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Effects of Urbanization on Community Composition and Conditions of Birds in Wetland Ecosystems

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Abstract

Urbanization in wetlands has negatively impacted bird species diversity and populations. It is important to be able to predict the consequences for avian biodiversity and to identify wetlands of special value to the maintenance of local wetland communities. This study involved conducting point counts across four permanent urban wetlands at the University of Florida and three retention ponds in the Gainesville, FL vicinity to observe patterns in wetland bird species diversity and populations. This study also utilized data from the Florida Museum of Natural History (FLMNH) to explore differences in phenotypes of wetland bird specimens. The local wetlands showed trends where specific species thrived in one type of area versus the other. Egrets were frequently observed in larger wetlands, and double-crested cormorants were observed more frequently in smaller ones. Additionally, retention ponds showed promise as a conservation method, dependent on their depth and size. The largest retention pond attracted many bird species in great numbers, showing promise for methods to negate negative the impact of human activity and climate change. Characterization for data collected at the FLMNH on both weight and species analyzed across numerous regional locations showed a negative trend between specimen weight and time progression.

Keywords: urbanization, wetlands, avian

Background

Wetland Species Diversity and Community Composition

As one of the richest types of ecosystems, wetlands serve as a significant habitat for many bird species. Over time, birds have evolved adaptations to take advantage of these resources and thrive in wetland habitats (Figure 1; Weller, 1999). However, the number of wetlands has been decreasing and makes up less than 5% of land in the continental United States due to increasing urbanization and climate change (Stewart, 1996). While urbanization is a reason for the decline of wetlands, urbanization can coexist with wetlands as seen in present-day urban environments with permanent wetlands used for water treatment or retention wetlands.

Long-term adaptations	Shorter-term or regional variation
Anatomy and morphology	Specific foods
Rear leg placement for swimming/diving	Feeding tactics
Bone and lung modifications for diving	Feeding flights
Eye modifications for nocturnal and underwater vision	Local flight paths
Flight adaptations for aerial divers	Vegetation species and life form
Webbed and lobed feet	Nest sites and vegetation types
Long legs for wading	Water depth preference
Bill specializations for grabbing, straining, digging, etc.	Roosting patterns
Water-resistant plumage	
Behavioral adaptations of preening and drying	
Specialization for general types of food	
Physiology: respiratory, digestive tract	
Breeding strategies	
Social behavior: spacing, aggression,	
Water depth adaptations	
Wetland types, water dynamics and salinity	
Long-range mobility/resource exploitation	

Figure 1: Avian adaptations to wetland habitats at two arbitrary levels. Taken from Weller (Weller, 1999).

Researchers found that retention ponds, artificial pits designed to hold runoff from excessive rain, may act as temporary foraging grounds for a variety of wetland bird species. Retention ponds increase wetland bird adaptability through their water level. Food availability is high when there are shallow waters present with aquatic prey. When natural wetlands are dry due to a lack of rain, wetland birds must move to different isolated wetlands to forage, which increases their ability to adapt to new environments (Evans et al., 2020). Urban wetlands serve as alternate locations for wetland birds to nest, forage, and rest in a time period when climate change is occurring, causing many natural wetlands to disappear (Murillo-Pacheco et al., 2017).

Gainesville, Florida is an ideal area to observe how wetland birds adapt to urbanization, as it is filled with an abundance of natural and man-made wetland areas, both within and adjacent to its city limits. In Gainesville, wetland birds can move from large wetland areas, such as Paynes Prairie Preserve State Park or Sweetwater Wetlands Park, to smaller permanent ponds throughout the University of Florida's campus or even to retention ponds around popular shopping plazas in the urban sections of the city. Investigating the effects of urbanization on bird populations locally will provide crucial insights into unique local

challenges that vary from other regions such as land use, habitat fragmentation, pollution and human-wildlife interactions.

Trends in Wetland Bird Conditions

In addition to changing habitats, another impact of urbanization is that select foods become more accessible. Migrating birds are inclined to stop in urban areas, as there is readily available food from humans such as from ornamental plants, bird feeders, or human food from restaurants, stores, or waste facilities. This available food acts as an unhealthy, but sustainable food source for many birds (Chace & Walsh, 2006). However, a challenge with increased food waste includes increased trash volume in urban environments which could negatively impact birds' health (Mak & Drewitt, 2023). For example, urban juvenile house sparrows were found to be not gaining enough fat because of the differences in food types provided in urban environments versus in rural environments (Meillère et al., 2015). This lack of nutrition may lead to issues in their growth and development during the remainder of their lives.

