# WILDLIFE CONSERVATION IN A DEVELOPING LANDSCAPE: INTERFACING BIOLOGICAL RESEARCH AND SCIENCE-BASED PUBLIC AWARENESS

by

GREGORY MICHAEL SKUPIEN

(Under the Direction of Kimberly M. Andrews)

ABSTRACT

Development associated with human population growth often places humans and wildlife in close proximity to one another. Top predators are vulnerable to the effects of development because their dietary needs and large home ranges put them in direct conflict with humans. As a result, top predators are often removed from the system to reduce the risk to humans. In the southeastern United States, the American alligator (*Alligator mississippiensis*) is an important member of coastal ecosystems where it is a top predator and ecosystem engineer. We conducted a study on Jekyll Island, Georgia that included population surveys, telemetry studies, and public education in order to maintain viable alligator populations while reducing risks to humans. We found that alligators are more likely to inhabit large lagoons with low salinities. Home range sizes for adult alligators ranged from 27.5 – 1093.9 ha. Public education proved successful at changing attitudes and perceptions towards alligators.

INDEX WORDS: American alligator, *Alligator mississippiensis*, Habitat Use, Home Range, Interpretation, Outreach, Risk, Spatial Ecology, Urban, Wildlife Attitudes

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DEDICATION

This thesis is dedicated to my parents, Anthony and Rachel. From a young age they instilled in me a love for nature and encouraged my exploration of it. My father has always exemplified what it means to be hardworking, organized, and well-prepared; character traits that I have found particularly useful in my young career. My mother's spontaneous, inquisitive, and adventurous personality inspired me to travel the world and gave me the courage to jump on that first alligator. Her dedication to teaching has motivated me to do a little teaching of my own. I could not have done this without them. I thank them both for their continual love and support.

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# INTRODUCTION AND LITERATURE REVIEW

## Introduction

As the human footprint expands, conservation in urban and suburban areas is essential to preserving biodiversity. In these developed areas human-induced perturbations, such as habitat fragmentation and food supplementation, may result in changes in wildlife behavior and ecology (Beckmann and Berger 2003, George and Crooks 2006). Habituation of wildlife to humans is also a growing area of concern in wildlife management in urban areas (Bounds and Shaw 1994, Kloppers et al. 2005). These biological trends elicit the need to further understand the effects of human development on wildlife species.

Historic patterns in the relationship between people and wildlife are epitomized by the plight of the American alligator (*Alligator mississippiensis*) in the southeastern United States. Habitat destruction and overexploitation caused drastic declines in the American alligator population during the early 1900s and the species was listed as endangered in 1967. Under federal protection, populations recovered and in 1987 the species was downgraded to "threatened due to similarity of appearance." Today, the American alligator is common throughout the southeastern United States and alligator populations are increasing throughout their range (USFWS 1987). In Georgia, the alligator population was first estimated in 1973 at 29,954. Today, the alligator population in estimated to be over 222,000 (Waters et al. 2010).

Concurrent with increasing alligator populations is the expansion of human development in the southeastern United States. Coastal areas in the southeast have been particularly affected by development due to improved transportation, tourism, and retirement opportunities (Napto et al. 2010). In coastal Georgia, historical and current land use changes and infrastructure expansion have led to the loss of more than 1.1 million acres of forested wetlands in recent decades (GA EPD 2009). Human population densities in coastal areas far exceed the national average and are predicted to increase (Crossett et al. 2014). As its preferred habitat is lost, alligators are increasingly forced into human-dominated landscapes which has resulted in an increase in the number of complaints received about "nuisance" alligators over the last three decades. Most complaints about nuisance alligators come from coastal areas with high human population densities (Waters et al. 2010). In Florida alone, nuisance complaints increased from 4,024 to 15,036 between 1980 and 2013 (FL FWC 2013). Although rare, alligator attacks on humans have been reported in multiple states throughout the species' range (Langley 2005, 2010). Small pets, especially cats and dogs, resemble natural prey items and are more frequently attacked (Harding and Wolf 2006).

Wildlife officials must manage growing alligator populations in order to reduce the likelihood of human-alligator conflict while ensuring continued alligator population viability. This necessitates an increased understanding of the ecology of the American alligator in human-dominated areas. Further, there is a need for wildlife biologists to effectively communicate actual versus perceived risks and translate research findings to the public. This thesis is a collection of three manuscripts in which we explore the ecology of the American alligator on a developed barrier island through the use of population surveys and telemetry studies. Additionally, we examine the effectiveness of two conservation education programs designed to increase tolerance for and acceptance of the American alligator.

## Alligators in Human-dominated Landscapes

Top predators are vulnerable to the effects of development because of their dietary needs and large home ranges (Ripple et al. 2014). Predators living in close proximity to developed areas frequently enter the urban environment resulting in road mortality, persecution by humans, and other human-wildlife conflicts (Beier 1995). As a result of these negative human-wildlife interactions, top predators are often removed from the system to reduce risks to humans, human property, and stocks of valuable game species (Graham et al. 2005, Treves and Naughton-Treves 2005). The removal of predators from developed areas may result in population declines and may have unintended ecosystem effects (Crooks and Soule 1999, Prugh et al. 2009).

Wildlife managers rely on information collected from population monitoring programs to make data-based decisions regarding alligator management strategies (Moore and Crawford, unpublished data). In addition to annual efforts undertaken by state agencies, several studies on alligator population dynamics have been conducted throughout their range (Chabreck 1966, Thompson and Gidden 1972, Wood et al. 1985, O'Brien and Doerr 1986, Taylor et al. 1991, Altrichter and Sherman 1999, Fujisaki et al. 2011). These studies, however, lack data on how alligator population dynamics vary in urban landscapes. As such, research is needed to determine the biotic and abiotic factors influencing alligator activity and abundance in human-dominated landscapes in order to inform wildlife officials tasked with managing alligator populations in developed areas.

An understanding of the spatial ecology of alligators in developed areas is also important now that populations have recovered. Studies on the ecology of predators in developed landscapes have been restricted to mammalian predators (e.g. Beier 1995, Gibeau 1998, Tigas et al. 2002, Lyons 2005) while reptilian predators, such as crocodilians, have largely been ignored.

Research is needed on the spatial ecology of crocodilians in developed areas because of the potential for conflict with humans (Eversole et al. 2014).

Telemetry studies have been used to understand the movements, home range, and territoriality of wild populations of American crocodiles (*Crocodylus acutus*, Kushlan and Mazzotti 1989), Nile crocodiles (*Crocodylus niloticus*, Hocutt et al. 1992), saltwater crocodiles (*Crocodylus porosus*, Kay 2004, Brien et al. 2008, Campbell et al. 2013), and Indian gharials (*Gavialis gangeticus*, Lang and Whitaker 2008). Extensive research has been conducted on the spatial ecology of American alligators (Joanen and McNease 1971, 1973; Goodwin and Marion 1979; Subalusky et al. 2009; Rosenblatt and Heithaus 2011). However, there is a lack of information on the spatial ecology of crocodilians inhabiting human-dominated landscapes.

Telemetry once relied heavily on the use of very high frequency (VHF), or radio, telemetry. Radio telemetry remains the most affordable technology. However, manually tracking crocodilians is inherently difficult because of observer effects on crocodilian behavior, the challenge of pinpointing the exact location of the animal, and the difficulty of recapturing study animals to replace transmitters. Further, radio signals are greatly attenuated in brackish systems and may not be the most appropriate methodology for studying crocodilians in marine and estuarine environments. Recent advances in technology have provided researchers with more sophisticated means of remotely monitoring crocodilians, including the use of acoustic, satellite, and global positioning system (GPS) telemetry. These systems are more expensive, but address some of the limitations of VHF telemetry (Franklin et al. 2009). Ultimately, selection of the appropriate telemetry technology will depend on the study system, species, and the quantity and type of data needed to meet research objectives.

## The Value of Conservation Education

Direct removal of the nuisance animal is the most common method for dealing with problem alligators. This type of response, designed to change human behavior by modifying the social context of the behavior, is often referred to as a "structural fix" by Heberlein (2012). Structural fixes have been employed in the management of alligators in human-dominated landscapes (Hayman et al. 2014). However, if the goal is to maintain reproductively viable populations of alligators at an ecologically relevant level, removal may not be an effective management technique.

In situations where direct removal of alligators in not an option, wildlife managers must consider "cognitive fixes" designed to influence the cognitive factors underlying human-alligator conflicts through conservation education programs (Hayman et al. 2014). Although the use of cognitive fixes has been heavily criticized because of the low correlation between attitudes and behaviors (Heberlein 2012) numerous studies highlight the benefits of conservation education programs on fostering pro-environmental attitudes and influencing subsequent behaviors (e.g., Ballantyne and Packer 2005, Zeppel and Muloin 2008). Effective conservation education programs designed to promote tolerance of and coexistence with predators often explicitly account for wildlife acceptance capacity.

Wildlife acceptance capacity (WAC) can be broadly defined as the maximum wildlife population that is acceptable to people (Decker and Purdy 1988). More specifically, WAC is defined as the point at which individuals or societies take actions designed to impact wildlife populations (Bruskotter and Fulton, 2012). Wildlife acceptance capacity is influenced by factors such as attitudes and beliefs towards the target species, perceptions of risk associated with the species, and the economic, aesthetic, ecological, and intrinsic values placed on the species by society (Decker and Purdy 1988).

Riley and Decker (2000b) suggest that attitudes towards the target species are one of the main predictors of WAC. Attitudes are defined as the favorable or unfavorable evaluation of a person, object, or action (Decker et al. 2012). Homer and Kahle's (1988) cognitive hierarchy model suggests a causal relationship between values, attitudes, and behaviors and places an emphasis on the mediating role of attitudes between values and behavior. Others have provided support for the mediating role of attitudes on the relationship between values and behaviors (Tarrant, Bright, & Cordell, 1997; Vaske & Donnelly, 1999). Bruskotter et al. found strong associations between attitudinal measures towards a predator (i.e., wolves) and measures of prior behavior towards the species (in press). Positive attitudes have also been associated with higher levels of acceptance for other predators (Riley & Decker, 2000b, Smithem, 2005). Milfont et al. (2010) expanded Homer and Kahle's hierarchy model by including perceived environmental threat as a predictor of environmental attitudes. They found that environmental attitudes mediate the impact of both values and threats on ecological behavior. As such, negative attitudes may lead to higher risk perceptions towards an object (Sjöberg 2000).

Risk perception is also recognized as an important predictor of acceptance capacity (Riley & Decker, 2000a; Bruskotter & Wilson, 2014). For example, lower risk perceptions towards cougars are associated with higher acceptance capacity for cougars (Riley and Decker 2000*a*). Similarly, low risk perception had a significant effect on acceptable levels of future American crocodile (*Crocodylus acutus*) populations in south Florida (Smithem 2005).

The concept of wildlife-associated "risk" means different things to different people. An expert's assessment of risk often correlates with annual human fatalities, while the public generally assesses risk based on factors such as catastrophic potential, threat to future generations, and level of control (Slovic 1987). Hazards that have a low probability of occurrence and high consequence often lead to feelings of dread. Wildlife-related hazards with these properties, such as an attack by a predator, may elevate perceptions of risk and subsequently lower WAC (Riley and Decker 2000*b*). In situations where predators threaten human safety wildlife managers must find ways to achieve conservation goals while minimizing risks to humans.

Sustainable coexistence is often the end goal for predator management. Wildlife managers tasked with promoting coexistence between humans and predators are challenged with the need to develop effective communication and management strategies capable of modifying WAC (Riley and Decker 2000*a*). Effective conservation education programs often involve a direct encounter with captive animals or a field-based component that allows participants to view non-captive wildlife in native habitats. Direct encounters have unique potential to impact visitors' attitudes and behaviors (Ballantyne, Packer, Hughes, & Dierking, 2007). For example, researchers found that providing a safe, direct encounter with wildlife can be more effective in changing attitudes toward wildlife than simply showing animals to an audience (Morgan and Gramann 1989). Evidence also suggests that field excursions, such as marine mammal tours, can foster positive environmental attitudes and subsequently change human behaviors towards wildlife (Zeppel and Muloin 2008). While both approaches have been shown to facilitate positive attitudes and behaviors, there are several costs that should be considered before implementing either approach (Ballantyne et al., 2007). Direct encounters with captive animals may seem unnatural to the audience, and reduced visibility of the non-captive species is often considered a major limitation of field excursions. Given these benefits and costs, there is a need to explore the effectiveness of conservation education programs that offer close encounters with captive animals and those that allow visitors to view non-captive wildlife (Ballantyne et al., 2007).

Unfortunately, evaluation mechanisms are rarely in place. Given the limited resources allocated to conservation initiatives, program evaluation methods must be adopted to determine the effectiveness of conservation efforts (Ferraro and Pattanayak 2006). Some researchers have even suggested that the evaluation of wildlife-related education programs should be a requirement of their implementation (Gore et al. 2008). Others have called for a systematic review of education campaigns designed to reduce negative human-wildlife interactions (Treves and Karanth 2003).

Successful strategies that facilitate coexistence between humans and predators address the economic, affective, and cognitive factors influencing human-predator conflicts (Dickman et al. 2011). Education programs designed to lower risk perceptions and foster positive attitudes towards top predators may help maintain viable populations of wildlife species, increase public safety, and facilitate coexistence (Thornton and Quinn 2010). By creating a positive interface between people and managers, communicating actual versus perceived risks to the public, and translating sound science to increase confidence in wildlife management agencies, conservation education programs have great potential to increase WAC and the potential for coexistence between humans and wildlife, especially large predators.

## Statement of Purpose

We conducted a multi-year monitoring program of the American alligator on Jekyll Island, Georgia using repeated count surveys in order to examine the effects of season, lagoon size, salinity, distance to nearest lagoon, and shoreline vegetation on the activity and abundance of alligators inhabiting human-made stormwater lagoons. Additionally, we compared the results from a completed VHF telemetry study and an in progress GPS telemetry study in order to present the advantages and limitations of both techniques and their applicability in researching the spatial ecology of alligators in urban landscapes. We used VHF and GPS telemetry to calculate the home ranges and habitat use of adult American alligators inhabiting a developed barrier island. Finally, we assessed the effectiveness of two educational programs (a classroom-based lecture and a field excursion) on key elements of wildlife acceptance capacity for the American alligator. Specifically, we examined participants' positive attitudes, perceived risk, and potential for coexistence towards the American alligator.

