RELATIONSHIP BETWEEN HUMAN INTRUSION AND AVIAN BODY MASS:
DO RECREATIONISTS HINDER BIRDS’ ABILITIES
TO ACQUIRE FAT DURING MIGRATION?

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ABSTRACT

Many North American landbirds undergo biannual migration, which is energetically costly. Quality stopover sites are crucial to avian survival, as they provide opportunities to quickly replenish fat stores, rest, and avoid predation. One component of habitat quality that is often overlooked is the level of pedestrian activity, which birds interpret as potential predators. If intrusion levels are high, birds will flush readily and may not adequately restore energy reserves, which hinders successful migration. I compared body mass index between birds at different intrusion levels, testing the hypothesis that birds near continuous intrusion are less capable of replenishing body fat. Results between migratory guilds indicate long-distance migrants require areas of low intrusion to sufficiently acquire fat stores. In contrast, resident species are able to replenish body mass despite human intrusion. Since Neotropical migrants show increased sensitivity to human presence, conservation measures should focus on reducing pedestrian activity for quality stopover habitats.
DEDICATION

I would like to dedicate this work to my unborn son. It has been a miracle feeling him grow, kick, and dance inside the womb, and his impending birth has given me the final motivation to finish this work.
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LIST OF ABBREVIATIONS

ANOVA, Analysis of Variance
CI, Condition Index
BL, Bluff site, low intrusion
BMI, Body mass index
GW, Greenway site, high intrusion
HOV, Homogeneity of variance
LDM, Long-distance migrants (Neotropical)
RES, Resident birds
SDM, Short-distance migrants (Wintering)
SMA, Standardized Major-Axis Regression
SMI, Scaled Mass Index
CHAPTER I

INTRODUCTION

1.1 Migration

Approximately two-thirds of forest birds that breed in the eastern United States are Neotropical migrants: birds that migrate intercontinentally to tropical habitats in Mexico, Central and South America during the non-breeding season (Moore, 2000). Migration places high energy demands on migratory species (Moore et al., 1995), and adult bird mortality is nearly 15 times higher during migration compared to non-migratory periods (Sillett & Holmes, 2002). Migration can persist only if a bird’s ability to survive and reproduce is greater than the risk incurred during migration, which evolutionarily has been established as a successful life strategy for many species (Moore & Simons, 1992). Many birds take this risk because they benefit from: 1) greater survivorship during winter months, 2) the ability to exploit seasonal food abundance, and 3) reduced nest predation in temperate areas during the breeding season (Moore, 2000).

Moore et al. (1995) outline six potential costs during migration: 1) high energetic costs to travel 2) continuous adjustment to new surroundings, 3) the balance between acquiring food and avoiding predators, 4) competition with other migrants or resident birds for resources, 5) stochastic weather patterns, and 6) erroneous navigation. Historically, significant declines in migratory species have been attributed to habitat loss, such as fragmentation and urbanization on the breeding and wintering grounds (Petit, 2000). However, within the past 20 years, evidence for the importance of stopover habitat is being recognized as just as significant. Conservation efforts that focus on temperate breeding or Neotropical wintering grounds are valuable, but not sufficient on their own if stopover habitat requirements are not
met (Moore et al., 1995). In this literature review, I highlight the importance of stopover habitat for migrants and address the problems that they face in an urbanizing world.

1.2 Migratory Stopover

Migration consists of a series of flights in which birds must stop to replenish energy in the form of food consumption. These stopover sites can range in quality and size, from small urbanized parks to large protected forests (Mehlman et al., 2005). Stopover sites are defined as areas with the resources and conditions necessary to allow individuals to survive during a migratory journey. (Morrison et al., 1992). In other words, these are areas where birds must travel during migratory months to get to or from their breeding and wintering grounds. Resources that stopover sites provide include food, water, cover from predators, and shelter from adverse weather conditions (Moore et al., 1995). A Neotropical migrant must continually make habitat decisions *en route* during migration (Moore, 2000). How an individual “decides” which are most suitable, as well as in-depth knowledge of how migrants utilize stopover sites, is still understudied, but may be linked to innate preferences, learning, or both.

Migrants have the ability to offset the costs associated with migration by replenishing energy demands *en route* (Moore & Simons, 1992). The ability of a bird to regain lost fat stores, and thus gain mass, is the metric used to gauge habitat quality (Carlisle et al., 2012). Theory suggests that migrants should choose a stopover site that will be time optimal to maximize food intake while reducing predation and competition, which are considered two of the most important mechanisms to a successful migration (Carlisle et al., 2012). However, all habitats are not equal, and a migrant is faced with a heterogeneous matrix of habitat during stopover which varies, both temporally and spatially, in food availability, predators, and competitors (Moore & Aborn, 2000). Inevitably when choosing a stopover site, the migrant is unfamiliar with its surroundings and it must be able to assess habitat quality, an important task when energy demands are high (Moore & Aborn, 2000). Initially, a migrant must choose stopover habitat based on its intrinsic properties (Block & Brennan, 1993; Moore et al., 1995), but as it is explores an area, it
makes a decision to stay or risk leaving in the hopes of finding a higher quality site, which may or may not be readily available. This decision is even more imperative if the migrant is in poor body condition in the first place. Since fitness is the ability of an individual to survive and reproduce, and stopover habitat quality can affect a migrant’s capacity to survive and reach breeding grounds, then stopover habitat quality is directly related to fitness (Moore & Aborn, 2000).

The duration of time at a stopover location is dependent on four variables: 1) weather conditions, 2) physical condition of the individual (energy reserves, injuries, etc.), 3) assessed threats that could increase mortality, such as exposure or predation, and 4) availability of other suitable sites (Mehlman et al., 2005). Consider an individual arriving at a poor quality site in fat-depleted and exhausted condition: The bird must spend excess time there to replenish its poor energy reserves because of the increased effort and time needed to look for food. Additionally, lower quality sites may result in an increased risk of predation (Cimprich et al., 2005), not to mention stochastic factors such as weather that can be a further detriment to a migrant. This diminished ability to refuel at an inferior site translates either to delayed arrival at breeding grounds, thus an inability to choose successful territory or mate (thus declining reproductive success), or delayed arrival at tropical, warm weather wintering grounds, which can lead to death (Moore et al., 1995). Urban development is one factor that can reduce the quality of stopover habitats.

1.3 Impacts of Urbanization

Migratory birds are encountering increasingly urbanized habitats. Urbanization is defined as human presence and its effects that are concentrated in residential and industrial settings (Chace & Walsh, 2006). These include Urban Clusters, which are areas with 2,500-50,000 people, with a density of less than 386 persons/km², and Urban Areas, which have more than 50,000 people and a density greater than 386 persons/km² (US Census Bureau, 1995). Despite the fact that breeding bird density has been found to be greater in urban areas, richness is much lower, and the avian community generally consists of a few,
usually invasive, species. Thus, the composition of the community and ecosystem is widely different from native environs. Aside from introduced species, other guilds that are favored in an urbanized setting include omnivores, granivores, ground-dwelling and aerial insectivores, cavity nesters, and resident (versus migrant) species (Chace & Walsh, 2006). Other studies have found lower breeding densities in urban areas, citing less protective area, fewer food resources, increasing levels of predation and human intrusion as explanations for the reported decrease in avian richness and abundance (Fernández-Juricic & Tellería, 2000).

A study by Friesen et al. (1995) examined the effects of residential development on forest bird communities, specifically Neotropical migrants. As expected, amongst different sized woodlots, bird number and abundance decreased as forest size shrank. Residential development surrounding study sites yielded similar results, but to a stronger degree. The number of houses surrounding a woodlot was so influential on bird abundance and diversity that even a large woodlot with moderate housing development fared worse than a small woodlot with zero residential development surrounding it. The number of houses negatively correlated with both bird abundance and diversity, to such an extent that housing development negated the benefits (in number of species and individuals) of even a large forest plot. Furthermore, there was a nonsignificant interaction between size of plot and development level, meaning the forest size was not a factor in the effect of housing density on both abundance and diversity. These results are striking and somewhat disturbing: as urbanization continues at its rapid pace and metropolitan centers overflow into adjacent rural areas, the abundance and richness of migrants will be affected (Chace & Walsh, 2006).

Since the greatest hindrance on migratory birds is ability to regain fat stores, a high quality habitat is one in which birds regain mass at a higher rate relative to other available habitats (Moore et al., 1995; Seewagen, 2005). The amount and quality of stopover sites are likely to decline as human development continues, and this increasing urbanization can force migrants into progressively more unfavorable habitats (Carlisle et al., 2012; Seewagen, 2005). When this occurs, there is a potential for increased inter- and intra-competition, loss of food resources, and higher predation risk; thus these low
quality sites lack the key components of a profitable stopover site (Carlisle et al., 2012; Moore et al., 1995). Whether urbanization alone pushes migrants into compromising situations, or other factors, such as weather and climate change patterns work in tandem with loss of habitat, the future does not look bright given the challenging life history of Neotropical migrants. There are some studies, however, that demonstrate migrants utilize urban areas to a similar degree as non-urban areas, staying for multiple days and successfully replenishing fat stores (Seewagen & Slayton, 2008; Seewagen et al., 2010). Thus, even highly urbanized green spaces are crucial for preservation. It is imperative scientists understand how migrants are affected by urbanization and the further challenges that can bring, namely, the presence of humans. Below I highlight studies which examine the responses that human presence has to wildlife, specifically avifauna.

1.4 The Influence of Human Intrusion on Wildlife

Ecological disturbance is a broad term that refers to removal of all or part of an ecosystem which causes a pronounced change in that ecosystem (Rykiel, 1985). Humans are often associated with disturbance, such as deforestation, drilling, and forms of recreation, such as boating, biking, or horse riding (Knight & Cole, 1995b). However, even if direct community- and/or ecosystem-level impacts are minimal, the mere presence of humans in an environment can have significant ecological impacts. The impacts of human presence, which is termed intrusion, are wide-reaching and generally negative (Gutzwiller et al., 1994). Despite the fact that intrusion does not include the habitat alterations or other changes associated with humans, the presence of humans in proximity to wildlife is ubiquitous, pervasive, and can lead to changes in avian behavior (Gutzwiller et al., 1994).

In general, intrusion causes displacement of birds, limits access to food and other resources, and reduces reproduction and survival (Fernández-Juricic & Tellería, 2000; Gutzwiller et al., 1998; Smith-Castro & Rodewald, 2010a). In addition, intrusion can lead to increased alertness due to human presence, preventing birds from engaging in normal activities, such as foraging, singing, and territorial
displays (Fernández-Juricic & Tellería, 2000; Gutzwiller et al., 1998; Gutzwiller et al., 1994) Fernández-Juricic and Tellería (2000) found that Blackbirds (*Turdus merula*) moved in different patterns, foraged less, and were more vigilant when human visitors were present. As intrusion increased, they also were found further from trails, nearer to cover, and occurred in less density compared to unintruded sites. The mere presence of humans was negatively related to breeding success and altered spatial patterns of bird communities (Fernandez-Juricic, 2000).

