FACTORS INFLUENCING THE EFFECTIVENESS OF CANADA GOOSE RELOCATION IN GEORGIA, USA

by

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DEDICATION

This work is dedicated to my parents, Bill and Karen Beard, who instilled in me a deep appreciation of natural resources. Without them, I would never have an understanding of the continuous work and meticulous care that are required to properly steward our natural environment. They showed me the value of being a lifelong student and how a dedication to conservation yields the gift of perpetual learning.

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ABSTRACT

An iconic species of North American waterfowl, Canada geese (*Branta canadensis*) have established an overabundant resident population in Georgia, USA. As a consequence, wildlife managers respond to a growing number of complaints from landowners in urban areas where Canada geese pose a threat to property and human safety. Some landowners rely on relocation when other methods are unsuccessful at sites with nuisance Canada geese; however, some studies show that relocation may be ineffective when geese return to their original capture site. To analyze factors that may influence returning geese that were relocated in Georgia, I gathered data from USDA-APHIS on nuisance Canada geese that were captured, banded, and relocated to rural, hunted areas within Georgia from 2010 to 2019. I compared the nonrecaptured population with the recaptured population for differences in age, sex, and relocated distance. I found a relationship between age and recapture status (X^2 (1, N = 4,058) = 14.17, p = .0002) as well as relocated distance and recapture status (X^2 (2, N = 4,059) = 9.54, p = .0085), but no evidence of an association between sex and recapture status. There were fewer juvenile Canada geese than expected among the recaptured sample. In addition, among the recaptured sample, there were fewer than expected geese that were relocated greater than 250 kilometers away. I found an overall 2.5% recapture rate by USDA-APHIS personnel at nuisance sites. I recommend continuing relocation efforts at distances greater than 150 kilometers and at least 250 kilometers when possible. Due to nuisance complaints at recurring sites throughout the 10-year period, I recommend increasing initiatives to educate urban landowners in preventive and pre-planned measures (e.g., egg addling, predator decoys) to manage nuisance populations.

CHAPTER ONE

INTRODUCTION

Background

An iconic species of North American waterfowl, the Canada goose (*Branta canadensis*) has been appreciated by birdwatchers, hunters, and residents for hundreds of years. Migratory Canada geese typically breed in southern Canada, then migrate south to latitudes throughout the United States to winter (Snyder, 1993). Factors such as changes in farming practices, hunting pressure, and climate change have contributed to a northward shift of the southern boundary for wintering grounds of migratory Canada geese (Dorak et al., 2017; Fox & Abraham, 2017).

To restore diminishing populations of the iconic bird to Georgia and other southeastern states, wildlife managers initiated restocking efforts. Between 1975 and 1987, the Georgia Department of Natural Resources, Wildlife Resources Division (GAWRD) relocated 8,000 migratory Canada geese from northern states in the Atlantic Flyway to the state of Georgia (Balkcom et al., 2021). These relocated geese established a non-migratory presence in Georgia and became part of the Atlantic Flyway Resident Population (Figure 1) (Klimstra & Padding, 2012). A resident population is defined as one that breeds and dwells predominantly within the contiguous United States as opposed to migratory geese that breed in northern regions of Canada (Ankney, 1996; Powell et al., 2003; Balkcom et al., 2010). The Atlantic Flyway Resident Population (AFRP) in Georgia is regarded as a closed-resident population due to the lack of recorded migrants into or out of Georgia from surrounding states (Balkcom et al., 2021).