These data will add to growing body of data on the ecology of top predators in developed areas and will be directly applicable in assisting state and local officials in developing management guidelines that reduce the risk to humans while ensuring continued population viability of these top predators. Further, this research highlights the importance of cognitive fixes, such as conservation education programs, in fostering positive attitudes and lower risk perceptions towards a top predator in a developed landscape.

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# CHAPTER 2

# FACTORS INFLUENCING THE ACTIVITY AND ABUNDANCE OF THE AMERICAN ALLIGATOR (*ALLIGATOR MISSISSIPPIENSIS*) ON JEKYLL ISLAND, GEORGIA, USA [1]

[1]Skupien, G. M. and K. M. Andrews. To be submitted to *Copeia*

## Abstract

Long-term management of viable American alligator (*Alligator mississippiensis*) populations necessitates a more detailed understanding of the species' ecology in human-dominated areas. We conducted a multi-year monitoring program of the American alligator on Jekyll Island, Georgia, USA in order to investigate seasonal fluctuations in activity and the abiotic and biotic (habitat) factors influencing alligator abundance in human-made stormwater lagoons. Evening spotlight surveys were conducted monthly from April 2011 to September 2014. Data on the number of alligators detected were recorded. We found that alligators exhibit year-round activity on the island. However, significantly fewer individuals were active in the winter season (November to February) than in the mating (March to June) and nesting (July to October) seasons. Data on lagoon salinity, percent shoreline vegetation, distance to nearest lagoon, and lagoon area were collected throughout the study period. We used the second-order Akaike Information Criterion ($AIC_c$) and subsequent model averaging techniques to examine the relationship between these factors and alligator abundance. We found lagoon area to be the most important predictor of alligator abundance relative to the other three independent variables. Elucidation of these biological trends will allow land managers to better predict when and where human-alligator conflicts may occur. Additionally, these data may provide developers with valuable information on how to construct stormwater lagoons in order to promote or discourage lagoon colonization by the American alligator.

## Introduction

Habitat destruction and overexploitation caused drastic declines in the American alligator (*Alligator mississippiensis*) population during the early 1900s leading to its listing as an endangered species in 1967. Under federal protection, populations recovered and in 1987 the species was downgraded to "threatened due to similarity of appearance." Today, *A. mississippiensis* is common throughout the southeastern United States and alligator populations are increasing throughout their range (USFWS, 1987).

Concurrent with increasing alligator populations is the expansion of human development in the southeastern United States. Coastal areas in the southeast have been particularly affected by development due to improved transportation, tourism, and retirement opportunities (Napto et al., 2010). In coastal Georgia, historical and current land use changes and infrastructure expansion have led to the loss of more than 1.1 million acres of forest wetlands in recent decades (GA EPD, 2009). Human population densities in coastal areas far exceed the national average and are predicted to increase (Crossett et al., 2014). As its preferred habitat is lost, *A. mississippiensis* is increasingly forced into human-dominated landscapes which has resulted in an increase in the number of complaints received about "nuisance" alligators over the last three decades. Most complaints about nuisance alligators come from coastal areas with high human population density (Waters et al., 2010). In Florida, nuisance complaints have increased from 4,024 in 1980 to 15,036 in 2013 (FL FWC, 2013). Although rare, alligator attacks do occur with some resulting in fatality (Langley, 2005, 2010).

Wildlife managers are tasked with the challenge of reducing the likelihood of human-alligator conflicts while simultaneously ensuring continued alligator population viability. These managers rely on information collected from population monitoring programs to make data-based decisions regarding alligator harvesting regimes and nuisance control programs (Moore and Crawford, unpublished data). In addition to efforts undertaken by state agencies, several studies on alligator population dynamics have been conducted throughout their range (Chabreck, 1966; Thompson and Gidden, 1972; Wood et al., 1985; O'Brien and Doerr, 1986; Taylor et al., 1991; Altrichter and Sherman, 1999; Fujisaki et al., 2011). These studies, however, lack data on *A. mississippiensis* population dynamics in urban landscapes.

We conducted a multi-year monitoring program on Jekyll Island, Georgia using repeated count surveys to examine the effects of season on *A. mississippiensis* activity. Additionally, we examined the effects of lagoon area, salinity, distance to nearest lagoon, and shoreline vegetation on the abundance of *A. mississippiensis* inhabiting human-made stormwater lagoons. This research will provide coastal developers and management officials with additional information needed to manage viable alligator populations in human-dominated areas while mitigating the risk to humans and their property.

## Materials and Methods

*Study Site*

Jekyll Island State Park is a 2,238-hectare barrier island located in southeastern Georgia and is managed by the Jekyll Island State Park Authority. The island is connected to the city of Brunswick (Glynn County) by a causeway that brings >1 million guests to the island each year. Jekyll Island is fronted by the Atlantic Ocean and backed by an extensive system of salt marsh dominated by smooth cordgrass (*Spartina alterniflora*, Figure 2.1). Interspersed within the native upland habitat (e.g., maritime live oak hammock, pine forest, beach dunes) are 651 hectares of developed land including residential areas, multiple hotels, a historic district, and four golf courses. Development on the island has led to the creation of 34 freshwater and brackish stormwater lagoons. The majority of these lagoons (n = 23) are located on the island's golf courses.

*Census Regime*

We conducted monthly daytime and spotlight surveys of *A. mississippiensis* from 28 April 2011 to 15 September 2014 using methods similar to those previously described (Wood et al., 1985; Altrichter and Sherman, 1999). For the purposes of this study we focus on the analysis of spotlight survey count data. A survey route incorporating all 34 stormwater lagoons was established at the beginning of the study period. We completed each route within the first week of each month. Routes began approximately 30 minutes after sunset, or when it was dark enough to detect eyeshine. The order in which sites were visited was varied monthly in order to reduce temporal effects and other sampling biases. We drove a golf cart between survey sites located on the golf course. A pickup truck was used to complete the remainder of the survey route. Vehicles were parked several meters away from lagoons and researchers approached lagoons on foot in order to minimize the risk of scaring alligators before they were detected. At each location two experienced researchers used a powerful 600-lumen Q-Beam® spotlight (Brinkmann, Dallas, TX) to detect eyeshine. If necessary, counts were made from multiple locations along the shoreline to ensure complete coverage of the water body. Once an alligator was observed, the size of the alligator was estimated and placed in one of four size classes (<0.91 m, 0.92-1.83 m, 1.84-2.74 m, >2.75 m). The total number of alligators in each size class was recorded at each lagoon. This was repeated at all 34 sites until the survey route was completed. Survey time varied with season depending on the amount of alligator activity and, in order to allow for thorough counts of all detectable alligators, survey effort was not time constrained or standardized.

We collected data on four lagoon characteristics: salinity, area, percent shoreline vegetation, and distance to nearest lagoon. We measured salinity using a handheld hydrometer (Instant Ocean®, Blacksburg, VA) six times during the study period. Two salinity measurements were taken for each season. We used these values to calculate mean salinities across years for each lagoon. Parameters for lagoon area, percent shoreline vegetation, and distance to nearest lagoon were calculated using aerial imagery in ArcMap10 (Environmental Services Research Institute, Redlands, CA). Stormwater lagoons on Jekyll Island are routinely chemically treated making it difficult to accurately measure aquatic and emergent vegetation. As such, we calculated percent shoreline vegetation as the percent of the lagoon boundary intercepted with terrestrial vegetation.

*Data Analysis*

We used three continuous years of spotlight survey route data (April 2011 to April 2014, n = 36 survey routes) to examine the effect of season on alligator activity. We divided the year into three seasons based on alligator behavior. In southeast Georgia, alligators emerge from brumation and mate from March to June (mating season). Nesting and hatching takes place during the months of July to October (nesting season). Ambient and water temperatures drop and alligators typically enter den sites between November and February (winter season). A one-way ANOVA was conducted in software R (R Foundation for Statistical Computing, Vienna, Austria; http://www.r-project.org/) to assess the effect of season on alligator activity. We examined the main effect of season by comparing the difference in mean alligator activity among the three seasons using a Tukey HSD post hoc test.

We used the second-order Akaike Information Criterion ($AIC_c$) to assess a set of candidate models predicting alligator abundance. Ten possible subsets of the four predictor variables (i.e. salinity, log area, percent shoreline vegetation, and log distance to nearest lagoon) were modeled using a Poisson regression with a log link and included a random effect for lagoon. The number of alligators observed was considered the response variable. Previous research has suggested a relationship between alligator abundance and salinity, lagoon size, shoreline vegetation, and spatial orientation (Wood et al., 1985; O'Brien and Doerr, 1986; Altrichter and Sherman, 1999) justifying inclusion of the predictor variables in our model. To minimize detection biases during model selection analyses, we only used observations collected during the mating and nesting seasons when *A. mississippiensis* is active (n = 1020 observations).

Selection of the best model in a set of candidate models is based on examination of the Akaike weights ($\omega_i$). The $\omega_i$ is the weight of evidence in favor of a model being the best model in a set of candidate models. The evidence ratios, or the ratio of Akaike weights ($\omega_i / \omega_j$), can also be used to judge the strength of a model compared to others in the set. We examined both $\omega_i$ and the evidence ratios in order to assess the 10 candidate models. When no one model is clearly superior to the others, as was observed here, model-averaging is suggested (Burnham and Anderson, 2002). In cases where there is a high degree of model uncertainty inferences must be based on all candidate models (Symonds and Moussalli, 2011). As such, we calculated full-model averaged estimates and unconditional measures of precision using package MuMIn

(Barton, 2014) in software R. Further, we assessed relative variable importance by summing $\omega_i$ for each variable across all models where a particular variable occurred.

**Results**

Mean salinity ranged from 0.0 to 23.5 ppt among lagoons (mean = 2.3 ppt, SE = 0.9 ppt). Lagoon area was highly variable (mean = 1.1 ha, SD = 2.2 ha). The largest lagoon was 11.0 ha and the smallest was 0.04 ha. The straight line distance to nearest lagoon ranged from 3.8 to 889.1 m (mean = 107.7 m, SD = 175.5 m). Percent shoreline vegetation ranged from 0.0% to 94.9% (mean = 47.9%, SD = 33.2%). Five highly-manicured lagoons located on the golf course were completely void of all shoreline vegetation.

Alligators were observed in all 34 lagoons. There was a significant effect of season on alligator activity ($F_{2,33} = 14.13$, $p < .001$). Post hoc comparisons using Tukey HSD indicated that the mean number of alligators active in the winter (mean = 40.2, SD = 20.9) was significantly different from the mean number active during the mating (mean = 82.8, SD = 19.0) and nesting (mean = 74.7, SD = 22.5) seasons. There was no significant difference between the number of alligators observed during the mating and nesting seasons (Figure 2.2).

The 10 candidate models predicting alligator abundance in human-made stormwater lagoons are ranked according to the $AIC_C$ differences ($\Delta_i$) in Table 2.1. Model 1 was indicated as the best model and had $\Delta = 0$. However, examination of the data indicates model uncertainty. In this case, seven of our 10 candidate models had a $\Delta AIC < 7$. Early literature suggests that models with a $\Delta > 2$ should be dismissed. However, more recent literature recommends that $\Delta AIC$ between 2-7 should also be considered (Burnham et al., 2011). Further, examination of $\omega_i$ and the evidence ratios may also be used to assess the model strength (Burnham and Anderson, 2002). Model 1 had a $\omega_i$ of 0.34 while the second model had a $\omega_i$ of 0.28. This offers relatively weak support that Model 1 is the best model in our candidate set. Models 2, 3, and 4 all had evidence ratios < 5.0 further indicating a high degree of model uncertainty (Table 2.1).

Due to the high degree of model uncertainty we employed full-model averaging. The average parameter estimates indicate a negative relationship between salinity and the number of alligators in a lagoon. We observed positive associations between the log area, percent shoreline vegetation, log distance to nearest lagoon, and the number of alligators in a lagoon (Table 2.2).

Estimates of relative variable importance were made by summing the $\omega_i$ for each variable across all candidate models where that variable was present. Variables with greater values are thought to be more important relative to other variables (Burnham and Anderson, 2002). In this way we were able to rank the importance of the four variables affecting alligator abundance in human-made stormwater lagoons. The log area ranked highest and was followed by salinity, percent shoreline vegetation, and log distance to nearest lagoon, in descending order of importance (Table 2.3).

## Discussion

We found that *A. mississippiensis* exhibited year-round activity and was most active during the mating and nesting seasons (March through October). Alligator activity patterns are significantly correlated with water temperatures (Lutterschmidt and Wasko, 2006). Temperature constraints during the winter months place restrictions on alligator activity, even in relatively moderate coastal climates. In temperate areas of their range alligators typically brumate in underground den sites. This thermoregulatory behavior likely accounts for the decreased alligator activity observed during the months of November through February. Alligators were most active during the months of March through October. This seasonal difference in alligator activity is reflected in the number of nuisance alligators reported. During the study period, we received 41 alligator complaints on Jekyll Island (Andrews and Skupien, unpublished data). All of these complaints were received during the months of March through October when alligators are most active. In developed areas, such as on golf courses, freshwater habitat is often highly fragmented and alligators must make terrestrial movements between water bodies. Wildlife managers should be prepared to receive and respond to nuisance complaints during these months as alligator move between discrete ecosystems.

We observed a positive association between the number of alligators in a lagoon and the log area, percent shoreline vegetation, and log distance to nearest lagoon. We found that the log area was the most important predictor of alligator abundance relative to the other variables. Others have observed a positive correlation between alligator abundance and the log of pond area (Altrichter and Sherman, 1999). Larger lagoons may provide more complex habitat preferable to alligators. Further, adult *A. mississippiensis* can be highly territorial and larger stormwater lagoons provide more area for multiple individuals. Salinity was the second most important predictor (sum $\omega_i$ = 0.88). We observed a negative relationship between salinity and the number of alligators. Increased salinity levels can negatively affect alligator physiology and may even be lethal to juveniles (Laurén, 1985). These data indicate that *A. mississippiensis* is most likely to be abundant in large stormwater lagoons with lower salinity.