When outdoor recreation was a new concept, there were fewer people, recreationists specifically, and there was more space for them to engage in activities. However, recreational intrusion can no longer be considered neutral to ecosystems, and ecologists are beginning to recognize the consequences of human presence (Flather et al., 1995). A paper by Boyle and Samson (1985) reviewed published studies of the impact of outdoor recreationists on wildlife and found 81% showed a negative impact. In the past, human intrusion was considered too dilute and widespread across a large area; however most researchers now realize this has a more serious impact on wildlife (Flather et al., 1995). As the world’s population grows, two changes occur: 1) urbanization increases and 2) areas for people to engage in outdoor activities decreases. This renders wild areas increasingly populated by recreationists and other forms of human intrusion (U.S. Department of the Interior et al., 2011). Furthermore, most forms of nonconsumptive recreation, such as hiking and mountain biking, are expected to increase 63% to 142% over the next 30 years (Flather et al., 1995).

Human activities that impact wildlife can range from exploitive-direct killing of wildlife through hunting or trapping- and indirect impacts such as habitat modification (i.e. trampling plants and soil) and pollution. Intrusion on trails is considered a direct impact and can be intentional (such as harassment of an animal by chasing or spooking) or unintentional (from hiking or nature viewing). To date, most research on intrusion has also been done on waterbirds in non-forest environments (Bolduc & Guillemette, 2003; Burger, 1986; Klein et al., 1995; Marzano & Dandy, 2012; Skagen et al., 2001) and year-round resident passerines (Gutzwiller et al., 1998; Gutzwiller et al., 1994; Riffell et al., 1996). Many studies conducted
on various waterbirds, such as Trumpeter Swans (*Cygnus buccinator*) and Common Sandpipers (*Actitis hypoleucos*), found that they respond behaviorally by leaving the area when a pedestrian approaches, and most return after the intrusion is over (Flather et al., 1995). Very few studies have investigated the impacts of human presence on migratory passerines (but see Gutzwiller et al., 1998), or compared the relationship between intrusion and breeding migrants (species that breed in an area but migrate during the non-breeding season), passage migrants (species that pass through en route), wintering migrants (species that breed elsewhere but spend the winter in an area), and resident species. In the following subsections, I review key factors that influence avian responses to human presence: an intruder’s type of activity, how predictable that behavior is, the frequency and magnitude of intrusion, the timing, and the location intrusion occurs.

1.4.1 Type of Activity: Pedestrians can have unintended consequences on wildlife. Simply walking, talking, or jogging through a park or nature preserve impacts birds and other wildlife in both direct and indirect ways (Knight & Cole, 1995b; Marcum, 2005). Even mild levels of conversation can impact wildlife (Marzano & Dandy, 2012). In birds specifically, the presence of pedestrians has been shown to decrease species abundance and richness, as well as other population and community level impacts (Fernandez-Juricic, 2000; Fernández-Juricic, 2002). Pedestrian presence results in behavioral changes of various avian guilds (Skagen et al., 1991) and changes in feeding habits (Fernández-Juricic & Tellería, 2000).

1.4.2 Predictability: Predictability refers to the patterns of human intrusion, and if the wildlife in an area is accustomed to these patterns. This can refer to whether the intrusion is restricted to a pre-determined course, such as a trail, or if human intruders are able to wander off trails at will. When the intrusion is nonthreatening and expected, wildlife become accustomed to it and display no evident response (Knight & Cole, 1995a). Similarly, birds show more tolerance to on-trail than off-trail human approaches most likely because they become habituated to the set patterns trails provide (Miller et al., 2001). Northern cardinals (*Cardinalis cardinalis*) were more likely to flush off nests when directly
approached off trail compared to on-trail intrusion (Smith-Castro & Rodewald, 2010b). Similarly, Fernández-Juricic et al. (2004) found as distance to walkways increased, so did the flight distance. Bay-winged Cowbirds (*Molothrus badius*) and Spot-winged Pigeons (*Columba maculosa*) both flushed sooner when approached by pedestrians when this interaction was further from a trail. They proposed this may be due to the predictability of human movement on trails. If the bird was approached at a location farther from a predictably disturbed trail, the risk was perceived as greater. Additionally, Burger and Gochfeld (1991) found birds could become desensitized to large groups of people approaching. This could be from habituation, which occurs when, after repeated exposure, intrusion is no longer viewed as a threat to wildlife (Fernández-Juricic et al., 2009). For example, Belding’s Savannah Sparrows were more sensitive to intrusion (through greater alert and flight distances) when human visitation rate is lower because they are unaccustomed to human presence. However, in areas with regular intrusion, the alert and flight distances decrease, indicating reduced sensitivity. “Risk allocation” is another proposed mechanism, where animals preferentially engage in certain behaviors (such as foraging in the open) despite predation risk in order to take advantage of food resources when there are limited opportunities to do so, as there are in highly intruded areas (Fernández-Juricic et al., 2009).

### 1.4.3 Frequency and Magnitude

Studies vary on the impact that magnitude, in the form of user density (number of people intruding an area) has on bird behavior. Vaske et al. (1995) state that user density does not have a linear relationship with degree of impact on wildlife: more significantly factors such as are frequency (how often users disturb an area) and behavior of visitors (i.e. Loud or silent? Fast or slow?), as well as type of use (i.e. motorized vs. non-motorized intrusion) those visitors employ. In avifauna, however, Burger and Gochfeld (1991) found that when a larger group of people was approaching a bird, the distance it took a bird to flush increased. However, when the group was smaller, yet closer in distance to birds, the birds did not flush as quickly, indicating that small groups may be less intrusive to birds. In this study, flush distance was strongly correlated with the number of approaching pedestrians. Fernández-Juricic and Tellería (2000) concluded similarly that an increased number of park
visitors decreased Blackbird density. Interestingly, Gutzwiller et al. (1994) found that a low magnitude of intrusion changed singing patterns in subalpine birds more than high intrusion. When 100% of a plot was disturbed, bird song occurrence was higher compared to plots where intrusion was on 25% of the plot, which could indicate quick habituation to intruders. Overall, studies assume that both of these factors, the number of visitors in a group and the frequency of human intrusion over time both increase the response intensity by avifauna (Burger & Gochfeld, 1991; Fernández-Juricic et al., 2003; Fernández-Juricic et al., 2004). Because user density (magnitude) data are less consistent, Fernández-Juricic and colleagues (2004) have been predicted that small birds, which flush shorter distances and return to the area quickly, would benefit from a management style that allows larger groups in concentrated numbers disturb an area less frequently. On the other hand, larger species could be displaced less frequently by restricting pedestrians to a small area on a refuge or preserve (Fernández-Juricic et al., 2004).

1.4.4 Timing: In general, research reveals wildlife is most sensitive to intrusion during the breeding season, but there are inconsistencies. In birds, if species are disturbed during nesting season, they are more likely to abandon their nests (Knight & Cole, 1995a). In areas of high intrusion, Fernández-Juricic et al. (2009) found alert and flight distances to be greater during the pre-nesting season for Belding’s Savannah Sparrow (Passerculus sandwichensis beldingi). This trend was reversed in the low intrusion sites: birds tolerated humans more during the non-breeding season. This may be from aggregation in small but vigilant flocks vs. pairs during the breeding season or less attachment to sites that are not territories. Distance fled was lower during the breeding season, which could be a result of territoriality during breeding season. Either way, intrusion during the breeding still has indirect impacts on reproductive success.

1.4.5 Location: It appears that birds which are disturbed closer to cover from vegetation or other habitat features are less wary of intruders than birds in the open or far away from cover. Fernández-Juricic et al. (2009) proposed this as an explanation for the reduced distance Belding’s Savannah Sparrows detect and flee from intruders: using nearby cover as an “escape plan;” birds in these locations may tolerant
closer human presence in order to more effectively utilize resources. Tree height or stem density can increase tolerance to intrusion because provide a refuge for flying birds and obstruction for ground-dwelling birds. Both would also allow birds to keep track of intruder’s movements as it approached (Fernández-Juricic et al., 2004).

1.5 Avian Responses to Intrusion

1.5.1 Guild Specific Responses

Burger and Gochfeld (1991) found migratory guild was a significant contributor to a bird’s response to human presence: migrants were found to be less tolerant of intrusion. Conversely, resident species tolerated both more people nearby and a closer approach distance. Klein et al. (1995) similarly found that migrants were more sensitive to intrusion (both foot and vehicle traffic), but in waterbirds compared to passerines.

The effect of species’ size is inconsistent: Burger and Gochfeld (1991) found larger species of birds more tolerant to intrusion that smaller ones, but many other studies concluded the opposite (Blumstein, 2006; Cooke, 1980; Hill et al., 1997). For example, some studies found larger species of birds fly further and perch higher when disturbed (Fernández-Juricic, 2002; Fernández-Juricic et al., 2004). It has been proposed that flight distances are species-specific, even when habituation effects are accounted for (Fernández-Juricic et al., 2004). Gutzwiller et al. (1998) found no relationship to body size, but it may be because they analyzed overall smaller body size ranges compared to other studies. Smaller birds have a greater surface area to body weight ratio, and thus expend energy more readily. Constant flight to evade some intrusion could be unnecessary when energy is an expensive commodity. This may explain why smaller birds display higher tolerance to intrusion to maximize energy conserved (Knight & Cole, 1995a).

Birds that flock together are more tolerant of intrusion by humans due to having other individuals to be vigilant, but this only applied when flocks were of the same species (Gutzwiller et al., 1998; Knight & Cole, 1995a). However, there is no difference in tolerance to intrusion when the group is composed of
heterospecifics (Gutzwiller et al., 1998). Fernández-Juricic et al. (2001) found no difference in alert distance—when a bird stops normal behavior and switches to vigilance—between flock size of either conspecifics or heterospecifics. But their sample size was small and they admit statistical power was not strong. Brighter colored species show less tolerance (greater approach distances) than cryptic species due to their conspicuous nature. In addition, ground-dwellers and foragers had greater approach distances, meaning species that are active higher in trees are more tolerant (Gutzwiller et al., 1998).