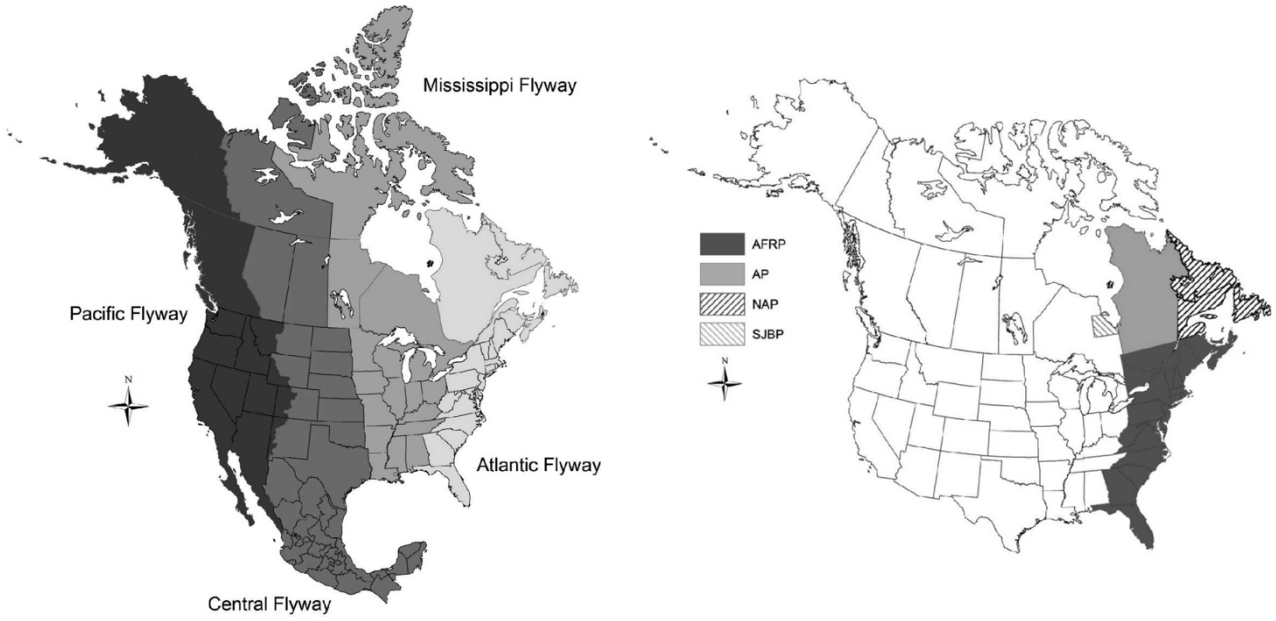

Figure 1: The four flyways for waterfowl in North America (left). The map on the right displays breeding ranges for the four populations of Canada geese that occur in the Atlantic Flyway: Atlantic Flyway Resident Population (AFRP), Atlantic Population (AP), North Atlantic Population (NAP), and Southern James Bay Population (SJBP). The AFRP found in the state of Georgia breeds and nests within the state. Maps created by Klimstra & Padding (2012).

From 1970 to 2012, the AFRP increased from 11,000 to 880,000 birds; in the same time period, migratory geese in the Atlantic Flyway increased from 137,000 to 262,000 birds (Dolbeer et al., 2014). The dramatic increase in AFRP to numbers that surpass the migratory population is attributed to an increased availability of preferred habitat (e.g., residential and commercial landscaping), absence of predators and hunting in urban areas, and relatively short distances required to fly to wintering locations (Dorak et al., 2017; USFWS, 2002). The 2011 AFRP Management Plan adopted by the Atlantic Flyway Council established a population goal of 700,000 by 2020; however, the U.S. Fish and Wildlife Service (USFWS) estimated the AFRP in

2019 to be approximately 1,040,000 birds (Atlantic Flyway Council, 2011, p. 18; USFWS, 2020, p. 9).

Impacts

Although Canada geese are a native species in North America, the overabundance of the AFRP is now a source of human and wildlife conflict. Property damage to agriculture and landscaping, noise, and aggressive behavior constitute a large proportion of complaints from property owners (Donaldson et al., 2018; Sherman & Barras, 2004; Powell et al., 2003). In addition, Canada geese pose a safety threat to aircraft (Dolbeer et al., 2014) and are disease vectors for *E. coli*, *Cryptosporidium*, *Giardia*, and *Camplyobacter* (Kulas et al., 2002; Kass et al., 2001; Delnatte et al., 2014; Fox et al., 2006). Public health agencies have raised concerns of water quality issues in areas of concentrated goose populations (Woodruff et al., 2004).

Current Management Methods

Historically, sport hunting has been used as a primary control method of Canada goose populations. Hunting significantly decreases Canada goose populations but can only be used in locations where hunting is permitted; necessary restrictions on hunting in areas with high human densities limit its utility in controlling urban Canada goose populations (Liljeback et al., 2021). In Georgia, the AFRP dwells primarily in urban areas, limiting hunting as a tool to address AFRP overabundance (Iverson et al., 2014; Ladin et al., 2020; Balkcom et al., 2010; Lowney et al., 1997). For this reason, wildlife managers must rely on strategies for urban Canada goose population control that are distinct from techniques that are effective in rural areas (Beston et al., 2016; Holevinski et al., 2006; Powell et al., 2003). Some states use capture and euthanasia

techniques for overpopulated areas (Lowney et al., 1997), but many private businesses are opposed to this strategy due to concerns regarding a negative public image (Coluccy et al., 2001).

When consulted by landowners, GAWRD initially recommends that managers employ hazing techniques such as propane cannons, balloons, chemical repellent, pyrotechnics, laser devices, and predator decoys (Georgia Department of Natural Resources, n.d.; Preusser et al., 2008; Sherman & Barras, 2004; Mott & Timbrook, 1988; Villano & Drake, 2003). Hazing can be used throughout the year except during the molting season (June-July), when the birds are flightless and cannot relocate. However, hazing techniques have limitations. They are most successful when geese first arrive at a site. The likelihood of causing permanent displacement due to hazing decreases after geese become accustomed to the site, particularly during nesting (Georgia DNR, n.d.). Additionally, hazing techniques can require excessive time, money, and monitoring, may pose safety hazards to humans, and many times Canada geese become desensitized to these attempts or only temporarily relocate (Titchenell & Lynch, 2010; Nichols, 2014; Lowney et al., 1997, Sherman & Barras, 2004).

If hazing proves ineffective, GAWRD recommends egg addling, which involves coating eggs in oil to prevent hatching. A fairly simple process, landowners can easily addle eggs themselves. Addling is effective because hens continue to incubate the inactive eggs instead of re-nesting (M. Ondovchik, U.S. Department of Agriculture, personal communication, October 14, 2021). Although this method is effective, it can only be accomplished during the nesting season. Most complaints occur after goslings hatch, when egg manipulation is no longer an option. In addition to public concerns for the ethical treatment of animals, egg addling is not

deemed practical for large, overly abundant goose populations (Woodruff et al., 2004; Christens et al., 1995; Coluccy et al., 2001). As a next step, GAWRD may recommend relocation services by U.S. Department of Agriculture – Animal and Plant Health Inspection Service (USDA-APHIS) whereby nuisance Canada geese are captured and translocated to rural areas that allow hunting. Despite some risks such as the introduction of wildlife diseases and overpopulation to new areas (Woodruff et al., 2004), relocation has been identified as an ethically acceptable method for population control in urban environments (Powell et al., 2003; Michelfelder, 2003; Lowney et al., 1997). However, Canada geese generally use the same nesting location each year, and the return of relocated geese to their capture site is a concern for the effectiveness of relocation strategies (Snyder, 1993).

