

WILDLIFE USE OF SPOIL ISLANDS IN LAKE TOHOPEKALIGA, FLORIDA

By

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To my parents, for supporting my dreams; and to my wife, for encouraging me to see them through

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Abstract of Thesis Presented to the Graduate School
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WILDLIFE USE OF SPOIL ISLANDS IN LAKE TOHOPEKALIGA, FLORIDA

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Restoration of aquatic habitat and improvements to shipping channels and harbors creates large amounts of left over material termed spoil. The dredge spoil has either been stored off-site in upland locations or stored on-site as created islands. Many studies have documented the use of spoil islands by wildlife. The majority of these studies were on coastal spoil islands with a particular focus on ground-nesting avian species. The creation of spoil islands as a result of freshwater lake restoration has begun to gain favor with lake managers due to the increased costs of spoil transport to off-site locations and the lack of accessibility to those locations. The objective of this study was to assess ecological factors traditionally overlooked on spoil islands in an attempt to form a more complete picture of spoil island ecology. The influence of spoil island characteristics and habitat on use by small mammals, red imported fire ants, and nesting turtles was studied in Lake Tohopekaliga, FL. Several island characteristics were found to influence small mammal occupancy including distance from shore and lake location as well as vegetation height heterogeneity. Red imported fire ant mounds were found in high densities on the spoil islands but were not significantly influenced by island characteristics and showed no effect on ground-dwelling wildlife. Artificial turtle

nests were used to examine relative differences in predation between different island and shoreline nesting habitats. Only islands ≥ 300 m from shore showed greater turtle nest survival than shoreline locations. This study documented wildlife use of freshwater lake spoil islands resulting from the influence of island and habitat characteristics. Inter-species influences were also examined. This study has expanded current knowledge of spoil island ecology and made recommendations for future island creation and research to benefit wildlife species on the islands.

CHAPTER 1 INTRODUCTION

Manuscript Organization

This thesis was organized in journal format due to the 3 separate studies contained within. The Introduction chapter contains a statement on the objectives of this study and an overview of the study site. The following 3 chapters contain the individual studies conducted for this thesis. Each chapter is organized as a journal submission containing separate Introduction, Methods, Results, and Discussion sections. Figures for these chapters were placed at the end of the respective chapter. A Conclusion chapter follows the individual studies to synthesize the results from this thesis. A literature review on past wildlife use of spoil island studies is contained in Appendix C.

Study Objectives

The objective of this study was to assess ecological factors traditionally overlooked on spoil islands in an attempt to form a more complete picture of spoil island ecology. Historically, spoil island studies have focused principally on avian nesting mentioning other animal guilds only in relation to avian nest predation or as passing observations. This avian-centric focus of past research has left a large gap in the knowledge of spoil island ecology and managers with many unanswered questions. This study focused on the use of in-lake spoil islands by small mammals, red imported fire ants, and freshwater turtle nesting success on spoil islands.

The role of small mammals in spoil island ecology has been nearly completely neglected save a few observations (Stieglitz and Wilson 1968, Landin and Newling 1987) and a single qualitative study (Hulon et al. 1998). The occurrence of small

mammal species on spoil islands has been assumed to be ephemeral, playing a small, if any role in the ecology of the islands. This study sought to challenge those assumptions by using patch occupancy to investigate spoil island use by small mammals and the influence of associated island characteristics. The results from this study were presented in Chapter 2.

Red imported fire ants (*Solenopsis invicta*, fire ants), along with nearly all invertebrate species, have been overlooked in spoil island research. Fire ants were found on every spoil island in Lake Tohopekaliga during preliminary investigations, but nothing was known about their possible associations with island characteristics. It was assumed that these ants may affect the occurrence and distribution of island dwelling species. I related fire ant mounds densities to island characteristics and occurrence of ground dwelling wildlife species. The results from this study were presented in Chapter 3.

Freshwater turtles have only been reported utilizing and nesting on spoil islands in a single study (Hulon et al. 1998). I sought to evaluate the assumption that these islands are good nesting locations for freshwater turtles, and more broadly for ground nesting species, or if they function as population sinks. Freshwater turtles utilized the islands for nesting sites. Preliminary observations suggested that a large percentage of those nests were depredated, possibly by raccoons (*Procyon lotor*). An artificial turtle nest natural experiment was used to determine if nest depredation rates were indeed lower on the islands compared to the shoreline and if island distance from shore affected nest success. The results from this study were presented in Chapter 4.

Study Site

Restoration of aquatic habitat and improvements to shipping channels and harbors creates large amounts of left over material termed spoil. Dredge spoil has traditionally been stored in off site, upland locations where possible. In coastal waters, spoil has been used to form islands for future spoil retention. Between the mid-19th century and 2004, over 2000 spoil islands were constructed in Atlantic and Gulf coast estuaries (Yozzo et al. 2004). The majority of U.S. coastal dredging took place during the 1920's construction of the Intracoastal Waterway along the Atlantic and Gulf coasts (Parnell et al. 1986). Spoil islands have also been created in the prairie pothole region of the United States and Canada to provide nesting habitat for ground nesting avian species. Freshwater in-lake spoil island creation has recently begun to gain favor with lake managers due to the increased costs of spoil transport to off-site locations and the lack of accessibility to those locations.

Lake Tohopekaliga is a 7612 ha freshwater lake located near the city of Kissimmee, FL (Figure 1-1). This is a shallow water, eutrophic lake at the northern extent of the Kissimmee Chain of Lakes. The lakeshore is primarily bordered by residential development and cattle grazed pasture. The northern shoreline is bordered by the city of Kissimmee, FL. The southern half of the lake is predominantly undeveloped cattle pasture. The lake averages 2.1 m in depth. Historically (1942-1964), the lake fluctuated within a range of 3.2 m but was constrained to a fluctuation of 0.91 m after 1970. This restriction in water level fluctuation coupled with past sewage discharge (beginning in the 1950's through 1987) created the highly eutrophic lake conditions which predicated the decision to undertake a massive restoration effort (Desa 2008). In 2004, a large scale habitat restoration effort was initiated by the

Florida Fish and Wildlife Conservation Commission. Restoration efforts included an extreme draw down and mechanical removal of thick stands of emergent vegetation and underlying organic muck. Approximately 1351.25 hectares of lake bottom were scraped and over 6,094,855.48 cubic meters of material were removed. The majority of the dredge spoil was stored in-lake as spoil islands intended for use by wildlife and for storage of future dredge material and harvested vegetation.

Twenty-nine islands were constructed in-lake from the dredge spoil. Three main characteristics were used to describe and select the study islands. Those 3 characteristics were the islands distance from shore, method of construction, and presence of grazing by domesticated cattle. Geographic location of the islands was determined by the islands physical distance from the nearest shoreline. Laser rangefinders were used in the field to determine the actual distance of each island from shore. Islands included in the study ranged from 0 m from shore, acting as peninsulas during low water levels, to 500 m from shore. For purposes of island selection, islands between 0 and 100 m were considered proximal islands and islands ≥ 200 m from shore were considered distal islands. There were no islands between 100 and 200 m from shore included in this study. Both construction method and presence of grazing was determined through direct observation on the islands. During construction, islands were either graded smooth or left in rough heaps of spoil material and identified as either smooth or rough respectively. Several of the islands were subjected to grazing by domesticated cattle as they occurred along shoreline pastures. These islands were identified as grazed while others were labeled as un-grazed. All measurements and classifications were made in May 2005 by the Florida Fish and Wildlife Cooperative

Research Unit while the lake stage was at low pool, 16.07 m NGVD (National Geodetic Vertical Datum).

Twelve islands were selected for the study to include duplicates of all available combinations of the 3 main island characteristics. There were no distally grazed islands limiting island selection to 6 total combinations of islands. The locations of the study islands in Lake Tohopekaliga are presented in Figure 1-2. The islands ranged in size from 0.73 ha (Island 3) to 1.21 ha (Island 17). The average island size of the 12 study islands was 0.94 ha with a standard error (*SE*) of 0.069 ha. Island sizes were taken from Hoyer et al. 2006. Islands were also grouped into lake locations based on their geographic distribution and labeled with commonly used location names. Islands were grouped into 4 locations. Goblet's Cove location consisted of Islands 3, 4, 5, and 8. Whaley's Landing location consisted of Islands 10 and 12. Brown's Point location consisted of Islands 14, 15, and 17. Lanier Point consisted of Islands 19, 20, and 22.

Island vegetation was variable, but characteristic of early successional habitat. Over 120 species were identified on the islands between 2007 and 2009. The most common vegetative species identified on the islands were para grass (*Bracharia mutica*), white twine vine (*Sarcostemma clausum*), dog fennel (*Eupatorium capillifolium*), water primrose (*Ludwigia* spp.), poke weed (*Phytolacca americana*), fireweed (*Erechtites hieraciifolius*), alligator weed (*Alternanthera philoxeroides*), wild water-pepper (*Polygonum hydropiperoides*), morning glory (*Ipomoea alba*), and Bermuda grass (*Cynodon dactylon*). Tree growth was primarily restricted to the islands wetted fringe and consisted predominantly of willow (*Salix* spp.). No islands included in this study had been planted or managed (Shoger et al. 2009).

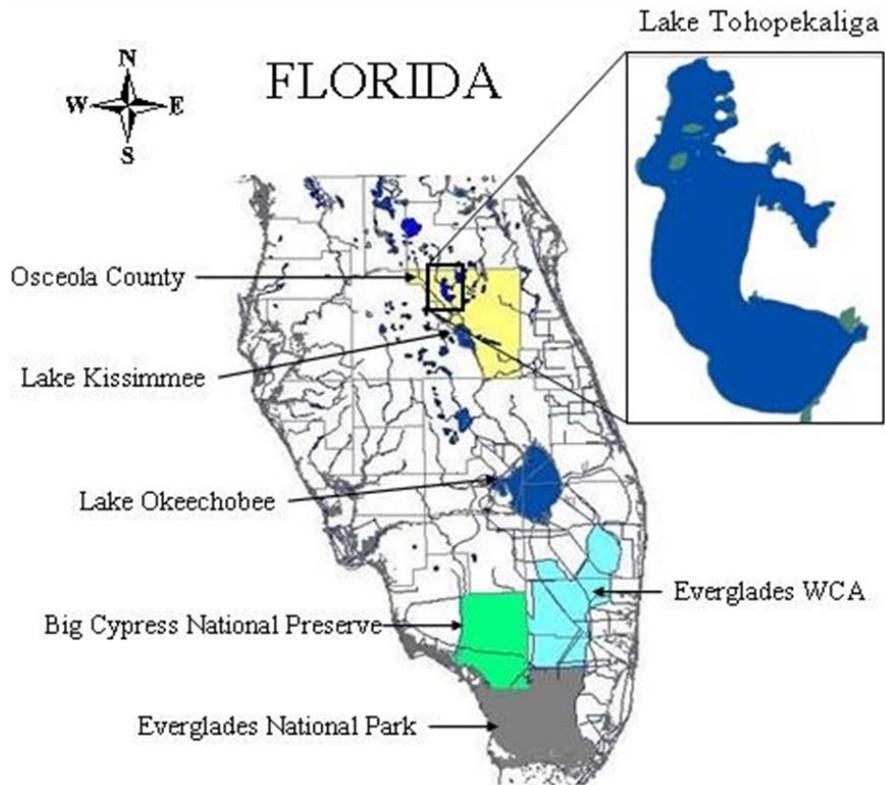


Figure 1-1. Map of Florida showing the location of Lake Tohopekaliga within the greater Everglades watershed (map source: Brush 2006).

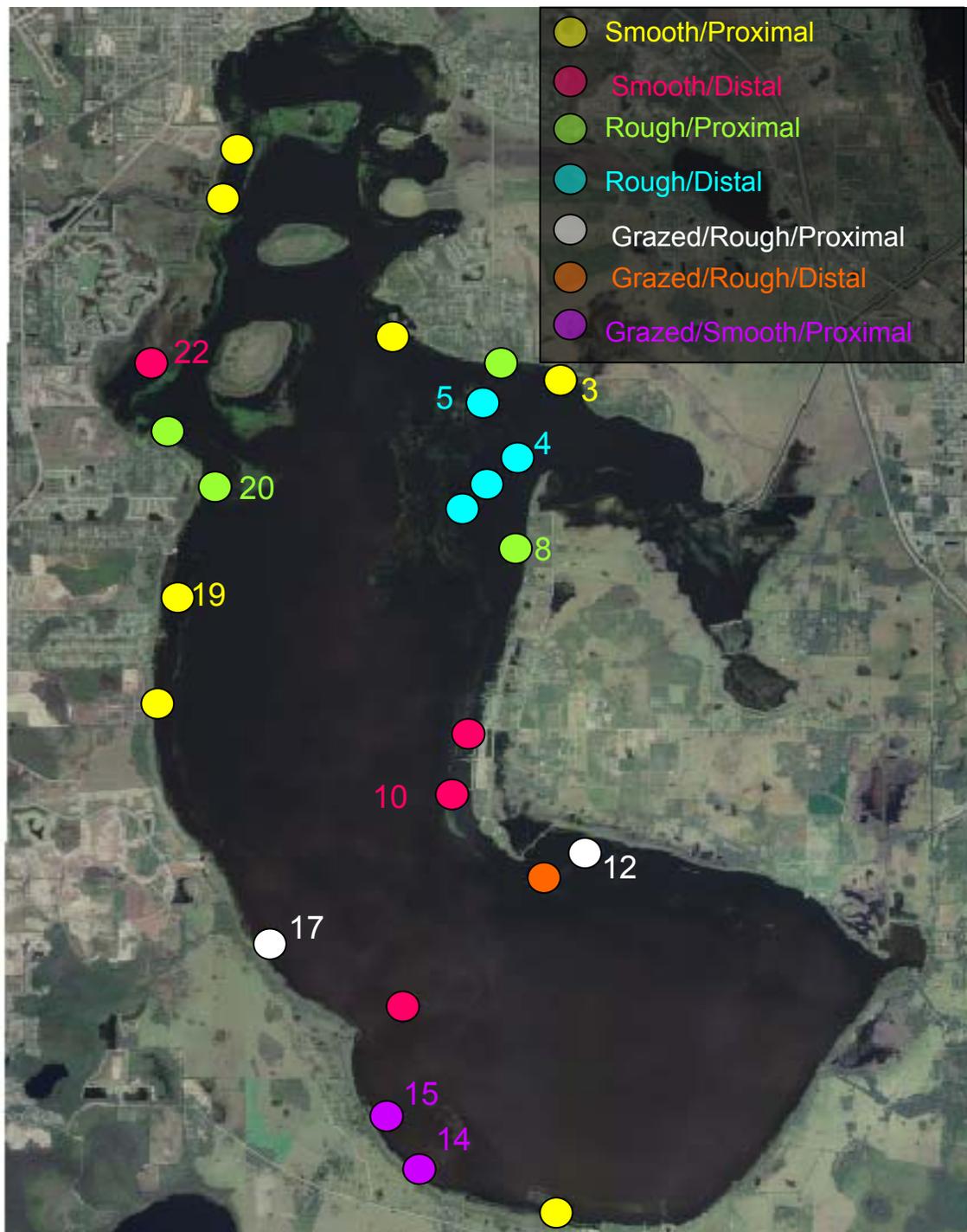


Figure 1-2. Map of Lake Tohopekaliga showing the location and designation of study islands.