In Florida, there is a population increase rate of 1.9%, which would lead to the population of 22 million people doubling within the next 40 years (Perry et al., 2023). As urban areas in Florida continue to grow at such a rapid rate, it is imperative to conduct studies on the complex relationships of how urbanization growth will affect the foraging methods, the health, and overall, the phenotypes of birds over a long period of time.

Methods

Sites

The study sites include a series of permanent wetlands and retention ponds in Gainesville, Florida, in order to study the population distributions and behavioral patterns of wetland birds within urban regions: Dairy Pond, Liberty Pond, Lake Alice, and Depot Park. These wetlands are pictured and mapped in Figure 2.

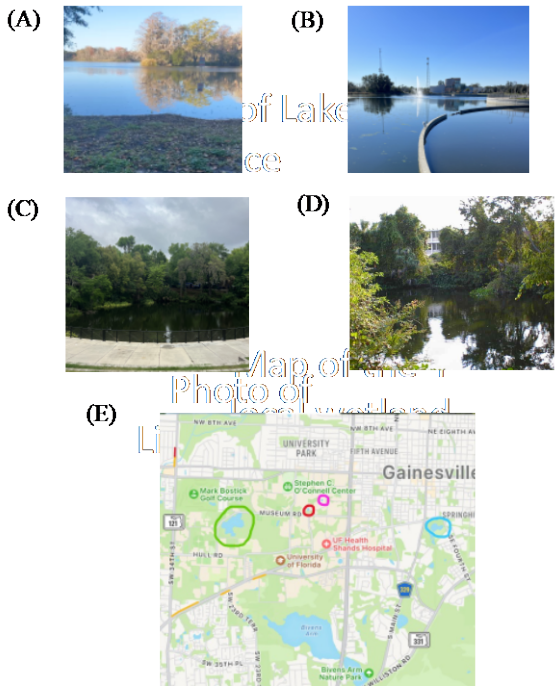

Figure 2: Photographs and map of local permanent wetlands used as observation sites. A) A photograph of Lake Alice. Largest permanent wetland in study. Located near an active road but also surrounded by natural landscape. B) A photograph of the Depot Park site. Located within urban park. C) A photograph of Liberty Pond. Located next to student union and bus station. D) A photograph of Dairy Pond. Located near classroom buildings and sidewalks with frequent usage. Photo taken from https://www.uflib.ufl.edu/ufarch/dairypond.htm E) A map showing the locations of the permanent local urban wetland sites: green circle represents Lake Alice (Figure 2A), blue circle represents Depot Park site (Figure 2B), red circle represents Liberty Pond (Figure 2C), pink circle represents Dairy Pond (Figure 2D).

The retention ponds studied include three wetlands located near shopping plazas in west Gainesville and are referred to as (1) Target Pond, (2) Bass Pro Shops Pond, and (3) Home Depot Pond (Figure 3). Retention pond water levels often fluctuate greatly, as they can go from being full of water to being completely dry in a short time period (Hancock et al., 2010). These fluctuations force wetland birds that utilize retention ponds to be able to adapt to new and changing environments.

Target Pond consistently had water present within the wetland. However, it was often filled with bulky clumps of soil and vegetation (Figure 3B). Bass Pro Shops Pond did not maintain its water level well and did not have water in it at the time it was photographed (Figure 3C). For these landscape related reasons, Target Pond and Bass Pro Shops Pond did not produce that much useful data throughout the

study. However, Home Depot Pond consistently had a shallow water level and a large area which made it a model retention pond within this study (Figure 3A).