Current Policies

As the AFRP continues to rise in Georgia (Balkcom et al., 2021), federal and state agencies have adopted policies that permit various management methods such as relocation. Both migratory and resident Canada geese are protected under the Migratory Bird Treaty Act of 1918 (16 USC § 703-711), which allowed the re-introduced Georgia population to thrive. Nuisance complaints of resident Canada geese escalated quickly, causing USFWS to publish a Final Environmental Impact Statement (FEIS) in 2005. This document distinguishes migratory from resident Canada goose populations and establishes corresponding control strategies. Ultimately, the 2005 FEIS adopts an integrated damage management and population reduction alternative, which allows states and local agencies to develop and implement a broad range of management techniques within federal guidelines to address damage complaints. Specifically, the 2005 FEIS establishes special “Depredation Orders” in addition to expanded hunting seasons

that states may implement to allow landowners to remove Canada geese in areas of conflict with humans. The Nest and Egg Depredation Order (50 CFR § 21.50) is the policy that allows landowners to terminate Canada goose nests and eggs (via addling or other destructive methods) on their property with a special permit from USFWS "to resolve or prevent injury to people, property, agricultural crops, or other interests". The Agricultural Depredation Order (50 CFR § 21.51) allows agricultural producers to obtain a similar permit to conduct lethal and non-lethal management strategies on resident Canada geese that damage agricultural crops. Finally, the Public Health Control Order (50 CFR § 21.52) allows similar strategies for resident Canada geese that pose "a direct threat to human health". The relocation services offered by USDA-APHIS to landowners in Georgia are permitted under the conditions outlined in these Depredation Orders.

From 2009-2011, USFWS estimated the mean Atlantic Flyway Resident Canada goose populations to be about 999,400 in North America, which was well above the goal of 650,000 (USFWS, 2011). As a result, USFWS published a Final Supplemental Environmental Impact Statement in 2013, which simplifies the process of implementing additional harvest seasons for Canada geese in resident population zones such as the state of Georgia. USFWS recognizes that increasing hunting limits and seasons substantially impacts resident Canada goose populations only when combined with methods such as relocation (USFWS, 2013). The combination of relocation with hunting in Georgia has been met with relative success (Powell et al., 2003). The simplification of the process for expanding harvest opportunities complements USDA-APHIS relocation services in Georgia because all release sites permit hunting.

Behavioral Factors

Return rates of relocated Canada geese studied in the northern United States and Canada are related to age. In general, adults are more likely to return to capture sites than juveniles (Flockhart & Clark, 2017; Holevinski et al., 2006; Lowney et al., 1997). In Georgia, relocated adult geese exhibit greater ranges of movement patterns than juveniles (Donaldson et al., 2018). However, Canada goose survival and distribution among both migratory and resident populations are unrelated to sex (Pilotte et al., 2014; Donaldson et al., 2018; Holevinski et al., 2006). To date, neither age nor sex have been included in studies of Canada goose return rates in Georgia.

There seems to be an indirect relationship between distance from capture site to relocation site and return rates of Canada geese (Table 1). For example, adult migratory populations in Saskatchewan, Canada, experience a relatively high probability of return (0.89) even at distances >400 km (Flockhart & Clark, 2017). For areas with residential goose populations, USDA recommends relocating geese at least 320 km from the capture site (USDA, 2016). However, most studies within the United States used shorter distances because most relocation efforts take place within the same state of capture. Adult Canada geese in New York that were relocated about 150 km away demonstrated about a 25% return rate within the first 10 months, which may be explained by a behavioral response to high levels of hunting pressure at release sites (Holevinski et al., 2006). Of the Canada geese relocated at distances less than 160 km in Virginia, about 12% returned to the capture site, whereas no geese returned when relocated greater than 480 km away from the capture site (Lowney et al., 1997). In Georgia, <1% of Canada geese relocated about 135 km away were recovered near original capture sites between 1993-1996 (Powell et al., 2003), although in 2007 about 3% returned when relocated

greater than 160 km (Stephens et al., 2007). Although USDA's recommendation to relocate geese at least 320 km most likely eliminates the chance that geese will return, this distance is rarely feasible when relocation efforts occur within the same state. Overall, these studies suggest that shorter relocation distances (<150 km) may be associated with lower return rates in Georgia than in locations north of Georgia.

Table 1. Some studies of return rates of relocated Canada geese in North America. In general, study areas further north tend to have greater relocation distances than studies in southern areas. Flockhart & Clark (2007) concluded that relocation did not seem to be an effective control method for migratory Canada geese.