1.5.2 Levels of Impacts

Intrusion can result in three types of effects: direct, indirect, and community. Direct, also known as individual, effects are the animal’s immediate behavioral response the intrusion, such as flushing or defensive posture, which affect species at an individual level (versus populations or communities). Most studies to date have looked at direct effects of human intrusion by studying response or alert distances (Burger & Gochfeld, 1991; Fernández-Juricic et al., 2001; Gutzwiller et al., 1998; Thiel et al., 2007), changes in foraging pattern or food habits, and other essential behaviors (Burger, 1981, 1986; Skagen et al., 1991), abnormal vigilance (Gutzwiller et al., 1998), or even immediate survival (Burger & Gochfeld, 1991). Certain types of direct effects from intrusion may include nest abandonment and physiological changes. These affect individuals but may have cascading impacts into a population level (Knight & Cole, 1995b). Conversely, there also may exist effects of intrusion with no immediate responses to wildlife, but over time and repeated intrusions, cumulative changes may arise (Riffell et al., 1996).

Indirect effects may be the synergistic or additive effects that result after the direct interference from humans, which affect birds at a population level. For example, the direct impact of nest abandonment from intrusion can result in poor reproductive success, an indirect impact. Studies focusing on indirect effects of intrusion mainly assess reproductive success, such as clutch size or number of successful fledglings (Bolduc & Guillemette, 2003; Safina & Burger, 1983). For example, Common Sandpipers were found to have a reduction in the breeding populace, but overall there was little effect on
the breeding success of the species due to restructuring of the community (Knight & Cole, 1995b). Knight and Swaddle (2007) examined indirect impacts from intrusion on eastern bluebirds (*Sialia sialis*). Interestingly, they found intermediate levels of human presence resulted in most productive nests, but there were complex, non-linear relationships between human presence and measures of fitness, such as chick survivorship. They found a strong negative relationship between high levels of human activity and adult self-maintenance. They concluded that in areas of high intrusion, adult bluebirds could be transferring the cost disturbance causes to themselves in order to protect their young. If intrusion continues, future broods could be negatively impacted due to these sub-lethal effects on the parent. These indirect effects may change seasonally as well, such as increased sensitivity by birds during breeding season or migration. This is a critical period in a bird’s life cycle in which intrusion should be minimized or completely avoided (Knight & Cole, 1995a). Since birds are likely to abandon nests in the presences of humans, reproductive success or failure may be caused by poor intrusion timing by humans. A case study involving common eiders (*Somateria mollissima*) found that human presence caused them to leave the nest, thus draining critical body reserves for incubation. Upon return, the energy needed to reheat the cool eggs was greater, and fecundity suffered as a result of intrusion. Since the females do not eat during this time, even a small amount of intrusion lead to drastic body weight losses. This loss prevented females from properly caring for their young once hatched or possibly abandon nestlings or eggs during incubation (Gabrielsen & Smith, 1995). Provoking or removing baby birds from the nest is harmful as well. One study found merely touching a nestling penguin causes it to spend valuable energy (and two to three hours’ time) to return core body temperature. Over time, repeated provocations undoubtedly translate into reduced breeding success (Gabrielsen & Smith, 1995). To species that are extremely sensitive to intrusion, the impacts of a humans walking even quietly in an area can lead to behaviors such as nest abandonment or lowered nest attentiveness (Gutzwiller et al., 1998).

Community impacts are those in which a community is affected by the intrusion, such as avian diversity or abundance. These effects from human presence are usually negative as well, such as causing
an entire species to leave an area (Marcum, 2005), or decline in species richness and abundance (Fernandez-Juricic, 2000; Riffell et al., 1996) and diversity (Skagen et al., 1991). However, results are mixed: some studies have found an increasing in diversity due to recreationists (Knight & Cole, 1995b). Again, these intrusions tend to favor certain guilds, such as introduced species or edge species, whereas interior forest dwelling species suffer (Chace & Walsh, 2006). Intrusion can affect ecosystems in layered ways both locally and regionally. Habitat suitability decreases at a local level as foraging and breeding opportunities are limited and at a regional level by transforming a source habitat into a sink. At highly intruded sites, regional extinction increases while colonization likelihood diminishes (Fernández-Juricic et al., 2003). Proper care is needed to disentangle the many variables involved when looking at guild or community level impacts.

1.5.3 Stress Responses

The relationship between habitat quality and anthropogenic intrusion, amongst other factors, could be determined by the measure of stress response, which are coping mechanisms via physiological and behavioral routes (Romero, 2004), in avifauna. Any noxious stimuli, such as pedestrian intrusion, to wildlife is considered a stressor, and the level of stress response, whether physiological or behavioral, is one way in which biologists define habitat quality. Physiological changes occur within an individual as a direct result of human presence, but may cause indirect changes in a bird’s physiology (Knight & Cole, 1995b). Typical responses during stress include increased hormone levels, heart rate, blood flow, respiration, body temperature, and blood sugar (Gabrielsen & Smith, 1995). Monitoring the hormones cortisol and corticosterone is common way biologists determine stress response (Holberton et al., 1996). Migrating birds have elevated hormone levels of corticosterone during stopover periods, which facilitates fat deposition via hyperphagia and lipidogenesis. Compared to nonmigratory birds of the same species, corticosterone levels remained higher than baseline during capture and handling of migrating birds, and they seem to have the ability to suppress typical stress responses. Interestingly, no relationship was found
between stress hormone levels and fat reserves. Even though fat deposition is facilitated by increased corticosterone levels, this relationship was not linear. This suggests that increased hormone levels during migration does not necessarily translate to increased fat stores as one might expect. Furthermore, it seems that migrants become preconditioned to stress during migration, so that additional stressors may not compound the physiological effects of intrusion.

Most literature investigating the responses of human presence has focused on behavioral responses of wildlife, most likely because these data, such as flushing distances, are the easiest to measure (Knight & Cole, 1995b). However, both physiological and behavioral responses are crucial in determining how intrusion affects wildlife. Prior to deciding on whether or not to flee, animals display an “orienting response” in attempt to identify the threat. If the threat is neutral, they will continue regular behaviors, but if the threat is real and sustained, they will either defend passively or actively. Passive defense includes staying motionless, dropping to the ground, hiding to nearby cover, decreased breathing and heart rate, and in some cases, a death-feint. If the threat leaves, the animal will soon return to pre-stimulus levels. However, if the threat, such as dog or a human, approaches closer, the active defense will be initiated and the animal flees, increasing heart rate substantially (Gabrielsen & Smith, 1995). This is key to my study that follows the assumption that humans are perceived as potential predators to birds--and so, human intrusion can be assessed in a similar way as predation studies (Fernández-Juricic & Tellería, 2000). Small levels of non-threatening intrusion may not elicit an active response in birds, or if they do actively flee as a result of intrusion, they will likely return fairly quickly. Unless habituated, a bird foraging in a highly intruded area will be on alert fairly consistently and regularly activate its defense to flee. This also causes birds to spend more energy on their metabolic functioning to aid in the flight response. Furthermore, more time in a defensive posture or in flight translates to less time and energy to forage, further depleting fat stores. My research will examine the potential reduction in fat reserves in correlation with these pedestrian intrusions.
CHAPTER II

THESIS RESEARCH

Migration is a costly life strategy which requires significant energetic demands, and successful passage depends primarily on a bird’s ability to acquire resources to fulfill those energetic needs of flight (Moore, 2000). Stopover sites allow migrants to refuel, and thus one of the criterion used to determine stopover habitat quality is a bird’s ability to gain mass (Carlisle et al., 2012). If a stopover site is of high quality that provides abundant food resources, cover from predators, and/or diminished predator abundance, birds will successfully acquire body fat. If the habitat quality is poor, migrants are more susceptible to predation and less likely to accumulate the necessary food requirements for a safe passage. Urbanization is a major threat to biodiversity, and is an increasing, but understudied, problem for Neotropical migrants (MacGregor-Fors et al., 2010). As urbanization increases, so does human intrusion in parks or natural areas. Intrusion refers to the presence of pedestrians, such as runners, hikers, or nature observers. To determine the association of human intrusion in urbanized nature parks to a birds’ ability to acquire food during migration, I investigated differences in body mass index of birds caught at areas of high and low pedestrian activity.

2.1 Research Questions

A question yet to be addressed in the scientific literature is whether or not individuals are able to compensate for energy losses, from decreased foraging and increased flight distances, due to recreational intrusion (Knight & Cole, 1995b). These energetic condition changes are alluded to frequently in the literature, but very few studies have been done to test their relationship. My research seeks to address this question by examining whether individuals in areas of high pedestrian activity will be in similar body
condition as individuals caught in areas of less pedestrian activity. My study follows the theory that humans are perceived as potential predators to birds (Fernández-Juricic & Tellería, 2000). Because of this, human intrusion can be assessed in a similar way as predation studies. Birds are expected to change behaviors if a threat is sensed by increasing time spent being vigilant, moving, or searching for cover and decrease foraging rates (Fernández-Juricic & Tellería, 2000). This will lead to decreased feeding success and food acquisition by birds. Birds near intrusion must find cover more readily, and thus their normal feeding activities would be continually interrupted (Fernández-Juricic & Tellería, 2000). My research will attempt to answer the following questions:

1) Are there differences in human intrusion level, food availability, and vegetation structure between the two sites? A difference in bird body mass index between two sites may be attributed to intrusion level or another parameter. By quantifying food availability and foliage density, I attempt to rule out food and amount of cover as factors that could confound bird body mass. This will also help me address the habitat suitability for avifauna since a higher quality stopover habitat is one which birds regain fat stores successfully (Moore et al., 1995; Seewagen, 2005). If avifauna cannot acquire body mass at sites that are more visited by pedestrians, these sites would be considered lower quality. Though many factors must be assessed to determine habitat quality, such as edge effects, invasive species, and other physical and biotic parameters, I specifically am interested in the relationship between human intrusion and habitat quality. If other factors, such as food supply and amount of vegetation between the sites is fairly consistent, then human presence could be a crucial driving force behind a bird’s ability to gain body mass. Thus, areas of high human presence also indicate low quality stopover habitat.

2) Is there relationship between human intrusion and the ability of avifauna to acquire food supplies and regain fat stores? Based on intrusion studies, most birds are sensitive to human presence (see Burger & Gochfeld, 1991; Knight & Cole, 1995b); therefore, I predicted that birds at sites with higher levels of intrusion will have lower body mass indices. At sites with higher levels of intrusion, birds will be more likely to flush, or leave the area. When a bird flushes, two things happen: it uses energy to escape
the intrusion, and it has less time to spend foraging to replenish those fat stores (Marzano & Dandy, 2012). Fernández-Juricic and Tellería (2000) found that as pedestrian levels increase, birds stop foraging to take cover or move to a less visited area. Overall, such patterns would be reflected by catching birds with lower body mass indices compared to areas away from intrusion.

3) Is there relationship between human intrusion and the fat reserves of birds of different migratory guilds? Migrant species have been reported to be less tolerant of human presence than permanent resident birds (Burger & Gochfeld, 1991). Regardless of distance covered or length, migration poses unique challenges that may be exacerbated by pedestrian intrusion. Conversely, because resident species in urban areas are constantly exposed to pedestrian presence, they are likely to have adapted to this life challenge in order to access resources, such as food, more efficiently (Fernández-Juricic et al., 2009). Since I use body mass index as a metric of fat reserves, I predict that the body mass index of migratory bird species will show a more negative relationship to human presence than the body mass index of resident species.