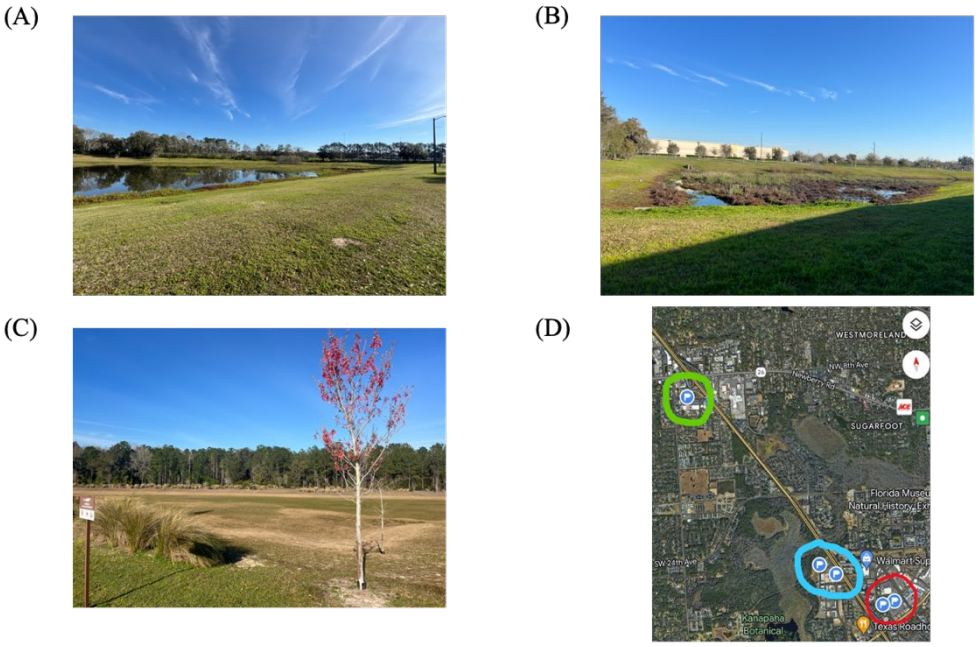

Figure 3: Photographs and map of retention ponds used as observation sites. A) A photograph of Home Depot pond. B) A photograph of Target pond C) A photograph of Bass Pro Shops pond D) A map showing the locations of the retention ponds: green circle represents Home Depot pond (Figure 3A), red circle represents Target pond (Figure 3B), blue circle represents Bass Pro Shops pond (Figure 3C).

Point Counts

The data used in this study were collected primarily through point counts. This method is used to systematically document bird species, their abundance, and their distribution across different wetland habitats. In this study, point counts were conducted in 10-minute increments at a fixed location, and birds were recorded in unlimited circular plots or without a prescribed distance of the station (Johnson, 1995). The data recorded during each point count included the date, the location, the time, the temperature, the weather, the species observed, the number of birds of a species observed, the method of observation (heard or seen), and additional notes about the behavior or specific location of the bird. These data points were analyzed by using qualitative statistics and identifying trends to compare the permanent ponds and retention ponds.

FLMNH Specimen Analysis

For the second part of this study exploring wetland bird body conditions and phenotypes, the Florida Museum of Natural History (FLMNH) provided data with details about phenotypes of specific wetland bird specimens. This information included date collected, genus, species, subspecies, UF ID number, locality collected, weight, sex, wing length, tail length, tarsus length, and culmen length. These specimens were collected from the Southeastern region of the United States of America, with most specimens being from the state of Florida. The wetland bird species being examined included tricolored herons, snowy egrets, great blue herons, and boat-tailed grackles. Female boat-tailed grackles generally weigh less than male boat-tailed grackles, so these data were separated by sex. The weights of each specimen were represented in linear regression models according to the year of when they were initially collected. Data that did not include the weights of the specimens collected were excluded from the study. This design using linear regression models was done to determine if human population growth and increases of urbanization over time have affected the conditions of wetland birds in Florida.

Results

There was a total of 248 observations from the point counts conducted at the four on-campus permanent wetlands: Lake Alice, Liberty Pond, Depot Park, and Dairy Pond (Figure 4). Since locations were visited an unequal number of times, bias was removed through normalizing the data by dividing the number of birds observed of each species by the number of visits at the respective pond.

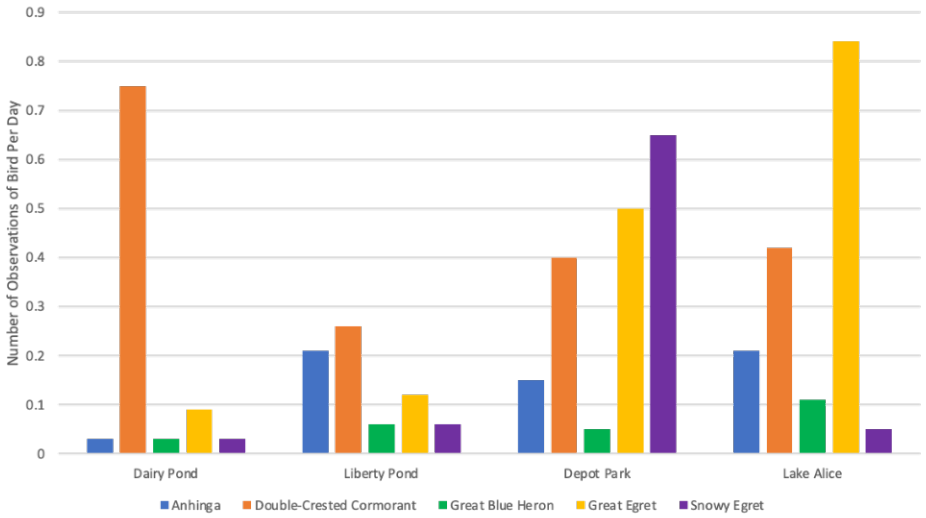

Figure 4: Observation counts of species per a visit that visited all four local wetlands grouped from previous data.