Location	Population	Distance Relocated	Return Rate	Author
Saskatchewan	migratory	>400 km	89%	Flockhart & Clark, 2017
New York	resident	150 km	25%	Holevinski et al., 2006
Virginia	resident	160 km	12%	Lowney et al., 1997
Georgia	resident	135 km	<1%	Powell et al., 2003
Georgia	resident	>160 km	3%	Stephens et al., 2007

Relocation efforts for urban Canada goose populations in Georgia have continued throughout recent years; however, there has been little modification of capture techniques based on evidence from previous Georgia translocation data (M. Ondovchik, USDA-APHIS, personal communication, October 14, 2021). In Georgia, Canada goose relocation efforts typically include banding birds and collecting data on age, sex, geographical coordinates, and if individuals were previously relocated. The objective of this study was to use data on relocated Canada geese within Georgia to analyze differences of age, sex, and relocation distances between two populations: geese that were previously captured and those that were not previously captured.

My goal was to develop criteria to improve techniques in relocation efforts to increase effectiveness (e.g., lower return rates). I hypothesized that recaptured Canada geese in Georgia would have higher than expected counts of adults than juveniles, higher than expected counts of geese relocated less than 150 km from capture sites, and that there would be no association between sex and recapture status.

CHAPTER TWO

METHODS

Between 2010-2019, USDA-APHIS personnel responded to requests for removal of nuisance Canada geese at private businesses and residential areas throughout Georgia. At each site, USDA-APHIS asked that landowners pre-bait geese with bread to accustom the birds to humans. All capture events occurred June through July to coincide with molting season, when the birds are flightless. Personnel used a drive trap and corralled geese toward V-shaped panels, which funneled the birds into a net-covered pen (Figure 2). Geese were individually assessed for

Figure 2. Drive traps used by USDA-APHIS personnel to collect geese (left, right). Although birds are typically flightless during this time, a mesh cover prevents any geese escaping that may grow flight feathers early. Photo courtesy of USDA-APHIS.

age and sex. Any flight feathers beginning to grow on wings were clipped. Handlers used band pliers to attach a standard numbered USFWS aluminum leg band to each bird. Geese were relocated to various public Wildlife Management Areas within the state of Georgia or to private ponds where landowners had requested geese. All captured geese that already had a leg band were considered recaptures from previous relocation efforts; these were euthanized.

I collected records provided by USDA-APHIS for Canada geese that were captured, banded, and relocated in Georgia from 2010-2019. I compiled data to include status (recapture or nonrecapture), original year banded (year group), age (juvenile/adult), sex, and geographical coordinates of each capture, relocation, and recapture site. Coordinates were accurate to 11 m^2, but not published for confidentiality purposes. I determined the relocated distance for each goose using the haversine formula with the geographical coordinates of each original capture site and release site.

Figure 3. A Canada goose with USFWS aluminum leg bands. The geese in this study were only banded on one leg. Photo courtesy of USFWS.

I consulted with the Statistical Consulting and Research Services (SCRS) of Montana State University for guidance on developing and executing statistical methods to evaluate characteristics of the recaptured geese using the data provided by USDA-APHIS. Of the Canada

geese banded from 2010-2019 in Georgia, I compared the recaptured and nonrecaptured populations using the chi-square test of independence ($\alpha = 0.05$) to analyze for association with each of the following variables: year group, age, sex, and relocated distance. I selected the chi-square test for this study because of the following characteristics described by McHugh (2013):

1. Variables were measured as categories at the nominal level. For testing relocated distance, I separated distance into three bins and treated these as nominal data. Year group was also treated as a nominal variable.
2. I assumed each observed Canada goose was independent of other observations.
3. This study used counts of Canada geese.
4. Geese were categorized in either the recaptured or nonrecaptured population, but not both.
5. Variables (e.g., juvenile or adult; male or female) were mutually exclusive.
6. I evaluated each test for expected counts of five geese or more.

I evaluated associations of variables and populations using p-values and standardized residuals from chi-square tests of independence. I used R software to complete all statistical analysis. I defined a recaptured goose as any banded Canada goose recaptured by USDA-APHIS personnel at a nuisance site, and I defined a nonrecaptured goose as a Canada goose that was banded and not recaptured by USDA-APHIS personnel at a nuisance site.

CHAPTER THREE

RESULTS

I collected records from USDA-APHIS on 4,059 nuisance resident Canada geese that were banded and relocated within Georgia, United States, from 2010-2019. Of these, 102 Canada geese were recaptured between 2012-2020. During this time, 1,307 Canada geese were relocated but not banded or recorded due to unavailability of bands. Seven geese were recaptured with no available data on original capture site, which I also did not include. Some (<10) recaptures only had data for geographical coordinates but not age and/or sex. Because I tested each variable separately, I only excluded recaptured geese in a given analysis if data were not available for that variable.

Year

On average, recaptured geese were caught 1.8 years after initial banding. There was a possibility that geese from recent year groups would not have the same amount of time as earlier year groups to return to the capture site and be recorded in this dataset as recaptured geese. This could affect the assumption that geese from each year group had an equal chance of being recaptured. I evaluated this using a chi-square test of independence. In one year (2014), the expected count was low (< 5) (Table 2). To account for this, I randomly permuted year group relative to recapture status to obtain a test statistic from a recreated null distribution. My results indicate that there is likely no relationship between year group and status, X^2 (9, N = 4,059) = 5.14, p = .82. A mosaic plot of chi-square residuals with the permuted data shows no apparent trend in values of observed and expected counts throughout year groups (Figure 4).

Table 2. Observed and expected counts of relocated Canada geese by original year captured. The expected counts of recaptured geese in 2014 were low (< 5).