4) Is there relationship between human intrusion and fat reserves of birds of different families or species? Even within the same species, wildlife responses to humans can vary prominently (Knight & Temple, 1995). It is thus imperative to analyze not only all species to see general trends, but also to analyze more similar groups of passerines as to obtain a more precise measure of body mass differences between sites. When analyzing families or individual species when sample size allows, I predict similar results mentioned above depending on the migratory guild; that is, for a migratory family (i.e. Parulidae) or species (i.e. Hooded Warbler) I predict body mass index to be greater than the BMI of birds caught away from intrusion. However, for a resident species (i.e. Northern Cardinal), I predict higher body condition near intrusion, as a result of lifestyle acclimation to pedestrian activity (Fernández-Juricic et al., 2009).

Despite the growing body of literature on intrusion, very little is known about the indirect body consequences due to human presence. My study is novel in that I will investigate the indirect, body mass
changes that occur in individual birds associated with human intrusion. By evaluating changes in body condition by migrants, I can better assess how avian individuals, species, and guilds respond to intrusion. This has significant implications for conservation purposes. If intrusion is correlated with major negative changes to a bird’s physiology, then wildlife and park managers may have to change their approaches to natural systems management. Since my research will specifically address stopover migrants, this may have implications throughout the western hemisphere, as migrants utilize vast expanses of North, Central, and South America.

2.2 Research Design and Methods

2.2.1 Study Site

Greenway Farms (35° 07’ N, -085° 13’ W) is a 220-ha park along the North Chickamauga Creek in Hixson, TN, with habitat consisting mainly of oak (Quercus spp.)–hickory (Carya spp.) forest, 12 ha of overgrown field, and 11 ha of regularly mowed turf grass. The average age of most of the trees in the wooded habitat is between 40 and 50 years (Seeber). The park is surrounded on all sides by suburban development; housing density averages 12 houses/ha, and the population density is 550 people/km² (City-Data, 2014).

The park is naturally divided into two areas: the Greenway and the Bluff (see Figure 1). The Greenway area is framed by North Chickamauga Creek and has an average elevation of 201 m above sea level. This area also contains multiple parking lots, a large managed lawn, a dog park, gardens, a storage building, and a small office. In addition, the Greenway serves as the central area where all visitors to the park enter and most visitors use. The overgrown field was an area that was cleared and planted with native warm-season grasses in 1997. No additional management has been done, and the area has since become overgrown with Chinese privet (Ligustrum sinese), Japanese honeysuckle (Lonicera japonica), Amur honeysuckle (Lonicera maackii), blackberry (Rubus fruticosus), and scattered Bradford pear (Pyrus calleryana), Eastern red cedars (Juniperus virginiana), and sweetgums (Liquidambar styraciflua).
Two study sites located on the Greenway Farms land in Hamilton County, Tennessee. Greenway site has high intrusion (top, pink). Bluff site has low intrusion (bottom, orange).

The Bluff site is at an elevation of 268 m and a paved trail runs up the bluff and continues to the west end of the park. Invasive species were common but less abundant at the upper site, and there were more open areas of forest floor with native flora.

2.2.2 Pedestrian Rate

Studies examining relationship of wildlife to pedestrian intrusion have quantified it as number of pedestrians passing in a given time frame (Fernandez-Juricic, 2000). Pedestrian rate was determined by two methods: Stationary observation and passive walking observation. These two methods were necessary as the sample size for stationary observations were not sufficient, due to limited manpower.
2.2.2.1 Stationary Observation

For various days in spring and fall 2014, a volunteer observer counted the number of pedestrians that passed from a stationary location on random days. The observer sat in a single spot and documented any person or group of persons that passed them on the trail. Since the nets were located on trails that formed a loop, I assume that any passerby would have disturbed all or nearly all nets in the area. Also, the observer varied between three people. This may result in additional inconsistencies due to inter-observer errors; however, counting the number of people that pass is quite a discrete task compared to a more subjective task, i.e. judging amount of fat. Thus interobserver error most likely plays an insignificant role in my study.

The observations were conducted from ~30 minutes after sunrise until 1200 EST. This way the intrusion calculated corresponds with the same time and days I banded and collected data. The number of people passing per hour over 11 days of stationary sampling (n=7 for Greenway, n=4 for Bluff) was calculated. I used a Mann-Whitney test (SPSS) to compare averages at an alpha level of 0.05.

2.2.2.2 Passive Observation

Due to limitations of manpower, I was unable to obtain sufficient sample size for stationary observation. Thus, banders collected data on the passive amount of intrusion: the number of people encountered by chance on trails during net checks. This was documented for as many days as possible, and recorded by the primary bander on a given day (n=6 for Greenway, n=47 for Bluff). For the Bluff site, data were collected both spring and fall seasons of 2013 and 2014 by myself (LKM) and Samuel Clark (SC). Data were collected fall 2014 at Greenway site by David Aborn (DA). Because intrusion rates by the banders are mostly equal between sites, bander and banding assistants were not documented unless they comprised of more than three individuals on a given day. I compared average number of people passing per hour between lower and upper sites using a Mann-Whitney test (SPSS) where $\alpha = 0.05$. 
2.2.3 Mist Net Setup

Based on the calculations above, Greenway was considered high intrusion and Bluff was considered low intrusion. Sixteen mist nets (12 m x 2.6 m, 30 mm mesh) were set up along both transects (8 nets per site, Fig. 1). Length of transects were approximately 0.5 km for Greenway (high intrusion, Fig. 1, pink) and 1.2 km for Bluff (low intrusion, Fig. 1, orange). Nets at Greenway were located in discrete positions no more than 20 m from the highly intruded trails. Nets at Bluff were located between 50-100 m from the intrusion, on a less-used trail to the south of the main trail.

Mist netting data were collected during the spring and fall migration periods of 2013 and 2014. Fall migration occurs from late August through October and spring migration occurs late March through the end of May. Nets were opened within 30 minutes of local sunrise and checked approximately every 45 minutes until 1200 EST. Nets were closed when the ambient temperature exceeded 27° C, wind speed exceeded 10 km/h, or if more than a light drizzle was falling (Ralph et al., 1993).

2.2.4 Body Condition

Captured birds were placed in mesh bags and walked back to the processing station. Birds were banded with aluminum US Fish and Wildlife Service leg bands, had their unflattened wing chords (to nearest mm) and tarsal lengths measured, and weighed to the nearest 0.1 g using an electronic balance. Visible subcutaneous fat in the furcurnal hollow and abdomen was rated on a 6-point scale similar to that described by Helms and Drury (1960): (0) no visible fat, (1) trace of fat, but not completely lined, (2) completely lined with thin fat layer, (3) filled with fat but still concave, (4) filled with fat even with pectoralis or slightly bulging, (5) filled to bulging and at least partially covering keel. Fat classes were assigned by the same observers (LM and SC at upper site, DA at lower site) throughout the study to minimize inter-observer variation (Krementz & Pendleton, 1990). All netting was done in accordance with approved IACUC protocol #0406DAA-02.
2.2.5 Food Sampling and Vegetation Structure

Since body mass indices are impacted by the amount of food availability in an area, we conducted fruit and insect sampling in see if food availability was an additional factor. Many passerine species switch diets seasonally, from fruits in fall to insects and arthropods in spring (Fristoe, 2014). A standard method to sample fruit is via fruit count: randomly selecting fruiting branches in the fall and counting the number of berries present (Lashley et al., 2014). Trails were walked by a trained observer stopping every 50 m (at lower site) and 75 m (at upper site, since the trail was longer) and randomly selecting three branches (one right along the trail and two branches ~5 m off the trail to both the right and the left) near the trail to count berries. This was performed at ten stops per site in 2013 and 2014, resulting in \( n = 30 \) spatially independent sampling points per site per year. As most plants fruit in the autumn, and many migrants increase frugivory during fall migration, fruit availability was measured during the fall migration period (early to mid-October) (Baird, 1980).

For arthropod availability, since most of my target species are gleaners (i.e., they pick off crawling insects on branches and leaves as opposed to catching airborne insects), a common method to quantify food is to collect branch samples (Ozanne, 2005). During the breeding season, macroinvertebrates compose the majority of forest bird diets, and as this food source changes, it can have indirect, cascading effects on bird reproductive success and body condition (Casey et al., 2010). Arthropod sampling was performed in the spring when there is a flush of invertebrates. We walked along the trails where the nets are located, and stopped every 50-75 m. Again, three branches were randomly selected one right along the trail and two branches ~5 m off the trail to both the right and the left. Height of branches selected correlated with average height of mist nets to directly compare arthropod availability in the layer of forest which we were most commonly mist-netting birds. Branches were covered with a 50 l plastic trash bag, household insecticide was sprayed into the bag, and then the bag was tied closed with a drawstring. After 1 hr, the branch was shaken to dislodge the insects. The bag was then removed carefully to ensure insects stayed inside. This occurred at ten stops per site in 2013 and 2014, resulting in \( n=30 \).
spatially independent sampling points per site per year. Bags were placed in a freezer until arthropod sorting and counting could be performed. The bag was carefully opened and contents were extracted and sorted. Arthropods were sorted and classified into order, and abundance was counted.

The amount of vegetation present can have a confounding correlations on bird body mass by blocking visual contact with pedestrians. If avifauna cannot see pedestrians, they do not pose a threat, and thus do not hinder normal activities such as foraging and fat acquisition (Fernández-Juricic et al., 2009). To examine differences in foliage density, which can also alter bird numbers and behavior (Marshall & Cooper, 2004; Robinson & Holmes, 1984), we used a vegetation profile board similar to that described by Nudds (1977). The profile board consisted of a standard 0.30 m * 1.22 m board painted in five alternating segments of black and white (35 cm each) with a total height of 1.75 m. A stake was attached to the bottom so that the board could be inserted into the ground and samples could be completed by one person. Four samples were taken every 50 m; one at either edge of the trail, and one 20 m away from the edge on either side of the trail. Foliage was visually estimated by the percent of each board segment covered by vegetation to the nearest 5%. Readings were taken with eye level at a height of one meter starting with the bottom segment and moving to the top (see Mitchell & Hughes, 1995). The vegetation profile board method has been used in previous bird studies (MacArthur & MacArthur, 1961; Recher, 1969). A total of 10 points were evaluated at each site, and the results were averaged to give the mean percent foliage density at each site.