Species that were observed at all four permanent wetlands included anhingas (*Anhinga anhinga*), double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea Herodias*), great egrets (*Ardea alba*), and snowy egrets (*Egretta thula*). Anhingas were seen at the highest counts per day in Liberty Pond and Lake Alice, with 0.21 birds observed per a visit at both sites. Dairy Pond had the nearly twice the number of double-crested cormorants (.XX) observed per visit when compared to Liberty Pond with the second highest double-crested cormorant observations. Great egrets were seen at higher numbers in Lake Alice (.82 times/day) and Depot Park (.5 times/day) . Great blue herons were not commonly observed, as the highest count per visit was 0.11 great blue herons in Lake Alice . Great blue herons were seen consistently at low levels among all the permanent pond sites. Snowy egrets were the most observed at Depot Park by more than an order of magnitude. There were 0.65 snowy egrets counted per visit at Depot Park and only 0.06 at Liberty Pond, 0.05 at Lake Alice, and 0.03 at Dairy Pond .

Out of the three retention ponds studied, Target Pond and Bass Pro Shops Pond did not produce much data. However, Home Depot Pond produced a greater amount of data and was served as the model retention pond when comparing retention pond trends with permanent pond trends in this section. In the Home Depot retention pond, white ibises (*Eudocimus albus*) were the most observed bird with 13.8 birds counted per visit (Figure 5). Muscovy ducks (*Cairina moschata*) were the second most observed bird with 6.7 birds counted per a visit and wood storks were the third most observed bird with 4.5 birds counted per a visit (Figure 5). Species that were unique to Home Depot Pond included black-bellied whistling ducks (*Dendrocygna autumnalis*), muscovy ducks, wood storks (*Mycteria americana*), and blue-winged teals (*Spatula discors)* (Figure 6). Home Depot Pond had similar bird abundances to Depot Park, with species such as white ibises, snowy egrets, little blue herons (*Egretta caerulea*), and great egrets (Figure 6). Besides the little blue heron, Home Depot Pond demonstrated a higher number of observations per visit of each of each of these species than Depot Park did (Figure 6).

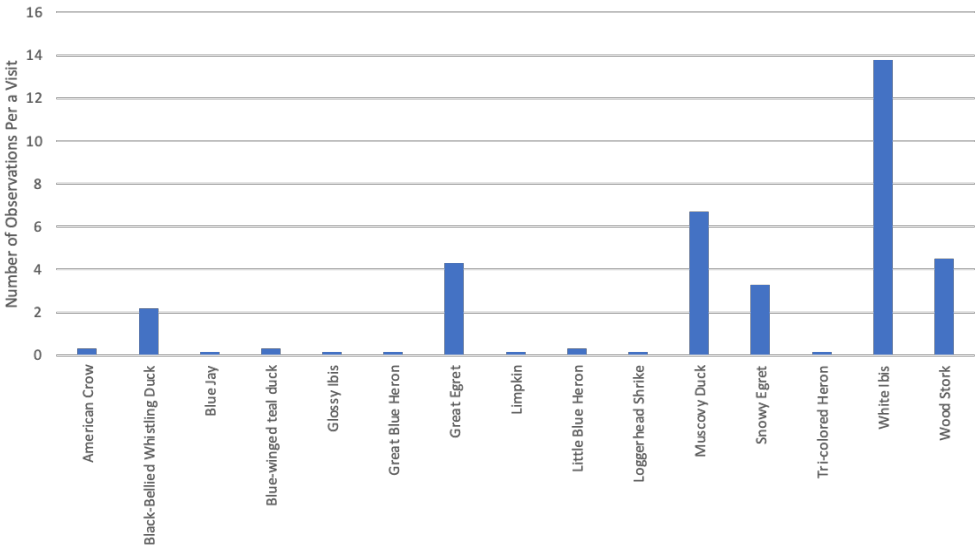

Figure 5: Observation counts per a visit of different bird species in the retention pond Home Depot pond.