Observed Counts

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Nonrecaptured	460	341	561	605	61	227	381	326	747	248
Recaptured	5	14	15	38	0	4	10	3	8	5

Expected Counts

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Nonrecaptured	453.31	346.08	561.53	626.84	59.47	225.2	381.17	320.73	736.03	246.64
Recaptured	11.69	8.92	14.47	16.16	1.53	5.8	9.83	8.27	18.97	6.36

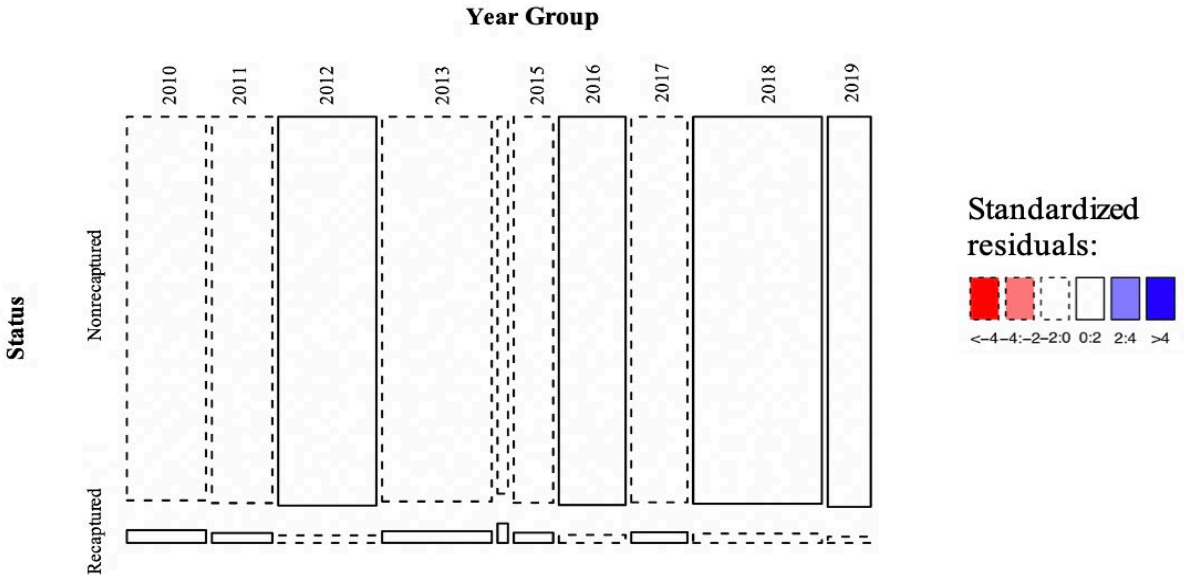

Figure 4. Mosaic plot of year that Canada geese were initially captured (Year Group) and recapture status after year group was permuted relative to recapture status. A lack of colors within the plot indicates no extreme standardized residuals; additionally, there are no apparent trends in negative or positive residuals from 2010-2019.

Age

Among recaptured Canada geese, I found that there is a relationship between age and recapture status (X^2 (1, N = 4,058) = 14.17, p = .0002). Observed and expected counts of juvenile and adult geese varied substantially (Table 3). There were noticeably fewer geese that were juveniles at the time of banding than would be expected if there were no association between age and recapture status (Table 4, Figure 5).

Table 3. Observed and expected counts by age of relocated Canada geese. All expected counts were accepted as large (> 5).

	Observed Counts		Expected Counts	
	Recaptured	Nonrecaptured	Recaptured	Nonrecaptured
Juvenile	6	866	21.92	850.08
Adult	96	3090	80.08	3105.92

Table 4. Standardized residuals for chi-square test of independence for age and status (recapture, nonrecapture) of relocated Canada geese.

	Recaptured	Nonrecaptured
Juvenile	-3.40	0.55
Adult	1.78	-0.29

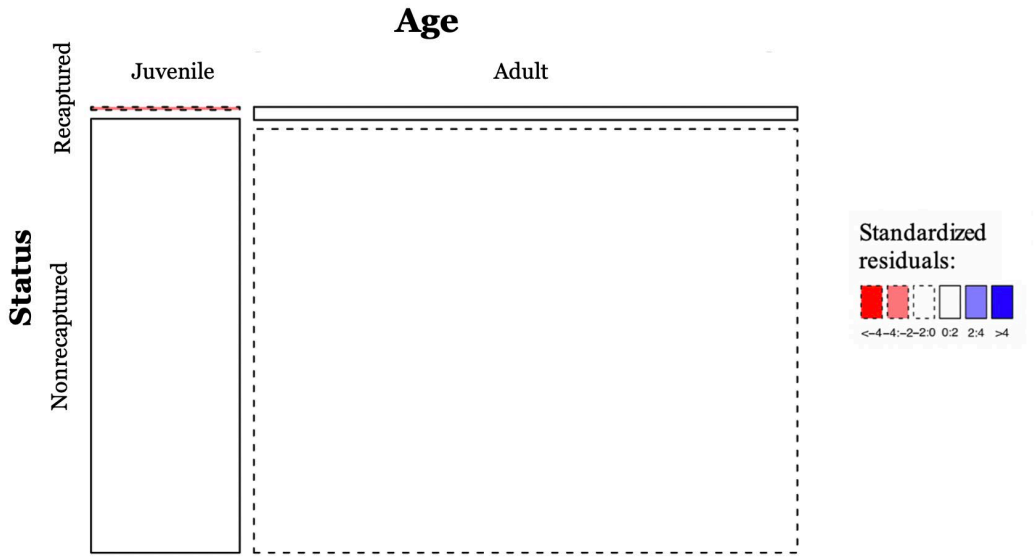

Figure 5. Mosaic plot for standardized residuals of a chi-square test of independence for age of Canada geese and status (recaptured, nonrecaptured). Residuals are shown in borders and colors. Observed counts of juvenile recaptures were substantially lower than expected.