Percent shoreline vegetation and the log distance to nearest lagoon were relatively less important predictor variables (sum $\omega_i$ = 0.49, 0.20, respectively). In our study, we measured the terrestrial vegetation bordering the lagoon. Other studies indicate that aquatic and emergent vegetation is an important determinant of alligator abundance. Newsome et al. (1987) suggested that the optimal habitat for *A. mississippiensis* has 20-40% open water with highly interspersed water and emergent vegetation. Others have noted that adult alligators prefer deeper, less vegetated open-water habitats while subadults tend to inhabit shallower, more heavily vegetated habitats (Webb et al., 2009). Further research is needed to determine the optimal amount of vegetation. Altrichter and Sherman (1999) found that alligator abundance was not significantly correlated with the log distance between semi-permanent ponds and the nearest permanent water body. Alligators are highly vagile species capable of making long distance terrestrial movements between water bodies. This behavior may explain the low importance of the log distance between lagoons relative to the other variables in our model.

In this study we examined the effect of season and four stormwater lagoon variables on alligator abundance. Notably, we did not include water depth in our models. Changes in water level can significantly affect the number of alligators observed by forcing alligators into densely populated pools in times of drought (Wood et al., 1985; Altrichter and Sherman, 1999; Fujisaki et al., 2011). Further research is needed to explore the effect of water depth and additional characteristics of human-made stormwater lagoons that may affect *A. mississippiensis* abundance. Such factors may include: prey levels and whether the lagoon is stocked with fish, creation of islands or artificial basking platforms, bank slope, engineering of the littoral shelf, and human interactions with alligators (e.g., supplemental feeding).

## Conclusions

The construction of residential areas, tourist attractions, and golf courses in coastal landscapes has led to the destruction of natural aquatic habitats. Simultaneously humans have created novel permanent freshwater habitats in the form of stormwater lagoons. The construction of freshwater habitats in human-dominated areas in conjunction with the recovery of the *A.*

*mississippiensis* has led to an increase in human-alligator conflicts in recent decades. The goal of wildlife managers should be to maintain viable populations of *A. mississippiensis* in developed areas while mitigating the risk to humans and their property. A better understanding of the biotic and abiotic factors influencing alligator abundance in human-made stormwater lagoons will allow land managers to better predict when and where human-alligator conflicts may occur. Model averaging techniques suggest that alligators are more likely to occur in large lagoons with low salinities. Wildlife managers should be prepared to deal with alligator complaints in these habitat types during the months when alligators are most active (i.e., March through October). Officials may elect to take proactive measures to mitigate the risk of human-alligator conflicts before they occur. Protective barriers (i.e., fences) and educational signage placed around human-made stormwater lagoons may help to prevent conflict with alligators. These data may also provide developers with valuable information on how to construct stormwater lagoons in order to promote or discourage colonization of human-made stormwater lagoons by *A. mississippiensis*. In order to promote colonization of lagoons, developers should avoid constructing stormwater lagoons that are connected with brackish systems, such as saltwater marshes in coastal landscapes. Creating large lagoons with a mixture of open and vegetated terrestrial edges would provide suitable habitats for alligators. Placing lagoons closer together may prevent alligators from making long distance terrestrial movements that may result in human-alligator conflicts.

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Figure 2.1. Map of Jekyll Island, Georgia. Jekyll Island is a barrier island located in southeastern Georgia, USA. The island is fronted on the east by the Atlantic Ocean and backed by an extensive system of saltwater marsh.

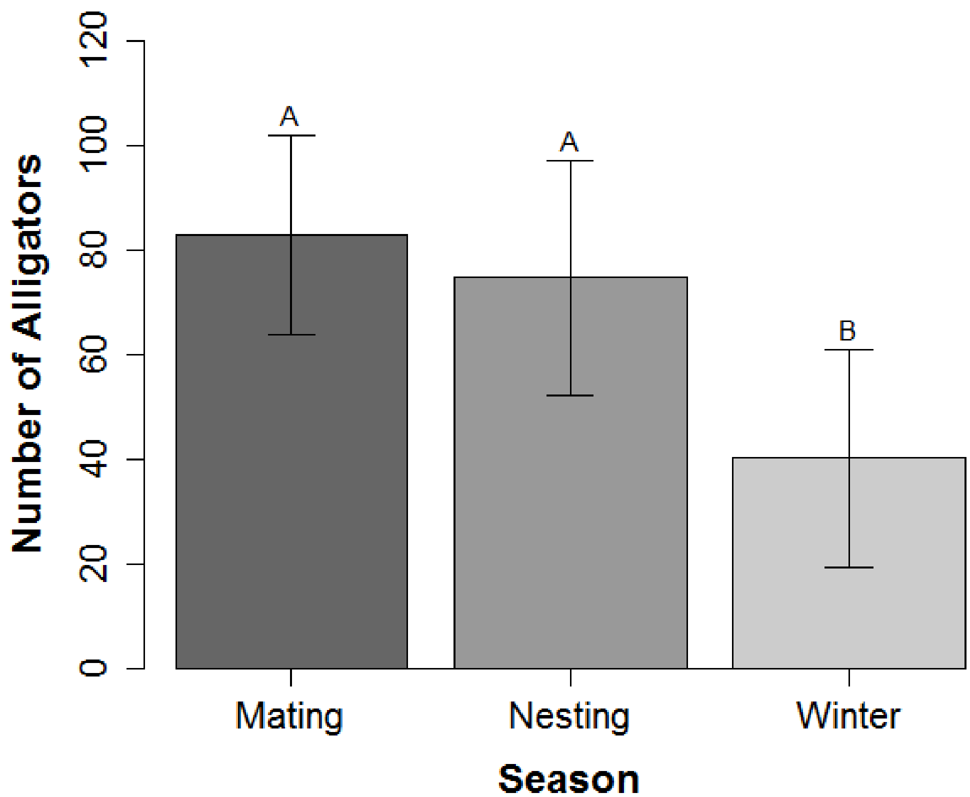


Figure 2.2. Seasonal differences in alligator activity on Jekyll Island, Georgia. The mean number of alligators active during the winter season was significantly different from the number of alligators active during the mating and nesting seasons. Letters indicate significance at the $p < .05$ level.

Table 2.1. Summary of ranked Poisson regression models examining the effect of lagoon characteristics on the abundance of American alligators.

| | **Candidate Models** | **K** | **log(£)** | **AICc** | **$\Delta_i$** | **$\omega_i$** | **Evidence Ratio** |
|---|---|---|---|---|---|---|---|
| 1 | S + A | 4 | -1751.74586 | 3511.5316 | 0.00 | 0.34 | 1 |
| 2 | S + A + V | 5 | -1750.928384 | 3511.9167 | 0.39 | 0.28 | 1.21232 |
| 3 | S + A + NL | 5 | -1751.709461 | 3513.4789 | 1.95 | 0.13 | 2.64749 |
| 4 | S + A + V + NL | 6 | -1750.908778 | 3513.9016 | 2.37 | 0.11 | 3.27055 |
| 5 | A + V | 4 | -1753.455393 | 3514.9507 | 3.42 | 0.06 | 5.52638 |
| 6 | A + NL | 4 | -1753.989502 | 3516.0189 | 4.49 | 0.04 | 9.42761 |
| 7 | A + NL + V | 5 | -1753.346179 | 3516.7523 | 5.22 | 0.03 | 13.6035 |
| 8 | S + V | 4 | -1755.786321 | 3519.6126 | 8.08 | 0.01 | 56.8526 |
| 9 | S + NL + V | 5 | -1755.454611 | 3520.9692 | 9.44 | 0.00 | 112.029 |
| 10 | S + NL | 4 | -1756.526136 | 3521.0922 | 9.56 | 0.00 | 119.137 |

S = salinity; A = log area; V = percent shoreline vegetation; NL = log distance to nearest lagoon

Table 2.2 Full model-averaged coefficients with unconditional standard errors.

| **Variable** | **Coefficient** | **SE** |
|---|---|---|
| Log area | 0.42447 | 0.14594 |
| Salinity | -0.07222 | 0.04413 |
| Vegetation | 0.32555 | 0.49554 |
| Log distance to nearest lagoon | 0.0114 | 0.07002 |

Table 2.3. Relative variable importance of four predictor variables explaining American alligator abundance on Jekyll Island, Georgia, USA.

| **Variable** | **Variable Rank** | **Relative Importance** | **N containing Models** |
|---|---|---|---|
| Log area | 1 | 0.99 | 7 |
| Salinity | 2 | 0.88 | 7 |
| Vegetation | 3 | 0.49 | 6 |
| Log distance to nearest lagoon | 4 | 0.30 | 6 |

# CHAPTER 3

# AMERICAN ALLIGATOR SPATIAL ECOLOGY: A COMPARISON OF VHF AND GPS TELEMETRY [2]

[2] Skupien, G. M. and K. M. Andrews. To be submitted to *Journal of Wildlife Management*

**Abstract**

American alligators (Alligator mississippiensis) historically occupied freshwater habitats such as isolated wetlands, lakes, rivers, bottomland swamps, and floodplains in coastal and inland sites. Due to the loss of many aquatic habitats, alligators have resorted to inhabiting human-made lagoons on golf courses and other aquatic habitats in close proximity to developed areas. We conducted a telemetry study on adult (>1.5 m) alligators to evaluate the efficacy of VHF and GPS telemetry for understanding the spatial ecology of the American alligator in a developed landscape. We calculated home ranges using minimum convex polygons (MCP) and adaptive local convex hulls (a-LoCoH). Data collected using GPS technology allowed for the construction of larger, more biologically accurate home ranges. VHF telemetry allowed alligators to be detected in underground habitats where they could not be detected with GPS telemetry. These data provide information on how alligators are adapting to development and highlight the importance of choosing the correct telemetry technology based on habitat type, species, and research objectives.

## Introduction

As the human footprint expands, conservation in urban and suburban areas is essential to preserving biodiversity. In these developed areas human-induced perturbations such as habitat fragmentation and food supplementation may change wildlife behavior and ecology (Beckmann and Berger 2003, George and Crooks 2006). Habituation of wildlife to humans is also a growing area of concern in wildlife management in urban areas (Bounds and Shaw 1994, Kloppers et al. 2005). These trends highlight the need to further understand the effects of human development on wildlife species, particularly top predators that may be perceived as dangerous or even persecuted by humans.

Predators are particularly vulnerable to the effects of development because of their dietary needs and large home ranges (Ripple et al. 2014). Predators living in close proximity to developed areas frequently enter the urban environment resulting in road mortality, persecution by humans, and other human-wildlife conflicts (Beier 1995). As a result of these negative human-wildlife interactions, predators are often removed from the system to reduce risks to humans, human property, and stocks of valuable game species (Graham et al. 2005, Treves and Naughton-Treves 2005). The removal of predators from developed areas may result in population declines and may have unintended ecosystem effects, such as mesopredator release (Crooks and Soule 1999, Prugh et al. 2009).

Understanding temporal and spatial organization of wildlife is a central question in the field of ecology (Kernohan et al. 2001). Understanding the spatial ecology of predators in developed areas is increasingly important now that populations of many persecuted species have recovered. Studies on the ecology of predators in developed landscapes have been restricted to mammalian species (e.g. Beier 1995, Gibeau 1998, Tigas et al. 2002, Lyons 2005) while reptilian predators have largely been ignored. Research is needed on the spatial ecology of crocodilians in developed areas because of the potential for conflict with humans (Eversole et al. 2014)

Telemetry studies have been used to understand the movements, home range, and territoriality of wild populations of American crocodiles (*Crocodylus acutus*, Kushlan and Mazzotti 1989), Nile crocodiles (*Crocodylus niloticus*, Hocutt et al. 1992), saltwater crocodiles (*Crocodylus porosus*, Kay 2004, Brien et al. 2008, Campbell et al. 2013), and Indian gharials (*Gavialis gangeticus*, Lang and Whitaker 2008). Extensive research has been conducted on the spatial ecology of American alligators (Joanen and McNease 1971, 1973; Goodwin and Marion 1979; Subalusky et al. 2009; Rosenblatt and Heithaus 2011). However, there is a lack of information on the spatial ecology of crocodilians inhabiting human-dominated landscapes.

Telemetry once relied heavily on the use of very high frequency (VHF), or radio, telemetry. Radio telemetry remains the most affordable technology. However, manually tracking crocodilians is inherently difficult because of observer effects on crocodilian behavior, the challenge of pinpointing the exact location of the animal, and the difficulty of recapturing study animals to replace transmitters. Further, radio signals are greatly attenuated in brackish systems and may not be the most appropriate methodology for studying crocodilians in marine and estuarine environments. Recent advances in technology have provided researchers with more sophisticated means of remotely monitoring crocodilians, including the use of acoustic, satellite, and global positioning system (GPS) telemetry. These systems are more expensive, but address some of the limitations of VHF telemetry (Franklin et al. 2009).

For this study we compared the results from a completed VHF telemetry study and an in progress GPS telemetry study. Our primary goal was to assess the efficacy of VHF and GPS telemetry for understanding the spatial ecology of the American alligator in a developed landscape. We assessed the ability of the two techniques to detect alligators in natural and human-made habitat types. Additionally, we examined how home range sizes compared between VHF and GPS telemetry. These data will assist researchers in selecting the appropriate telemetry technology to study predators in developed areas. Understanding the ecology of urban predators will aid state and local officials in developing management guidelines that reduce the risk to humans while ensuring continued population viability of wildlife.

## Study Area

Jekyll Island State Park is a 2,238-hectare barrier island located in southeastern Georgia, USA and is managed by the Jekyll Island State Park Authority. Jekyll Island is fronted on the east by the Atlantic Ocean and backed on the west by an extensive system of salt marsh dominated by smooth cordgrass (*Spartina alterniflora*). The interior of the island was primarily comprised of maritime live oak (*Quercus virginiana*) hammock. The understory was dominated by species such as saw palmetto (*Serenoa repens*), cabbage palmetto (*Sabal palmetto*), wax myrtle (*Morella cerifera*), yaupon holly (*Ilex vomitoria*), fetterbush (*Lyonia lucida*), American holly (*Ilex opaca*), and muscadine (*Vitis rotundifolia*). The slash pine (*Pinus elliotti*) forest ecosystem was also abundant on the island.