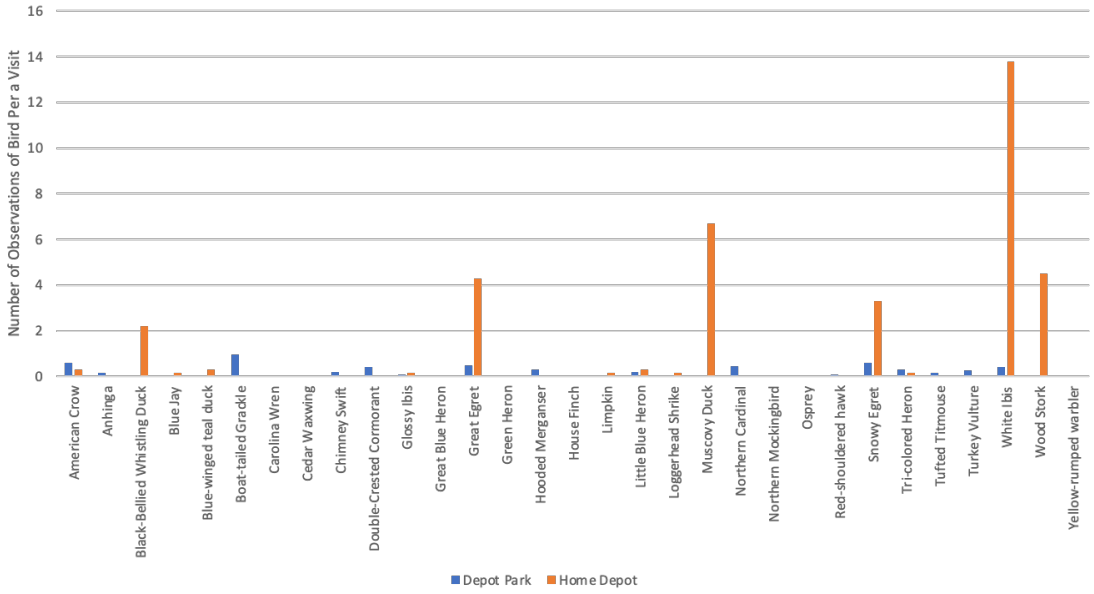

Figure 6: Observation counts of different bird species in the retention pond Home Depot pond versus the observation counts of different bird species in the permanent wetland Depot Park.

Raw data from FLMNH were organized and analyzed in order to see if there is a relationship between four species wetland birds' weights and the years they were collected. All four bird species studied — boat-tailed grackles, great blue herons, snowy egrets, and tricolored herons — showed a negative correlation between the weight of the bird in grams and the year collected. Each graph displayed a negative trendline when using a linear regression model. The weights of great blue herons collected have a slope of -7.3612 and an R^2 value of 0.0989 when compared to the year collected (Figure 7). The maximum weight was 3400 grams from a specimen collected in 1951, and the minimum weight was 932.5 grams from a specimen collected in 2011.

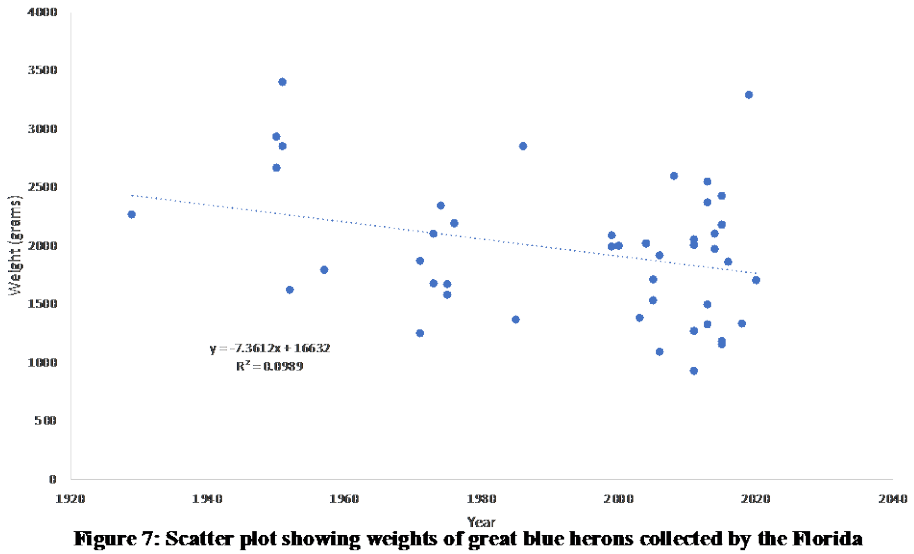

Figure 7: Scatter plot showing weights of great blue herons collected by the Florida Museum of Natural History and the year the specimen was collected.

The weights of tricolored herons collected have a slope of -1.1008 and an R^2 value of 0.1152 (Figure 8). The maximum weight was 478.4 grams from a specimen collected in 1950, and the minimum weight was 173 grams from a specimen collected in 2003.