Sex

My results indicated there was not enough evidence to show that there was an association between sex and recapture status for relocated Canada geese, X^2 (1, N = 4,050) = 2.62, p = .11. I failed to reject the null hypothesis because the observed counts were similar to expected counts (Table 5). Although fewer males were recaptured near the original site than would be expected with no association between sex and recapture, this difference may simply be due to random chance ($p > 0.05$). Interestingly, there seemed to be a higher number of females than males in each category. A post-hoc one-sample t-test identified a significantly higher proportion of females than males (t= 4.31, $p < 0.0001$). I am 95% confident that the true proportion of banded female Canada geese in Georgia is between 0.5183 and 0.5493.

Table 5. Observed and expected counts by sex of relocated Canada geese. All expected counts were accepted as large (>5), and expected counts were similar to observed counts.

Observed Counts			Expected Counts		
	Recaptured	Nonrecaptured		Recaptured	Nonrecaptured
Male	39	1849	Male	47.55	1840.45
Female	63	2099	Female	54.45	2107.55

Distance

Among recaptured Canada geese, I found a significant relationship between relocated distance and recapture status, X^2 (2, N = 4,059) = 9.54, p = .0085. I saw higher observed values than would be expected for recaptured geese that were relocated < 150 km from capture sites, and the greatest variation from expected counts occurred with the observed counts for recaptured geese relocated a distance greater than 250 km, which were significantly lower than expected (Tables 6 and 7, Figure 6).

Table 6. Observed and expected counts by relocated distance of banded Canada geese in Georgia.

Observed Counts			Expected Counts		
	Recaptured	Nonrecaptured		Recaptured	Nonrecaptured
<150 km	21	604	<150 km	15.71	609.29
150-250 km	71	2477	150-250 km	64.03	2483.97
>250 km	10	876	>250 km	22.26	863.74

Table 7. Standardized residuals for chi-square test of independence for relocation distance of Canada geese by status (recaptured, nonrecaptured).

	Recaptured	Nonrecaptured
<150 km	1.34	-0.21
150-250 km	0.87	-0.14
>250 km	-2.60	0.42

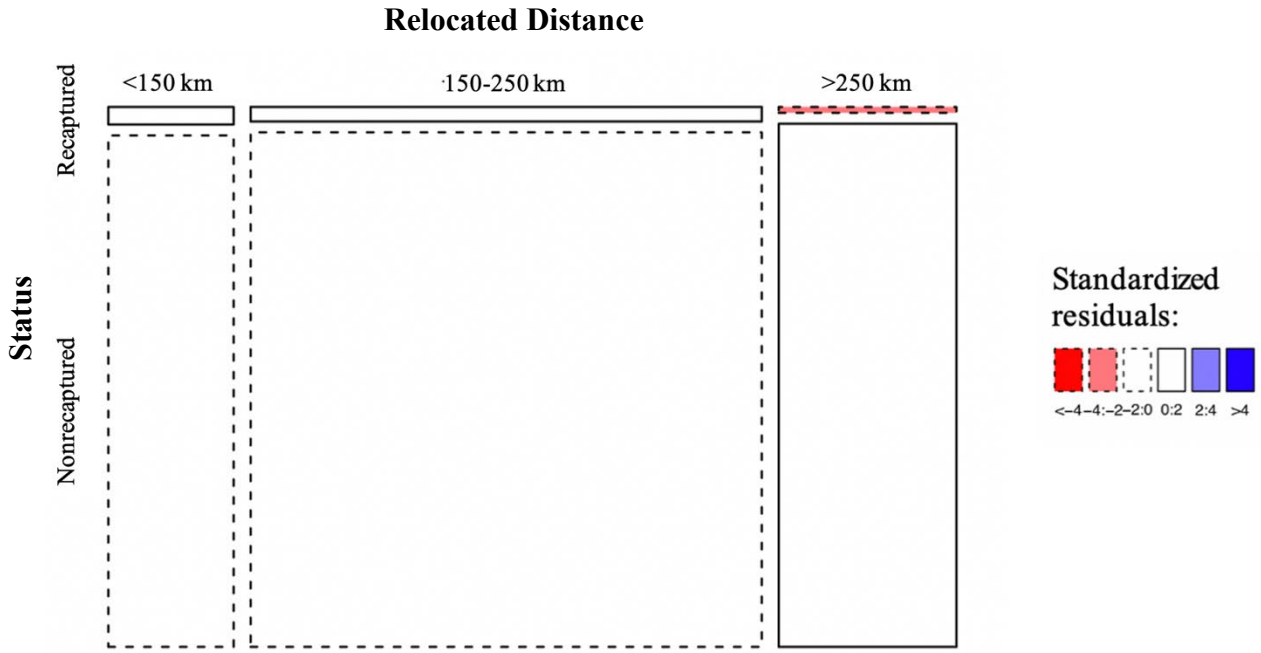

Figure 6. Mosaic plot of relocated distance of banded Canada geese and recapture status. Standardized residuals of chi-square test of independence shown in borders and colors. Observed values for recaptured geese that had been relocated > 250 km were noticeably low, but in general there were higher than expected counts of recaptured geese that had been relocated < 250 km.