CHAPTER 2 SMALL MAMMAL OCCUPANCY OF SPOIL ISLANDS

Introduction

Spoil islands have been used for dredge disposal and storage in aquatic systems throughout the United States. Research on wildlife use of these islands has traditionally focused on avian species, only rarely incorporating passing observations of non-avian species. Small mammal use of spoil islands has been nearly completely neglected save a few observations (Stieglitz and Wilson 1968, Landin and Newling 1987) and a single qualitative study (Hulon et al. 1998). Small mammals of the family Rodentia may play a large role in habitat development and interspecies relationships on spoil islands. These mammals can influence habitat succession by eating both herbaceous vegetation and seeds making them agents of seed dispersal and propagation as well as a control of vegetative growth through herbivory. Small mammals also serve as an important prey item for a plethora of predators. The presence of small mammals on the islands in sufficient numbers may draw predators to the islands in search of prey, possibly increasing predation on other animals utilizing the islands. Preliminary results have found several small mammal species inhabiting the islands, both adults and juveniles (Shoger et al. 2009). This study used small mammals as indicators of a wider range of wildlife use of spoil islands and to further expand knowledge of spoil island ecology. I used patch occupancy to investigate spoil island use by small mammals and the influence of associated island characteristics.

Hulon et al. (1998) reported the use of in-lake spoil islands by several small mammal species but did not test for island characteristics influencing occupancy. By incorporating island and habitat characteristics, this study is intended to give managers

options for future island creation projects depending on their goals for wildlife use as well as provide a more complete ecology of in-lake spoil islands.

Garden et al. (2007) reported that habitat structure, not vegetation composition was the primary factor influencing mammal species. Research has indicated a link between the soil disturbance caused by foraging small mammals and topsoil health and vegetation biodiversity. The scratching and burrowing actions of small mammals mix the top layer of soil, spread fungi spores, and transport seeds throughout the inhabited area (Martin 2003). Vegetation diversity may be a result of increased small mammal usage of the islands, but not the causal factor attracting small mammals to the islands. By taking vegetation structure into account as well as species richness, it may be determined which of these factors, or combination are most important to small mammal occupancy on the islands.

Small mammals have been reported to influence predation on other species (Angelstam et al. 1984). The small mammals on the islands may be bringing predators onto the island which could then influence other potential prey species. This study will attempt to determine whether there was any association between small mammal total captures and occurrence of predators on the islands.

My working hypothesis is that small mammal occupancy on the spoil islands is influenced by distance from shore, presence of grazing, vegetation structure, and abundance of fire ants. Specifically, small mammals are negatively associated with island distance from shore and fire ant mound densities and positively associated with grazing activity and vegetation structure and species. Distance traveled over water should act as a natural barrier to island colonization as the distance increases with the

most distal islands having the lowest occupancy rates. Fire ants negatively affect nearly all vertebrate, and invertebrate, species they encounter and should have a similar effect on the insular small mammals that exist in a more restricted habitat. Spoil island grazing activity was found associated with vegetation species richness (Shoger et al. 2009). A more diverse vegetative habitat may provide better foraging opportunities to small mammals. A more structurally diverse habitat may support a higher number of species possibly having a positive effect on small mammals. Further, I hypothesize the marsh rice rat (*Oryzomys palustris*) has higher occupancy rates on distal islands than the other 2 species. The marsh rice rat is a semi-aquatic species that may be more capable of colonizing more distal islands than the other studied species. Within the constraints imposed by this study, I hypothesized that island construction, size, and lake location would have no effect on occupancy. Lastly, small mammal predator occurrence would also be greater on islands with higher numbers of total small mammals trapped.

Study Site

Lake Tohopekaliga is a 7612 ha freshwater lake located near the city of Kissimmee, FL (Figure 1-1). This is a shallow water, eutrophic lake at the northern extent of the Kissimmee Chain of Lakes. The lakeshore is primarily bordered by residential development and cattle grazed pasture. The northeastern shoreline is bordered by the city of Kissimmee, FL. The southern two-thirds of the lake is predominantly cattle pasture. The lake averages 2.1 m depth.

In 2004, a large scale habitat restoration effort was initiated by the Florida Fish and Wildlife Conservation Commission on the lake. Restoration efforts included an extreme draw down and mechanical removal of thick stands of emergent vegetation and

underlying organic muck. The majority of the dredge spoil was stored in-lake as spoil islands intended for use by wildlife and for storage of future dredge material and harvested vegetation.

Twenty-nine islands were constructed in-lake from the dredge spoil. Three main characteristics were used to describe and select the study islands. Those 3 characteristics were the islands distance from shore, method of construction, and presence of grazing by domesticated cattle. Geographic location of the islands was determined by the islands physical distance from the nearest shoreline. Laser rangefinders were used in the field to determine the actual distance of each island. Islands included in the study ranged from 0 m from shore, acting as peninsulas during low water levels, to 500 m from shore. For purposes of island selection, islands between 0 and 100 m were considered proximal islands and islands ≥ 200 m from shore were considered distal islands. There were no islands between 100 and 200 m from shore included in this study. Both construction method and presence of grazing was determined through direct observation on the islands. During construction, islands were either graded smooth or left in rough heaps of spoil material and identified as either smooth or rough respectively. Several of the islands were subjected to grazing by domesticated cattle as they occurred along shoreline pastures. These islands were identified as grazed while others were labeled as un-grazed. All measurements and classifications were made in May 2005 by the Florida Fish and Wildlife Cooperative Research Unit while the lake stage was at low pool, 16.06 m NGVD (National Geodetic Vertical Datum).

Twelve islands were pseudo-randomly selected for the study to include duplicates of all available combinations of the 3 main island characteristics. There were no distally grazed islands limiting island selection to 6 total combinations of islands. The locations of the study islands in Lake Tohopekaliga are presented in Figure 1-2. The islands ranged in size from 0.73 ha (Island 3) to 1.21 ha (Island 17). The average island size of the 12 study islands was 0.94 ha with a standard error (SE) of 0.069 ha. Island sizes were taken from Hoyer et al. 2006. Islands were also grouped into lake locations based on their geographic distribution and labeled with commonly used location names. Islands were grouped into 4 locations. Goblet's Cove location consisted of Islands 3, 4, 5, and 8. Whaley's Landing location consisted of Islands 10 and 12. Brown's Point location consisted of Islands 14, 15, and 17. Lanier Point consisted of Islands 19, 20, and 22.

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Methods

A 90 m transect consisting of 10 Sherman live traps set at 10 m intervals was set on each of the study 12 islands. Transect start and end points were randomly located using a random number generator and grid overlain onto aerial photos of the islands. The random numbers generated were used as the coordinates for the start and endpoints and were adjusted when needed in order to keep the entire transect above the high water mark at all times of the year. Small mammal trapping took place monthly from March 2008 through March 2009. Traps were set for 4 days and checked each morning. Sherman traps were baited with a bird seed mixture and polyester batting was provided in colder months. All animals caught were identified to species, weighed, and then released at the point of capture. This transect approach was intended to provide a larger spatial scale and better community assemblages than grid trapping schemes by allowing more species the opportunity for capture due to the increase in home range overlap and different micro-habitat factors (Pearson and Ruggiero 2003).

A monthly estimate of vegetation structure was made in a 5 m radius around each trap. Vegetation structure was estimated visually and categorized by height class. Bare ground, 0-0.3 m, 0.3-1.22 m, 1.22-2.44 m, and over 2.44 m were the five height classes. In addition, a biennial vegetation sampling was undertaken on each of the islands. Vegetation surveys were conducted in June and January beginning in June 2007 through January 2009. Two perpendicular belt transects were established on each island, 1 running north-south and the other east-west. Vegetation was sampled every 5 m along each transect using a 1 m² quadrat. All vegetative species present were recorded and percent cover was approximated using a line-intercept method modified from Phillips (1959). Vegetation species percent cover was approximated by counting

the number of times a species crossed a rod set on a diagonal across the quadrat (Wallace et al. 1996). The diagonal was divided into 14 equal segments (10 cm) giving a species crossing the diagonal 14 times a percent cover of 100%. This modified belt transect survey method was also used in Bossart (2002), and Prenger et al. (2006).

A small mammal predator index was used in analyses for this study. The data on predator occurrence were collected during island surveys from 2007-2009 and documented in Shoger et al. (2009). Small mammal predators, both avian and herpetofaunal, were recorded during avian surveys and drift fence trapping. A timed area search method was used on the islands to conduct avian surveys. Surveys were conducted biweekly on each island beginning at sunrise. Two observers searched the entire island by foot for a specified amount of time based on the islands total area. A baseline of 30 minutes search time per hectare of island was used. Only birds perched or foraging on or over the island were recorded. Herpetofaunal trapping consisted of a single drift fence array constructed on each of the islands in a “Y” shape. Each leg of the drift fence consisted of 15 m of industrial silt fencing. Two of the drift fence legs pointed toward the littoral fringe of the island with the remaining leg pointing into the islands upland area. Each array was outfitted with 18 double-ended funnel traps constructed of window screen. The traps were unbaited with wetted sponges and shaded by landscaping cloth (Enge 1997, 2001). Herpetofaunal trapping was concurrent with the small mammal trapping and consisted of the same 4 night trapping period with traps checked daily and all captures identified to species, weighed, and released.

Analysis

The total number of small mammals trapped and small mammal species richness from the 13 month study was analyzed using simple linear regression (SAS © Institute, Inc., 1985) for correlation with vegetation species richness and the predator index. Vegetation species richness was calculated by the total number of species found on the last survey in winter 2008-2009. The predator index was the total capture or observation of small mammal predators by island throughout the entire study. Shapiro-Wilk tests (Shapiro and Wilk 1965, Allen et al. 1997) and normal probability plots were used to determine data distribution normality. An $\alpha > 0.1$ was used to indicate data distribution normality. The predator index and vegetation species richness were normally distributed. Total small mammal captures was log transformed for the regression analyses. Small mammal species richness was not normally distributed but was not transformed. Three islands had a 1 species, 8 islands had 2 species, and only 1 island had 3 species. The homogeneity of species richness values may have skewed the normality test results.

The 3 most commonly trapped small mammals found on the islands were the hispid cotton rat (*Sigmodon hispidus*), marsh rice rat, and house mouse (*Mus musculus*). These 3 species were the main focus of the study due to their ease of trapping on the islands and representation of different habitat associations, upland and wetland (Whitaker et al. 1998).

Island patch occupancy for the 3 most commonly trapped small mammal species was modeled using program PRESENCE 2.3 (Hines 2006). Patch-occupancy was chosen instead of relative or absolute abundance because of the shorter time and smaller financial expense and the likelihood of insufficient recapture rates to allow for a

meaningful estimate of population size. Patch occupancy estimates the proportion of an area occupied by a species. Parameters used for this study were occupancy, colonization, and detection probability. Occupancy (ψ) was the probability an animal occurred in a patch at any period in time based on modeled covariates. For example, an occupancy estimate of 0.3 signifies the species occupies 30% of the area. Occupancy estimation was based on detection histories for each species. Detection histories were recorded for each species as a “0” for not occupied and “1” for occupied. Detection histories were constructed through repeated sampling. Colonization (γ) was the probability a patch would be colonized between seasons. For example, a γ of 0.3 signifies a 30% chance of an unoccupied patch to become occupied. Colonization was only estimated in multi-season models. Detection Probability (p) was the probability that an animal would be detected at an occupied site. PRESENCE software allows for imperfect detection allowing for an unbiased estimate of detection probability. For example, a detection probability of 0.3 signifies a 30% chance of detecting an animal at an occupied site.

I used multi-season occupancy modeling to examine relationships between small mammal occupancy and island characteristics. The occupancy model uses a multinomial maximum likelihood formula for computation of parameter estimates. This model is closely related to mark-recapture models with sites being used as individuals and the incorporation of covariates (Mackenzie and Bailey 2004). The “season” in multi-season occupancy refers to the survey period, not calendar season. “Season” for this study was defined as the 4 consecutive day trapping period with 13 total seasons in the multi-season model. The multi-season model makes several assumptions. The

model assumes that detections are independent of each other at each location and that species are identified correctly. The multi-season model allows for immigration and emigration between defined seasons but not during a season (MacKenzie et al. 2006). The multi-season occupancy model essentially functions as an open population model between seasons but a closed population model within the season. No immigration or emigration was assumed to take place during the 4 day trapping season, but was allowed between the seasons.

Hypothesis formulation and model building was based on research on landward habitat characteristics of the small mammal species used in this study (Whitaker et al. 1998, Pederson et al. 2003, Kruchek 2004, Cameron and Kruchek 2005, Cameron and Spencer 2008). All combinations of covariates were not considered for analyses. This method of model building was not completely a priori as this was a partially exploratory study and included insight gained from previous analyses of the data periodically throughout the study. However, this method should also not be considered complete data dredging as covariates and their effects on the study species were considered before model construction based on non-insular habitat associations and field observations. Further, Burnham and Anderson (2002) suggest in their book that using an information-theoretic approach may function better for exploratory analyses than traditionally used hypothesis testing. The model building method used in this study fell somewhere between the ideal all a priori model development and the scourge of data dredging.

I used a bottom up approach to model building within program PRESENCE. Custom models were built in the Design Matrix in PRESENCE. I first constructed a null

model with all model terms set as constant. I then modeled detection probability, inserting and alternating covariates and comparing the results to the AIC from the null model. Covariates were then added to the occupancy and colonization parameters until all logical combinations had been explored.

The “best” model or models were chosen for inference by evaluating the change (Δ) in Akaike’s Information Criterion (AIC) between models, the model weight, and by examining model output. Models with a Δ AIC of 2 or less were considered to have substantial support following guidelines set by Burnham and Anderson (2002). Model outputs were examined to determine if there were any computing errors (“Numerical convergence was not reached.”) or spurious parameter estimates. When there was support for multiple models, combined model weights were used to identify and provide additional support for important common covariates. AIC was used instead of the AIC_C correction for small sample size. Inference was made about occupancy on the 12 islands, as well as within island habitat patches ($n = 120$). Detection probabilities were modeled for each trap. For these occupancy models, the sample size varied between occupancy and detection probability and between island covariates and the single patch covariate, vegetative structure. This “effective sample size” problem was described by MacKenzie et al. (2006). The result of using AIC instead of AIC_C , was that more complex models could be ranked higher than they should be.