2.3 Data Analysis

2.3.1 Food Sampling and Vegetation Structure

To determine if there was a difference in the fruit biomass between sites, I averaged the number of berries across three branches (n=10 for each site and year), and performed an ANOVA (SPSS) at an alpha level of 0.05. Site was treated as a fixed factor and the average number of berries was treated as the response variable. To quantify arthropod abundance between sites, I calculated the average number of
arthropods and compared the average between sites using a Fisher’s Exact Test (SAS) to test the null hypothesis ($\alpha=0.05$) that the frequencies of arthropods found between sites were proportionally equal independent of location. In other words, if frequencies were similar, close to 50% for each site, then there was not difference in food availability (in terms of arthropod numbers) between sites.

2.3.2 Body Mass Index

I classified birds into one of three migratory guilds: Resident species (non-migrants), Short-Distance Migrants (Wintering species), and Long-Distance (Neotropical) migrants. Resident species are those that stay in the study area, year-round. Wintering birds are species that live in the area in winter only, migrating from further north in the fall and leaving in the spring before breeding season--thus, they not breed in our area. Neotropical migrants (referred to as migrants from here on) are species that breed in the United States and Canada, and migrate to Central and South America and the Caribbean during the non-breeding season (Moore et al., 1995).

Wing length and mass were used to calculate the Scaled Mass Index (SMI) (Peig & Green, 2009) to compare measure of body condition. SMI scales individuals being compared to produce a better indicator of body condition based on relative size. The formula for SMI is:

$$SMI_i = M_i \left( \frac{L_o}{L_i} \right)^{b_{SMA}}$$

where $M_i$ and $L_i$ are the body mass and wing length of an individual, respectively. $L_o$ is the arithmetic mean of wing length for all birds being considered in the scaling calculations, and $b_{SMA}$ is the slope derived from the standardized major-axis (SMA) regression between body mass and wing length, excluding outliers (Peig & Green, 2009; Rosalino et al., 2013).

SMI has withstood comparisons to Traditional Condition Indices (CI) in small mammals (Rosalino et al., 2013), snakes, starlings (Peig & Green, 2009), and fish (Maceda-Veiga et al., 2014).
Traditional Condition Indices usually estimate body size of an individual by regressing the individual’s body mass against a linear body measure (i.e. wing, tarsus, or tail length). However, physical condition cannot be accurately measured with this calculation since traditional CI does not take into account fat or protein amounts in a body, which can alter body size more than a morphological measurement. SMI is a more powerful measurement of body condition because it scales body size and morphological measurements for the group being analyzed, whereas past methods are biased toward larger individuals. Furthermore, SMI takes into account the changes in body measurements (such as mass and wing length) and body condition as an individual grows whereas other methods do not (Peig & Green, 2010).

For every analysis, seasons were kept separate because of differences in behavior, certain physiological parameters (e.g. reproductive hormone levels), and motivational state (breeding versus non-breeding) that exist between spring and fall migrations. In fall birds are gaining weight preparing for migration, whereas in spring, avian mass may be reduced as they are migrating and simultaneously preparing for the breeding season (Morris et al., 1994). Data for recaptured birds were disregarded if the bird was caught in the same year and season; however if they same bird was caught the next season or year, I kept the data. For example, a Northern Cardinal caught for the first time on 8/26/2013 was a unique data point. This bird was recaptured on 9/2/2013, and even though its mass may have changed, these data were removed from analysis since it would skew results slightly in favor of recaptured birds. If the bird was recaptured the next year or season, the earliest date from each (if applicable) was kept. For example, if the same cardinal was caught again twice in spring 2014 and twice in fall 2014, the earlier date for both seasons would be kept and subsequently analyzed. Though we acknowledge that this does not eliminate pseudoreplication, it minimizes it, and such instances were rare ($n=13$).

Because avifauna families differ substantially in terms of body size, foraging behavior, etc., I partitioned my analysis into three major subsections: all species, family, and species. All Species included every individual captured; Family included all members of a taxonomic family for which I had sufficient sample sizes ($n$=greater than 30), and Species included members of individual species for which there
was sufficient sample size to see if trends in body mass appeared for a more taxonomically focused group of organisms. SMI was recalculated depending on which group I was analyzing. For example, when all species were analyzed, I calculated SMI for all species for both the Greenway and Bluff site, keeping years together but seasons separate (see below). When I analyzed SMI by certain families or individual species, I recalculated the SMI for those groups, thus rescaling the body mass and wing-length relationship. Prior to beginning SMI calculations, I created a scatterplot of wing length x mass to see if outliers existed (Peig & Green, 2009). If so, they were taken out of the analysis and explained below. I also calculated the standardized major axis (SMA) regression slope of ln mass vs. ln wing, as part of the scaled mass index calculation.

2.3.3 Data Transformation

SMI was usually not normally distributed, so the non-normal data were both log and rank transformed. Then the normality and homogeneity of variance (HOV) were examined using histogram and Q-Q plots for normality and Levene’s test of equality for HOV. If histograms of all transformations looked non-normal and HOV was not met at a 0.05 significance level, I used rank SMI, which better satisfies the ANOVA test assumptions for normality and HOV. In most cases, rank SMI showed less violations of normality and homogeneity of variances; as such, rank SMI was used in most parametric analyses (described in detail below). However, even after transformation, the distribution of observed SMI values was significantly different from normal, and variances were not homogenous among groups. Thus, I additionally used non-parametric tests between SMI and each main factor. I used Mann-Whitney U tests to compare SMI by year (2013, 2014) and location (Greenway, Bluff), and used Kruskal-Wallis to compare SMI by migratory guild (long-distance migrant, short-distance migrant, and resident).
2.3.4 Parametric Statistical Analysis

To examine the relationship between location and SMI across migratory guilds and years, I used a three-way mixed-factor ANOVA. Location (Bluff and Greenway) and Migratory Guild (long-distance migrants, short-distance migrants, and residents) were treated as fixed effects. Year was treated as a random effect because year was not a treatment of interest, but instead a sample of two specific years meant to be representative of a larger subset of all possible years (Gotelli & Ellison, 2004). I included all two-way interactions (i.e. the interactions between location and migratory guild, location and year, and migratory guild and year) in the model. Because there was no a priori biological reason to hypothesize that a three-way interaction (location x migratory guild x year) would exist, and because including additional terms in the model can reduce statistical power to detect other significant relationships, I did not include the three-way interaction in the model (Gotelli & Ellison, 2004). I used Tukey post-hoc tests to determine differences between migratory guilds in order to isolate which means were significantly different. All statistical analyses were run using either SPSS™ or Sigma Stat™.

2.3.5 Non-Parametric Analyses

Since my study incorporated both main and interaction effects, relying on the results on the non-parametric tests alone may increase likelihood of committing a Type I error in my interpretation, which would result in rejecting a null hypothesis that is actually true. Therefore, I compared the qualitative results of both parametric and non-parametric tests. If results deviated significantly from the ANOVA results, I describe and discuss the non-parametric results below. However, because both the parametric and non-parametric analyses revealed qualitatively similar results with respect to the relationships between SMI and guild and between SMI and location, I present only the results of the more thorough parametric ANOVA analysis in the results section for those analyses. I also view the parametric results as more informative in comparison to the non-parametric analyses, as the parametric analyses revealed interaction effects, which in many cases were significant, that non-parametric tests cannot assess.
CHAPTER III

RESULTS

3.1 Overall Results

A total of 1,160 birds were analyzed for this project. 595 birds were caught at the more intruded Greenway site, and 565 birds were caught and banded at the less intruded Bluff site. More birds were banded in fall: 791 birds (68.2%) in the fall season compared to 369 (31.8%) in spring. Out of the total 1160 birds captured, 95 had been banded in a previous year. We recaptured 13 birds in both years (n=6 in spring, n=7 in fall) and these low numbers are unlikely to affect overall results.

Table 1 Total birds caught between Sites, Years, Seasons, and Migratory Guilds. LDM = Long-distance Migrants, SDM = Short-distance Migrants, RES = Residents

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Season</th>
<th>Migratory Guild</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>LDM</td>
</tr>
<tr>
<td>Greenway</td>
<td>247</td>
<td>348</td>
<td>195</td>
</tr>
<tr>
<td>Bluff</td>
<td>308</td>
<td>257</td>
<td>174</td>
</tr>
</tbody>
</table>

3.1.1 Sampling Effort, Diversity, and Similarity

Sampling effort was equal between sites, with a total effort of 8,640 total net-hours (net-hour= 1 net open for 1 hour). Our capture efficiency was 13 birds per 100 net-hours.

Shannon’s Diversity Index (H’) for Greenway was -3.52 and H’ for Bluff was -3.02, indicating Greenway has slightly higher diversity, which may be a result of the variety of habitat at the Greenway site compared to a homogenous forest habitat at Bluff. Jaccard’s Index of Similarity was 0.66, which
means the sites share about 2/3 of the same species. At Greenway location we caught a total of 59 species, and 17 of those were unique to that site. Bluff site caught 44 total species, and only 2 were unique to the site. Bluff site caught 206 individual thrushes compared to 40 at Greenway, but Greenway resulted in a higher diversity of warblers, 218 individuals, whereas Bluff caught 116.

3.2 Site Differences

3.2.1 Intrusion Level

Stationary Observations: Level of intrusion was measured based on the number of people that passed on the trails per hour. The mean number of people passing/hour was significantly different between sites (Z= -2.485, p=0.006). Greenway and Bluff trails had a mean (+/- SE) of 3.55 (± 0.44) and of 0.57 (± 0.48) people passing per hour, respectively. Greenway trails had a significantly greater amount of pedestrian activity than Bluff trails. Greenway site had approximately 6.2 times more people passing per hour than the less intruded Bluff site.

Passive Observations: Greenway and Bluff trails had a mean (+/- SE) of 1.63 (+ 0.20) and of 0.45 (+ 0.06) people passing per hour, respectively. Again, Greenway trails had a significantly greater amount of pedestrian activity than Bluff trails (Z= -3.775, p<0.001). Greenway site had 3.5 times more pedestrians per hour than the less intruded Bluff site.

3.2.2 Food Availability

Fruit Sampling: There were 1.8 times more berries per branch at Greenway site compared to Bluff site. Greenway and Bluff trails contained a mean (+/- SE) of 30.3 (± 5.2) berries per bush and 17.2 (± 3.8) berries per bush, respectively. However, the number of berries per branch was not significantly higher at Greenway than at Bluff (F_{1,1}=5.011, p=0.267).

Arthropod Sampling: In 2013 arthropod frequencies between sites did not differ significantly ($\chi^2=0.0635$, df=1, $p=0.8502$). Greenway contained 50.8% of arthropods and Bluff site yielded 49.2% of
arthropods. For 2014, the number of arthropods differed between sites ($x^2=16.265$, df=1, $p<0.0001$): Greenway had fewer arthropods with 41.0% and Bluff contained 59.0%. Comparing years together, I found there to be unequal proportions between locations: Bluff had a higher percentage of total arthropods, 55.73%, compared to Greenway, which had 44.27% of total arthropods which was significantly different ($x^2=6.553$, df=1, $p=0.0127$).

