	0.011[F]*	1	12	0.08	1[F]
Conine	D	35	98			82	51			12	121			1	132		
	U	2	12	0.97	0.519[F]	5	9	3.53	0.06	5	9	8.82	0.012[F]*	1	13	3.86	0.182[F]
Deer	D	36	91			84	43			5	122			2	125		
	U	0	1	0.39	0.999[F]	1	0	0.51	0.999[F]	0	1	0.04	1[F]	0	1	0.02	0.999[F]
Jessie	D	66	86			72	80			11	141			1	151		
	U	5	21	5.42	0.02*	13	13	0.06	0.803	8	18	12.9	0.002[F]*	0	26	0.17	1[F]
Marsh																	
Buckeye	D	14	43			5	52			14	43			22	35		
	U	8	11	2.13	0.144	2	17	0.05	1[F]	6	13	0.36	0.547	3	16	3.36	0.067
Conine	D	26	52			7	71			10	68			32	46		
	U	10	10	1.9	0.168	1	19	0.335	0.999[F]	5	15	1.82	0.293[F]	4	16	3.03	0.082
Deer	D	220	222			21	421			86	356			100	342		
	U	11	13	0.14	0.707	1	23	1.04	0.999[F]	10	14	6.87	0.017[F]*	0	24	6.91	0.009*
Jessie	D	49	50			3	96			8	91			34	65		
	U	9	2	4.15	0.042*	1	10	1.03	0.348[F]	1	10	0.01	1[F]	0	11	5.47	0.017[F]*

Winter guild behavior, continued.

	D/U	Foraging				Resting				w/Young				Alert/Fleeing			
	D/U	**Forage**	**Other**	χ^2	**P-value**	**Rest**	**Other**	χ^2	**P-value**	**w/ Young**	**Other**	χ^2	**P-value**	**Alert/ Flee**	**Other**	χ^2	**P-value**
Divers																	
Buckeye	D	n/a	n/a			39	13			9	43			4	48		
	U	n/a	n/a	n/a	n/a	23	9	0.1	0.752	7	25	0.27	0.605	1	31	0.74	0.645[F]
Conine	D	2	56			41	17			11	47			3	55		
	U	0	13	0.46	0.999[F]	9	4	0.01	1[F]	3	10	0.11	0.711[F]	1	12	0.13	0.563[F]
Deer	D	n/a	n/a			23	33			24	32			9	47		
	U	n/a	n/a	n/a	n/a	1	2	0.07	1[F]	2	1	0.66	0.578[F]	0	3	0.57	0.999[F]
Jessie	D	3	96			76	23			15	84			4	95		
	U	0	51	1.89	0.287[F]	37	14	0..32	0.57	14	37	3.27	0.07	0	51	2.12	0.3[F]
Ducks																	
Buckeye	D	n/a	n/a			n/a	n/a			5	0			0	5		
	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5	4	3.11	0.221[F]	4	5	3.11	0.221[F]
Conine	D	n/a	n/a			n/a	n/a			0	25			25	0		
	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	0	27	0.003[F]*	0	2	27	0.003[F]*
Deer	D	13	616			53	576			412	217			41	588		
	U	0	19	0.4	1[F]	0	19	1.74	0.391[F]	13	6	0.07	0.791	0	19	1.32	0.625[F]
Jessie	D	n/a	n/a			9	79			79	9			n/a	n/a		
	U	n/a	n/a	n/a	n/a	0	10	1.13	0.592[F]	10	0	1.13	0.592[F]	n/a	n/a	n/a	n/a

[F]P-value based on Fisher's exact test.

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BIOGRAPHICAL SKETCH

Ashley Traut was born in Sacramento, California, on January 31, 1972. His tumultuous arrival, after going some time without oxygen in the womb, made for lively lectures in his father's biochemistry class on basic metabolic pathways for many years to come. Mr. Traut attended grade school in Pleasantville, New York, and Bethesda, Maryland, and middle and high school in Baltimore, Maryland. He journeyed northward for his undergraduate education, receiving a Bachelor of Science degree in terrestrial ecology from the University of Vermont in 1994. Before tackling the formidable challenge of graduate school, Mr. Traut trundled from Maryland to Hawaii to Texas in search of gainful employment in wildlife-related pursuits. His list of previously held positions includes environmental educator, wildlife rehabilitator, veterinary technician, wildlife biologist, and yes, bicycle mechanic. He looks forward to this list growing considerably over the years as he continues to explore, learn, and apply himself.