CHAPTER FOUR

DISCUSSION

Knowledge Gained

As resident Canada goose populations rise and nuisance complaints increase, landowners continue to rely on relocation as a strategy to manage populations in Georgia (Balkcom et al., 2021). Typically, USDA-APHIS relocates nuisance geese in urban environments to rural Wildlife Management Areas that also permit hunting activities (M. Ondovchik, USDA-APHIS, personal communication, October 14, 2021). This strategy has been successful; between 2010-2019, only 102 out of 4,059 birds (2.5%) were recaptured at a nuisance site following relocation. Before this study, differences between relocated geese that are recaptured and those that are not recaptured as far south as Georgia have not been evaluated. Although recapture rate is distinct from return rate, the identification of factors that differentiate recaptured and non-recaptured geese may facilitate increased effectiveness of relocation efforts as well as a more comprehensive understanding of Canada goose behavior in Georgia. In this study, I analyzed records on relocated Canada geese to compare differences in the composition of recaptured and non-recaptured populations. Using chi-square tests for age, sex, and relocated distance, I identified an association between recapture status and age as well as distance, but no association between recapture status and sex.

I hypothesized that a higher proportion of adult geese would be associated with the recaptured population. My results supported this hypothesis; I found a significantly lower number of juvenile recaptures than would be expected if age was not associated with recapture

status as well as a higher than expected number of recaptured adult geese. This outcome corresponds with the findings of other relocation studies in which adult Canada geese are more likely to return to the capture site than juveniles (Flockhart & Clark, 2017; Holevinski et al., 2006; Lowney et al., 1997). Possible explanations for this difference include low fidelity of juvenile geese to capture sites (Flockhart & Clark, 2017; Donaldson et al., 2018) and a lack of family presence for adults at the release site (Holevinski et al., 2006). The return rates of relocated adult Canada geese are much higher in migratory than resident populations, and relocated adult geese are less likely to remain in hunted areas than juveniles (Beaumont et al., 2013). The high return rate of adults in migratory populations considerably reduces the effectiveness of relocation as a management tool in northern regions (Flockhart & Clark, 2017; Beaumont et al., 2013). Although adult resident geese show higher movement patterns than juveniles, the recapture rates of adult resident geese in Georgia are low enough to consider relocation of all geese an effective measure, regardless of age (Donaldson et al., 2018).

The lower than expected counts of recaptured juveniles in my study may also be related to survival rates of relocated geese. Geese are relocated during molting season, when they are flightless and most vulnerable to predators. Adult geese may have a higher survival rate than juveniles after relocation because they have already survived at least one molting season (Pilotte et al., 2014). Therefore, if relocated juveniles have lower survival rates than adults during molting, they would have reduced opportunity to return to the capture site. Balkcom et al. (2011) reported a 62% survival rate for relocated Canada geese in Georgia and 76% survival for non-relocated Canada geese, even with equal hunter harvest rates for both relocated and non-

relocated populations (8%). The lower survivability of relocated geese than non-relocated geese may further reduce the likelihood of recapturing juvenile geese.

In general, females have higher survivability among polygamous game birds and males have higher survivability among monogamous game birds (Latham, 1947). Past studies recognize instances of both monogamy and polygamy in Canada geese (Brakhage, 1965; Kossack, 1950; Kozak, 2019; Lengkeek, 1973). Canada goose populations have a higher proportion of females than males due to a higher mortality rate for males, even with equal hunter harvest rates (Imber, 1968; Latham, 1947). My results were consistent with previous findings; females composed 53% of all banded Canada geese in Georgia between 2010-2019. Both recaptured and non-recaptured geese had a higher proportion of females than males, and my results indicate that behavioral and survival differences between sexes are not substantial enough to cause a significant difference within recaptured populations. This result is consistent with studies of resident and migratory populations in northern areas, such as New York and Quebec (Pilotte et al., 2014; Holevinski et al., 2006).

My results indicate that recaptured geese are less likely to originate from groups that were relocated greater than 250 km from the capture site. In addition, higher than expected amounts of recaptured geese that were relocated less than 150 km support my hypothesis. In my study, 3.5% of geese relocated less than 150 km were recaptured, 2.9% of geese relocated between 150-250 km were recaptured, and 1.1% of geese relocated greater than 250 km were recaptured. My results coincide with other findings that resident geese are less likely to return to their capture site when relocated at greater distances (Lowney et al., 1997; Powell et al., 2003; Stephens et al., 2007).

The overall recapture rate of relocated Canada geese (2.5%) over the 10-year period of my study is noticeably lower than other studies. Only 3.5% of geese relocated less than 150 km away were recaptured at a nuisance site; in contrast, Holevinski et al. (2006) found a 25% return rate of Canada geese relocated 150 km from the capture site. One reason for the substantially lower proportion of recaptured birds in my study is that movement of banded birds is only tracked through recovery at certain nuisance sites, potentially limiting the number of returned birds that were actually recorded. Most studies on Canada goose movement involve transmitting radio collars or data from banded birds recovered from hunters, which allow for a more comprehensive understanding of movement patterns (Rutledge et al., 2015; Stephens et al., 2007; Powell et al., 2003; Donaldson et al., 2018).