Jekyll Island is connected to the city of Brunswick (Glynn County) by the two-lane Downing-Musgrove Causeway that brings >1 million guests to the island each year. In addition, 805 residents live on the island (U.S. Census Bureau 2010). Interspersed within the native upland habitat were 651 hectares of developed land. Four golf courses comprising 63 holes were located in the interior of the island. Other major developed areas included a historic district, residential areas, multiple hotels, paved roads, and bike paths. Construction of numerous ditches, culverts, and stormwater lagoons has altered the natural hydrology of the island. The most prominent hydrological features on the island were 34 human-made stormwater lagoons ranging in size from 0.04 to 11.04 ha. The majority (n = 23) of these stormwater lagoons were located on the island's golf courses.

## Methods

### *Alligator Capture*

We captured 8 adult male alligators from July 2012 to May 2014. We captured alligators by attaching a weighted treble hook to braided fishing line. The treble hook was cast beyond the alligator using a heavy duty fishing pole and reeled in slowly until the hook made contact with the animal. Once hooked, we reeled the alligator in towards the shoreline and used a cable snare attached to a 2.4 meter extendable paint pole to noose the alligator. We pulled the alligator on shore and restrained it prior to transmitter placement. Individuals ranged in size from 209.3 cm to 339.1 cm ($\bar{x}$ = 265.8, SD = 43.5) total length. We caught all 8 alligators in human-made stormwater lagoons located on the island.

### *VHF Transmitter Placement*

We implanted a Holohil Systems Ltd. (Ontario, Canada) VHF transmitter (Model SI-2, 36 month battery projected life, 13.5g, $300 per unit) in 1 of the individuals using the technique described in Norton et al. (2013). After capture, we transported the alligator to the Jekyll Island Authority Georgia Sea Turtle Center where a veterinarian implanted the radio transmitter in the tail of the alligator (Figure 3.1A).We allowed the alligator to recover completely before release.

We encountered challenges with locating the alligator with the internal transmitter in brackish waters. In an attempt to increase tracking reliability, Advanced Telemetry Systems (ATS, Isanti, MN) developed a prototype of a larger transmitter (model A2930B, 321 day battery projected life, 60.0g, $183 per unit) that could be attached to nuchal scutes. We conducted external VHF transmitter placement in the field at the time of capture on 5 individuals. This allowed us to reduce handling time and eliminate surgical procedures. After manually restraining the animal, we administered an injection of Ketoprofen® (Fort Dodge Animal Health, Fort Dodge, Iowa), a non-steroidal, anti-inflammatory drug. We then cleaned the nuchal shield using 3 alternating applications of Betadine Scrub® (Purdue Products L.P., Stamford, CT) and isopropyl alcohol. After cleaning, we injected a local anesthetic, Lidocaine® (Vedco, Inc., St. Joseph, MO), subcutaneously in the area surrounding the nuchal shield. We drilled 4 small holes into the nuchal scutes with a sterilized drill bit. We threaded sterilized galvanized steel wire through the holes and secured the ATS VHF transmitter through 4 loops on the side of the transmitter. Finally, we placed WaterWeld® Epoxy Putty (J-B Weld, Sulphur Springs, TX), a marine grade epoxy, around the transmitter to increase transmitter retention time (Figure 3.1B).

*GPS Logger Attachment*

While reception was increased using external transmitters, signal attenuation in marsh habitats was still substantial enough to prevent us from securing locations at regular intervals, even when tracking was attempted using a boat. As a result, we worked with ATS to develop a prototype GPS logger with built-in VHF transmitter and remote download capability (model W510, ≥437 day projected life, 65g, $1,225 per unit). The built-in VHF transmitter allowed us to continue to manually radio track alligators after the GPS logger was operational. We recaptured the 6 alligators previously fitted with VHF-only transmitters and captured 2 new alligators. We placed GPS loggers with built-in VHF transmitters on all 8 individuals using the external placement method described above (Figure 3.1C). We conducted all placements methods in accordance to protocols approved by the University of Georgia Institutional Animal Care and Use Committee (Animal Use Protocol A2012 07-025-A2).

*Radio Telemetry Monitoring*

We tracked the 8 alligators using VHF telemetry between 26 July 2012 and 18 September 2014. We first tracked alligators on the day following transmitter placement. Subsequent radio tracking took place an average of twice per week. We continued manually tracking alligators with VHF telemetry after the alligator was fitted with a GPS logger. During the summer months, we tracked animals more frequently during the morning hours before temperatures reached levels that restricted alligator activity. In the winter, alligators tended to remain submerged during the cooler portions of the day and tracking efforts were undertaken midday to increase detection probability. We recorded relocations using a Trimble Juno 3B® (Sunnyvale, CA) handheld computer with Global Navigation Satellite System (GNSS). We accomplished most tracking on foot. On occasion, alligators moved into the marsh necessitating the use of a boat to locate the animal.

We tracked the 8 male alligators using GPS loggers between 20 April 2014 and 16 September 2014. GPS loggers were programmed to take 10 positions per day during the study period. Once a month, we remotely downloaded data collected from the GPS loggers using a remote communication module and antenna, a laptop computer, and the program ATSFixes for Loggers® (ATS, Isanti, MN).

*Data Analysis*

We used post-processing software to increase accuracy of locational data collected via VHF telemetry. We performed differential corrections using Trimble GPS Pathfinder® (Sunnyvale, CA). We screened data collected from GPS loggers before analyses. We eliminated 2-dimensional locations with HDOP values <4 using the data screening approach suggested by Lewis et al. (2007).

We assessed habitat use in ArcMap 10 (Environmental Services Research Institute, Redlands, CA). We classified habitats as either developed or undeveloped. We classified culverts, lagoons, ditches, fairways, roads, and residential areas as developed habitats types. We considered marshes, wetlands, and forests as undeveloped habitats. We used Student's two-tailed t-test for paired samples (n = 8) to compare the total number of habitats used per individual.

We calculated home ranges for 6 male alligators. We excluded 2 of the adult male alligators from home range comparisons because of a lack of VHF relocations (<60). We performed home range analyses with both VHF and GPS data by calculating minimum convex polygons (MCP) and adaptive local convex hulls (a-LoCoH) using package adehabitatHR (Calenge 2006) in software R. We selected values for the parameter *a* for the a-LoCoH analyses using the heuristic methods described by Getz et al. (2007).

## Results

The total number of days tracked per animal using VHF telemetry ranged from 127 to 785 days ($\bar{x}$ = 403.0, SD = 221.0). We collected a total of 708 relocations ($\bar{x}$ = 88.5, SD = 57.1) on the 8 male alligators during the study period. We failed on 92 out of 800 attempts (11.5%) to successfully relocate the target alligator using VHF telemetry. The mean number of relocations per day per animal was 0.21 (SD = 0.05).

At the time of analysis, the total number of days tracked using GPS telemetry ranged from 72 to 159 days ($\bar{x}$ = 109.4, SD = 27.9). A total of 9214 GPS fixes were attempted during this time period and 4739 fixes ($\bar{x}$ = 592.4, SD = 290.0) remained after removing 2-dimensional locations with HDOP values <4. Mean GPS success rate, or the number of successful fixes relative to the number of attempted fixes, was 50.2% (SD = 11.2). We recorded a mean of 5.2 (SD = 1.4) successful relocations per alligator per day using GPS loggers. Three of the GPS loggers (37.5%) failed during the initial stages of the study and were replaced.

All 8 alligators tracked with both VHF and GPS telemetry exhibited the use of multiple habitat types. There was a difference in the number of habitats used based on data collected from GPS ($\bar{x}$ = 4.0, SD = 1.5) and VHF ($\bar{x}$ = 3.1, SD = 1.9) telemetry ($t_7$ = 3.86, p = 0.006). Alligators most frequently used human-made stormwater lagoons (Table 3.1). The telemetry techniques differed in their ability to collect relocations in underground habitats and marsh systems. VHF telemetry was better able to locate alligators in underground culverts (10.6% of all relocations) compared to GPS telemetry (0.4% of all relocations). GPS telemetry yielded a larger portion of relocations (25.7% of all relocations) in marsh habitats compared to VHF telemetry (5.4% of all relocations).

GPS telemetry produced larger 100% MCP home range sizes (range = 67.0 to 1094.0 ha) when compared to VHF telemetry (range = 27.5 to 596.0 ha; Table 3.2). Core home range size as calculated by a-LoCoH was similar for both telemetry techniques but diverged as home range size approached the 100% isopleth (Table 3.2). The 100% isopleth levels were larger for data collected via GPS telemetry (range = 16.4 to 386.4 ha) than VHF telemetry (range = 4.6 to 105.9 ha).

## Discussion

GPS telemetry exceeded VHF telemetry in identifying the number of habitats used by alligators on Jekyll Island. In particular, GPS telemetry captured movements into saltwater marshes. VHF telemetry was not effective when alligators moved off the island and into the surrounding marsh habitat. Brackish waters in these systems greatly attenuated the radio signal and made detecting individuals challenging. Further, the logistics and resources needed to manually radio track alligators in an expansive aquatic environment limited our ability to locate individuals in the marsh. VHF telemetry exceeded GPS telemetry in identifying underground habitat usage. We tracked alligators using VHF telemetry to underground den sites and human-made culverts.

The use of multiple habitats by American alligators inhabiting Jekyll Island has been observed elsewhere. Previous research indicates that alligators move between wetlands and creeks (Subalusky et al. 2009), marshes and canals (Joanen and Mcnease 1973), and marine and estuarine systems (Rosenblatt and Heithaus 2011). In our study, human-made stormwater lagoons were the most frequently used habitat type irrespective of the telemetry technique. Our research highlights the importance of human-made stormwater lagoons located on golf courses and in other developed areas as a primary source of freshwater habitat for coastal populations of alligators.

The larger amount of spatial data collected through the use of GPS telemetry allowed for the construction of larger, more biologically relevant MCP home ranges (Figure 3.2). Others have noted that GPS telemetry is more accurate than VHF telemetry at estimating home range sizes for other taxa due to the increased frequency in location records (e.g., Girard et al. 2002). GPS telemetry is also able to obtain previously unavailable data, such as nocturnal movement patterns (Land et al. 2008). We observed 100% MCP home ranges that varied in size from 67.0 to 1094.0 ha for GPS telemetry and from 27.5 to 596.0 ha for VHF telemetry. The MCP home ranges reported here fall within the range previously described in the literature. Jonanen and McNease (1973) reported home range sizes between 182.9 and 5,082.9 ha for adult male alligators in coastal Texas. Home ranges as large as 256.7 ha have been reported for male alligators inhabiting freshwater lakes in north Florida (Goodwin and Marion 1979).

Core use areas (i.e. 20% isopleths) were similar when home ranges were constructed using a-LoCoH. This suggests that both technologies may be effective techniques for determining core areas needed to conserve crocodilians. The 100% isopleth levels were greater for data collected via GPS telemetry indicating that GPS telemetry may be more appropriate for determining the total amount of space used by individual. To our knowledge, this is the first study to use a-LoCoH to calculate home ranges for any species in the Order *Crocodilia.* LoCoH is the preferred method for computing utilization distributions and home range for species inhabiting landscapes with hard boundaries, such as ponds and stormwater lagoons (Getz et al. 2007).

GPS telemetry captured the use of more habitat types and allowed us to construct more accurate home ranges. However, there are several limitations to the GPS technology that must also be considered. Our GPS success rate was low ($\bar{x}$ = 50.2%, SD = 10.4 SD) compared to studies involving other free-ranging predators (e.g., Gau et al. 2004, Allen et al. 2013). Given the aquatic and secretive nature of American alligators, we expected reduced GPS success rates. The

GPS loggers were ineffective at capturing the use of underground habitats further reducing GPS success rates. These types of missing data are common when vegetation and terrain interfere with satellite signal and are one of the major limitations of GPS telemetry (Frair et al. 2004).

The large datasets produced by GPS technology may be beneficial but also present unprecedented challenges for wildlife biologists. Researchers must address data storage and management issues when dealing with large datasets in order to minimize errors and increase reliability and reproducibility (Urbano et al. 2010). Additionally, it is important to establish standards for when it is appropriate to include points of varying accuracy.

The cost of each GPS loggers used in this study was $1,225 compared to the $183 to $300 spent on each VHF transmitters. These price differences make GPS telemetry cost restrictive. Researchers who wish to use GPS loggers often opt for smaller samples sizes thus sacrificing robust study design and limiting the population-level inferences that can be made (Hebblewhite and Haydon 2010). Although the up-front cost of GPS telemetry may be more expensive,  when other variables such as researcher salaries, fix frequency, and study duration are considered, the total project investment for GPS telemetry may actually be more cost effective than VHF telemetry (Recio et al. 2011). Further, we expect the cost of GPS loggers to decrease as GPS technology improves and demand increases.

In addition to price constraints, some degree of unit failure is expected to further reduce sample size (Gau et al. 2004). We replaced 3 failed units, which resulted in data gaps and required recapture of study animals. It is critical that biologists working with new technology remain in close communication with production engineers in order to troubleshoot issues with the equipment and to prevent mistakes experienced by biologists trialing the technology. Further, developing a relationship with telemetry companies is important for developing custom products that meet specific researcher needs; particularly those using emerging technologies such as GPS transmitters. Ultimately, when choosing between telemetry technologies biologists must take many factors into account (Table 3.3). Others have noted the benefits of satellite telemetry in the study of American alligators in estuarine habitats (Fujisaki et al. 2014). However, our study is the first attempt to directly compare the effectiveness of GPS and VHF telemetry in the study of crocodilians.

## Management Implications

In order to create successful conservation and management programs for American alligators, researchers and wildlife managers must be informed by the most biologically accurate data available. Both VHF and GPS telemetry offer insight into the spatial ecology of the American alligator inhabiting a developed landscape. The use of GPS telemetry frees the researcher from the task of manually tracking animals and allows the researcher to pursue other tasks relevant to the study organism (Hebblewhite and Haydon 2010). However, data collected with GPS telemetry excludes many underground habitat types such as culverts and dens. These habitats are vitally important to alligators and may indicate how the species is adapting to life in developing areas. Similarly, the use of VHF telemetry alone does not accurately reflect the use of essential marsh habitat by alligators which could result in managers underestimating the critical importance of this habitat and total amount of space needed to conserve the species. A combination of the two technologies may provide the most effective means of studying top predators, especially highly vagile species such as crocodilians. Others have suggested the dual use of VHF and GPS telemetry in the study of top predators (Miller et al. 2010, Ruth et al. 2010). We recommend the use of traditional VHF telemetry to allow researchers to directly observe animal behaviors and obtain data on key parameters in conjunction with GPS telemetry to capture previously unavailable data. This approach will directly aid wildlife managers in identifying the habitat needed to maintain populations of American alligators in developing landscapes.