There was no goodness of fit test available for multi-season occupancy models at the time of writing. However, in an attempt to explore the fit of the multi-season occupancy models, additional single-season models were run. MacKenzie and Bailey (2004) developed a goodness of fit test for single-season occupancy models. This test

was based on bootstrapping detection histories and assigning X^2 values based on the difference between the number of observed unique histories versus the number of simulated histories. An overdispersion factor (\hat{c}) was also calculated. \hat{c} values close to 1 indicate a well fit model, while values greater than 1 indicate overdispersion and values less than 1 indicate underdispersion. If a model had a significant chi-square value and high overdispersion factor, the \hat{c} estimate was inflated in the model and QAIC was used for model selection.

Single-season occupancy models were also run for the 2 most widespread species, hispid cotton rat and marsh rice rat, to provide additional support for the multi-season models. The 13 month study was divided into 4, 3 month seasons. The seasons were spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February). A single month during each season was chosen as representative of the season. Months were chosen based on the number of detections for each species. A minimum of 7 detections during a month were needed to successfully model occupancy. When detections were fewer than 7, and even some greater than 7, model outputs tended to estimate very high occupancy rates. These high occupancy rates were driven by low detection probabilities resulting from a low number of detections. Due to these spurious results, if a season contained no month with sufficient detections to allow modeling, single-season occupancy modeling was not performed and occupancy deemed inestimable. The single month with the highest number of detections was chosen as representative for that season.

Goodness of fit for both the most global model and the top model single-season models were determined. The seasonal models were compared to the original full study multi-season model to assess possible model fit. In addition, \hat{c} was adjusted within program PRESENCE for the multi-season full study model to assess the “best” model’s sensitivity to overdispersion. \hat{C} was increased in 0.5 increments until the model order was changed. If the “best” model did not change position until \hat{c} was increased > 4.0 , that model was considered fit to the data. Burnham and Anderson (2002) stated that \hat{c} should not exceed 4 for real data due solely to overdispersion. I did not find any report of a $\hat{c} \geq 4$ in background research, so it was assumed that if a model did not change in rank with such a high degree of overdispersion, that model was sufficiently insulated from overdispersion.

Covariates were used in the model to test hypotheses regarding island and habitat characteristics which may have influenced small mammal occupancy. Covariates used to assess occupancy were island distance from shore, method of construction, presence of heavy grazing, lake location, density of red imported fire ant mounds, island size, and vegetation structure. The predator occurrence index was not used in the occupancy models. Predator occurrence was assumed caused by small mammal occupancy, not a causative factor of small mammal occupancy. Red imported fire ant mound densities were determined for each island in methods described in Chapter 3. Covariates used to assess island colonization were distance from shore and lake location. Detection probability covariates were vegetation structure, average daily temperature, and presence of vegetative trap coverage. Traps were either recorded as

covered by living vegetation or not when deployed and kept in the same location throughout the 4 day season. No interaction variables were used in these models.

The top 5 occupancy model outputs run for the multi-season and single-season models are reported in Appendix B. An example output could appear as $\psi(D+LL)$, $\gamma(\cdot)$, $p(VH)$. This model indicates that for this species, occupancy (ψ) differs by the combined effect of distance from shore and lake location, colonization (γ) is constant across all sites and times, and detection probability (p) differed by vegetative height category.

Results

There were 378 total captures in 6240 trap nights along the small mammal transects from March 2008 through March 2009. Capture success (number of captures/number of trap nights) was 6.06%. A total of 4 small mammal species were captured on the small mammal transect. The hispid cotton rat (*Sigmodon hispidus*), marsh rice rat (*Oryzomys palustris*), and house mouse (*Mus musculus*) were the most commonly captured small mammal species and were the only species with sufficient captures to allow analysis. A single Southern least shrew (*Blarina carolinensis*) was also captured on Island 12 but was not included in analyses due to the singular capture. The Sherman traps used in this study are usually not sensitive enough to capture diminutive shrews, nor are they baited for shrew capture. Therefore, shrew captures are purely coincidental. A single cotton mouse (*Peromyscus leucopus*) and 3 Eastern woodrats (*Neotoma stephensi*) were captured on the islands prior to 2008 and were included in the islands species list but not in any analyses (Appendix A).

Island 15 had the highest number of captures with 129 captures. Island 20 had 48 captures while Island 17 had 47 captures. Islands 4 and 14 had the lowest number of

captures. There was only a single capture on Island 4 and only 5 captures on Island 14. The total number of captures by island is shown in Figure 2-1. The 3 most commonly trapped small mammal species total number of captures for each island was shown in Figure 2-2.

The total number of small mammals trapped by island was analyzed to determine any possible correlation with vegetation richness or predator occurrence on the islands. Neither the total number of small mammal captures nor species richness showed any correlation with island vegetation richness or the predator index. Total small mammal captures was not correlated to vegetation richness ($r^2 = 0.0119$, $P = 0.736$) or the predator index ($r^2 = 0.0001$, $P = 0.9776$). Small mammal species richness also was not correlated to vegetation richness ($r^2 = 0.0601$, $P = 0.1494$). Small mammal species richness was significantly correlated to the predator index ($r^2 = 0.2464$, $P = 0.0021$).

Hispid Cotton Rat

The hispid cotton rat was the most commonly captured small mammal with 275 captures. Hispid cotton rats were trapped in every month of the study, with the majority of captures during March and April of 2008. Island 15 had the most hispid cotton rat captures with 55 followed 47 captures on Island 20 and 44 captures on Island 17. Juvenile cotton rats were captured on all islands where adults were captured except Island 19. Hispid cotton rats were captured on all islands except Islands 4 and 14.

Full study multi-season occupancy

The top model for the Hispid Cotton Rat set occupancy as a factor of vegetation height, colonization a factor of lake location, and detection probability constant over both time and site. The second model also set occupancy a factor of vegetation height,

but colonization and detection probability were both constant over time and site. Both top models indicated occupancy was related to vegetation height and had a combined model weight of 0.64 supporting vegetation height as an important factor in hispid cotton rat occupancy. The top model showed some sensitivity to overdispersion. When \hat{c} was increased to 1.5, the second model became the top model and remained the top model until the overdispersion factor was increased well over 10. For this reason, occupancy estimates from the second model were presented here. Occupancy was set as a function of the number of vegetative height categories present in a 5 m radius around the trap location. Occupancy ranged from 0.2005 ($SE = 0.035$, 95% CI 0.1404, 0.2779) for locations with 4 height categories to 0.4144 ($SE = 0.0133$, 95% CI 0.3886, 0.4406) at patches with only a single height category (Figure 2-3). No Hispid Cotton Rats were captured in locations with all 5 vegetative height categories. These patches were only found on Island 5 which had only 2 cotton rats captured the entire study, neither in a patch with all 5 height categories. Occupancy was not estimated at patches with all 5 height categories. The top model set colonization as a function of lake location while the second model set colonization as constant. The increase in AIC weight by including the lake location covariate into the colonization parameter of the model was only 0.0161. In addition, the 5th ranked AIC model (ΔAIC 3.4) with occupancy and detection set as constant and colonization a function of lake location only had a weight of 0.0603. I presented colonization estimates from the second model (γ (.)) due to the low weight attributed to this covariate. Colonization for the second model was constant and estimated at 0.0865 ($SE = 0.0118$, 95% CI 0.0660, 0.1125). Detection probability was

set as constant over both season and site. Detection probability was estimated at 0.1795 ($SE = 0.0153$, 95% CI 0.1514, 0.2114).

Spring single-season occupancy

The month of April was chosen for the spring single-season occupancy model because it had the most captures. The top AIC ranked model set occupancy as a function of an islands distance from shore and detection probability as a factor of vegetation height. The most global model for this month had a non-significant X^2 value ($P = 0.5694$) and a low \hat{c} value (0.8528) indicating fit to the data and all more parsimonious models from this dataset also fit. The top model had a non-significant X^2 value ($P = 0.5724$) and a low \hat{c} value (0.8598) indicating no overdispersion. Occupancy was modeled as a function of island distance from shore with the closest islands having an estimate of 0.5 ($SE = 0$, 95% CI 0.5, 0.5) and the farthest island estimated at 0.1401 ($SE = 0.0796$, 95% CI 0.0427, 0.373) (Figure 2-4). Four islands were measured at 0 m distance from shore. During this month, cotton rats were captured in 15 of the 40 traps on these islands. A single island had no detections while another had 16 detections in 8 of the 10 traps. The estimate of 0 for the standard error for these islands may have been caused by the discrepancy between the 2 islands, 1 with many detections and 1 with no detections. Detection probability was modeled as a function of vegetation height. The highest detection probability (0.4307, $SE = 0.0163$, 95% CI 0.3991-0.463) was found in patches with only a single vegetative height category. The lowest detection probability (0.2469, $SE = 0.0495$, 95% CI 0.1628, 0.3558) was found at patches with 4 vegetative height categories.

Summer single-season occupancy

The summer season top AIC model was the most global model and was fit to the data indicated by a non-significant X^2 (0.2837) statistic and \hat{c} value close to 1 (1.0985). This model was the top AIC model by a Δ AIC of 11.18. Having the most global model selected by AIC as the top model over all more parsimonious models indicated that during the summer season there may be an important covariate not identified by this study. The model output indicated that maximum likelihood estimates could not be approximated to the default of 7 significant digits. Hines (2006) presented a guideline that if the number of reported significant digits was >3 , the results would probably be accurate, between 1 and 3 the results should be treated with caution, and <1 the results should be ignored. The model output reported 0.04 significant digits indicating that the results from this model should be ignored. For this reason, the results from this model were not presented. However, the third, fourth, and fifth top models set occupancy as a function solely of island distance from shore following the other single-season models.

Fall single-season occupancy

The top model for the month of November modeled occupancy as a function of distance from shore and detection probability as constant over time and site. The most global model for this month had a non-significant X^2 value ($P = 0.4316$) and a low \hat{c} value (0.6481) indicating this model fit the data and all more parsimonious models from this dataset also fit. The top model had a non-significant X^2 value ($P = 0.4785$) and a low \hat{c} value (0.4659) indicating no overdispersion for this model. The top 4 models all included distance as a covariate for island occupancy. The top model had an AIC weight of 0.3705, almost twice the weight of the second ranked model. Occupancy on the closest islands were estimated at 0.5 ($SE = 0$, 95% CI 0.5, 0.5) and the farthest

island estimated at 0 ($SE = 0$, 95% CI 0, 0.9929). Four islands were measured at 0 m distance from shore. During this month, cotton rats were captured in 3 of the 40 traps on these islands. Two islands had no detections and there were only 4 detections on the other 2 islands. The estimate of 0 for the standard error for these islands may have been caused by 2 of the 4 islands at this distance having no detections, while the other 2 islands had detections. Detection probability was modeled as constant and estimated at 0.0627 ($SE = 0.0264$, 95% CI 0.027, 0.1389).

Winter single-season occupancy

The top model for hispid cotton rats during the month of January set occupancy as a function of distance from shore and detection probability as a function of mean daily temperature. The most global model for this month had a non-significant X^2 value ($P = 0.5305$) and a low \hat{c} value (0.5255) making this model fit to the data and all more parsimonious models from this dataset also fit. The top model had a non-significant X^2 value ($P = 0.5964$) and a low \hat{c} value (0.4308) indicating no overdispersion for this model. The top AIC ranked model had an AIC weight of 0.17. The top 4 models all indicated distance as the only covariate for occupancy, differing only by covariates used for detection probability. The combined weight of the top 4 models was 0.56 providing support for distance as an important factor for occupancy. Occupancy on closest islands were estimated at 0.5 ($SE = 0$, 95% CI 0.5, 0.5) and the farthest island estimated at 0.0467 ($SE = 0.0697$, 95% CI 0.0023, 0.513). Four islands were measured at 0 m distance from shore. During this month, cotton rats were captured in only 3 of the 40 traps on these islands with 4 total detections. The estimate of 0 for the standard error for these islands may have been caused by the low number of detections and 0 detections on 2 of the 4 islands at this distance. Detection probability was modeled as a

function of temperature with the lowest probability estimated at 0.0601 ($SE = 0.0232$, 95% CI 0.0278, 0.1251) which coincided with the highest average daily temperature. The highest detection probability was 0.123 ($SE = 0.0316$, 95% CI 0.0732, 0.1995) which coincided with the lowest average daily temperature.

Marsh Rice Rat

The marsh rice rat was the third most commonly captured small mammal with 44 total captures, but the second most widespread small mammal occupying all islands except Islands 10, 12, 19, and 22. Marsh rice rats were captured in every month with a majority of captures occurring in March of 2008. Island 15 had the most captures with 20 followed by Island 5 with 10 captures. Juvenile rice rats were captured on Islands 3, 4, 5, 15, and 17.

Full study multi-season occupancy

The full study multi-season top model set marsh rice rat occupancy as a function of lake location and both colonization and detection probability constant over both time and site. This full study multi-season model remained the top model until \hat{c} was changed to 4.5 indicating probable model fit. The lack of captures was the most probable reason for any potential lack of model fit. The second ranked AIC model (Δ AIC 0.95) differed from the top model only by including island construction in addition to lake location as covariates in the occupancy parameter. The combined model weight for these models was 0.798. This provides significant support to lake location being an important determinant for marsh rice rat occupancy on these islands. Parameter estimates from the top model were presented below. Occupancy was estimated as a function of lake location. Occupancy was highest in the Brown's Point location estimated at 0.6645 ($SE = 0.1495$, 95% CI 0.3473, 0.8806). The Goblet's Cove area

had the second highest occupancy rate estimated at 0.388 ($SE = 0.1084$, 95% CI 0.2057, 0.6081). The lowest occupancy estimate was in the Lanier Point area was estimated at 0.0497 ($SE = 0.0492$, 95% CI 0.0067, 0.2873). No marsh rice rats were captured in the Whaley's Landing area so no occupancy estimates were reported (Figure 2-5). Colonization and detection probabilities were modeled as constant over both time and site. Colonization was estimated at 0 ($SE = 0.0462$, 95% CI 0.0, 1.0). This extremely large confidence interval indicates a modeling error probably due to the very low colonization estimate. Detection probability was estimated at 0.0250 ($SE = 0.0054$, 95% CI 0.0163, 0.038).