The low recapture rates from this study may also be due to the less harsh winters in lower latitudes that create more amenable habitat throughout the state. Dorak et al. (2017) found that Canada geese are more likely to prefer urban habitats in the Chicago metropolitan area because of a high risk associated with leaving urban environments when temperatures drop. During winters in higher latitudes, geese likely prefer urban areas more than rural environments because of higher food availability, less extreme temperatures, and reduced predator risk (Guerena et al., 2016). Geese may be less likely to return to urban capture sites if there is a lower risk associated with rural habitats in Georgia than in northern regions. Balkcom et al. (2010) found that in Georgia, geese have higher survival rates in urban than rural habitats, which may explain why some geese still return to urban capture sites. However, the overall low recapture rates in Georgia may be due to milder winters allowing greater survivability at rural sites than in northern climates.

Hunting may also play an important role in the recapture of geese that are relocated to areas that permit waterfowl hunting. In this study, three geese were recaptured at sites greater than 10 km away from the original capture location. Two were relocated to a private pond where the landowner requested Canada geese to hunt (211 km away from the capture site); these were recaptured at nuisance sites 102 km away from the original capture site. One Canada goose was relocated 146 km to a Wildlife Management Area and later recaptured at a nuisance site 98 km from the original capture site. These three cases of extreme movement patterns following relocation may indicate a response to hunting pressure, especially for the two geese relocated for private hunting purposes. Resident juveniles relocated to hunting areas in southern Quebec experienced higher hunter harvest rates, which may be a factor in the low number of juvenile recaptures in my study (Pilotte et al., 2014). In New York, relocated Canada geese were 3.9 times more likely to be harvested by hunters than non-relocated birds during the September hunting season (Holevinski et al., 2006). A high harvest rate of relocated geese may be related to the low recapture rates of my study as well as the overall effectiveness of relocating nuisance geese to areas open to hunting. Resident geese in Quebec consistently vacated hunted areas several weeks before hunting season, showing a strong response to hunting pressure (Beaumont et al., 2013). The low recapture numbers in my study suggest that relocated geese in Georgia either do not display this type of hunter avoidance behavior, or they do not experience the same levels of hunting pressure as geese in Quebec.

Limitations

One limitation of this study is that the recaptured population only includes geese at sites that USDA-APHIS personnel repeatedly captured. About 68% of sites did not request relocation

services from USDA-APHIS after the first removal effort. Although these cases may indicate the reduction or elimination of nuisance geese, it also leaves a gap in my data because returning geese would not have the opportunity to be recaptured and recorded at sites with a non-repeat relocation event. Additionally, this study may be biased because geese may avoid recapture attempts after they have already been relocated once. This possible behavior could skew my results and cause a lower number of recaptures by affecting the independence of sampling. Although costly, live tracking instead of only banding relocated geese would yield a closer estimate of return rates as opposed to recapture rates. This method would contribute to a greater understanding of the effectiveness of relocation efforts for resident birds in Georgia.

The design of this study limits interpretation of results. By using chi-square tests of independence, I was not able to control for other covariates. I assessed for effects of singular variables at a time as opposed to multiple variables that may be interrelated (e.g., sex may impact age of geese through difference in survival rates). Interacting variables may create a more complicated relationship than this analysis can interpret. However, the chi-square tests used in this study yielded valuable insight into the associations of categorical factors and population type. Information about the effectiveness of all relocation efforts throughout the entire range of resident Canada geese could be highly useful, but the conclusions drawn from this study are limited to the population of Canada geese banded 2010-2019 in Georgia.

Future directions

Some land-use studies have identified types of habitat that are associated with high nest survival rates for resident Canada geese; further studies with relocated geese that evaluate the quality of relocation site habitat may increase our understanding of return patterns of relocated

geese. Additionally, a comparative experiment of relocated geese at varying latitudes could expand knowledge of climate effects on Canada goose behavior. Because local and state agencies dictate resident goose population management, the effect of regional climate on return rates and movement patterns may contribute to a more comprehensive impact on controlling populations in North America. Furthermore, variations in hunting seasons and harvest rates at individual Wildlife Management Areas in Georgia should be evaluated for the impact of hunting pressure on Canada goose movements to urban areas that have a greater likelihood of nuisance complaints.

CHAPTER FIVE

CONCLUSION

Although hunting is an effective population management tool for Canada geese that are in rural locations, geese located in urban areas where hunting is prohibited require alternative strategies. In Georgia, relocation of urban geese to rural locations with established hunting regulations is an effective strategy for nuisance geese at residential, industrial, and commercial sites. I recommend continuing current techniques of relocating all geese at a given site regardless of age or sex because of the overall low recapture rates for all relocated geese. However, transporting geese at distances greater than 150 km will likely be the most effective method to ensure successful relocation events.

Since federal policy began to distinguish between migratory and resident Canada goose populations (USFWS, 2002), USFWS has placed a large amount of management decision-making and strategies with local and state agencies. To improve population control as resident Canada geese numbers continue to rise, I recommend increased efforts toward reducing Canada goose presence at a slightly broader scale than individual locations. Information campaigns focused on educating landowners in the vicinity of known nuisance sites on simple and low-cost techniques such as egg addling may increase the effectiveness of relocation efforts. Continuing the population control techniques that are typically used as initial measures (e.g., predator silhouettes, chemical repellants) to avoid reestablishment of populations following relocation events may reduce negative effects of nuisance Canada geese at a regional scale.

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