## Acknowledgements

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Figure 3.1. Transmitter attachment techniques used in the study of free- ranging American alligators on Jekyll Island, Georgia: A) Internal placement of a VHF transmitter; B) External placement of a VHF transmitter; C) External placement of a GPS logger.

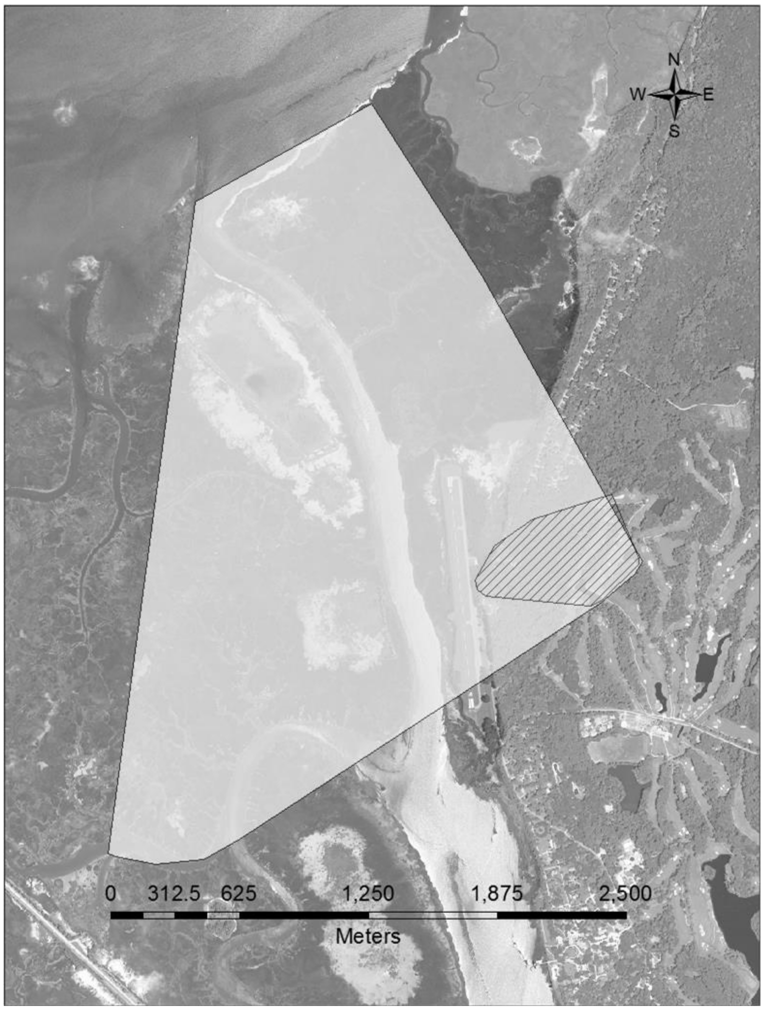

Figure 3.2 – The 100% minimum convex polygons for a 2.1-m male alligator inhabiting Jekyll Island, Georgia. Data collected from VHF telemetry produced a home range of 28.40 ha (hashed). Data collected using GPS telemetry produced a larger home range of 554.89 ha (solid).

Table 3.1. Habitat use (% of total relocations) of 8 adult male American alligators tracked using VHF and GPS telemetry between June 2012 and May 2014 on Jekyll Island, Georgia.

| | | Developed habitat | | Undeveloped habitat | | |
|---|---|---|---|---|---|---|
| Telemetry technique | Number of relocations | Culvert | Lagoon | Marsh | Wetland | Other |
| VHF | 708 | 10.6% | 71.4% | 5.4% | 10.2% | 2.4% |
| GPS | 4739 | 0.4% | 58.0% | 25.7% | 11.9% | 4.1% |

Table 3.2. The 100% MCP and a-LoCoH 20% and 100% isopleth levels (ha) estimated for 6 adult male alligators from data collected from VHF and GPS telemetry.

| | | VHF | | | GPS | | |
|---|---|---|---|---|---|---|---|
| Alligator | Total Length (cm) | 100% MCP | 20% isopleth | 100% isopleth | 100% MCP | 20% isopleth | 100% isopleth |
| Charger | 241.3 | 27.5 | 0.9 | 9.4 | 67.0 | 0.7 | 16.4 |
| Duszka | 266.7 | 200.6 | 0.5 | 55.0 | 527.9 | 1.6 | 211.6 |
| Jesús | 209.6 | 28.4 | 0.8 | 4.6 | 554.9 | 3.0 | 161.7 |
| Kain | 245.0 | 128.1 | 0.7 | 27.0 | 116.3 | 0.6 | 17.0 |
| Solomon | 339.1 | 45.8 | 1.0 | 9.8 | 88.8 | 0.5 | 25.0 |
| Woody | 297.8 | 596.0 | 4.1 | 105.9 | 1094.0 | 7.7 | 386.4 |

Table 3.3. A comparison of the costs and benefits of VHF and GPS telemetry in the study of free- ranging crocodilians.

| Metric | VHF telemetry | GPS telemetry |
| --- | --- | --- |
| Budget | Fewer up-front costs | Expensive loggers may place restrictions on sample size |
| Species | Appropriate for species with low levels of movement | Useful to track highly vagile species |
| Objectives | Identify core use areas or the use of underground habitats | Data used to construct larger, more accurate home ranges |
| Habitat | Freshwater | Estuarine or marine |
| Effort | Researcher needed to manually track animals | Little post-attachment effort required |

# CHAPTER 4

# TEACHING TOLERANCE? EFFECTS OF CONSERVATION EDUCATION PROGRAMS ON WILDLIFE ACCEPTANCE CAPACITY FOR THE AMERICAN ALLIGATOR [3]

[3] Skupien, G.M., K. M. Andrews, and L.R. Larson. To be submitted to *Human Dimensions of Wildlife*

**Abstract**

Growing populations of American alligators in human-dominated landscapes present a challenge to wildlife managers concerned with promoting coexistence between humans and alligators. Where direct removal is not an option, cognitive fixes such as conservation education programs should be considered. We evaluated the effectiveness of two conservation education programs (a classroom-based program and a field excursion) on three outcome variables that help define wildlife acceptance capacity for the American alligator: positive attitudes, perceived risk, and potential for coexistence. We found that participants that took part in the education programs scored higher on the positive attitudes and potential for coexistence scales. Participants that did not undergo either intervention scored higher on the perceived risk scale. Data suggest that conservation education programs that communicate actual versus perceived risk and provide a safe encounter with wildlife can impact stakeholder attitudes and perceptions, ultimately influencing acceptance capacity for top predators in developed areas.

## Human-predator Interactions

Development associated with human population growth often places humans and wildlife in close proximity to one another. Frequently, the needs of humans conflict with those of wildlife species, especially large predators (Treves & Karanth, 2003). These problems are exacerbated now that populations of many large predators have recovered after decades of persecution (Chapron et al., 2014). To mitigate the likelihood of human-wildlife conflicts, some have suggested a separation approach which employs the use of fences or other artificial boundaries to divide humans from wildlife (Packer et al., 2013), but this strategy is often ineffective because many predators are capable of making long-distance movements. For example, reintroduction of the wolf (*Canis lupus*) in protected areas of North America has resulted in increased depredation of livestock in surrounding rural areas (Musiani et al., 2003). Direct removal of nuisance animals may also be used to reduce the risk of negative human-wildlife interactions (Hayman, Harvey, Mazzotti, Israel, & Woodward, 2014). However, such approaches are often impractical due to the rapidly expanding human influence on natural landscapes, making human-wildlife interactions somewhat inevitable. Some degree of human-wildlife coexistence is therefore necessary to maintain wildlife populations while mitigating risks to the human population (Dickman, Macdonald, & Macdonald, 2011).

Historic patterns in the relationship between people and large predators are epitomized by the plight of the American alligator (*Alligator mississippiensis*) in the southeastern United States. After decades of unsustainable harvest, populations of the American alligator have recovered throughout their native range. In Georgia, the alligator population was first estimated to be 29,954 in 1973. Today, the alligator population in estimated to be over 222,000 (Waters et al., 2010). Expanding human development in coastal areas where alligators are now common has led to increasing numbers of human-alligator conflicts. In Florida alone, nuisance complaints increased from 4,024 to 15,036 between 1980 and 2013 (FL FWC, 2013). Although rare, alligator attacks on humans have been reported in multiple states throughout the species' range (Langley, 2010). Small pets, especially cats and dogs, resemble natural prey items and are more frequently attacked by alligators (Harding & Wolf, 2006).

Direct removal of the nuisance animal is frequently employed in the management of alligators in human-dominated landscapes (Hayman et al., 2014). This type of response, designed to change human behavior by modifying the social context of the behavior, is often described as a "structural fix" (Heberlein, 2012). However, if the goal is to maintain reproductively viable populations of alligators at an ecologically relevant level, removal may not be an effective management technique. Alligators are known to exhibit top-down control (Nifong & Silliman, 2013), act as ecosystem engineers (Kushlan, 1974), and link discrete ecosystems through trophic interactions (Subalusky, Fitzgerald, & Smith, 2009).

As such, removal of large, reproductive alligators may negatively affect ecosystem dynamics. In situations where structural fixes are not possible, wildlife managers should consider "cognitive fixes" designed to influence the cognitive factors underlying human-alligator conflicts through conservation education programs (Hayman et al., 2014). Although the use of exclusively cognitive solutions for influencing human behavior has been criticized because of the low correlation between attitudes and behaviors (Heberlein, 2012), numerous studies highlight the benefits of conservation education programs on fostering pro-environmental attitudes and influencing subsequent behaviors (e.g., Ballantyne & Packer, 2005; Zeppel & Muloin, 2008). Effective conservation education programs designed to promote tolerance of and coexistence with predators often explicitly account for wildlife acceptance capacity.

## Wildlife Acceptance Capacity

Wildlife acceptance capacity (WAC) can be broadly defined as the maximum wildlife population that is acceptable to people (Decker & Purdy, 1988). More specifically, WAC is defined as the point at which individuals or societies take actions designed to impact wildlife populations (Bruskotter & Fulton, 2012). In this study, we assessed the impacts of conservation education programs on key predictors of WAC.

Wildlife acceptance capacity is influenced by factors such as attitudes and beliefs towards the target species, perceptions of risk associated with the species, and the economic, aesthetic, ecological, and intrinsic values placed on the species by society (Decker & Purdy, 1988). Socio-demographic factors among stakeholders are also important in determining WAC. Stakeholders are defined as, "individuals and groups who may be affected by or can affect fish and wildlife management decisions and programs" (Decker, Krueger, Baer, Knuth, & Richmond, 1996). People from diverse backgrounds with varying levels of stake can be considered stakeholders. In this research context, stakeholders were defined as anyone living in or visiting coastal Georgia that might come in contact with American alligators. Gender (Miller & McGee, 2000; Zinn & Pierce, 2002), age (Kleiven et al., 2004), education (Kellert & Berry, 1987; Kleiven et al., 2004; Riley & Decker, 2000a), knowledge (Kellert, 1985), and previous exposure to wildlife (Siemer, Hart, Decker, & Shanahan, 2009; Zinn & Andelt, 1999) may directly and indirectly affect WAC.

Riley and Decker (2000b) suggest that attitudes towards the target species are one of the main predictors of WAC. Attitudes are defined as the favorable or unfavorable evaluation of a person, object, or action (Decker, Riley, & Siemer, 2012). Homer and Kahle's (1988) cognitive hierarchy model suggests a causal relationship between values, attitudes, and behaviors and places an emphasis on the mediating role of attitudes between values and behavior. Others have provided support for the mediating role of attitudes on the relationship between values and behaviors (Tarrant, Bright, & Cordell, 1997; Vaske & Donnelly, 1999). Bruskotter et al. (in press) found strong associations between attitudinal measures towards a predator (i.e., wolves) and measures of prior behavior towards the species. Positive attitudes have also been associated with higher levels of acceptance for other predators (Riley & Decker, 2000b, Smithem, 2005). Milfont et al. (2010) expanded Homer and Kahle's hierarchy model by including perceived environmental threat as a predictor of environmental attitudes. They found that environmental attitudes mediate the impact of both values and threats on ecological behavior. As such, negative attitudes may lead to higher risk perceptions towards an object (Sjöberg, 2000).

Risk perception is also recognized as an important predictor of acceptance capacity (Riley & Decker, 2000a; Bruskotter & Wilson, 2014). For example, lower risk perceptions towards cougars are associated with higher acceptance capacity for cougars (Riley & Decker, 2000b). Similarly, low risk perception had a significant effect on acceptable levels of future American crocodile (*Crocodylus acutus*) populations in south Florida (Smithem, 2005).

The concept of wildlife-associated "risk" means different things to different people. An expert's assessment of risk often correlates with annual human fatalities, while the public generally assesses risk based on factors such as catastrophic potential, threat to future generations, and level of control (Slovic, 1987). Hazards that have a low probability of occurrence and high consequence often lead to feelings of dread. Wildlife-related hazards with these properties, such as an attack by a predator, may elevate perceptions of risk and subsequently lower WAC (Riley & Decker, 2000a). In situations where predators threaten human safety, wildlife managers must find ways to achieve conservation goals while minimizing risks to humans.

Sustainable coexistence is often the end goal for predator management. Wildlife managers tasked with promoting coexistence between humans and predators are challenged with the need to develop effective communication and management strategies capable of modifying WAC (Riley & Decker, 2000b). Successful strategies that facilitate coexistence between humans and predators address the economic, affective, and cognitive factors influencing human-predator conflicts (Dickman et al., 2011). Programs that promote positive attitudes, lower risk perceptions, and highlight the cultural benefits of wildlife species can help foster human-predator coexistence (Lagendijk & Gusset, 2008). Explicitly addressing these issues in conservation education programs may modify WAC and help promote coexistence between humans and predators in human-dominated landscapes.