Spring single-season occupancy

The top model for the month of March, modeled marsh rice rat occupancy as a function of lake location and the size of an island and detection probability as constant over time and site. The top AIC ranked model was chosen as the best model. This model had 0.568 of the AIC weight and was ΔAIC 2.54 above the next model. The most global model for this month had a non-significant X^2 value ($P = 0.1009$) but a high \hat{c} value (1.6168) indicating possible overdispersion and a lack of fit for this model. \hat{c} was adjusted to value indicated by the global model QAIC was used for model selection. The best model had a non-significant X^2 value ($P = 0.0699$) and a high \hat{c} value (1.7224) indicating overdispersion in this model. The standard errors were inflated by $\sqrt{\hat{c}}$ (1.27) to account for the overdispersion (Mackenzie and Bailey 2004). Occupancy, modeled as a function of an islands lake location and size, was estimate highest in the Brown's Point area and was inversely related to island size having higher occupancy on smaller islands. The highest occupancy was on Islands 14 and 15 estimated at 0.4296 ($SE = 0.1455$, 95% CI 0.1904, 0.7069) (Figure 2-6). The lowest

occupancy occurred in the Whaley's Landing and Lanier Point areas. There were no marsh rice rat captures in these areas during this month and detection probability was inestimable. Detection probability was modeled as constant and estimated at 0.3042 ($SE = 0.0844$, 95% CI 0.1667, 0.4886).

Summer, fall, and winter single-season occupancy

Occupancy could not be estimated for the summer season or fall seasons due to a lack of detections. There were only 2 marsh rice rat detections during the 3 month summer season. Both of the detections were during the month of August. There were only 3 detections during the moth fall season. The winter season yielded 11 total detections for the 3 month period. However, the occupancy model for January (6 detections) yielded spurious results and so was not reported. At least 7 detections in a month were required for this study to obtain reasonable single-season model results.

House Mouse

The house mouse was the second most commonly captured small mammal species with 60 total captures. The house mouse also had the most restricted range being only captured on 4 islands during the entire study. House mice were trapped on Islands 12, 14, 15, and 19. The majority of house mice were trapped on Island 15 with 54 captures. Three house mice were trapped on Island 12, with 2 captures on Island 19 and a single capture on Island 14. House mice were trapped in all months except February 2009 with the majority trapped in June and August of 2008.

Only the full study multi-season model was presented for the house mouse. This mouse was only trapped on a single island, Island 15, in numbers sufficient to estimate occupancy. This analysis was only based on a single island with 10 trapping locations. The results are presented here to inform any future studies on the islands of a

preliminary occupancy estimate and associations with detection probability. Single-season models were not run for this species.

Patch occupancy for the House Mouse was only modeled on Island 15. Although the mouse was captured on several islands, only Island 15 yielded enough captures to attempt occupancy modeling. The top multi-season full study model for the house mouse set occupancy and colonization as constant over time and site and detection probability as a function of both average daily temperature and occurrence of vegetative trap coverage. This model remained the top model until \hat{c} was changed to over 2.5. With a \hat{c} greater than 2.5, this model became the third best model with a Δ QAIC of only 0.3. A Δ QAIC of only 0.3 indicates a very low difference between this and the new top model. However, this change due to probable over dispersion of data may indicate either a lack of fit for this multi-season full study model or too few captures needed for a more robust model. Occupancy was estimated at 0.3313 ($S = 0.0614$, 95% CI 0.2235, 0.4602). Colonization was modeled at 0.2988 ($S = 0.0677$, 95% CI 0.1845, 0.4453). Detection probabilities ranged from 0.1292 with the lowest temperature at a trap directly covered with vegetation to 0.9397 with the highest temperature at a trap not directly covered with vegetation (Figure 2-7). The top 2 models both set detection probability as a function of temperature and vegetative trap coverage. The models had the same AIC and model weight. The difference between the models was that number vegetation height categories was a covariate in the occupancy parameter of the second model while the top model set occupancy as constant. The combined weight of these 2 models was 0.505 supporting that detection probability was a function of both temperature and vegetative trap coverage.

Discussion

This was primarily an exploratory study researching species typically overlooked on spoil islands. Burnham and Anderson (2002) recommend not publishing results from exploratory studies. In an ideal world, there would be money and time available for the original researchers to conduct further investigations into causal relationships found in their models. However, when further, more in depth research will be passed on to other scientists in the future, the results and insight provided from exploratory studies needs to be shared to avoid wasting time and money and advance scientific inquiry. In addition, research conducted in response to rarely occurring management actions (i.e. Extreme habitat restoration and freshwater in-lake spoil island creation) or natural phenomena may not have the ability to utilize a priori models for model construction. These studies still provide valuable knowledge to the scientific community and should be published when appropriate. Island inferences made from this study were hampered by the small sample size ($n = 12$), but the larger number of re-samples (13) provide support by drawing from data taken at many different times over a long times frame (1 year). Further, the models selected for inference about the system agreed with the raw data and field observations.

Small mammals have been linked to predator fluctuations in other systems and were correlated with alternative prey species. Brook et al. (2005) found a positive correlation between rodent abundance and lesser scaup (*Aythya affinis*) productivity in boreal forests based on alternative prey theory (Angelstam et al. 1984). Other studies have linked rodent abundances to waterfowl nest success (Pehrsson 1986, Ackerman 2002). I hypothesized that total small mammal captures by island and small mammal species richness would be correlated to higher observations of predators due to the

rodents attracting predators from the shoreline onto the islands. Due to the hypothesized attraction, other prey species on islands with high rodent numbers could be impacted by the higher number of predators. This study found no correlation between total number of small mammal captures and predator observation index. Small mammal species richness was correlated with the predator index ($r^2 = 0.2464$) indicating a higher number of predators on islands with higher small mammal species richness. This correlation was very small explaining only 25% of the data, indicating the predators are drawn to the islands for reasons in addition to hunting for small mammals. However, this study may have inadequately sampled the small mammal predator community using herpetofaunal traps that may have been more selective to smaller snake species and relying on mammalian predator sign to identify larger predators. The soil on the spoil islands is very sandy making for a poor tracking substrate and the chance of discovering a scat is slim. In addition, a multi-year study may be needed in order to sufficiently determine whether or not any correlation exists on the spoil islands between rodent and predator populations. The possible correlation between predator and small mammal occurrence may have an effect on island nesting success for ground nesting species and should be researched further if providing productive nesting area is a goal of island creation.

Hispid Cotton Rat

The hispid cotton rat is found predominantly in grass dominated habitats. It feeds primarily on grasses and other green vegetation, but is known to occasionally take the eggs of ground nesting birds. The hispid cotton rat is active during both day and night. The hispid cotton rat is the largest of the small mammal species studied on the spoil islands. The rat averages around 270 mm total length and weighs from 80-150 g.

Hispid cotton rats trapped on the islands weighed from 37-250 g. The average life span for the rats is approximately 6 months. Home ranges are generally 0.2-0.4 ha in size and densities of 25-30/ha are common, but have been recorded at 69/ha (Whitaker et al. 1998). The average size of a spoil island in this study was 1 ha making it possible to have between 25 and 69 hispid cotton rats on an island.

Neither the total number of small mammals captured nor small mammal species richness were correlated with vegetation richness. Garden et al. (2007) found that small mammal occurrence was primarily influenced by habitat structure, including vegetative structure, and less so by vegetative diversity. The full study multi-season model for the hispid cotton rat indicated that this species occupancy was associated with vegetation structure. This species favored less structurally diverse patches over more complex patches. Occupancy was estimated highest in patches with a single vegetative height category and lowest in patches containing vegetation heights from 4 categories (Figure 2-3). The higher occupancy rate found in less structurally diverse habitat patches most likely could be attributed to predator avoidance on the islands. More complex patches generally exhibited a more open understory allowing light penetration and the development of different levels of vegetation heights. Cameron and Spencer (2008) found that female hispid cotton rats avoided habitat patches with bare ground most likely due to predator avoidance. Open sight lines associated with open understory vegetation may allow easier hunting by avian and ground predators. The more open understory may not provide the level of cover favored by hispid cotton rats. Thicker vegetation generally prevented the formation of several vegetative height categories, but may have provided a more secure habitat for the rats.

Single-season occupancy models for the spring, fall, and winter found hispid cotton rat occupancy solely a function of an islands distance from shore (Figure 2-4). The summer season model also indicated that occupancy was a function of an islands distance from shore, but was not the only factor. As indicated by these models, hispid cotton rat occupancy was highest on islands that became peninsulas during periods of low water (0 m distance from shore) and lowest at the farthest island distance (500 m distance from shore). During the summer and winter seasons, there was a pronounced drop in occupancy between islands 80 m and 200 m from shore. This may indicate a barrier to island colonization for hispid cotton rats occurring between 80 m and 200 m from shore. However, the farthest islands were still colonized by hispid cotton rats. Hispid cotton rats are typically an upland grassland species not as well suited to wetland habitat and should have higher occupancy on more proximal islands as was confirmed by this study.

The multi-season and single-season models did not agree on the habitat factors responsible for hispid cotton rat spoil island occupancy. The most probable explanation for the discrepancy was the number of detections and trapping seasons included in the models. Single-season models were based on months the months with the most detections while multi-season models incorporated both high detection months and low detection months (from a high of 64 to a low of 2 detections in a month). The multi-season model also allowed for the inclusion of captures on islands that may have yielded no detections or very few during the single-season 4-day trapping period. Both vegetation structure and island distance from shore were found to affect hispid cotton rat occupancy of the spoil islands. Island distance from shore may indicate a barrier to

colonization as a function of swimming distance required and vegetation structure may indicate the most likely patches a cotton rat is to be found on occupied islands.

Marsh Rice Rat

The marsh rice rat is found predominantly in wet meadows and marshes. It feeds mainly on green vegetation and seeds as well as fungi, fruit, snails, crustaceans, and insects. This rat is an accomplished swimmer and is primarily nocturnal. The marsh rice rat is the second largest rodent species studied on the islands. The average total length for the marsh rice rat is 245 mm, with weights ranging from 40-68 g. Marsh rice rats trapped on the spoil islands weighed from 53-110 g. The average life span is around 1 year. Home ranges are generally 0.23-0.37 ha in size and densities around 10/ha are common, but can exceed 50/ha (Whitaker et al. 1998). The average size of a spoil island in this study was 1 ha making it possible to have between 10 and 50 marsh rice rats on an island.

The majority of marsh rice rat captures (19, 43%) occurred during the first month of trapping, in March 2008. Captures then fell dramatically during the summer (2 captures) and fall (3 captures) seasons and never recovered to the level of the initial month's success. This decrease in number of captures could be attributed to several causes including trap aversion, shifts in home range or foraging area towards the island fringe due to dry upland habitat and vegetation senescence, or local population declines. This study could not verify any of the causes for this large decrease in captures after the first month. A multi-year study may be needed to identify the cause of this shift.

The full study multi-season model identified marsh rice rat occupancy of the spoil islands as a function of lake location with the highest occupancy in the Brown's Point

and Goblet's Cove areas and the lowest in the Lanier Point and Whaley's Landing areas (Figure 2-5). There were no rice rat captures in the Whaley's Landing area and only 2 captures in the Lanier Point area. The spring single-season model also indicated occupancy as a function of lake location. These models well supported the data indicating that rice rat occupancy on the islands was mostly determined by the existence of a shoreline population capable of colonizing local islands and less a function of island characteristics. The semi-aquatic nature of the marsh rice rat makes it an excellent candidate for island colonization wherever it occurs. The lack of detections in 2 of the 4 areas may indicate a small population along the shorelines in those areas. The single-season model was assessed for fit and showed some degree of overdispersion ($\hat{c} = 1.742$). The multi-season model showed some insulation from an increased overdispersion factor remaining the top model until \hat{c} was elevated to 4.5, much higher than the single season indicated. This may have indicated a well fit multi-season model. Both models indicated that none of the modeled detection covariates had any effect on marsh rice rat detection probability.

The spring (March) seasonal occupancy model indicated higher marsh rice rat occupancy on smaller islands (Figure 2-6). Trapping effort was concentrated in the central, upland portion of the island. The trapping transect on smaller islands was in closer proximity to the wetted fringe more typical of marsh rice rat habitat. Martin et al (1991) found habitat partitioning between marsh rice rats and harvest mice along levees in coastal marshes. Marsh rice rats were captured more frequently on levee edges than on the tops of levees. Rice rats and hispid cotton rats may present similar habitat partitioning on the spoil islands with cotton rats occurring in greater numbers in the

central island area and rice rats higher in number near the wetted fringe. Cameron and Kruchek (2005) found a negative correlation between hispid cotton rat and marsh rice rat densities in coastal wetlands in Texas. Marsh rice rats had higher densities in wetland areas while hispid cotton rats had higher densities in upland areas. This would reasonably explain the rice rat association with smaller islands where the trapping transect would more likely cross into habitat frequented by rice rats. This could also explain the much higher number of detections for hispid cotton rats. The trapping effort was concentrated in upland habitat typical of hispid cotton rat occurrence, not marsh rice rat.

House Mouse

The house mouse is an introduced species from Europe now found worldwide. The mouse can be found in a variety of habitats and can swim, climb, and jump well. The diet is variable, consisting of nearly anything edible. The house mouse is mainly nocturnal. The average life span for house mice is around 2 years. The mouse averages 169 mm total length and weighs from 17 to 25 g. House mice captured on the islands weighed from 10 to 63 g. Home ranges are generally 0.6 ha and population densities are variable, recorded as high as 1235-205,000/ha. (Whitaker et al. 1998).

House mice were the most geographically restricted island rodent species on the spoil islands of Lake Tohopekaliga. The mice were found on only 4 islands with 90% of the captures on a single island, Island 15. For this reason, multi-season occupancy was only estimated on Island 15. The lack of island colonization by this mouse may indicate low abundances on the adjacent shorelines or relatively recent island colonization that may increase in the future.

The full study multi-season model indicated house mouse patch occupancy on Island 15 was not a function of vegetation height class. Vegetation height class was the only covariate used for modeling occupancy as the other covariates differ between islands, not individual site. The multi-season model showed some sensitivity to overdispersion becoming the second best model when \hat{c} was increased to 2.5. However, the original top model only decreased by ΔQAIC of 0.3 still indicating support for the model.

Temperature was found to be an important covariate for house mouse detection probability. The full study model (Figure 2-7) indicated a positive correlation between mean ambient air temperature and detection probability. Most of the detections (69.8%) occurred during the summer and fall seasons with the lowest number of detections occurring during the winter (0.9%). House mice may move around more in warmer temperatures. This would reasonably explain the lack of detections during the winter season when temperatures are lowest. The mice may simply move around less during cold temperatures, decreasing the probability of capture. House mouse detection was also related to vegetative trap cover. Detection probability for the house mouse may change with additional seasonal influences not identified in this study causing the overdispersion in the multi-season model.