Table 2 Arthropod totals and proportions between locations (Greenway and Bluff) and years (2013 and 2014). Percentages are based on proportions of the grand total of individuals collected in the study.

<table>
<thead>
<tr>
<th>Location</th>
<th>2013</th>
<th>2014</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Total</td>
<td>Percentage</td>
<td>Raw Total</td>
</tr>
<tr>
<td>Greenway</td>
<td>128</td>
<td>50.8</td>
<td>204</td>
</tr>
<tr>
<td>Bluff</td>
<td>124</td>
<td>49.2</td>
<td>294</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
<td>33.6</td>
<td>498</td>
</tr>
</tbody>
</table>

### 3.2.3 Arthropod Composition

In 2013, arthropod composition varied between Greenway and Bluff sites to a greater magnitude than the 2014 composition. Greenway had greater evenness of multiple families, with Psocodea being the highest at 26.6% (Fig. 2). On the contrary, Bluff had very few Psocodea representatives. Also Bluff had a majority of Hemiptera (34.7%, Fig. 2) whereas Greenway only had 19.5%. The rest of the families (Hymenoptera, Araneae, and Diptera) were fairly even (within 5% of each other) between sites.

In 2014, Hymenoptera was the greatest family for both sites. Diptera was higher in Greenway than Bluff, but the majority of the families were even between both sites (Fig. 3).
Figure 2  Arthropod composition at Greenway and Bluff sites for 2013
3.2.4 Vegetation Structure

The Greenway had a mean (+/- SE) of 36.75 (± 2.3)% cover, while Bluff had 39.75 (±2.4)% cover, which was not significantly different (U=711.00, Z=-0.877, \( p=0.380 \)).

3.3 Body Condition Differences

3.3.1 All Species

As per the first step in the Scaled Mass Index calculations (Peig & Green, 2009), a simple bivariate plot was created using the wing length x mass for all data (all species and years) to see if there were any outliers or inconsistencies. This scatterplot revealed two outliers which were excluded from the SMI calculations: Tree Swallow (\textit{Tachycineta bicolor}) and Pileated Woodpecker (\textit{Dryocopus pileatus}).
Since wing length was the body measurement used in our SMI calculation, and these two species have noticeably longer wing length compared to body size, they skewed my data. Their unusual body shape deviated from what the average bird exhibited in our study. Furthermore, since there was only one individual of each species caught, removing them from our dataset had minimal impact on results.

3.3.1.1 Fall:

There was no significant relationship between location and rank SMI (F_{1,1.278}=1.566, p=0.393) or between year and rank SMI (F_{1,1.654}=0.219, p=0.694). However, there was a significant relationship between migratory guild and rank SMI (F_{2,1.989}=48.279, p=0.021), implying the guild to which a bird belongs to may be the primary determinant of its SMI. Specifically, the SMI for long-distance and short-distance migrants was not significantly different (Tukey HSD, mean difference=60.057, p=0.083), but resident bird’s SMI was significantly greater than both SDM (mean difference=172.549, p<0.0001) and LDM (mean difference=232.606, p<0.0001)

There was significant interaction between location and migratory guild (F_{2,781}=35.204, p<0.0001, Fig. 4). Specifically, SMI was higher in long-distance migrants at the less intruded site (Bluff) than at the more intruded site (Greenway). Short-distance migrants’ SMI differed minimally with respect to location, with SMI being greater at the less intruded site than the more intruded site (Fig. 4). In contrast, resident birds were in higher body condition at the more intruded site than at the less intruded site, which is qualitatively different than the pattern observed in Neotropical migrants and short-distance migrants (Fig. 4).
Figure 4  Mean Rank SMI for Migratory Guild (long-distance, short-distance, and resident) between Greenway and Bluff sites observed during the fall season for 2013 and 2014 study periods. Whiskers indicate +/- 1 standard error

The interaction between year and location was significant; specifically, rank SMI was much greater at the low intrusion site than at the high intrusion site in 2014, but this difference was not significant for the year 2013 ($F_{1.781}=10.855, p=0.001$, Fig. 5).
There was a marginally significant trend suggesting a possible interaction between year and migratory guild ($F_{2,781} = 2.567, p = 0.077$, Fig. 6). Specifically, both migratory guilds (long-distance and short-distance) were not significantly different between years, but resident birds had slightly higher rank SMI in 2013 compared to 2014 (Fig. 6).
Non-parametric tests suggested that SMI did vary significantly among the years ($Z = -3.279, p=0.001$), which contradicted my ANOVA results. However, due to the significant interactions between year and location, and between year and migratory guild, the variation in years is probably a result of multiple other factors (i.e. interaction effects) that cannot be accounted for in non-parametric tests. Similarly, the non-parametric relationship between SMI and location was significant such that birds caught in the unintruded site (Bluff) had higher body mass indices than birds at the intruded site.
(Greenway) \((Z= -5.944, p<0.0001)\), which contradicted my parametric tests. However, since the parametric interactions between location and both year and migratory guild were significant or marginally significant, the differences from these interaction effects are not able to be detected with non-parametric tests. Consistent with my parametric results, the relationship between SMI and migratory guild was significant: long-distance migrants had lowest BMIs and resident birds had highest BMIs \((\chi^2 = 167.448, \quad n=791, \quad p<0.0001)\).

### 3.3.1.2 Spring:

Similar to fall, there was no significant relationship between location and rank SMI \((F_{1,1.366} =3.856, \quad p=0.244)\) or between year and rank SMI \((F_{1,0.903} =1.685, \quad p=0.435)\). However, there was a significant relationship between migratory guild and rank SMI \((F_{2,2.112} =51.321, \quad p=0.016)\), again implying the guild to which a bird belongs to may be the primary determinant of its SMI. Post-hoc results indicate the SMI for all three guilds were significantly different: long-distance migrants had the lowest SMI compared to both short-distance migrants (Tukey HSD, mean difference= -59.440, \(p<0.0001\)) and resident birds (mean difference= -97.998, \(p<0.0001\)). Short-distance migrants had SMIs lower than residents (mean difference= -38.557, \(p=0.016\)) yet higher than long-distance migrants.

There was a marginally significant trend suggesting a possible interaction between location and migratory guild \((F_{2,359}=2.642, \quad p=0.073, \; \text{Fig. 7})\). Specifically, SMI was higher in both long-distance and short-distance migrants at the less intruded site (Bluff) than at the more intruded site (Greenway). In contrast, resident birds did not significantly differ in higher body condition between sites (Fig. 7). The remaining two way interactions (year x location and year x migratory guild) were not significant \((F_{1,359}=1.831, \quad p=0.177\) and \(F_{2,359}=0.814, \quad p=0.444\), respectively).
Non-parametric results for spring were qualitatively similar for parametric results with respect to all factors. SMI did not vary across years ($Z= -0.435, p=0.664$), nor did SMI vary across locations ($Z= -0.671, p=0.502$). Migratory guilds did vary with respect to SMI ($\chi^2=63.245, n=369, p<0.0001$); specifically, long-distance migrants had lowest BMIs and resident birds had highest BMIs.
3.4 Family Analyses

3.4.1 Family Turdidae - Thrushes

3.4.1.1 Fall:

Resident species were left out of the analysis because their sample size was not sufficient \((n=3\) at Greenway, \(n=14\) at Bluff). Thus, the only migratory guilds analyzed were long-distance and short-distance. There was no significant relationship between year and rank SMI \((F_{1,0.176}=1.275, p=0.748)\) or between migratory guild and rank SMI \((F_{1,0.931}=1.321, p=0.467)\). However, there was a significant relationship between location and rank SMI \((F_{1,88.634}=14.133, p<0.0001,\) Fig. 8); specifically, the less intruded site (Bluff) contained birds of higher rank SMI than the more intruded site (Greenway). Therefore, for thrushes, both long and short-distance migrants showed a relationship with level of intrusion: regardless of migratory distance, thrush BMI was greater near areas of lower pedestrian activity. No interactions were significant \((year \times location: F_{1,179}=0.024, p=0.878; year \times migratory guild: F_{1,179}=1.398, p=0.239; location \times migratory guild: F_{1,179}=1.193, p=0.276)\).
Non-parametric tests indicate there was no significant interaction between SMI and year ($Z= - .176, p=0.860$), but there was a significant interaction between SMI and location such that rank SMI at Bluff was higher than Greenway ($Z= -3.444, p=0.001$). These results were both qualitatively similar to the parametric results above. However there was a significant interaction between SMI and migratory guild such that long-distance migrants were in higher body condition compared to short-distance migrants ($Z= - .40$).
2.450, \( p=0.014 \). This differed from my parametric results, and could be from the relationship between higher BMI calculated by LDM in Bluff site only, which may have caused significant differences between migratory guild when only guild as a factor was analyzed. The variation in guild is probably a result of multiple other factors (i.e. interaction effects) that cannot be accounted for in non-parametric tests.

### 3.4.1.2 Spring:

Sample size was low for both RES \((n=4 \text{ at Greenway}, n=0 \text{ at Bluff})\) and SDM \((n=7 \text{ at Greenway}, n=4 \text{ at Bluff})\). Therefore, only a two-way ANOVA between location and year was analyzed. None of the main effects nor the interaction factor indicate significant differences in rank SMI \((\text{year: } F_{1,1}=0.034, \ p=0.884; \ \text{location: } F_{1,1}=0.083, \ p=0.821; \ \text{year x location: } F_{1,67}=1.936, \ p=0.169, \text{ Fig. 9})\). The non-parametric tests were qualitatively similar: SMI across years and SMI across locations did not vary \((Z=-1.213, \ p=0.225; \ Z=-0.385, \ p=0.700, \text{ respectively})\).
3.4.2 Family Parulidae – Wood Warblers

No resident wood warblers were caught, and sample size was low for SDM. Therefore, only a two-way ANOVA between location x year was analyzed for both fall and spring.
3.4.2.1 Fall:

The location x year interaction was significant such that rank SMI was much greater at the low intrusion site (Bluff) than at the high intrusion site (Greenway) in 2014, but this difference was not significant for the year 2013 ($F_{1,282}=10.369, p=0.001$, Fig. 10). This is quantitatively similar to the results for all species in the fall. The main effects of location and year were not significant ($F_{1,1}=1.255, p=0.464$ and $F_{1,1}=0.899, p=0.517$ respectively).
Non-parametric tests indicate there is a significant interaction for both year and location with regard to SMI: birds caught in 2013 had higher SMI than 2014 (Z= -4.600, p<0.0001) wood warblers caught at Greenway had lower body mass than birds at Bluff (Z= -4.458, p<0.0001). Even though these patterns differ from my parametric tests, in which no main effects were significant, they can be explained as a result of the interaction between the two factors.
3.4.2.2 Spring:

There was no significant interaction year and SMI or between location and SMI ($F_{1,1} =0.12$, $p=0.931$ and $F_{1,1} =0.008$, $p=0.945$ respectively). However, the interaction between year and location was significant ($F_{1,47} =7.133$, $p=0.010$, Fig. 11) such that each year had a qualitatively opposite trend between locations. Rank SMI decreased from 2013 to 2014 at the high intrusion site (Greenway), whereas at the low intrusion site (Bluff), rank SMI increased to a similar degree (Fig. 11). Non-parametric tests revealed that there was no significant relationship between SMI and year ($Z= -0.690$, $p=0.490$) and between SMI and location ($Z= -0.508$, $p=0.612$), which is qualitatively similar to my ANOVA. This however further reveals the importance of my ANOVA results, since the interaction would not have been detected with non-parametrics analyses.
Figure 11  Mean Rank SMI of Wood Warblers (family Parulidae) for Greenway and Bluff sites between years (2013 and 2014) observed during the spring season. Whiskers indicate +/- 1 standard error
3.5 Species Analyses

3.5.1 Northern Cardinal

3.5.1.1 Fall:

There were no significant interaction between SMI and year, SMI and location, or SMI and year x location or interactions (year: $F_{1,1}=0.686$, $p=0.560$; location: $F_{1,1}=1.383$, $p=0.449$; year x location: $F_{1,53}=0.470$, $p=0.496$). In other words, the body mass of cardinals did not differ with respect to variations in year nor intrusion level. The non-parametric tests revealed that there was no significant relationship between SMI and year ($Z=-0.517$, $p=0.605$) and between SMI and location ($Z=-0.703$, $p=0.482$), which was consist with parametric analysis.

3.5.1.2 Spring:

This was the only case in which I used raw SMI as my dependent variable since the assumptions of normality were met and HOV exceeded my set alpha level of 0.05 ($p=0.982$). However, similar to fall, there were no significant interaction between SMI and year, SMI and location, or SMI and year x location or interactions (year: $F_{1,1}=23.494$, $p=0.130$; location: $F_{1,1}=10.202$, $p=0.193$; year x location: $F_{1,58}=0.098$, $p=0.756$). The non-parametric tests were similar, although year was marginally significant: cardinals in 2013 had lower body mass indices compared to birds in 2014 (year: $Z=-1.880$, $p=0.060$; location: $Z=-1.577$, $p=0.115$).

3.5.2 Hooded Warbler

Only fall was analyzed since sample size was not adequate for spring. Years differed with respect to SMI: 2014 resulted in birds with lower SMI overall compared to 2013 ($F_{1,1}=253.871$, $p=0.040$). Location was marginally significant: rank SMI at the more intruded site was greater than the less intruded site ($F_{1,1}=71.684$, $p=0.075$). There was no significant interaction between year and location with regard to SMI ($F_{1,74}=0.006$, $p=0.94$, Fig. 12). The non-parametric tests, however, contradicted these above results:
no significance was found for year ($Z= -1.093, p=0.274$) or location ($Z= -0.376, p=0.707$). This may be because the non-parametric tests are less powerful in general, or because sample size was smallest for this analysis, which affects the power of the tests.

Figure 12  Mean Rank SMI of Hooded Warbler (*Setophaga citrina*) for Greenway and Bluff sites between years (2013 and 2014) observed during the fall season. Whiskers indicate $+/- 1$ standard error
CHAPTER IV
DISCUSSION

When all species were considered together, there was no relationship between SMI and location, which does not support my broad hypothesis that bird body mass will be lower in more intruded areas. However, when my data were broken up into migratory guilds, significant trends emerged. Migrants, specifically long-distance migrants, tended to have increased SMI away from intrusion, which supports my hypothesis that migrants will have an increased sensitivity to human presence, which displays itself through reduced body fat. The converse was true as well: near human presence, resident species acquired greater body mass. Resident species consistently had higher SMI than migratory species. Thrushes (in fall season only) gained significantly more body mass away from intrusion, yet wood warblers seemed to be impacted by yearly differences between locations. Northern Cardinals’ SMI showed no relationship to intrusion, and Hooded Warblers had contradictory trends overall.

4.1 Site Differences

Despite the fact that there were statistically no differences in food availability between the two sites, there was 1.8 times more berries per branch at Greenway, which may have led to an ecological preference of that site by birds, which visually locate fruit based on abundance (Greenberg, 1981). This in turn may account for minor differences in body condition. Fruit availability, in particular, might have some correlation, since many differences in body condition were found during fall migration, when fruit consumption is higher (Greenberg, 1981; Parrish, 1997, 2000). Most of the fruiting plants in both areas were invasive, such as Chinese privet and bush honeysuckle, however one study found that birds do not seem to take this preference into account, consuming both native and non-native fruits at equal rates and
preferences (Drummond, 2005). There is also evidence birds do not eat more of a less nutritious food source in order to compensate quality for quantity (Johnson et al., 1985). Therefore, since there was no significant difference in fruit between sites, and birds were in better condition at the Bluff site, the quality and availability of the food is unlikely to be the main source of the condition differences. While there were differences in arthropod availability between the two sites, these differences were minimal as there was a much greater magnitude of difference in pedestrian activity. Furthermore, studies indicate that food availability differences do not deter migrating birds from accumulating sufficient mass during stopover (Cimprich et al., 2005). This suggests that differences in bird body condition would be more strongly correlated to pedestrian activity. From vegetation analysis, there were no differences in vegetation structure between sites, which further supports any differences in body condition I detected can be attributed to differences in pedestrian activity over habitat structure.

4.2 All Species

Location only: My first research question was: Is there relationship between human intrusion and the ability of avifauna to acquire food supplies and regain fat stores? When all species of avifauna was analyzed, the results indicate that for both seasons the level of intrusion had no relationship to SMI. This contradicted my hypothesis which stated that human intrusion will reduce the ability of all birds to successfully put on mass. Because of the diversity of species caught and analyzed, it is understandable that different species would have varying responses to intrusion. For example, some species prefer and thrive in edge habitat (Yahner, 1988), and those adapted to this lifestyle would have thrived at the Greenway site, which has more edge habitat. Therefore, comparing all species together may have resulted in nonsignificant results.

Intrusion x migratory guild: To further tease out the variables that might correlate bird responses to intrusion, I asked: Is there relationship between human intrusion and birds of different migratory guilds? For both seasons, migratory guild and location interaction was significant, with a qualitatively
similar trend between guilds. Long-distance migrants and short-distance migrants both retained higher body mass in the less intruded location. However, this trend was reversed in resident birds, which had higher body mass near intrusion (which was significant in fall but not spring). This supports my original prediction that a) migratory birds would have an increased sensitivity to pedestrian activity and b) resident birds may become habituated to pedestrian activity.

Long-distance Migrants: In the low intrusion site, long-distance migrants had higher BMI compared to more intruded location; indeed, the magnitude of this trend was twice as great in the fall (Fig. 4), and the difference was also substantial in the spring (Fig. 7). Since migration is an energetically costly and challenging time in the life cycle of a bird (Moore, 2000; Sillett & Holmes, 2002), it is understandable that they require stopover habitat which has minimal human presence in order to have the best chance of a successful migration.

Short-distance Migrants: The BMI of short-distance migrants did not differ as markedly between intrusion levels. SMI was slightly higher at the less intruded Bluff location for both seasons (see Figs. 4 and 7), but the difference is not great enough to comment about the association of intrusion for short-distance migrants. Most likely they show sensitivity as well, but my sample size may not have been large enough to detect such differences.

Residents: In the fall, resident birds had higher SMI near intruded areas, but this difference was not substantial for the spring. This implies year-round avifauna may have benefitted from the human-altered habitat that results from continuous presence of intruders. Substantial evidence in the literature suggests resident birds may learn to become acclimated to varying levels of human intrusion (Fernández-Juricic et al., 2003; Fernández-Juricic et al., 2009). This tolerance could give residents an advantage to exploit food resources that may otherwise be inaccessible. Year-round avifauna have varying home ranges, anywhere from 0.7 (Carolina wren, Thryothorus ludovicianus; Haggerty & Morton, 2014) to 120.8 hectares (Eastern bluebird; Gowaty & Plissner, 1998). Most resident species increase their home ranges in winter to access a wider range of food supplies. This range decreases during breeding season, in
which males usually spend energy defending a smaller territory and the resources there around a nest location. Regardless, year-round birds are very familiar with their territory, including predictability of intrusion. One might conclude that since residents are acclimated to their territory, they might be willing to access resources other birds are not aware of, or because that food source is located too close to human presence. In fact, Fernández-Juricic et al. (2003) suggested a “resource-use-disturbance trade-off hypothesis” to explain why some species may benefit near human presence. House Sparrows (Passer domesticus) benefitted at intermediate rates of pedestrian intrusion for both breeding success and food consumption. These birds may be attracted to human presence since they seem humans as a cue to finding food, but high levels of intrusion also discouraged foraging rates. Similarly, the resident species in our study may associate humans with unexploited food resources—and are thus attracted to those areas with pedestrians and their associated alterations—yet avoid high quantities of intrusion.

Migratory guild only: SMI of migrants was found to be lower compared to their resident counterparts, regardless of location (and thus level of intrusion). In spring, long-distance migrants had significantly lower SMI compared to short-distance migrants, whereas migration distance was not significant in the fall. Resident birds had the highest BMI for both seasons. This implies a sensitivity that Neotropical migrants have that is not related to human intrusion. This also may explain my nonsignificant results when all species were analyzed together: since the resident birds have increased BMI while the migrants had lower BMI, an overall trend would have been negated due to these conflicting interactions.

In an urbanizing world, migratory birds have a greater chance of suffering due to habitat loss, not only during stopover but on the breeding and wintering grounds as well. Resident birds, on the other hand, have not evolved the strategy of migration, which works in their favor given the challenges and high mortality rate of the Neotropical journey. It is true that for residents, more energy is spent to keep warm in winter (Fristoe, 2014), but with supplemental feeding that is commonplace, especially in residential areas, the overall risk has paid off evolutionarily (Brittingham & Temple, 1988). Also, a paper by Fristoe (2014) concluded that energy consumption was correlated with distance of migration: the
longer the distance travelled, the more energy was eventually consumed on that bird’s breeding grounds after migration. It is then no surprise to see residents in better body condition on average than migrant birds, even regardless of whether humans were present or not. Furthermore, considering the constant push toward urbanization and suburbanization, and consequential habitat loss, adapting to a permanent, year-round territory may have become a more successful life strategy than long-distance migration. I conclude that resident birds were in overall higher body mass index near intrusion due to a combination of acclimation towards intruders and a reduced energy consumption due to their non-migratory existence.