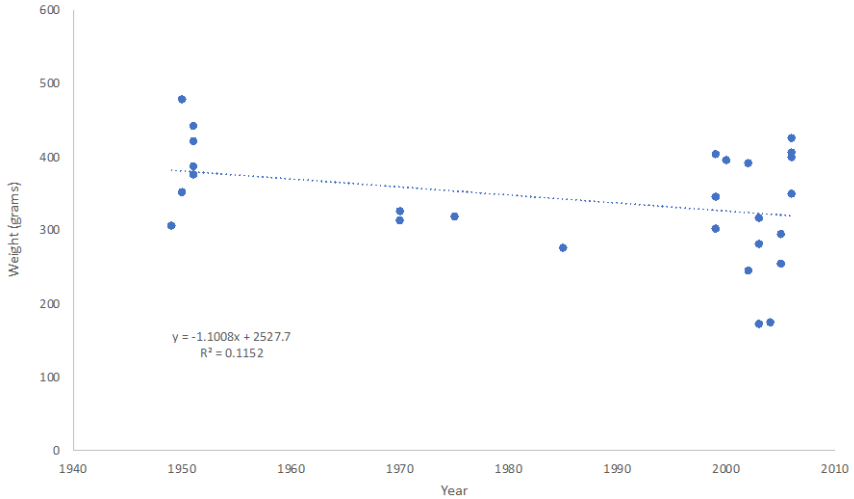

Figure 8: Scatter plot showing weights of tri-colored herons collected by the Florida Museum of Natural History and the year the specimen was collected.

The weights of snowy egrets collected have a slope of -1.3196 and an R^2 value of 0.1546 (Figure 9). The maximum weight was 481.5 grams from a specimen collected in 2005, and the minimum weight was 199 grams from a specimen collected in 1970.

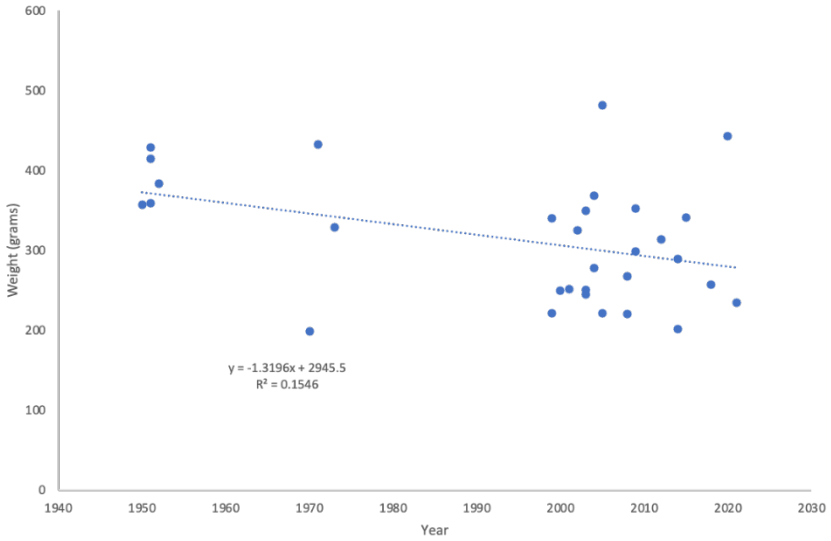

Figure 9: Scatter plot showing weights of snowy egrets collected by the Florida Museum of Natural History and the year the specimen was collected.

The weights of boat-tailed grackles collected have a slope of -0.5993 and an R^2 value of 0.0938 (Figure 10). The maximum weight was 208.07 grams from a specimen collected in 1961, and the minimum weight was 76.6 grams from a specimen collected in 2002. However, it is important to account for the smaller size of female boat-tailed grackles compared to male boat-tailed grackles. When looking at the weights of female boat-tailed grackles versus male boat-tailed grackles, both sexes showed a negative correlation to time progression. Female boat-tailed grackles collected have a slope of -0.0115 and an R^2 value of 0.0003 (Figure 11). Male boat-tailed grackles collected have a slope of -0.7571 and an R^2 value of 0.3317 (Figure 11). Male boat-tailed grackles had a more negative slope than female boat-tailed grackles.