Colonization

Colonization for the 3 small mammal species studied was not influenced by either island distance from shore or lake location. Colonization may be influenced by other covariates not measured in this study such as the productivity of local shoreline and nearby island populations. Hispid cotton rat colonization was estimated at 8.65%. Marsh rice rat colonization was estimated at 0%. No colonization for this species may

indicate an important covariate not identified in this study or a steady or decreasing rice rat population on the islands. House mouse colonization was estimated at 29.88% signifying either a growing or very dynamic population on Island 15.

Conclusions

Small mammals play an important role in ecosystem development in all systems in which they occur. Rodent species have been traditionally overlooked in spoil island research but may play a role in predator attraction, vegetation succession, and interspecies competition. Marsh rice rat occupancy on spoil islands was mainly a factor of shoreline population sources and less a factor of island characteristics. Island distance from shore was shown to decrease occupancy for the hispid cotton rat while more homogeneous vegetation heights were shown to increase occupancy. Presence of grazing by domesticated cattle, island method of construction, and density of ant mounds had no effect on occupancy rates for any of the species.

This small mammal study examined all available combinations of island types with replicates on Lake Tohopekaliga giving it strong internal validity. The design allows the results from this study to be used for management decisions for all islands in Lake Tohopekaliga due to the islands geomorphic similarity and the wide distribution of the species being considered. The results from this study could cautiously be applied to future island construction and management decisions on other lakes where small mammals, of the same or similar species, play significant ecological roles. Hulon et al (1998) estimated marsh rice rats having the highest abundances of small mammal species on spoil islands in Lake Jackson, FL. Rice rats on spoil islands in Lake Tohopekaliga were the third most commonly captured rodent. That study was only conducted on 2 islands but demonstrates the possible variation between wildlife around

different lake systems and the possible mix and composition of species colonizing spoil islands.

There is a need for more in depth research on small mammal ecology on spoil islands. A multi-year study should be conducted to assess both colonization and extinction during the boom and bust cycles common in rodent species. A long term study may determine the effects of a potentially increasing house mouse population on native rodents. In addition, a multi-year study including vegetation succession and predator occurrence data may better evaluate the relationship between island small mammal occupancy and these characteristics. This study did not evaluate island elevation effects on small mammal occupancy but should be incorporated in future research. Island elevation may play a role in occupancy by small mammal species. The higher the elevation, the farther from the water table the center of the island becomes which would effect vegetation types, access to water, and amount of vegetation cover. Marsh rice rat use of spoil islands, due to their affinity for wetter habitats, may be highly affected by island elevation. Spoil islands have increasingly been used in a variety of habitats, coastal, lake, river, and marsh, and will continue to be created into the future signaling a need to include other aspects of island ecology with the more traditional avian-centric research.

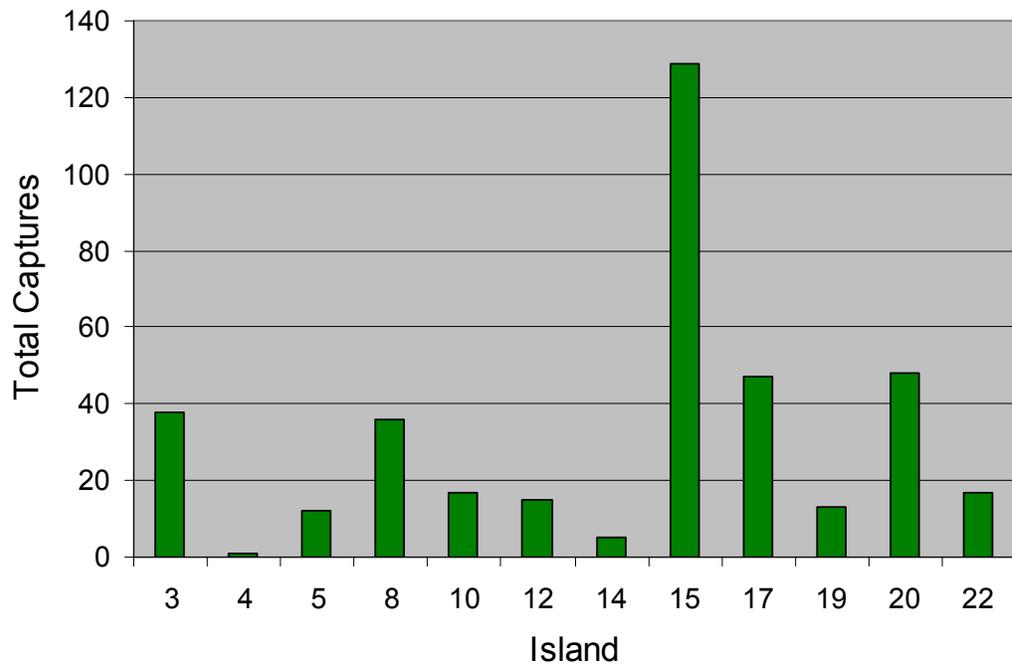


Figure 2-1. Total small mammal captures by island

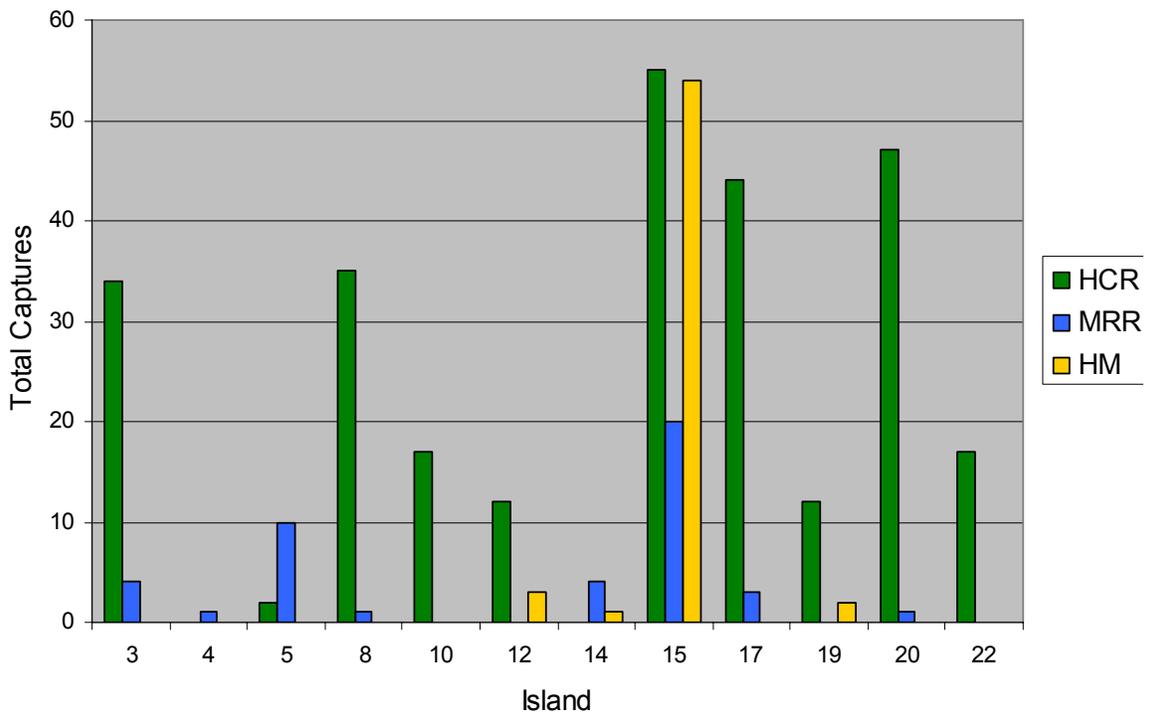


Figure 2-2. Total small mammal captures by species by island

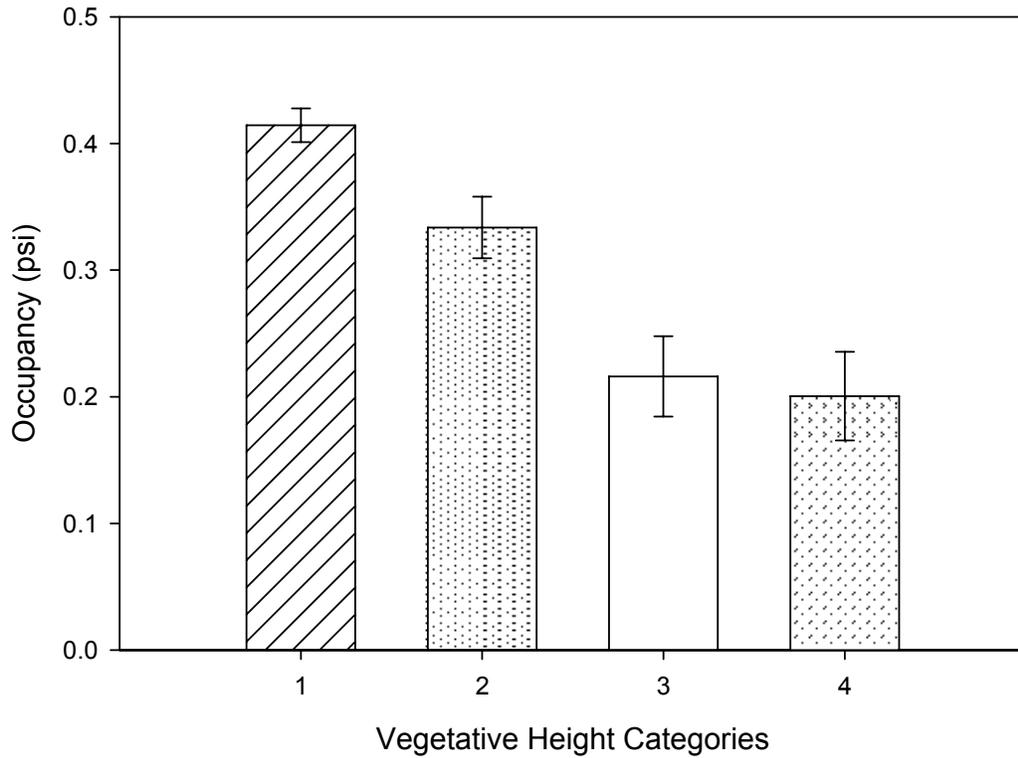


Figure 2-3. Hispid cotton rat occupancy estimates by number of vegetative height categories for the full study multi-season occupancy model

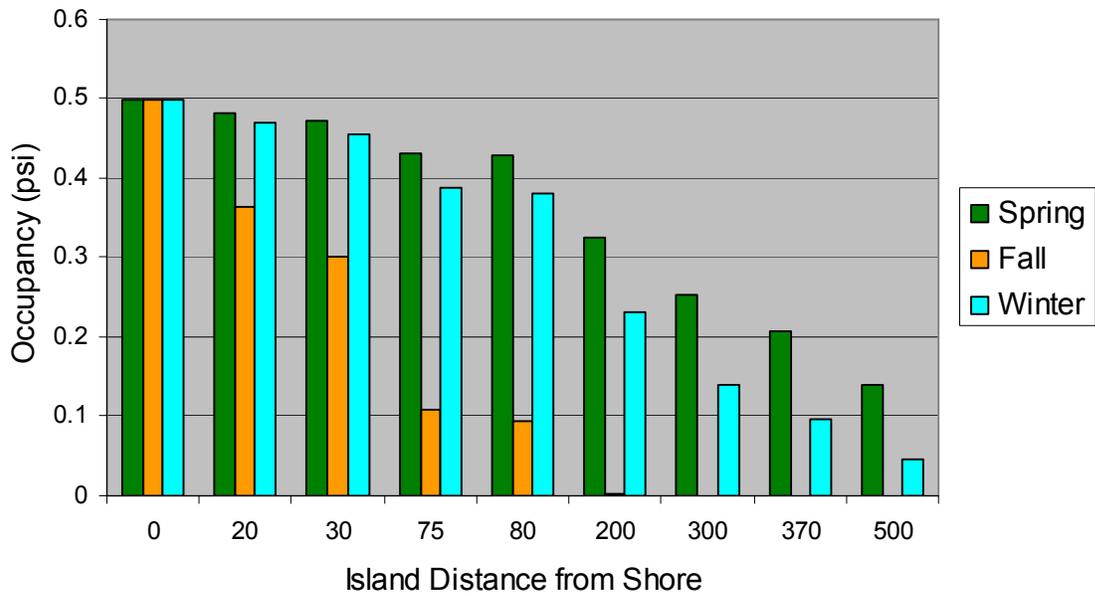


Figure 2-4. Hispid cotton rat seasonal occupancy by island distance from shore

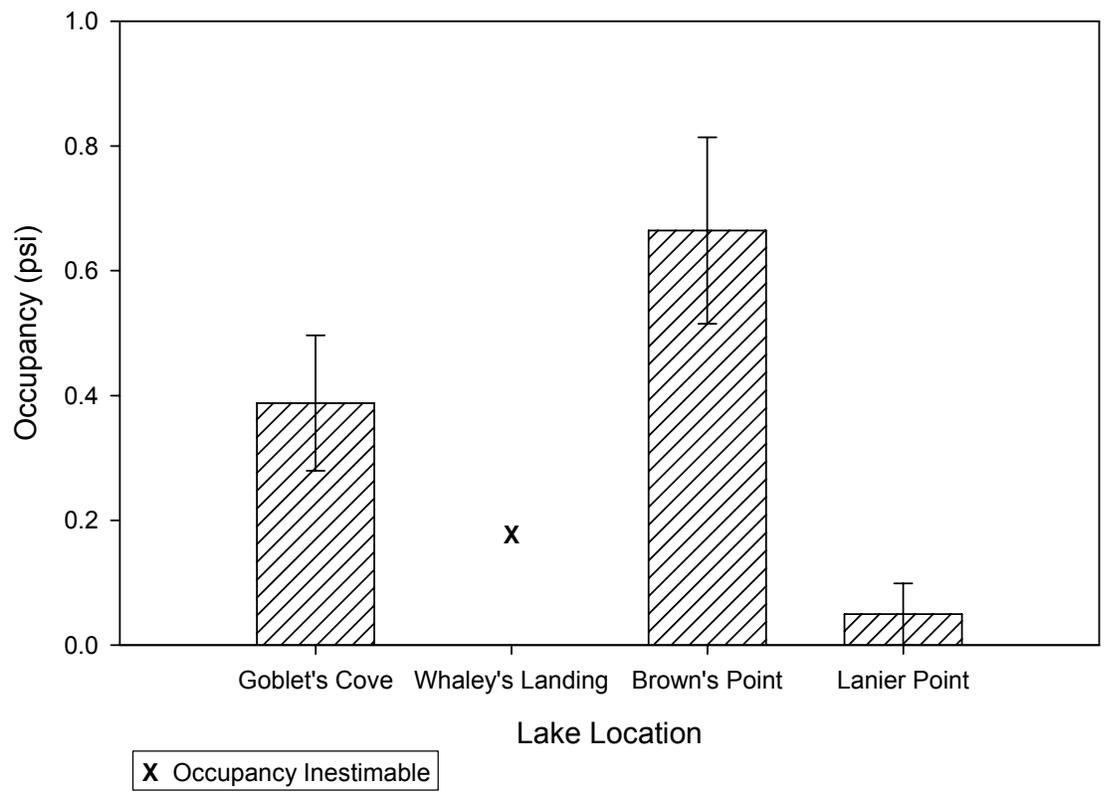


Figure 2-5. Marsh Rice Rat occupancy estimates by lake location for the full study multi-season model