According to my data, it seems as though migratory guild, and specifically distance of migration, has a substantial relationship to how sensitive birds are to intrusion. Recall that there was no relationship between location and rank SMI; however, significant trends appeared once migratory guild was examined. Thus, it was crucial to analyze not only every species together to see general trends, but also to tease out factors such as migratory status (where sample size allowed) to determine more subtle changes between intrusion levels. Long-distant migrants are in better energetic condition in areas away from human activity, and their body condition also declines the most near intrusion compared to other guilds.

Year: Despite the fact that year was not significant as a main effect for either season, interaction with year played a role in fall analysis: year x location was significant and year x migratory guild was marginally significant. Fig. 5 indicates this interaction is a result of 2014 data, specifically the lower BMI in birds at the more intruded Greenway location. The interaction graph between year and migratory guild (Fig. 6) suggests also that between years, the BMI of long and short-distance migrants did not differ, but resident bird’s BMI was lower in 2014 compared to 2013. Which begs the question, what was different in 2014 that caused birds, and mainly resident birds, to have lowered BMI? This could be a result of more pedestrian activity at Greenway in 2014 compared to 2013. Though I averaged pedestrian rates across years, perhaps one year had significantly higher rates of pedestrian activity, thus creating an interaction with year. Other explanations could be: higher bird numbers during 2014, thus increased competition for
food, weather changes (i.e. less rainfall), or a land-use change near the Greenway site that I was unaware of (i.e. increased mowing).

Seasonal Differences: Differences between fall and spring were fairly minimal. First, slightly stronger trends emerged overall in the fall. This could be for a few reasons: sample size was greater in the fall than the spring, allowing more pronounced trends appeared. Also, during spring season birds are focused on migrating and breeding, so they may be less sensitive to intrusion since they are concentrated on these other behaviors. However, fall migration is usually slower and more delayed for Neotropical migrants, as they are slowly making their way to the coast, storing up fat reserves before a long trans-Gulf crossing (Morris et al., 1994). Hatch-year birds born that summer will also be migrating for the first time, and these birds have no previous experience (Heise & Moore, 2003). These juvenile birds may not be able to compete with more experienced adults for stopover in the quality sites that contain better food resources. The higher quality sites will be occupied by more experienced birds, and the juveniles are then pushed into lowered quality sites. Since the low intrusion site is an indicator of high quality habitat, perhaps the birds caught at the Bluff site were experienced adults who were able to acquire more body mass compared to inexperienced juveniles at the intruded site (Greenway).

Second, there were more interactions between years in the fall, versus none in the spring. Again, this is due to the unusually low BMI exhibited in 2014 at the Greenway site, which I try to explain above. But interestingly, once migratory guild was factored in, the resident birds’ BMI was still high despite the overall low trend, which was a result mainly of the low BMI of long-distance migrants.

4.3 Family and Species Analyses

4.3.1 Turdidae

Fall: All thrushes analyzed were migratory to some degree, either long-distance or short-distance. Since only migrants were analyzed, results show that regardless of migratory distance, thrushes as a
whole obtain higher body mass away from intrusion. Guild level differences were not significant; however the trend indicates long-distance migrants may show more sensitivity to intrusion than short-distance migrants, since the BMI of LDM was much greater at the unintruded Bluff site compared to SDM (Fig. 8), even though this difference between migratory guilds was not perceptible for the intruded Greenway site. These findings support my overall results, indicating relationships between BMI and intrusion are not limited to a particular family. This is also consistent with my above findings which suggest birds that migrate longer distances will be more sensitive to human presence.

Spring: No differences in SMI were detected between intrusion levels. Since only migrants were analyzed, my spring results indicate intrusion has no relationship to migratory thrushes. Since fall analysis showed significant differences and spring analysis did not, a seasonal association may be playing a role beyond the scope of my study. Again, spring may have not revealed significant trends because birds, especially males, are focused on quickly reaching the breeding grounds and establish territory. Unlike fall, where birds focusing on storing body fat for the long journey ahead, most North American species are on the last leg of their northward migration to breeding grounds (Morris et al., 1994). Thus, fat levels may not have been as variable as fall results.

4.3.2 Parulidae

No wood warblers were resident birds—all migrate at least some distance. Furthermore, we captured very few wintering Parulids (n=3 for fall, n=4 for spring). Thus, our overall analysis for this family primarily showed how long-distance migrants acquire body mass between intrusion levels.

Fall: Similar to my results for all species (Fig. 5), the interaction between year and location indicated a significantly depressed body mass in birds caught at the Greenway site for 2014 only (Fig. 10). Again, since food availability does not fully explain this since fruit count similar between Greenway and Bluff, another factor that confounded with intrusion level and year must have caused the relationship to produce these results.
Spring: Although there were no overall trends, a significant year x location interaction was detected. The graph indicates that 2013 only, Greenway contained birds with higher SMI than Bluff; however the opposite was true in 2014 (Fig. 11). Food availability may partly explain this discrepancy: for 2013, arthropod availability was fairly even between sites (50.8% at Greenway and 49.2% at Bluff), so it is unlikely that food explains differences for this year. However, in 2014, arthropod count was significantly higher in the Bluff site (41.0% at Greenway and 59.0% at Bluff), so in addition to less intruded trails, migrants benefitted from greater food abundance at this site and year. It is uncertain what else may have caused these results, which are contrary to most of what we have found previously, that is to say, migrant birds are more successful at acquiring body mass near human presence in one year.

4.3.3 Northern Cardinal

As a resident, I predicted *C. cardinalis* would have higher body mass compared to migratory birds. Previously analysis for all species found this to be true for residents, and additionally resident birds seem to acquire more fat near intrusion, probably from acclimation. However, when I limited my analysis to one species, no trends were revealed between locations for either season. Perhaps the recalculation of SMI merely revealed there were no differences in birds of the same species, or the intrusion level was not detectable enough to see true trends being revealed. Or perhaps there were truly no differences in body condition at all. Furthermore, a few individuals that were originally banded at the Greenway site were recaptured at the Bluff site. This could mean a few things: either a) that Cardinals home range is large enough to cover both intruded and unintruded areas, or b) birds were moving away from intrusion in order to set up territories in a more favorable area. These are merely possible explanations and ideas for future research; the data are not nearly conclusive to determine what is driving this behavior.
4.3.4 Hooded Warbler

As Neotropical migrants, I predicted *S. citrina* would show decreased SMI values at the highly intruded Greenway location. However, my results were complex and contradictory. Parametric tests indicated that years were clearly different, with birds of lower BMI in 2014 compared to 2013. At the intruded Greenway site, these results coincide with figures 5 and 10: something caused the SMI of birds in the fall of 2014 to be lower. However, unlike the majority of my results above, *S. citrina* had depressed SMI at the unintruded Bluff site, regardless of year. Since the relationship between SMI and intrusion was marginally significant, this suggests this Neotropical migrant species is not as sensitive to pedestrians. Another confounding, undetected factor may be at play in this ecological relationship. One explanation could be my berry count, in which the number of berries per bush was 1.8 times higher at the intruded Greenway site compared to the Bluff site. Despite the fact that this was not statistically significant, the higher abundance may have ecological benefits for this species. Furthermore, Hooded Warblers are species that stay low to the ground, concealed by vegetation and shade, and could be less susceptible to pedestrian activity. However, trail use modeling suggests the opposite (Rodríguez-Prieto et al., 2014). Furthermore, the nonparametric tests did not agree with the parametric analysis. Since the year x location interaction was not significant, I cannot explain these results adequately.

4.4 Conclusion

Excluding single species analysis, my data suggest that migratory birds, specifically Neotropical migrants, are able to replenish fat store better in low levels of pedestrian activity. In addition, resident birds are able to gain more body mass than migrants, regardless of intrusion level. Below I propose further explanations for these trends, discuss conservation implications, and make recommendations for wildlife managers.
4.4.1 Conservation Implications

Since my data propose Neotropical migrants show reduced body mass in relationship to intrusion, consideration must be given to ensure these species are protected from the associations of human activity during stopover. To wildlife managers, I recommend that if possible, within their sites, have large plots of unintruded native forested areas for birds that are more sensitive to intrusion to rest, replenish food, and avoid predators. These plots should be away from residential housing, roads, and trails, and not allow visitors. Trail design is also an important factor: a bird community is more affected as trail length increases and it intersects with a larger number of habitats (McKinney, 2005). A simple trail design compared to a lengthier, more complex trail system reduces intrusion for birds and benefits forest communities (Rodríguez-Prieto et al., 2014). Where trails are in place, I recommend incorporating buffer zones that prevent pedestrians from close approaches to wildlife, and taking measures to discourage recreationists from straying off of trails.

Vegetation structure is an area of future research. Despite finding no differences in vegetation between locations, it could still be a valuable mechanism that provides a visual obstruction and cover from predators for forest birds (Fernández-Juricic et al., 2009). Birds may affiliate human pedestrians as a potential threat, and any vegetation blocking this visual detection could suppress the relationship of avifauna to intrusion. Blumstein (2006) hypothesized the opposite: that vegetation density may compromise visibility, and thus species in denser habitats react more warily to intrusion. However, no correlation between habitat structure and flightiness was detected in his analysis. Vertical height of vegetation can also reduce the potentially negative impacts of intrusion as well (Marzano & Dandy, 2012). Correlations between forest structure and human presence has been suggested in the literature (Fernández-Juricic et al., 2004; Fernández-Juricic et al., 2009; Gutzwiller et al., 1998; Marzano & Dandy, 2012), but to my knowledge, is still largely untested. Even though vegetation structure was not found to play a significant role in the bird BMI differences in my study, it could still be beneficial to integrate dense shrubbery along the trails, preferably native berry or nectar producers, such as American holly (*Ilex*...
*opaca*) or Sweetbay Magnolia (*Magnolia virginiana*) as a physical barrier than could block the visual cue warning birds of an oncoming predator.

### 4.4.2 Future Work

To expand upon my own research, I would want to examine differences in age and sex of birds caught, as well as fat score comparisons. Studying ages of birds caught between sites might explain seasonal differences if, as suggested above, inexperienced juveniles are forced into lower quality habitats during fall migration. In addition, there were a small number of recaptured birds, which I could analyze the rate at which these birds increase in mass for each site. Similarly, using time of capture, I could calculate hours after sunrise and create regressions using mass to determine which site allowed birds to gain mass at faster rates.

For future studies, I suggest examining patterns in body mass with regard to seasonal differences amongst migrants. Morris et al. (1994) found that migrants accumulate fat and mass differently during spring and fall stopover. These changes could be due to distance to breeding ground and ecological barriers: a bird trying to reach the breeding location to establish territory does not make fat stores a priority; however, a bird about to cross a large barrier will spend more time accumulating fat during stopover. My results suggest birds may be more sensitive in the fall, but future studies could tease out these seasonal differences further.
References


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