## The Value of Conservation Education

Increasingly, the general public receives information about wildlife-related issues from the media (Vaske, Needham, Stafford, Green, & Petchenik, 2006). In fact, more people receive information about American alligators from newspapers and television than from state or federal agencies (Smithem, 2005). Media sources often express negative sentiments about top predators (Houston, Bruskotter, & Fan, 2010). For instance, Gore and Knuth (2009) found an increase in perceived risk associated with black bears resulting from media coverage. Wildlife-related media coverage may also elicit strong emotional responses from the public (Heberlein & Stedman, 2009).

Because the public is increasingly involved with decisions regarding wildlife management issues (Riley et al., 2002), the preponderance of media influence on American's awareness of and attitudes toward species like alligators is concerning. In many cases, public opinions of management decisions are based on emotional and ethical issues while ecological considerations are ignored (Breitenmoser, 1998). Additionally, emotions may drive a person's behavior during a human-wildlife interaction (Hudenko, 2012). In developed areas, human-wildlife conflicts are often caused in part by human behavior (Savard, Clergeau, & Mennechez, 2000). In the case of the American alligator, human behaviors that may lead to human-alligator conflict include approaching an alligator too closely or illegally feeding wild alligators. As such, management plans often include education and outreach designed to increase public awareness of predators and promote positive attitudes through an emphasis on ecological and societal benefits (Slagle, Zajac, Bruskotter, Wilson, & Prange 2013). Such information creates an informed population that can more effectively inform the stakeholders who influence management decisions made by wildlife professionals. Education can also affect the human behaviors, such as wildlife feeding, that ultimately result in human-wildlife conflicts (Gore, Knuth, Curtis, & Shanahan, 2006). In some situations, stakeholders may even prefer cognitive fixes designed to reduce human-wildlife conflicts over other management actions, such as direct removal of the nuisance animal (Gore et al., 2006).

Conservation education programs are one type of cognitive intervention that may be used to manipulate WAC (Decker & Purdy, 1988). Education programs designed to lower risk perceptions and foster positive attitudes towards top predators may help maintain viable populations of wildlife species, increase public safety, and facilitate coexistence (Thornton & Quinn, 2010). By creating a positive interface between people and managers, communicating actual versus perceived risks to the public, and translating sound science to increase confidence in wildlife management agencies, conservation education programs have great potential to increase WAC and the potential for coexistence between humans and wildlife, especially large predators.

Effective conservation education programs often involve a direct encounter with captive animals or a field-based component that allows participants to view non-captive wildlife in native habitats. Direct encounters have unique potential to impact visitors' attitudes and behaviors (Ballantyne, Packer, Hughes, & Dierking, 2007). For example, researchers found that providing a safe, direct encounter with wildlife can be more effective in changing attitudes toward wildlife than simply showing animals to an audience (Morgan & Gramann, 1989). Evidence also suggests that field excursions, such as marine mammal tours, can foster positive environmental attitudes and subsequently change human behaviors towards wildlife (Zeppel & Muloin, 2008). While both approaches have been shown to facilitate positive attitudes and behaviors, there are several costs that should be considered before implementing either approach (Ballantyne et al., 2007). Reduced visibility of free-ranging individuals is often considered a major limitation of field excursions. Direct, staged encounters with captive animals may seem unnatural to the audience. Given these benefits and costs, there is a need to explore the effectiveness of conservation education programs that offer close encounters with captive animals and those that allow visitors to view non-captive wildlife (Ballantyne et al., 2007).

Unfortunately, evaluation mechanisms are rarely in place. Given the limited resources allocated to conservation initiatives, program evaluation methods must be adopted to determine the effectiveness of conservation efforts (Ferraro & Pattanayak, 2006). Some researchers have even suggested that the evaluation of wildlife-related education programs should be a requirement of their implementation (Gore, Knuth, Scherer, & Curtis, 2008). Others have called for a systematic review of education campaigns designed to reduce negative human-wildlife interactions (Treves & Karanth, 2003). In this study, we assessed the impacts of a classroom-based lecture and a field excursion on key elements of WAC for the American alligator at Jekyll Island, Georgia. Specifically, we examined program effects on participants' positive attitudes, perceived risk, and potential for coexistence towards the American alligator.

## Methods and Materials

### *Study Area*

Jekyll Island is a barrier island state park located off the coast of Georgia approximately 145 kilometers south of the city of Savannah, USA. The island is managed by the Jekyll Island State Park Authority (JIA) and receives no funding from the state of Georgia. As such, the JIA maintains one-third of the island as developed land in order to fund park operations. Development includes residential areas, multiple hotels, four golf courses, a water park, a historic district, and several restaurants. Additionally, Jekyll Island is home to the JIA Georgia Sea Turtle Center (GSTC), a state-of-the-art rehabilitation and education center for sick and injured sea turtles. These amenities, along with the island's natural features, attract over one million tourists per year to the island. In addition, approximately 800 residents inhabit the island. The alligator population on Jekyll Island consists of at least 125 individuals. Many of these alligators inhabit human-made stormwater lagoons located on golf courses and other highly-trafficked areas. Consequently, human-alligator encounters on Jekyll Island are a regular occurrence. In 2011, the JIA released a conservation plan with the mission to: "Preserve, maintain, manage, and restore Jekyll Island's natural communities and species diversity while providing nature-based educational and recreational opportunities for the general public" (Jekyll

Island Authority, 2011, p.1). The conservation education programs described in this study were designed to meet the goals of this mission.

*Conservation Education Programs*

Classroom-based programs and field excursions were offered from July to September 2013 and again from April to October 2014 on Jekyll Island, GA. Both educational programs were associated with the GSTC and offered as an extension of ongoing outreach and education initiatives at the institution. Topics covered in both programs included basic alligator biology and ecological benefits, a description of current research efforts on Jekyll Island, actual and perceived risks posed by alligators, and tips on how to safely observe alligators in the wild. The two programs were identical in terms of content, but differed in environment and format of wildlife exposure. A single interpreter employed by the University of Georgia with more than 5 years of experience in environmental interpretation (Skupien) led each program and conformed to a memorized script in order to maintain consistency in the content provided. The interpreter alternated between the two programs based on weather conditions and wild alligator activity. Prior to the start of the program participants did not know which program they were participating in. Flyers, billboards, press releases, and social media outlets (e.g., Facebook) were used to promote the programs to tourists and residents of Jekyll Island. In 2013, both programs were offered free of charge to the public. In 2014, a reservation system was instituted and a small fee of $2 was charged in order to more effectively manage attendance.

Classroom-based lectures were conducted in an outdoor classroom located on the grounds of the GSTC. The program consisted of a 15-minute lecture and an ensuing question-and-answer session. At the end of the program participants were given the opportunity to touch a live, captive juvenile alligator. The mean total duration of the classroom program was 28 minutes (SD = 4).

Field excursions required participants to drive approximately 5-7 minutes from a centralized meeting point at the GSTC to a nearby location on the island. There, participants received the same 15-minute lecture and were allowed to ask questions before accompanying the interpreter to track a radio telemetered wild, adult alligator. Approximately one hour before the start of the program the interpreter tracked multiple alligators and selected the individual in the most accessible location for the program. Due to the wild and aquatic nature of the animals, participants were not guaranteed a visual of the alligator, and alligator touching was not an option. The mean total duration of the field excursion was 32 minutes (SD = 6)

Following both programs, all participants age 18 or older completed a self-administered questionnaire (see details below). All potential survey participants were informed of the intent of the study, the voluntary nature of their participation, and the confidentiality of their answers prior to administration. Participants that attended either of the conservation education programs were asked to complete the survey immediately following completion of the program. To reduce experimenter expectancy effects the survey instrument was administered by a secondary observer (i.e. someone other than the interpreter who was not a participant). Feasibility of implementation prevented us from using a pre-post method. Although the use of a within-subjects design would have been optimal, we sought to maximize program attendance and generate increased interest in the conservation education programs offered at the GSTC. Using a pre-post method would have excessively lengthened program duration and reduced participation in the program. As such, we implemented an after-only with control design to examine the effects of both educational treatments (Tull & Hawkins, 1987).

The control group consisted of respondents intercepted at three popular beach locations using a convenience sampling method. Participants were usually sitting on the beach when approached. We approached every other person or group of people. If multiple individuals were present we sampled every other person in the group age 18 or older. If a subject declined, the refusal was recorded as a non-response and the interaction was terminated. If the subject agreed to participate, they were asked to fill out the self-administered questionnaire. In order to ensure that participants in the control group had not experienced either of the education programs, they were asked if they attended either of the alligator education programs prior to beginning the survey. If so, the participant was thanked and the researcher moved on to the next subject.

*Survey Instrument*

The three-page survey instrument focused on three key variables that contribute to WAC: 1) positive attitudes, 2) perceived risks, and 3) potential for coexistence. We measured positive attitudes using four items (e.g., The presence of alligators is sign of a healthy environment, Cronbach's alpha = 0.852) measured on a 5-point Likert-type scale (-2 = Strongly Disagree to +2 = Strongly Agree). We assessed perceived risk (e.g., While in areas where alligators are present how concerned are you for the safety of your family and children, Cronbach's alpha = 0.821) using three items rated on a 5-point scale (1 = Not at all Concerned to 5 = Extremely Concerned). We measured potential for coexistence using two items (e.g., Humans can safely coexist with alligators, Cronbach's alpha = 0.624) measured on a 5-point Likert-type scale (-2 = Strongly Disagree to +2 = Strongly Agree). Binary and multiple choice items were used to assess demographic factors (7 items) and previous experience with alligators (8 items). Both program participants and beachgoers in the control group typically took approximately 5-10 minutes to complete the survey. All study methods were approved by the University of Georgia Institutional Review Board (IRB ID: STUDY00000024) prior to implementation.

*Data Analysis*

Statistical analyses were performed using SPSS v22.0. The total sample was divided into three groups based on the educational treatment: 1) classroom-based program participants (n = 358); 2) field excursion participants (n = 343); and 3) control group participants (n = 363). We used chi-square statistics and frequencies to test the assumption that demographic characteristics and previous contact with alligators were similar across groups, which would suggest that observed differences in the outcome variables were primarily due to treatment effects. Similar approaches have been used in other after-only with control designs that tested impacts of conservation education programs (Sharp, Larson, Green, & Tomek, 2012). Principal component analysis with Varimax rotation was used to test the convergent validity of items in our three *a priori* WAC-related constructs. Estimates of internal reliability were measured using Cronbach's alpha. Principal component analysis supported our three *a priori* constructs (i.e., positive attitudes, perceived risks, and potential for coexistence) with acceptable levels of internal consistency (Chronbach's alpha > 0.6) and convergent validity (factor loadings > 0.4). Once validity and reliability were verified, we averaged individual items to create composite scores for each construct. We then used multiple-factor analysis of variance to examine the relationships between treatment group, demographics, previous experience with alligators, and our three constructs (i.e. the outcome variables). We calculated the eta-squared effect size statistic ($\eta^2$) using the equation: $\eta^2 = SS_{between} / SS_{total}$. Eta-squared is the proportion of total variability in the dependent variable that is accounted for by the variation in the independent variables and is a commonly reported estimate of effect size (Levine & Hullett, 2002). *Post hoc* pairwise comparison tests with Bonferroni corrections were used to explore differences between estimated marginal mean scores for the different treatment groups.

## Results

*Response Rates and Group Characteristics*

We conducted 60 programs (34 classroom, 26 field) during the course of the study in front of a total audience of 1347 people. Although our target audience for the study was adults over the age of 18, children and young adults under the age of 18 accounted for 43.6% of the total attendance. A mean of 22.5 participants (SD = 16) attended each program. Attendance was similar for both programs (classroom = 22.0 ± 14.0 SD participants, field = 23.0 ± 16.0 SD participants). We approached a total of 1190 individuals and received 1064 completed surveys. The total survey response rate was 89.4% (classroom = 93.2%, field = 91.2 %, control = 84.4%).

Analyses of group characteristics showed that respondents in all three treatment groups were similar in their previous experience with alligators (Table 4.1). The majority of respondents indicated that they had seen an alligator in the wild (mean = 84.7%) or in the media (mean = 79.1%). Less than one third of all participants indicated that they had attended an alligator education program before, Mean = 28.9%, $\chi^2$ (2, N=1054) = 1.215, p = 0.545. Slightly more participants in the control group (31.0%) had attended an alligator program before compared to participants in the classroom and field groups (28.4% and 27.4%, respectively), but these differences were not statistically significant. These similarities in exposure and previous attendance of an alligator education program suggest that participants in all treatments groups shared a relatively equal baseline interest in alligators.

However, the three groups were not homogenous in terms of their affiliation with Jekyll Island, age, pet ownership, or education level. Participants in the control were more likely to be residents, younger, less educated, and more likely to own a pet. The most significant group differences were observed for level of education, a variable which could theoretically have a strong influence on WAC, thereby confounding interpretation of program effects. To determine if pre-existing differences in education levels among the treatment groups were significantly influencing results, we analyzed subgroups with similar education levels (e.g., only individuals with higher degrees) to minimize this source of potentially confounding variation. Results of these separate models were nearly identical to the full model, providing evidence to suggest that observed differences among treatment groups stemmed from the treatments themselves, not pre-existing differences.

*Positive Attitudes*

The positive attitudes construct was comprised of four items, accounting for 70.5% of the total scale variance. Positive attitudes towards alligators were related to affiliation with Jekyll Island (positive effect for residents), having seen an alligator in wild (positive effect), attendance in a previous alligator program (positive effect), gender (negative effect for female), and education (positive effect for higher degree awarded; Table 4.2).

On average, participants in the conservation education program treatment groups scored higher on the positive attitudes scale than respondents from the control group (Table 4.3). We observed a significant effect of treatment group on positive attitudes ($F_{2,1011} = 192.04$, $p < 0.001$, $\eta^2 = 0.261$). We calculated estimated marginal means in order to control for the influence of the covariates and mitigate the effects of the non-random group assignment. According to post-hoc pairwise comparisons, estimated marginal mean scores for positive attitudes were significantly higher for respondents in the classroom and field programs (1.461 ± 0.055 SE and 1.459 ± 0.057 SE, respectively) than the control group (0.503 ± 0.055 SE, Figure 4.1). Estimated marginal mean scores were not significantly different between the two education programs.

*Perceived Risk*

Three items comprised the perceived risk construct and explained 74.2% of the total scale variance. Having seen an alligator in the wild and attendance in a previous alligator program were associated with lower perceived risks. Participants that were older, had seen an alligator in media, or had children under the age of 13 scored higher on the perceived risk scale (Table 4.4).