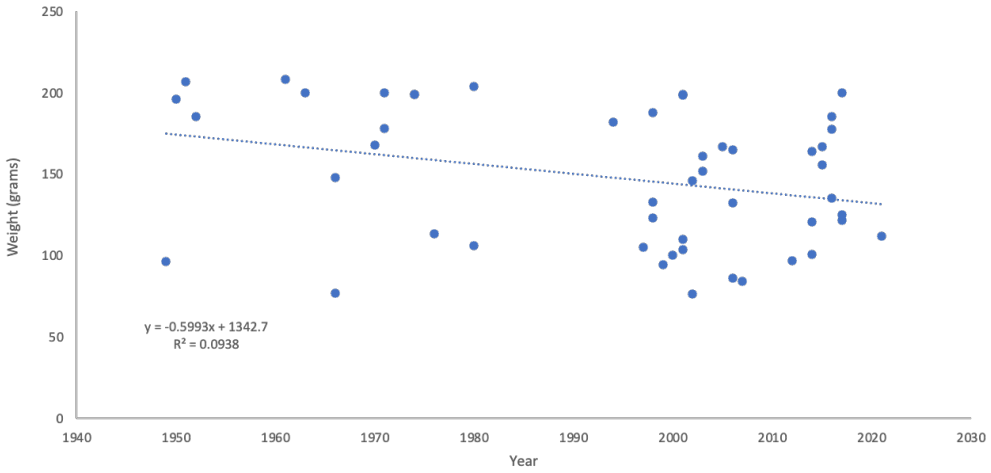

Figure 10: Scatter plot showing weights of boat-tailed grackles collected by the Florida Museum of Natural History and the year the specimen was collected.

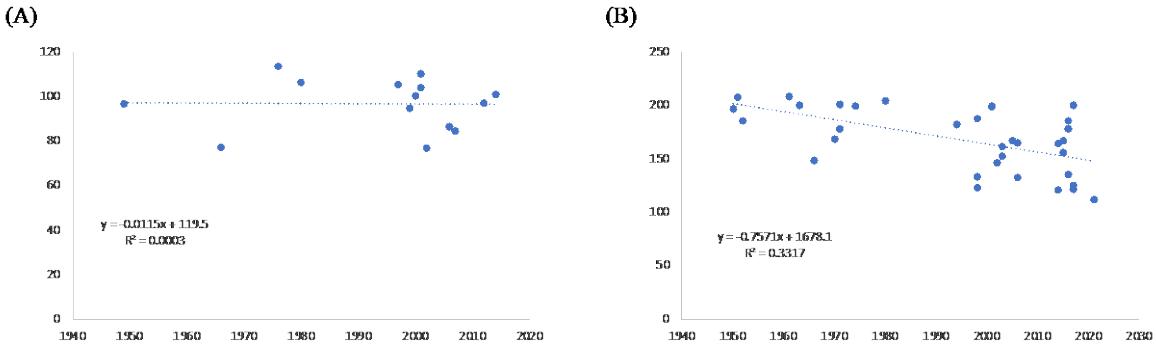

Figure 11: Scatter plots showing weights of female boat-tailed grackles and male boat-tailed grackles collected by the Florida Museum of Natural History and the year the specimen was collected. A) Weight of the female specimens and the year the female specimen was collected B) Weight of the male specimens and the year the male specimen was collected.

Every graph of each of the four wetland bird specimens has a low R^2 value, indicating that there is a high probability other factors are influencing the change of weight over time.

Discussion

Point Count Observations

When constructing permanent ponds or retention ponds in urban areas, there should be consideration of which species can utilize the ponds for needs such as roosting, foraging, breeding, and nesting behaviors (Stewart, 1996). In the observations conducted, great egrets were seen at higher levels in Depot Park and Lake Alice, which are both bigger wetland areas than Dairy Pond and Liberty Pond. A previous study found the factor that most impacted wetland bird species density was wetland area (Sica et al., 2020). Both snowy egret and great egret observations align with this hypothesis, as trends demonstrated increased abundance in larger wetland areas. Studies have also shown egrets favor estuarine emergent wetlands as they provide better foraging opportunities and lead to higher reproductive success (Kelly et al., 2008). The Home Depot Pond replicates this type of environment favored by egrets and provides foraging opportunities through its maintained shallow water level and aquatic vegetation.

On the other hand, double-crested cormorants were observed favoring smaller ponds during the permanent pond point counts. Double-crested cormorants had the highest count of birds seen per visit by 0.49 more in Dairy Pond than in the second highest site, Liberty Pond. Dairy Pond is the smallest of the permanent ponds used as study sites. Double-crested cormorants have a diet of primarily fish with a preference for fish larger than 75 millimeters, and forage by diving into waters (Glahn et al., 1998). The need to easily locate, dive, and catch fish may be attributed to the appeal of smaller wetlands such as Dairy Pond. In Home Depot Pond, no double-crested cormorants were observed. The shallow waters of Home Depot Pond and the unreliability of water levels in retention ponds in general may make retention ponds an unappealing habitat for diving birds such as the double-crested cormorant (Hancock et al., 2010). Periods of complete drying may also kill the fish they need for their diets.