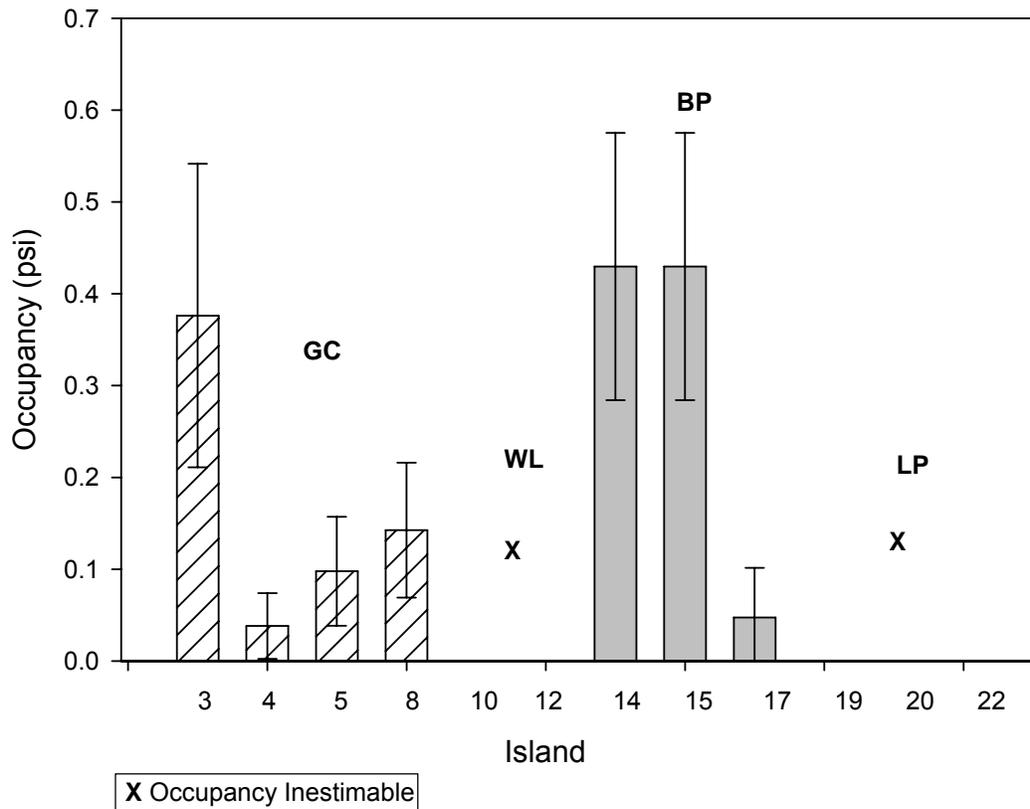


Figure 2-6. Marsh rice rat spring (March) occupancy by island lake location and island size. Occupancy was inversely related to island size. Occupancy could not be estimated for the Whaley's Landing or Lanier Point locations due to lack of captures. Lake locations:
 GC = Goblet's Cove (Islands 3,4,5,8)
 WL = Whaley's Landing (Islands 10,12)
 BP = Brown's Point (Islands 14,15,17)
 LP = Lanier Point (Islands 19,20,22)

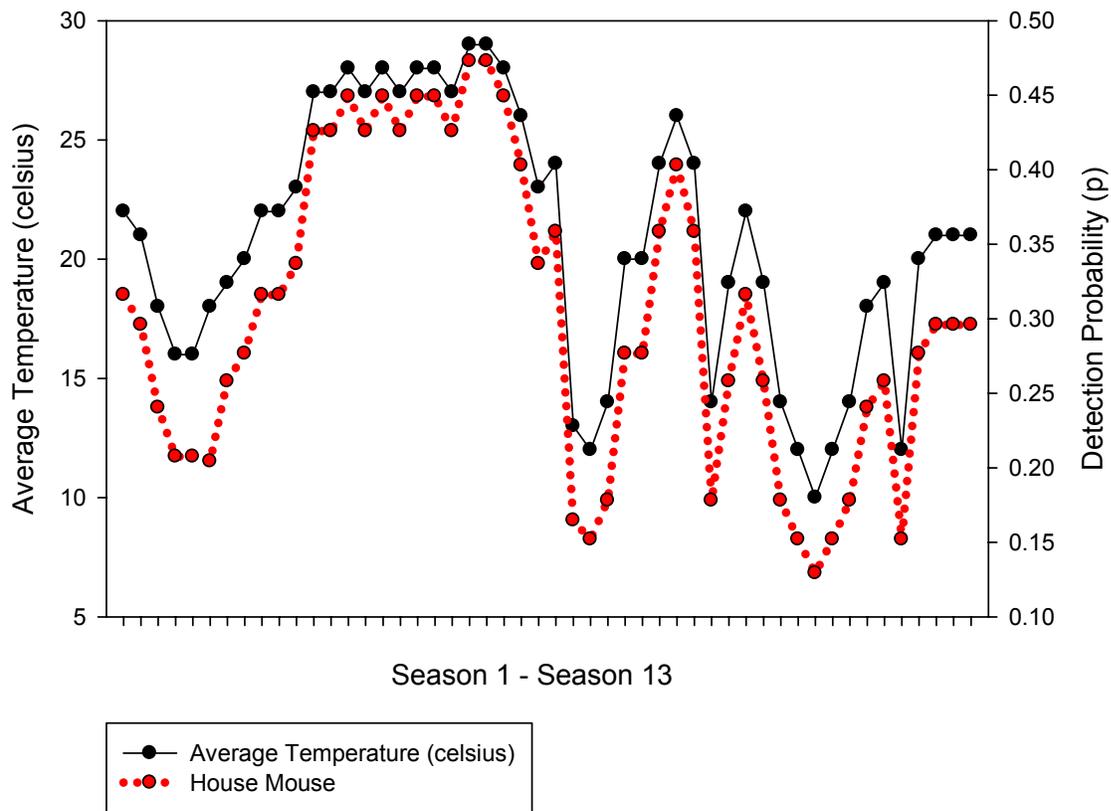


Figure 2-7. House Mouse detection probability by average daily temperature for the full study multi-season model

CHAPTER 3 RED IMPORTED FIRE ANT IMPACT ON SPOIL ISLAND WILDLIFE

Introduction

The red imported fire ant (*Solenopsis invicta*, fire ants) was first introduced into the United States during the 1930's. The ants entered the United States through the Port of Mobile, Alabama and spread throughout much of the Southeast and North into parts of Virginia and Maryland, and West from Texas into California. Polygyne fire ant colonies (multiple queen) were first noticed in the early 1970's and have since spread into Florida and other Southeastern states (Wojcik et al. 2001).

Since its introduction, fire ants have been reported to have a profoundly negative impact on native vertebrates (Wojcik et al. 2001, Allen et al. 2004). Fire ants have been implicated in population decreases and habitat and behavioral changes for birds (Allen et al. 1995, Giuliano et al. 1996, Smith et al. 2004), mammals (Lechner and Ribble 1996, Allen et al. 1997, Pedersen et al. 2003), and herpetofauna (Reagan et al. 2000, Allen et al. 1997, Smith et al. 2004).

Lake restoration activities are becoming increasingly common in Florida. Many of these restorations produce large amounts of spoil traditionally stored in upland areas away from the dredging site. Recently, the creation of in-lake dredge storage islands has gained favor amongst lake managers. These dredge spoil islands are usually labeled "wildlife islands". Fire ant densities and impacts on wildlife on spoil islands have not been previously studied. This study assessed fire ant mound densities on the spoil islands located in Lake Tohopekaliga, FL. Fire ants were encountered on all 12 of the study islands in seemingly high densities during the 2007-2009 study. With the expected increase in future creation of in-lake spoil islands in Florida and the large

impact fire ants have on wildlife, it is important to determine the effect of island characteristics on fire ant densities as well as any effect on island wildlife.

For this study, I examined the influence of spoil island characteristics of distance from shore, method of construction, presence of cattle grazing, and location within the lake in relation to fire ant mound densities. I also analyzed the possible influence fire ants may have over ground dwelling wildlife on the islands. I hypothesized that fire ant mound densities would be negatively correlated with distance from shore, but other island characteristics would have no effect on densities. I also hypothesized that total trap numbers for all wildlife species analyzed and island species richness would be negatively associated with fire ant mound densities.

Study Site

Lake Tohopekaliga is a 7612 ha freshwater lake located near the city of Kissimmee, FL. This is a shallow water, eutrophic lake at the northern extent of the Kissimmee Chain of Lakes. The lakeshore is primarily bordered by residential development and cattle grazed pasture. The northeastern shoreline is bordered by the city of Kissimmee, FL. The southern two-thirds of the lake is predominantly cattle pasture. The lake averages 2.1 m depth. In 2004, a large scale habitat restoration effort was initiated by the Florida Fish and Wildlife Conservation Commission. Restoration efforts included an extreme draw down and mechanical removal of thick stands of emergent vegetation and underlying organic muck. The majority of the dredge spoil was stored in-lake as spoil islands intended for use by wildlife and for storage of future dredge material and harvested vegetation.

Twenty-nine islands were constructed in-lake from the dredge spoil. Three main characteristics were used to describe and select the study islands. Those 3

characteristics were the islands distance from shore, method of construction, and presence of grazing by domesticated cattle. Geographic location of the islands was determined by the islands physical distance from the nearest shoreline. Laser rangefinders were used in the field to determine the actual distance of each island. Islands included in the study ranged from 0 m from shore, acting as peninsulas during low water levels, to 500 m from shore. For purposes of island selection, islands between 0 and 100 m were considered proximal islands and islands ≥ 200 m from shore were considered distal islands. There were no islands between 100 and 200 m from shore included in this study. Both construction method and presence of grazing was determined through direct observation on the islands. During construction, islands were either graded smooth or left in rough heaps of spoil material and identified as either smooth or rough respectively. Several of the islands were subjected to grazing by domesticated cattle as they occurred along shoreline pastures. These islands were identified as grazed while others were labeled as un-grazed. All measurements and classifications were made in May 2005 by the Florida Fish and Wildlife Cooperative Research Unit while the lake stage was at low pool, 16.07 m NGVD (National Geodetic Vertical Datum).

Twelve islands were pseudo-randomly selected for the study to include duplicates of all available combinations of the 3 main island characteristics. There were no distally grazed islands limiting island selection to 6 total combinations of island characteristics. The locations of Lake Tohopekaliga and the study islands are presented in Figures 1-1 and 1-2. The islands ranged in size from 0.73 ha (Island 3) to 1.21 ha (Island 17). The average island size of the 12 study islands was 0.94 ha with a standard error of 0.069

ha. Island sizes were taken from Hoyer et al. 2006. Islands were also grouped into lake locations based on their geographic distribution and labeled with commonly used location names. Islands were grouped into 4 locations. Goblet's Cove location consisted of Islands 3, 4, 5, and 8. Whaley's Landing location consisted of Islands 10 and 12. Brown's Point location consisted of Islands 14, 15, and 17. Lanier Point consisted of Islands 19, 20, and 22.

Island vegetation was variable, but characteristic of early successional habitat. Over 120 species were identified on the islands between 2007 and 2009. The most common vegetative species identified on the islands were para grass (*Bracharia mutica*), white twine vine (*Sarcostemma clausum*), dog fennel (*Eupatorium capillifolium*), water primrose (*Ludwigia* spp.), poke weed (*Phytolacca americana*), fireweed (*Erechtites hieraciifolius*), alligator weed (*Alternanthera philoxeroides*), wild water-pepper (*Polygonum hydropiperoides*), morning glory (*Ipomoea alba*), and Bermuda grass (*Cynodon dactylon*). Tree growth was primarily restricted to the islands wetted fringe and consisted predominantly of willow (*Salix* spp.). No islands included in this study had been planted or managed (Shoger et al. 2009).

Methods

Fire Ant mounds were surveyed during the summer of 2008. Fire ant mound abundance on the islands was surveyed following a modified circular plot design based on Brown et al. (1980). Two randomly chosen points on each island were selected using a grid overlay on aerial photos of the islands and a random number generator to produce point coordinates. Survey points were located on the islands by GPS and adjusted when needed so that all transects remained above the waterline. A 10 m length of rope was run from the central point in each of the 4 cardinal directions and all

ant mounds within a 1 m wide corridor along the length of the rope transects were counted. Sticks were used in areas of heavy groundcover to physically move and disturb the vegetation to aid in mound location. The total ant mound counts from each of the 2 plots per island were combined and the number of mounds/m² calculated.

Ground dwelling species indices by island, including herpetofaunal and small mammal species richness, total number of herpetofauna and small mammals trapped, and total number of the 5 most commonly captured ground dwelling species, were compiled from trapping results during the 2007-2009 Shoger et al. (2009) study. Small mammal trapping consisted of a 90 m transect consisting of 10 Sherman live traps set at 10 m intervals was set on each of the 12 study islands. Small mammal trapping took place monthly from March 2008 through March 2009. Traps were set for 4 days and checked each morning. Sherman traps were baited with a bird seed mixture and polyester batting was provided in colder months. All animals caught were identified to species, weighed, and then released at the point of capture. Herpetofaunal trapping consisted of a single drift fence array constructed on each of the islands in a "Y" shape. Each leg of the drift fence consisted of 15 m of industrial silt fencing. Two of the drift fence legs pointed toward the littoral fringe of the island with the remaining leg pointing into the islands upland area. Each array was then outfitted with 18 double-ended funnel traps constructed of window screen. The traps were unbaited with wetted sponges and shaded by landscaping cloth (Enge 1997, 2001). Herpetofaunal trapping was concurrent with the small mammal trapping and consisted of the same 4 night trapping period with traps checked daily and all captures identified to species, weighed, and released. Herpetofaunal trapping took place from September 2007-March 2009.