Mean scores for perceived risk were higher for respondents in the control group than respondents that participated in either conservation education program (Table 4.2). We observed a significant, though slightly less pronounced, effect of treatment group on perceived risk ($F_{2,1012} = 43.36$, $p < 0.001$, $\eta^2 = 0.075$). Estimated marginal mean scores were different between respondents in the control group (3.221 ± 0.079 SE) and respondents in the classroom (2.598 ± 0.079 SE) and field (2.547 ± 0.081 SE) groups (Figure 4.2). Estimated marginal means did not differ between participants in the two conservation education program treatment groups.

*Potential for Coexistence*

The potential for coexistence construct consisted of two items which together explained 72.9% of the total scale variance. Potential for coexistence was significantly related to having seen an alligator in wild (positive effect), gender (negative effect for female), and education (positive effect for higher degree awarded). However, the eta-squared values for these covariates were substantially smaller than the estimated effect size of the treatment group (Table 4.5).

Participants in the control group scored lower on the potential for coexistence scale than respondents in either of the conservation education program treatment groups (Table 4.2). We observed a significant effect of treatment group on the potential for coexistence ($F_{2,1003} = 105.26$, $p < 0.001$, $\eta^2 = 0.168$). Estimated marginal mean scores were higher for the potential for coexistence factor for participants of the classroom (0.939 ± 0.065 SE) and field program (0.967 ± 0.067 SE) when compared to respondents who did not undergo either intervention (0.118 ± 0.065 SE, Figure 4.1). We did not observe a significant difference in estimated marginal mean scores between respondents that participated in the conservation education programs.

## Discussion

Decker and Purdy (1988) first suggested that cognitive interventions, such as conservation education programs, may be used to increase wildlife acceptance capacity. Previous research indicates that such approaches have been successful at changing attitudes toward potentially dangerous and maligned species, such as snakes and bears (Ballouard, Provost, Barré, & Bonnet, 2012; Espinosa & Jacobson, 2012). Education programs may increase WAC by fostering positive attitudes and lowering risk perceptions (Riley & Decker, 2000b; Smithem, 2005). We found evidence that suggests cognitive fixes could indeed be used to influence key elements of WAC for the American alligator. In our sample of Jekyll Island visitors and residents, participation in a classroom-based program or field excursion led to changes in positive attitudes, perceived risk, and potential for coexistence towards the American alligator. Respondents that participated in the conservation education programs were more likely than those in the control group (i.e., those who did not undergo either intervention) to have positive attitudes towards the American alligator. Participation in the education programs was also associated with lower perceived risks. Respondents in the conservation education program treatment groups scored higher on the potential for coexistence scale, indicating that they were more likely to believe that humans and alligators can safely coexist.

Providing factual information is typically not enough to change attitudes and perceptions (Heberlein, 2012). Our programs may have been effective because we provided participants with information on the benefits of alligators and the actual risks associated with the species while providing participants with an opportunity to observe a live alligator. This additional program element (i.e., direct visual or tactile contact with an alligator) may have been a key agent of change (Morgan & Gramann, 1989).

Human-predator interactions can be classified as stressful and uncertain events. These characteristics suggest that automated, unconscious, and affective thought processes are important when evaluating human-predator interactions (Hudenko, 2012). Ballantyne et al. (2011b) found that the excitement associated with seeing a live animal often elicits a reflective response. Engagement in that reflective experience, which often involves an emotional connection to an animal, has been associated with short-term learning (Ballantyne, Packer, & Falk, 2011). Further, emotional response to wildlife viewing can foster a sense of empathy towards the animal and lead to concern and respect for not only the individual animals but for the species as well (Ballantyne, Packer, & Sutherland, 2011). Although we did not measure affective responses, it was clear that many participants experienced emotional responses when viewing the wild alligator or touching the captive alligator. These experiences may have helped reinforce key concepts presented during the 15-minute lecture presentation and may partially explain the observed increases in positive attitudes and potential for coexistence and the reductions in perceived risk. Future studies should explicitly measure this affective component when assessing the effectiveness of conservation education programs designed to influence WAC.

Education experiences centered on reptile and amphibians that incorporate an interactive technical component have been shown to be more effective than traditional classroom experiences (Ballouard et al., 2012; Randler, Ilg, & Kern, 2005). Field-based conservation education programs that employ the use of radio telemetry may also increase awareness and behavioral intentions to support wildlife (Awasthy, Popovic, & Linklater, 2012). The programs described in this study incorporated all of these best practices. They were designed to provide participants with factual information about the American alligator while engaging participants with a safe, staff-led viewing experience of wild or captive alligators. Although beneficial from an educational standpoint, this type of neutral or positive experience with wildlife may cause a person to become habituated to wildlife leading to the belief that it is acceptable to be or live around wildlife (Hudenko, 2012). However, when combined with science-based information on proper conduct in alligator habitat, these interactions can serve to promote coexistence between humans and alligators and increase wildlife acceptance capacity for alligators in human-dominated areas.

Although participants in both education programs scored better than the control group on all three WAC-related constructs, we did not observe differences in mean scores between the classroom-based program and field excursion. Nevertheless, there are several benefits and costs associated with each approach that should be considered when making programming decisions (Ballantyne et al., 2007). Classroom-based programs that incorporate the use of live animals evoke strong emotional responses, but display the animal in an artificial setting. Non-captive wildlife programs, such as field excursions, allow participants to see animals in their native habitat and observe natural behaviors.

Reduced visibility is a major limitation of non-captive programs and was an issue during field excursions to view wild American alligators. In order to increase the likelihood of observing a wild alligator, the interpreter located the most accessible alligator using radio telemetry on the morning of the program. The best site for viewing a wild alligator was often a 5-7 minute drive from the meeting location. Once at the site, behavioral responses to human encroachment and the inherent cryptic coloration of alligators often made it difficult or impossible for participants to observe alligators in the wild. Our data suggest that both programs were equally effective at influencing elements of WAC for the American alligator. However, the added time needed to locate an alligator and coordinate transportation to the field location in conjunction with reduced visibility of the wild alligator suggest that field excursions may be less practical in many cases. As such, if the educational goal is to enhance WAC, we recommend the use of a classroom-based program with an interactive live alligator viewing period. As wildlife tourism becomes more popular, additional research is needed to explore the specific benefits and costs of captive live animal programs and non-captive wildlife viewing for other species.

We observed significant effects of multiple covariates on participants' positive attitudes, perceived risk, and potential for coexistence toward alligators. The eta-squared estimate of effect size for these covariates on the outcome variables was small relative to the treatment effect. Because there is already an abundance of research on the effects of demographic characteristics on attitudes and risk perceptions towards predators (e.g., Kellert & Berry, 1987; Kleiven et al., 2004; Zinn & Pierce, 2002), the purpose of our study was to examine the main effect of treatment on the outcome variables while controlling for the effects of other demographic variables. While we provide estimates of effect size, elaborating on each variable individually is outside the scope of this paper. However, of particular note, is the effect of having seen an alligator in the wild prior to participation in the study. This variable was strongly associated with lower perceived risk and higher scores on the positive attitudes and potential for coexistence scales. Others have noted that positive personal experiences with predators may lower risk perceptions (Siemer et al., 2009). Although alligator-based field excursions are restricted by the aforementioned limitations, these data provide evidence that programs that allow participants to view animals in the wild may influence WAC. Additionally, having seen an alligator in the media was associated with high perceived risks. Wildlife-related education programs that communicate actual versus perceived risk may mitigate the effect of mass media exposure and help improve tolerance for and acceptability of predators.

Time constraints and feasibility of implementation are some of the many challenges that typically impact conservation education program assessment (Carleton-Hug & Hug, 2010). Our study was also subject to these constraints. As such, we were not able to test the long-term effects of the conservation education programs. Additionally, time constraints prevented us from employing a pre-post approach. However, our analyses suggest a single environmental intervention can cause changes in attitudes and behaviors towards wildlife (Dettmann-Easler & Pease, 1999; Marion, Dvorak, & Manning, 2008). As noted earlier, touching an animal has also been shown to make a lasting impression on participants of education programs (Ballantyne, Packer, & Falk, 2011). Therefore, it is plausible that the conservation education programs could have lasting effects. Additional longitudinal research on this subject would be beneficial to determine the long-term benefits of conservation education programs.

A more significant limitation is the potential non-random assignment of subjects to each treatment group. Following other models outlined in the literature (e.g., Sharp et al., 2012; Tull & Hawkins, 1987), we attempted to use an after-only with control design to mitigate the problems associated with non-random assignment. While statistical tests suggest the three treatment groups were relatively similar in terms of demographics and previous experience with and exposure to alligators, baseline cognitions (e.g., values, beliefs, attitudes) were not measured prior to program implementation. Entry narratives have been shown to influence short-term affective and cognitive reactions to conservation education interventions (Falk, Heimlich, & Bronnenkant, 2008). Future research could therefore attempt to minimize the confounding effects of these variables on observable program impacts through pre- and post- research designs. Additionally, future research should measure the impacts of conservation education programs on the human behaviors that ultimately affect predator populations in human-dominated landscapes.

## Conclusions

State agencies frequently use lethal techniques to deal with nuisance American alligators. However, in state parks and other public areas, management agencies seek to maintain alligator populations at levels that will ensure their long-term viability and sustain their role in the ecosystem. In these situations, wildlife managers should consider cognitive fixes, such as conservation education programs that offer participants close encounters with captive wildlife or viewing opportunities with non-captive wildlife, to influence human behavior and reduce the risk of negative human-alligator interactions. We observed significant treatment effects on all three outcome variables related to WAC: positive attitudes, perceived risks, and potential coexistence with alligators. While these results should be cautiously interpreted due to limitations mentioned above, our data suggest that both classroom-based and field-based programs were generally effective at influencing key elements of WAC for the American alligator. Through the provision of safe, close, guided encounters with intimidating species, conservation education programs have the potential to help shift acceptance capacity for wildlife and promote coexistence between humans and predators like the American alligator.

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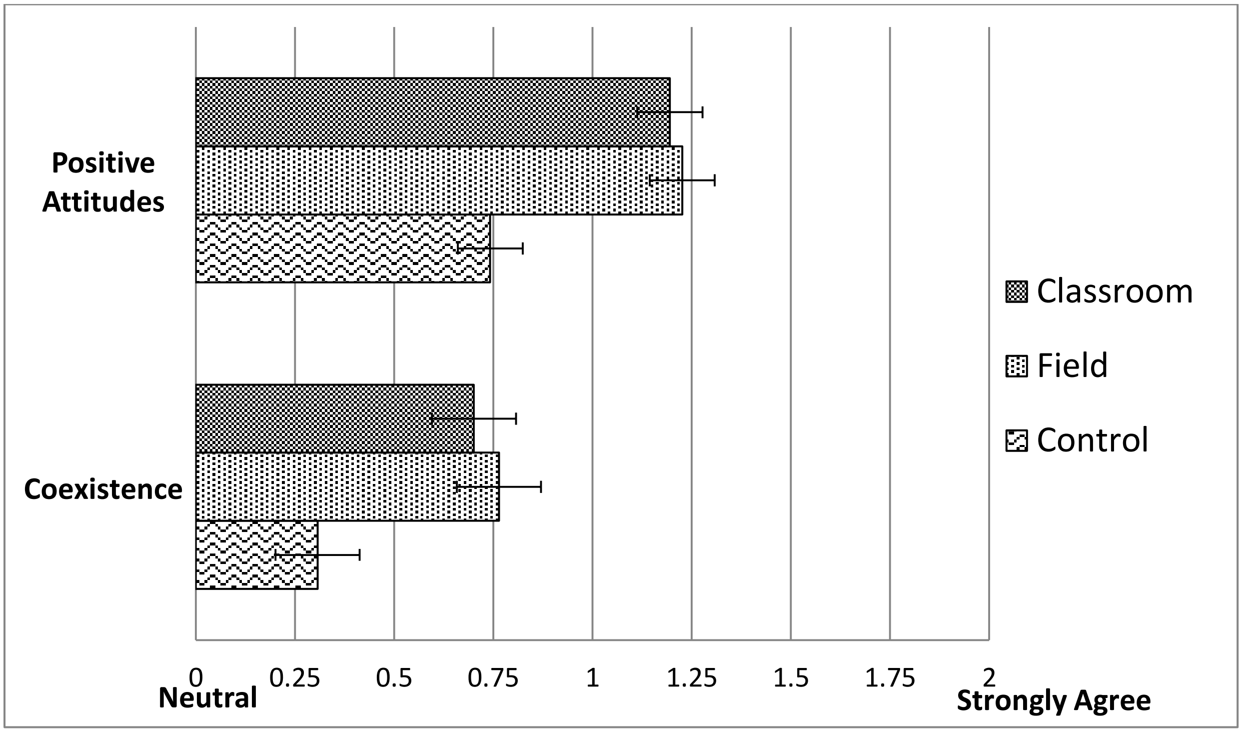


Figure 4.1**.** Estimated marginal means (SE bars) for two outcome variables related to wildlife acceptance capacity for alligators. Positive attitudes and potential for coexistence were assessed using a 5-point Likert-type scale (-2 = Strongly Disagree, +2 = Strongly Agree).