The retention pond, Home Depot Pond, proved to be an area that attracts different species than the other wetland sites in the study. When comparing the species observed in Home Depot pond versus Depot Park, Home Depot pond had similar species to Depot Park but also had additional species such as wood storks, black-bellied whistling ducks, blue-winged teals, and Muscovy ducks (Figure 6). These novel species within the study may be present at Home Depot Pond due to better foraging opportunities, as this retention pond is characterized by shallow waters. Research shows that wood storks prefer shallower waters with a preference for mean water depths of -25 cm to 25 cm for habitat selection (negative measurements indicating water depths below average ground elevation), likely due to their inclination to forage in shallower waters (Herring & Gawlik, 2011). Home Depot Pond provides this type of habitat and therefore, may be an appealing area for wood storks to forage and reside. The presence of wading birds such as black-bellied ducks, blue-winged teals, and Muscovy ducks were also only seen in Home Depot Pond (Figure 6). Home Depot Pond's easily accessible aquatic vegetation may attract wading bird species, as the foraging opportunities in shallower waters allow for less energy expenditure. This demonstrates that Home Depot Pond serves as foraging ground for a diversity of wetland bird species.

Within this study, Home Depot Pond was comparable with Depot Park in the species observed. Even as a retention pond, Home Depot Pond attracted higher numbers of birds from commonly-observed species compared to the volume of commonly observed species at Depot Park (Figure 6). This suggests that retention ponds can be a substitute for permanent wetlands as environmental changes and anthropogenic changes continue.

Trends in FLMNH Specimens

The data from this study show a trend where weight is negatively affected by the progression of time. While all graphs showed trendlines where time progression negatively correlated with weight of the bird collected, great blue herons displayed the most negative slope (-7.3612). This demonstrates that as time progressed, there has been a trend where great blue herons' weights decreased large amounts. The negative trend is seen with the other three bird species, but to a lesser extent as their slopes are closer to 0.

It is evident that there is a negative trend of weight when time progresses. As mentioned in the introduction, Florida's human population has been significantly increasing throughout the last several decades and is projected to double by 2040 (Perry et al., 2023). This increase of population may contribute to the decline of weight of wetland birds. As populations increase, urbanization increases, which has known effects on foraging behaviors and body conditions of other bird species. In another study done on house sparrows, birds in urban environments were consistently smaller and had worse body conditions than birds in rural habitats (Liker et al., 2008). Liker et al. term this the "credit card hypothesis," and suggest that urban areas cause high food predictability along with low mortality, which affects birds' foraging, reproductive, and rearing behaviors (2008). An increased availability of food leads to an increased population, which results in greater competition between birds. This study also suggests that the worsened body conditions and lower body masses may begin at the nestling stage of a bird's life, leading to problems during development. Although great blue herons had the most negative trendline, tricolored herons, snowy egrets, and boat-tailed grackles all had negative correlations, too. These trends suggest that the "credit card hypothesis" may also apply to wetland birds as higher food predictability over time with an increase of human population and urbanization has led to negative trends in bird weights.

Great blue herons are colonial nesters and are known to work together to find foraging grounds during nesting season (Krebs, 1974). The high food predictability in urban environments takes away an incentive to nest colonially nest, meaning that several young great blue herons would lose the opportunity of social learning and more reliable feedings (Liker et al., 2008; Krebs, 1974). Future studies could investigate the impact urbanization has on colonial nesting and explore if the lack of colonial nesting has attributed to declining weight trends observed in great blue herons over time.

Conclusion

Several observations from point counts demonstrated that there can be an increase of species diversity in wetland communities, despite changes due to urbanization. While urbanization may lead to the

decrease of natural wetlands, urban wetlands can still serve as suitable habitats for several wetland bird species. Different bird species prefer specific characteristics present within wetlands. When examining the point counts collected throughout this study, egrets preferred larger wetland areas while double-crested cormorants preferred smaller wetland areas (Figure 4). Retention ponds attracted wetland bird species that were not seen in permanent urban wetlands (Figure 5). Species that forage in shallow waters and feed on aquatic vegetation were seen in higher volumes in retention ponds (Figure 6). The Home Depot retention pond represented the benefits of retention ponds as it brought in great species diversity, while also maintaining a consistent water level and large area. The species seen in the Home Depot retention pond were similar to species seen in the permanent wetland Depot Park. These similarities demonstrate that creating retention ponds for stormwater control can be a conservation effort to preserve wetland bird biodiversity and can be as effective or even more effective, than permanent urban wetlands.

After using a scatter plot to display FLMNH's wetland bird specimens' data and adding a regression line, negative correlations were observed between the increasing level of urbanization over time and the body weights of wetland bird specimens. This may be attributed to the effects that increasing urbanization over time has had on foraging behaviors, as well as the impacts of human-food accessibility to wetland birds living in urban areas.

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