Analysis

Fire ant mound counts were analyzed using ANOVA's to determine any associations with island characteristics. Ant mound densities were analyzed for method of construction, presence of grazing, and lake location. Simple linear regression analyses were used to investigate correlations between fire ant mound density and island distance from shore, herpetofaunal and small mammal species richness, and total captures for the 5 most commonly trapped and widespread island species (the Southern leopard frog, Eastern narrow mouthed toad, pig frog, hispid cotton rat, and marsh rice rat). Shapiro-Wilk tests (Shapiro and Wilk 1965, Allen et al. 1997) and normal probability plots were used to determine data distribution normality. An $\alpha > 0.1$ was used to indicate data distribution normality. Fire ant mound densities, herpetofaunal species richness, and hispid cotton rat captures were normally distributed. Island distance from shore, total herpetofaunal captures, total small mammal captures, Eastern narrow mouthed toad captures, Southern leopard frog captures, pig frog captures, and marsh rice rat captures were log transformed for regression analyses. Small mammal species richness was not normally distributed but was not transformed. Three islands had a 1 species, 8 islands had 2 species, and only 1 island had 3 species. The homogeneity of species richness values may have skewed the normality test results. All analyses took place using SAS software (SAS © Institute, Inc., 1985).

Results

The average number of mounds counted along transects was 13.75 ($SE = 1.94$). The average island area was 0.94 ha. This gives an average of 1718.75 ($SE = 242.37$) mounds/ha on the spoil islands. Island 3 had the highest number of mounds counted at

26. Island 3 has the smallest land area giving the island the highest density of ant mounds at 3250/ha. All but 2 islands had at least 10 mounds counted. Islands 10 and 8 each had less than 10 mounds counted along transects. Island 10 had 7 (875/ha) and Island 8 had 1 mound (125/ha). Several black ant mounds were also discovered on Island 8, but were not included in this survey. These 2 islands have significant vegetative ground cover from vine and grass species and little open ground. Island 10 was predominantly covered in Balsam Apple (*Momordica charantia*) and Twine Vine (*Sarcostemma clausum*) and Island 8 was an almost complete monoculture of Para Grass (*Bracharia mutica*). As a result, there may have been a higher concentration of mounds in less vegetated portions of the island, where the ants have an easier time getting to the soil. Ant mound densities by island were presented in Figure 3-1.

Mound densities showed a possible association with island construction ($P = 0.0937$) with higher mound densities on smoothed islands. The average number of mounds on smoothed islands was $0.2125 / \text{m}^2$ ($SE = 0.0354$). The average number of mounds on rough islands was $0.1313 / \text{m}^2$ ($SE = 0.26$). Mound densities were not associated with either distance from shore ($r^2 = 0.1256$, $P = 0.3891$) or presence of grazing ($P = 0.5961$). Mound densities were also analyzed to discover if densities varied by island location within the lake. Ant mound densities were not associated with any of the 4 lake locations ($P = 0.4587$).

The total number of herpetofaunal captures, herpetofaunal species richness, and the 3 most frequently captured anuran species were analyzed relative to ant mound densities to determine any effect fire ant mound density may have on island herpetofauna. Ant mound densities were not correlated with either total herpetofaunal

captures ($r^2 = 0.0606$, $P = 0.4657$) or herpetofaunal species richness ($r^2 = 0.2361$, $P = 0.1297$). Total captures by island were not correlated with ant mound densities for the 3 most frequently trapped anuran species, the Eastern narrow mouthed toad ($r^2 = 0.1476$, $P = 0.2434$), the Southern leopard frog ($r^2 = 0.0051$, $P = 0.8353$), or the pig frog ($r^2 = 0.1247$, $P = 0.3512$).

The total number of small mammal captures, small mammal species richness, and the 2 most widely distributed rodent species were analyzed relative to ant mound densities to determine any effect fire and mound density may have on island rodent species. Ant mound densities were not correlated with total small mammal captures ($r^2 = 0.0535$, $P = 0.4696$) or small mammal species richness ($r^2 = 0.209$, $P = 0.1315$). Total captures by island were not correlated with ant mound densities for the hispid cotton rat ($r^2 = 0.0002$, $P = 0.9701$) or the marsh rice rat ($r^2 = 0.4105$, $P = 0.0869$).

Discussion

Polygyne red imported fire ant colonies have been reported at densities from 500-1,400 colonies/ha in the United States with densities of 5000 colonies/ha found in Australia (Allen et al. 2004). The average density found on the islands was 1718.75 mounds/ha. The densities found on the spoil islands were higher than those reported for the United States by Allen et al. (2004). Monogyne (single queen) colonies have been reported at much lower densities, around 100 mounds/ha. These colonies are territorial and are aggressive to other colonies. Polygyne infested areas typically exhibit a more homogenous coverage of foraging fire ants possibly having a greater impact on local wildlife (Allen et al. 2004).

I had hypothesized that fire ant mounds would occur in greater densities on proximal islands. Distance traveled over water may limit ant dispersal as the distance

increases. Many of the proximal islands also become peninsulas during the summer months when the lake level is lower further facilitating ant colonization of the islands. However, this study did not find any association between fire ant mound densities and distance from shore. Fire ants are prolific dispersers. I have personally observed fire ants floating on flood waters to new areas of dry land and could have floated to more distal islands from shore or from other islands after construction. The ants may have reached the islands during mating flights or during the drydown and island construction.

Fire ant mound densities had a possible association with island construction having higher numbers on islands that were mechanically smoothed during construction versus those left in rough heaps of material. The reasons for this association are unknown. However, rough islands may undergo more frequent erosion than the smoothed islands. The substrate on smoothed islands may have undergone additional compaction by the heavy machinery used to smooth the islands after dumping the material. The smoothed profile of these islands may also lead to less wind, rain, and biota induced erosion than rough islands. The lessened erosion in turn could allow for more stable ant colonies and longer lasting mounds. Many of the ant mounds were not very large. This may be an effect of the erosive nature of the spoil islands substrate or an indication that the porosity of the spoil substrate negates the need to construct large mounds for the colony to utilize. In addition, the sandy substrate comprising spoil islands may undergo shifting and compaction more frequently on rough islands not compacted by grading equipment. The shifting substrate could limit the longevity of ant mounds causing them to be smaller and shorter lived.

The possible association of ant mounds with island construction may have had an effect on island herpetofauna. Herpetofaunal species richness was found higher on rough islands than smoothed islands. Snakes in particular were highly associated with rough islands than smoothed islands. Snakes in particular were highly associated with rough islands (Shoger et al. 2009). Although not a direct correlation with fire ants densities, the preference of these ground dwelling reptiles for rough islands may be partly influenced by fire ants. Most snake captures on the spoil islands were of smaller snake species which utilize worm and invertebrate prey, particularly the Florida brown snake (*Storeria dekayi victa*) and the peninsula ribbon snake (*Thamnophis sauritus sackenii*). Wojcik et al. (2001) noted the local decline of the peninsular intergrade kingsnake (*Lampropeltis getula floridanus*) following the invasion of polygynous fire ants and a similar decline by the southern hognose snake (*Heterodon simus*) was also attributed to fire ant invasion (Allen et al. 2004). However, Smith et al. (2004) observed a Texas rat snake (*Elaphe obsoleta lindheimeri*) seemingly unaffected by swarming fire ants while depredating 3 black-capped vireo (*Vireo atricapilla*) hatchlings. While fire ants have been found to negatively impact snake communities, some snake species may be more immune to fire ant stings than others. The smaller snake species captured frequently on the islands may be more susceptible to fire ant stings. In addition, the fire ants may pose some interspecific competition for invertebrate prey. Fire ants have been found to reduce the abundance of numerous invertebrate species and reduce overall arthropod richness (non-ant). The ants were also found to prey on tree snails (Wojcik et al. 2001). The combined effects of increased fire ant stings and harassment and a possibly depauperate invertebrate community on smoothed islands may be the cause of the snake association to rough islands.

I found no correlation between density of fire ant mounds and the total number trapped of any of the anuran or small mammal species analyzed. However, all 5 of the species analyzed suffered fire ant related mortalities when confined in traps overnight indicating that fire ants can prey on these species when they are immobilized in some manner. Of the species I analyzed, only the hispid cotton rat has been studied by other researches in relation to fire ant impacts. Lecher and Ribble (1996) found hispid cotton rats were unaffected by the presence of smashed fire ants in 1 arm of a constructed maze. Another rodent, the Northern pygmy mouse (*Baiomys taylori*), readily avoided the area of the maze with the crushed ants. However, Pederson et al. (2003) found the opposite to be true in a study using catch-per-unit-effort. They found that hispid cotton rats altered their habitat use during the summer, but not winter, in response to fire ant densities while Northern pygmy mice did not alter habitat use during either season. Neither hispid cotton rat nor marsh rice rat total captures were affected by fire ant mound density on the islands. Additional research is needed to determine if these rodent species alter micro-habitat use based on fire ant mound densities. Allen et al. (2004) reported only 1 observational study on fire ant impact on an anuran species by Freed and Neitman (1988). They observed fire ants preying on Houston toad (*Bufo houstonensis*) toadlets as they came up onto the shore and onto terrestrial vegetation. I found no correlation between fire ant mound densities and total captures of Southern leopard frogs, pig frogs, or Eastern narrow mouthed toads. Fire ant effects on tadpoles and toadlets were not evaluated in this study but should be considered for additional research.

Fire ants have been reported to have profound impacts on wildlife wherever they occur. I found very high red imported fire ant mound densities on in-lake spoil islands in central Florida. Fire ants on these spoil islands do not appear to have an effect on commonly occurring wildlife. The lack of significant wildlife effects from a very dense fire ant population was surprising. The species occurring on these islands may be more immune to fire ants than species occurring elsewhere. Fire ant densities showed a possible association with smoothed islands. Managers may wish to leave islands in rough heaps rather than mechanically smoothing them as a precautionary measure to limit fire ant densities.

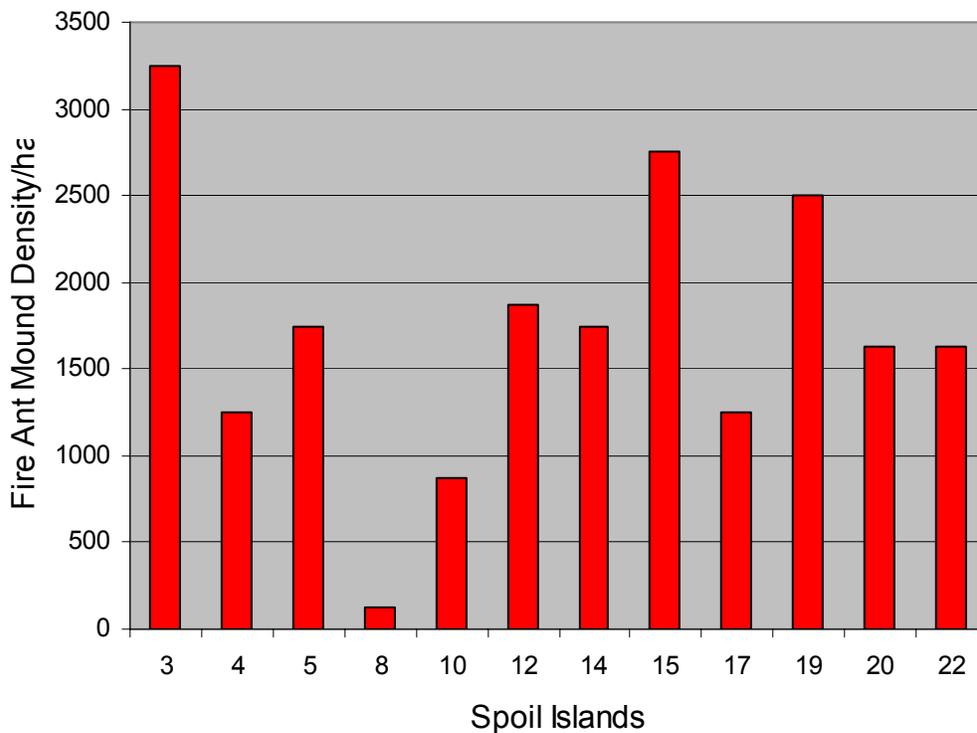


Figure 3-1. Fire ant mound densities/ha by island

CHAPTER 4 TURTLE NEST DEPREDATION ON IN-LAKE SPOIL ISLANDS

Introduction

In 2004, 29 spoil islands were created in Lake Tohopekaliga, Osceola County, FL as a byproduct of a massive lake restoration effort. These islands were designated as “wildlife islands.” One of the major functions of island creation projects has been to provide high quality breeding habitat. Spoil islands have been heralded as productive nesting habitat for ground nesting species due to real and perceived protection from mammalian predators. Most studies assessing the productivity of nesting on spoil islands have focused on avian species, with shorebirds and terns on coastal spoil islands (Landin and Soots 1978, Toland 1992, Erwin et al. 2003, Spear et al. 2007) and waterfowl on interior islands (Giroux 1981, Wilms and Crawford 1989, Lokemoen and Woodward 1992). Studies on interior islands attributed much of the protection from mammalian predators to distance from shore (Giroux 1981) and the presence of an open water barrier between the island and other dry land (Giroux 1981, Wilms and Crawford 1989, Lokemoen and Woodward 1992). Hulon et al. (1998) found evidence of turtle reproduction on 2 in-lake spoil islands in Florida but did not assess the possible productivity of those islands.

Numerous ground nesting species were found nesting on the Lake Tohopekaliga spoil islands including several turtle species, American alligator (*Alligator mississippiensis*), and avian species (Shoger et al. 2009). The Shoger et al. (2009) study found turtle nest remnants on every island from 2007-2009. Several Florida soft-shelled turtles were observed digging nests on multiple islands and neonate turtles of several species were captured in funnel traps along the drift fence arrays on numerous

occasions. American alligator, mottled duck, and sandhill crane nests were also found on several islands (Shoger et al. 2009).

This study sought to evaluate the potential productivity of spoil islands for ground nesting species. Ground nesting species were chosen due to their vulnerability to mammalian and fire ant predation. Mammalian predators or their sign was found on many of the spoil islands in Lake Tohopekaliga including raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), and canid scat of either a large grey fox (*Urocyon cinereoargenteus*) or coyote (*Canis latrans*). Fire ant presence on the islands was also very high (Shoger 2009) making the possibility of additional underground depredation of turtle nests and young very likely. The occurrence of mammalian predators combined with high densities of fire ants on the islands may create circumstances turning the safety of island nesting into a smorgasbord for predators. I used freshwater turtle nest success to assess both the potential productivity of spoil islands for nesting turtles and possible implications on other ground nesting species. I implemented a turtle nest survival study using artificial nests to test for differences in relative predation rates between different lake nesting habitats: shoreline, proximal islands, and distal islands

I hypothesized that as a result of small island size, limited nesting areas, and ease of access to predators during the breeding season due to low water levels, proximal islands would have the highest rates of depredation for freshwater turtle nests. Distal islands would have the lowest nest mortality rates due to the increased distance from shore limiting predator access. The shoreline locations would fall within the reported rates of depredation found for freshwater turtle nests, lower than the proximal islands and greater than the distal islands. Proximal islands would not provide additional

protection from shoreline predators resulting from island distance from shore and due to the constrained search area, may increase the foraging efficiency of some mammalian predators. Raccoons have been found to reduce the amount of search time for ground nests with experience (Bowman and Harris 1980) and the small size of the islands may increase the foraging efficiency of raccoons that have learned to exploit island turtle nests in the past.