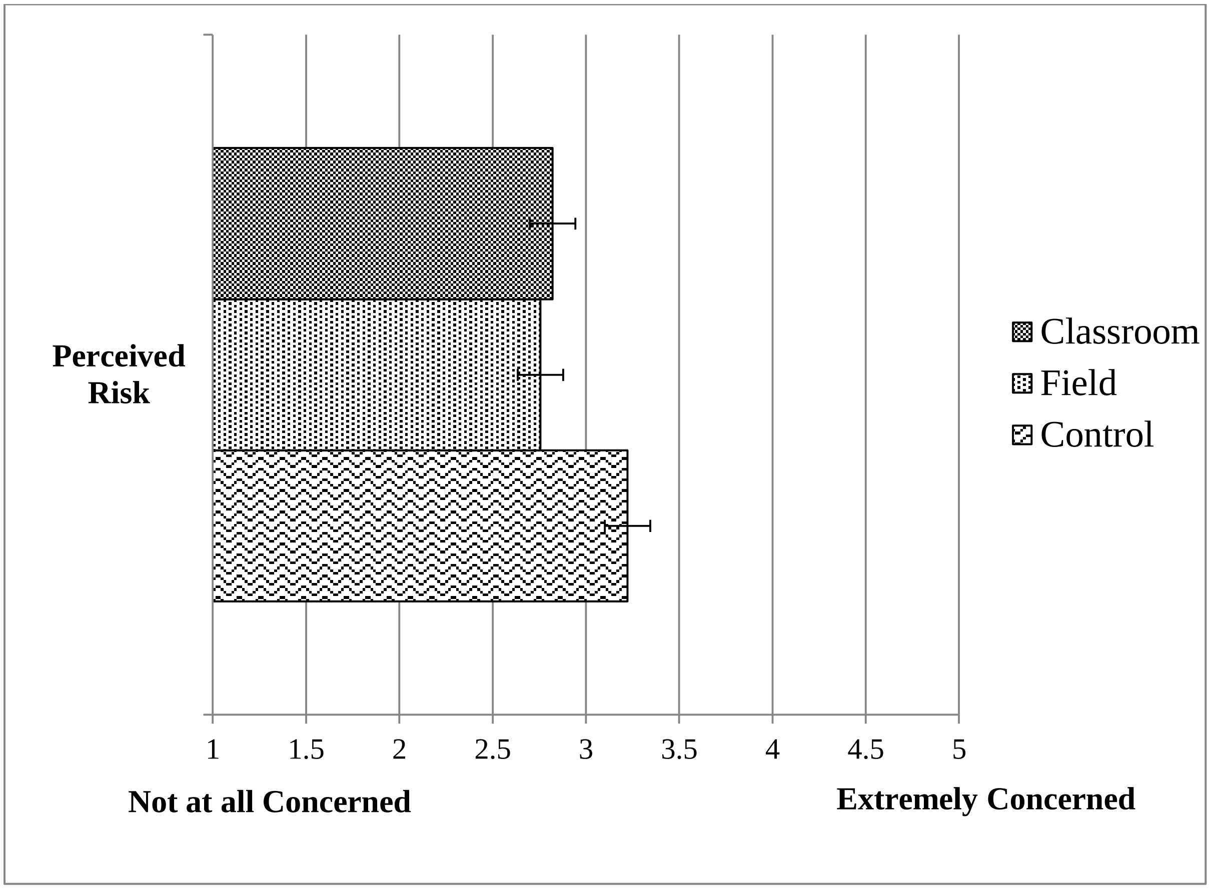


Figure 4.2. Estimated marginal mean scores (SE bars) for perceived risks associated with American alligators. Perceived risk was measured on a 5-point scale (1 = Not at all Concerned, 5 = Extremely Concerned).

Table 4.1. Comparison of treatment group characteristics using chi-square difference tests

| Variable | Treatment Group: Classroom | Field | Control | Total | Diff. stat. |
|---|---|---|---|---|---|
| N | 358 | 343 | 363 | 1064 | |
| Education (% with college degree) | 72.30% | 77.40% | 58.90% | 69.40% | $\chi^2(2) = 30.011$, $p < 0.001$ |
| Pet Ownership (% that own cat and/or dog) | 66.40% | 67.60% | 82.00% | 72.10% | $\chi^2(2) = 26.522$, $p < 0.001$ |
| Affiliation to Jekyll Island (% Visitor) | 82.10% | 85.30% | 74.60% | 80.60% | $\chi^2(2) = 13.791$, $p = 0.001$ |
| Age (% over 40) | 67.60% | 63.10% | 55.10% | 61.90% | $\chi^2(2) = 12.062$, $p = 0.002$ |
| Children (% with children under the age of 13) | 42.10% | 37.10% | 45.90% | 41.80% | $\chi^2(2) = 5.586$, $p = 0.061$ |
| Exposure to alligators (% seen in wild) | 84.60% | 82.70% | 86.70% | 84.70% | $\chi^2(2) = 2.222$, $p = 0.329$ |
| Education program (% attended an alligator program before) | 28.40% | 27.40% | 31.00% | 28.90% | $\chi^2(2) = 1.215$, $p = 0.545$ |
| Exposure to alligators (% seen in media) | 80.40% | 77.40% | 79.30% | 79.10% | $\chi^2(2) = 0.982$, $p = 0.612$ |
| Gender (% female) | 62.00% | 61.90% | 60.70% | 61.60% | $\chi^2(2) = 0.158$, $p = 0.924$ |

Table 4.2. Multiple ANOVA examining main effects of treatment group, demographic variables, and previous experience with alligators on positive attitudes towards alligators

| **Source** | **Type III SS** | **df** | **F** | **p** | **$\eta^2$** |
|---|---|---|---|---|---|
| Treatment | 190.331 | 2 | 192.044 | 0.000 | 0.261 |
| Gender | 10.684 | 1 | 21.561 | 0.000 | 0.015 |
| Education | 7.728 | 1 | 15.595 | 0.000 | 0.011 |
| Seen Alligator in Wild | 7.265 | 1 | 14.662 | 0.000 | 0.010 |
| Affiliation to Jekyll Island | 6.014 | 1 | 12.136 | 0.001 | 0.008 |
| Attended Alligator Program Before | 3.471 | 1 | 7.005 | 0.008 | 0.005 |
| Seen Alligator in Media | 1.465 | 1 | 2.957 | 0.086 | |
| Children | 1.346 | 1 | 2.717 | 0.100 | |
| Age | 2.951 | 3 | 1.985 | 0.115 | |
| Pet Ownership | 0.832 | 1 | 1.679 | 0.195 | |
| Error | 497.522 | 1004 | | | |

Table 4.3. Comparison of group means (± SD) for all three outcome variables. Participants in the control group reported lower positive attitudes, higher perceived risks, and a lower potential for coexistence towards American alligators on Jekyll Island, Georgia.

| | Treatment | | | |
|---|---|---|---|---|
| | **Classroom** | **Field** | **Control** | **Total** |
| **Positive Attitudes** | 1.53 ± 0.60 | 1.52 ± 0.65 | 0.61 ± 0.92 | 1.21 ± 0.86 |
| The presence of alligators is a sign of a healthy coastal environment | 1.64 ± 0.66 | 1.63 ± 0.72 | 0.96 ± 1.00 | 1.40 ± 0.87 |
| Alligators are important components of Jekyll Island's natural environment | 1.81 ± 0.470 | 1.76 ± 0.65 | 1.01 ± 0.99 | 1.53 ± 0.82 |
| I enjoy seeing alligators when I'm on Jekyll Island | 1.38 ± 0.92 | 1.44 ± 0.90 | 0.38 ± 1.30 | 1.06 ± 1.17 |
| Seeing alligators improved my visit to Jekyll Island | 1.30 ± 0.96 | 1.25 ± 0.95 | 0.08 ± 1.16 | 0.87 ± 1.17 |
| **Perceived Risk** | 2.67 ± 1.01 | 2.62 ± 0.98 | 3.23 ± 1.09 | 2.85 ± 1.06 |
| While in areas where alligators are present how concerned are you for the safety of yourself | 2.13 ± 1.08 | 2.08 ± 0.98 | 2.73 ± 1.26 | 2.32 ± 1.15 |
| While in areas where alligators are present how concerned are you for the safety of your family and children | 2.79 ± 1.16 | 2.71 ± 1.19 | 3.45 ± 1.23 | 2.99 ± 1.24 |
| While in areas where alligators are present how concerned are you for the safety of your pets (or pets in general) | 3.11 ± 1.33 | 3.09 ± 1.28 | 3.52 ± 1.29 | 3.25 ± 1.31 |
| **Potential for Coexistence** | 0.98 ± 0.80 | 1.04 ± 0.79 | 0.21 ± 0.96 | 0.74 ± 0.94 |
| It is safe for alligators to live around people | 0.46 ± 1.07 | 0.55 ± 1.10 | -0.30 ± 1.16 | 0.23 ± 1.18 |
| Humans can safely coexist with alligators | 1.50 ± 0.81 | 1.51 ± 0.83 | 0.70 ± 1.14 | 1.23 ± 1.01 |

Positive attitudes and potential for coexistence were assessed using a 5-point Likert-type scale (-2 = Strongly Disagree, +2 = Strongly Agree). Perceived risk was measured on a similar scale (1 = Not at all Concerned, 5 = Extremely Concerned).

Table 4.4. Multiple ANOVA examining main effects of treatment group, demographic variables, and previous experience with alligators on perceived risk

| **Source** | **Type III SS** | **df** | **F** | **p** | **$\eta^2$** |
|---|---|---|---|---|---|
| Treatment | 88.074 | 2 | 43.363 | 0.000 | 0.075 |
| Age | 18.644 | 3 | 6.12 | 0.000 | 0.016 |
| Seen Alligator in Media | 12.224 | 1 | 12.037 | 0.001 | 0.010 |
| Seen Alligator in Wild | 8.126 | 1 | 8.002 | 0.005 | 0.007 |
| Attended Alligator Program Before | 5.156 | 1 | 5.077 | 0.024 | 0.004 |
| Children | 4.839 | 1 | 4.765 | 0.029 | 0.004 |
| Gender | 3.594 | 1 | 3.539 | 0.060 | |
| Affiliation to Jekyll Island | 2.772 | 1 | 2.73 | 0.099 | |
| Pet Ownership | 0.606 | 1 | 0.596 | 0.440 | |
| Education | 0.031 | 1 | 0.03 | 0.862 | |
| Error | 1027.716 | 1012 | | | |

Table 4.5. Multiple ANOVA examining main effects of treatment group, demographic variables, and previous experience with alligators on potential for coexistence with alligators

| **Source** | **Type III SS** | **df** | **F** | **p** | **$\eta^2$** |
|---|---|---|---|---|---|
| Treatment | 144.905 | 2 | 105.262 | 0.000 | 0.168 |
| Seen Alligator in Wild | 7.176 | 1 | 10.426 | 0.001 | 0.008 |
| Education | 6.194 | 1 | 8.998 | 0.003 | 0.007 |
| Gender | 3.678 | 1 | 5.343 | 0.021 | 0.004 |
| Age | 4.863 | 3 | 2.355 | 0.071 | |
| Attended Alligator Program Before | 1.791 | 1 | 2.602 | 0.107 | |
| Affiliation to Jekyll Island | 1.551 | 1 | 2.253 | 0.134 | |
| Children | 1.166 | 1 | 1.694 | 0.193 | |
| Seen Alligator in Media | 0.166 | 1 | 0.242 | 0.623 | |
| Pet Ownership | 0.039 | 1 | 0.057 | 0.812 | |
| Error | 690.371 | 1003 | | | |

# CHAPTER 5

# CONLUSIONS

The construction of residential areas, tourist attractions, and golf courses in coastal landscapes has led to the destruction of natural aquatic habitats. Simultaneously humans have created novel permanent freshwater habitats in the form of stormwater lagoons. The construction of freshwater habitats in human-dominated areas in conjunction with the recovery of the American alligator (*Alligator mississippiensis*) has led to an increase in human-alligator conflicts in recent decades. The goal of wildlife managers should be to maintain viable populations of *A. mississippiensis* in developed areas while mitigating the risk to humans and their property.

A better understanding of the biotic and abiotic factors influencing alligator abundance in human-made stormwater lagoons will allow land managers to better predict when and where human-alligator conflicts may occur. In Chapter 1 we found that alligators were most active during the months of March through October. Further, model averaging techniques suggested that alligators are more likely to occur in large lagoons with low salinities. Wildlife managers should be prepared to deal with alligator complaints in these habitat types during the months when alligators are most active. Officials may elect to take proactive measures to mitigate the risk of human-alligator conflicts before they occur. Protective barriers (i.e., fences) and educational signage placed around human-made stormwater lagoons may help to prevent conflict with alligators. These data may also provide developers with valuable information on how to construct stormwater lagoons in order to promote or discourage colonization of human-made stormwater lagoons by *A. mississippiensis*. In order to promote colonization of lagoons, developers should avoid constructing stormwater lagoons that are connected with brackish systems, such as saltwater marshes in coastal landscapes. Creating large lagoons with a mixture of open and vegetated terrestrial edges may provide suitable habitat for alligators. Additionally, placing lagoons closer together may prevent alligators from making long distance terrestrial movements that may result in human-alligator conflicts.

In order to create successful conservation and management programs for American alligators, researchers and wildlife managers must be informed by the most biologically accurate data available. In Chapter 2, we examined the spatial ecology of the American alligator using two techniques, VHF and GPS telemetry. Both VHF and GPS provided insight into the spatial ecology of the American alligator inhabiting a developed landscape. The use of GPS telemetry freed the researcher from the task of manually tracking animals and allowed the researcher to pursue other tasks relevant to the study organism. However, data collected with GPS telemetry excluded many underground habitat types such as culverts and dens. These habitats are vitally important to alligators and may indicate how the species is adapting to life in developing areas. Similarly, the use of VHF telemetry alone did not accurately reflect the use of essential marsh habitat by alligators which could result in managers underestimating the critical importance of this habitat and total amount of space needed to conserve the species. A combination of the two technologies may provide the most effective means of studying top predators, especially highly vagile species such as crocodilians. We recommend the use of traditional VHF telemetry to allow researchers to directly observe animal behaviors and obtain data on key parameters in conjunction with GPS telemetry to capture previously unavailable data. This approach will directly aid wildlife managers in identifying the habitat needed to maintain populations of American alligators in developing landscape.

State agencies frequently use lethal techniques to deal with nuisance alligators. However, in state parks and other public areas, management agencies seek to maintain alligator populations at levels that will ensure their long-term viability and sustain their role in the ecosystem. In these situations, wildlife managers should consider cognitive fixes, such as conservation education programs, to influence human behavior and reduce the risk of negative human-alligator interactions. Increasingly, conservation education programs that offer participants a close encounter with captive wildlife and those that provide an opportunity to view non-captive wildlife are growing in popularity. Unfortunately, the effectiveness of such conservation education programs is rarely assessed. In Chapter 3, we observed significant treatment effects on all three outcome variables related to wildlife acceptance capacity for alligators: positive attitudes, perceived risks, and potential coexistence. While these results should be cautiously interpreted due to the aforementioned limitations, our data suggest that both classroom-based and field-based programs were generally effective at influencing key elements of WAC for the American alligator. Through the provision of safe, close, guided encounters with intimidating species, conservation education programs have the potential to help shift acceptance capacity for wildlife and promote coexistence between humans and predators like the American alligator.