Study Site

Lake Tohopekaliga is a 7612 ha freshwater lake located near the city of Kissimmee, FL. This is a shallow water, eutrophic lake at the northern extent of the Kissimmee Chain of Lakes. The lakeshore is primarily bordered by residential development and cattle grazed pasture. The northeastern shoreline is bordered by the city of Kissimmee, FL. The southern two-thirds of the lake is predominantly cattle pasture. The lake averages 2.1 m depth. In 2004, a large scale habitat restoration effort was initiated by the Florida Fish and Wildlife Conservation Commission. Restoration efforts included an extreme draw down and mechanical removal of thick stands of emergent vegetation and underlying organic muck. The majority of the dredge spoil was stored in-lake as spoil islands intended for use by wildlife and for storage of future dredge material and harvested vegetation.

Island vegetation was variable, but characteristic of early successional habitat. Over 120 species were identified on the islands between 2007 and 2009. The most common vegetative species identified on the islands were para grass (*Bracharia mutica*), white twine vine (*Sarcostemma clausum*), dog fennel (*Eupatorium capillifolium*), water primrose (*Ludwigia* spp.), poke weed (*Phytolacca americana*), fireweed (*Erechtites hieraciifolius*), alligator weed (*Alternanthera philoxeroides*), wild

water-pepper (*Polygonum hydropiperoides*), morning glory (*Ipomoea alba*), and Bermuda grass (*Cynodon dactylon*). Tree growth was primarily restricted to the islands wetted fringe and consisted predominantly of willow (*Salix* spp.). No islands included in this study had been planted or managed (Shoger et al. 2009).

Methods

Six locations were chosen for nest construction to test for differences in predation pressure between the lake shoreline and island locations. Two shoreline locations, 2 proximal islands, and 2 distal islands were selected for this study. Island distance from shore was measured by laser rangefinder in May 2006 at 52.71 ft (16.07 m) NGVD (National Geodetic Vertical Datum). Islands ≤ 100 m from shore were characterized as proximal while islands ≥ 300 m from shore were characterized as distal. Several islands were not included in the selection process due to possible confounding factors such as cattle grazing, thick grass cover, and outliers in island size. One group of locations (shoreline, proximal and distal) was located on the eastern side of the lake and the other on the western side. Sites were selected to allow for study design and provide plentiful nesting substrate. Island sites were randomly selected with the above restrictions. The shoreline locations served as the control for this study. Shoreline location 1 (Shore 1) and shoreline location 2 (Shore 2) were selected for the presence of bare ground nesting substrate. The only readily available nesting substrate on the shoreline within 50 m of the waterline occurred on raised dikes. All nests were constructed within 50 m of the waterline and within an area of approximately 1 ha, the average island size in Lake Tohopekaliga. Islands 3 and 19 were selected for the proximal islands. Island 3 was measured at 85 m from shore and Island 19 at 89 m from shore. Island 3 was 0.73 ha and Island 19 was 0.75 ha. Islands 4 and 22 were

selected for the distal islands. Island 4 was measured at 370 m from shore and Island 22 at 300 m from shore. Island 4 was 1.11 ha and Island 22 was 0.89 ha in size. All island area measurements were taken from Hoyer et al. 2006. Nesting site locations are indicated in Figure 4-1.

Nests were constructed to mimic natural nests of Florida softshell turtles. The Florida softshell turtle (*Apalone ferox*) was chosen due to its common occurrence and breeding status on the spoil islands. The Florida softshell turtle is the largest of the North American softshell turtles. This turtle is a common, long-lived, fecund species throughout its range. The species is sexually dimorphic with females larger than males. Females may reach up to 63 cm total length and weigh up to 24.95 kilograms with males reaching only 14 cm total length. The turtle has lived up to 30 years in captivity but longevity in the wild has not been determined. The Florida softshell turtle lives mainly in lake habitats. This turtle feeds mostly on invertebrates including crayfish and snails and occasional vertebrate prey including frogs, fish, and young waterfowl. Nesting season falls between mid-March and lasts through July. Nest chambers are dug in sandy soil in full, direct sunlight. The nest chamber is approximately 10 cm in diameter with an opening of approximately 5cm and a depth of 8–13 cm. During nest construction, the turtle may purge its bladder to soften the nesting substrate. After egg deposition, the turtle may move a few meters away and disturb the substrate to attract nest predators away from the real nest. Florida softshell turtles lay from 1 to 6 clutches per year of 4 to 23 eggs each. Hatchlings emerge after a 60 day incubation period (Ernst et al. 1994).

Twenty nests were constructed at each of the 6 locations for a total of 120 nests. Nest sites at the 6 locations were chosen randomly. A random point on the island was chosen from aerial photographs. From that first nest site, a random number of paces was walked in one of the 4 cardinal directions, chosen randomly, and then repeated with another random number of paces in another random direction 3 additional times before the second nest site was found. This process was repeated for all 20 nests at each location. Nests were dug in sandy soil in full sun and placed no closer than 10 m to any other nest. If the random placement of a nest was closer than 10 m, that nest was moved to be at least 10 m from all other nests. Nests were dug 8 – 13 cm deep and 10 cm in diameter. Four bobwhite quail eggs were placed in each nest around an ant trap designed to capture any fire ants foraging in the nest chamber. Quail eggs were obtained commercially from the Wadley Quail Farm (www.wadleyquailfarm.com, Wadley, GA). Ant traps consisted of 1 inch diameter PVC pipe cut into a trapezoidal shape with the top approximately 8 cm long and the bottom side approximately 6 cm long. Cutting the pipe with a longer top than bottom was to help keep dirt from filling the tube when the nest cavity was filled. A 2 inch by 4 inch piece of cardstock paper was cut and smeared on 1 side with petroleum jelly. The paper was then rolled into a 2 inch long tube and fit into the PVC holder. These ant traps were placed in the center of the nesting cavity. Simulated bladder water was sprinkled over the eggs and backfill dirt on each nest. Simulated bladder water was obtained from the Florida Aquarium Wetland's Exhibit in Tampa Bay, Florida. One Florida softshell turtle was captured from an aquarium exhibit and held in a separate container for approximately 48 hours in approximately 5 gallons of water. The turtle was feed once while in the holding

container and monitored by aquarium staff. Three gallons of the holding water was collected and used in the study as simulated bladder water. Each nest location was marked by GPS and flagged at least 5 m from the nest. Latex gloves were used during the construction of ant traps and nest cavities.

The turtle nest study took place in July 2009. Nests were monitored for a 21 day period and checked every 3 days for depredation events. It was assumed that the 3 day nest checking interval and the use of rubber gloves during nest construction would help to conceal any scent left by researchers and therefore not unnaturally influence depredation rates. Donalty and Henke (2001) concluded that any attempt to conceal odor from nest predators would be ineffective. This study was completed using artificial bird nests. However, Hamilton and Freedman (2002) and Wilhoft et al. (1979) found no significant difference between predation rates on artificial nests visited every day or nests created with specific olfactory or visual cues meant to attract predators.

Nest cavities were also examined for the presence of foraging fire ants at each check interval by probing the nest with a stick to entice the ants to come to the surface. After the 21 day study period all surviving nests were exhumed and examined for the presence of fire ants.

Turtle hatchlings captured during the Shoger et al. 2009 study on the Lake Tohopekaliga spoil islands were used to support nest survival findings from this study. Turtle hatchlings were captured from 2007-2009. Trapping consisted of a single drift fence array constructed on each of the islands in a “Y” shape. Each leg of the drift fence consisted of 15 m of industrial silt fencing. Two of the drift fence legs pointed toward the littoral fringe of the island with the remaining leg pointing into the islands

upland area. Each array was then outfitted with 18 double-ended funnel traps constructed of window screen and run monthly for a 4 night trapping period with traps checked daily and all captures identified to species, weighed, and released (Shoger et al. 2009).

Analysis

Kaplan-Meier survival, product limit method, was used to calculate survival curves by nesting habitat and location. This method was used for an artificial turtle nest experiment by Hamilton et al. (2002) and was found comparable to the Mayfield method by Farnsworth et al. (2000). Due to the 3 day nest checking schedule, the exact date of nest failure was unknown. For this study, the date of nest mortality was assumed at the mid-point between the last observation date the nest was still active and the observation date the nest was found predated. The 2 censored nests from Island 22 and Shoreline 1 were not included in the analyses due to the early occurrence of the nest censoring during the 21 day monitoring period. Log-rank tests were used to compare survival functions between nesting habitats. Log-rank tests were chosen over Wilcoxon tests due to the placement of more weight towards the end of the study when fewer nests are still alive (Hamilton et al. 2002). Since the majority of turtle nest depredation occurs during the first few days after deposition (Congdon et al. 1983) and the focus of this study was on factors allowing nests to survive full-term, the log-rank tests were most applicable. The Sidak adjustment for the log-rank test was used to make comparisons between multiple survival curves. Tukey-Kramer multiple comparisons (SAS Inst. Inc. 1985) were used to test for significant differences between 21-day survival means by habitat. An $\alpha = 0.05$ was used to determine significance for all tests.

Results

All nest locations, Islands 3, 4, 19, 22, and shoreline locations showed evidence of recent turtle nest depredations before the beginning of the study (Figure 4-2). Raccoons were the only nest predator able to be identified by tracks left at depredated nests. Raccoon tracks were identified at depredated nests on Islands 3 and 19 and at both shoreline locations. Only 14 of the 93 depredated nests had identifiable raccoon tracks (Figure 4-3). Two additional nest predators have been observed or identified on the islands but were not associated with any of the study nest depredations, the coyote and opossum. Other possible nest predators observed or expected along the shore but not identified on the islands are gray fox, striped skunk, and spotted skunk (*Spilogale putorius*).

The ant traps did not detect any ants in the nest chamber. However, fire ants were detected in 6 of the nests before depredation events. After a nest was depredated, ants were often found within the cavity. Ant traps were tested for functionality after the study was completed. Ten new traps were constructed and placed on top of a fire ant mound. The mound was disturbed to entice the ants to swarm the traps. Ants were able to walk through the petroleum jelly without being trapped. If potential egg predators need to be identified and sampled within the nest cavity, this trap design may be functional. However, a different spreadable trapping medium would need to be used, as petroleum jelly seemed ineffective at capturing and holding ants.

Total mortality among all 118 nests was 78.81%. Island 4 was the only nesting location with 100% survival. Nest mortality from all sites excluding Island 4 was 94.9%. All locations, except Island 4, experienced nest predation within the first 3 days.

Distal islands had a combined mortality of 50% ($SE = 50$). Distal island nests survived for an average of 11.9615 days ($SE = 6.8024$). The large standard error resulted from 1 of the islands having 100% mortality and the other having 0% mortality. Proximal islands had a combined mortality of 95% ($SE = 5$). Nests on proximal islands survived for an average of 5.7 days ($SE = 3.8069$). Shoreline locations had a combined mortality of 92.35% ($SE = 2.35$). Nests on shoreline locations survived for an average of 4.2308 ($SE = 4.1643$).

Nesting habitats were compared by mean number of nesting days and survival curves. Significant differences were found between mean survival days for nesting habitats ($F = 12$, $DF = 2$, $P = <0.0001$). Tukey-Kramer comparisons indicated the mean number of nest survival days on distal islands were significantly different than proximal and shoreline locations ($P = <0.05$). There was no significant difference between mean number of survival days on proximal islands and shoreline locations. Survival curves by nesting habitat were also found to be significantly different ($X^2 = 25.5525$, $DF = 2$, $P = <0.0001$). Sidak multiple comparisons between survival curves found significant differences between nesting habitats. Distal islands were significantly different from both proximal islands ($X^2 = 16.1272$, $P = 0.0002$) and shoreline nesting locations ($X^2 = 23.1843$, $P = <0.0001$). There was no significant difference between survival curves between proximal islands and shoreline locations ($X^2 = 0.2618$, $P = 0.847$). Kaplan-Meier survival curves by habitat are presented in Figure 4-4 and by island in Figure 4-5.

Discussion

Both island (proximal and distal) and shore habitat were analyzed, giving strong internal validity to this study. In addition, because the nest construction of Florida softshell turtles are similar to many turtle species, the results of this study could

reasonably be applicable to all island nesting turtle species in Lake Tohopekaliga. The findings from this study could also be applied to other ground nesting species utilizing freshwater lake spoil islands due to its insight into predation pressures between nesting habitats.

Freshwater turtles are cryptic in nature and not easily studied. Population estimates for many species are currently unknown and management practices are simply assumed to be adequate. Freshwater turtle nests are difficult to locate leading several researches to use artificial turtle nests to explore relationships between nest survival, predation, and habitat characteristics (Hamilton and Freedman 2002, Marchand et al. 2002). Artificial nest studies conducted to explore avian nesting success have drawn fire about the validity of inferences made in relation to natural nest success. Several of these potential biases are unique to avian studies. The presence of incubating adults, nest construction and aboveground placement, and influences of egg color, size, and shape on predators and predation rates are biases linked to avian studies (Major and Kendal 1996, Butler and Rotella 1998, Thompson and Burhans 2004) but probably less important to experiments with artificial turtle nests. Human scent left by researches has been faulted for biasing artificial nest studies (Whelan et al. 1994 and Donalty and Henke 2001) as well as visual cues such as flagging which predators may learn to associate with nests. However, Tuberville and Burke (1994) and Hamilton et al. (2002) did not find any association between visual clues at nest sites and increased predation rates. In order to minimize the impact of these potential biases, latex gloves were used when handling eggs, ant traps, and during construction of the nests. All habitats and nests were treated equally to both olfactory (human observer)

and visual (flagging) cues validating all inferences drawn regarding between habitat predation. In addition, I was concerned with habitat effects on relative predation rate and not the absolute natural predation rate negating the issues caused by any potential olfactory or visual biases.

Total nest mortality for the study on Lake Tohopekaliga was 78.81% ranging from 0-100% depredation by location. This was much higher than the total nest predation rate of 22% reported by Marchand et al. (2002) while less than the 88% reported by Hamilton and Freedman (2002) for artificial turtle nest studies. Natural turtle nest predation rates were similar to this study. Burke et al. (1998) reported an average of 84.2% total nest predation for a 3 year study while Congdon et al. (1983) reported an average of 67% nest predation ranging from 42% to 93% over a 6 year period. Total predation reported in this study was well within the limits of both natural and artificial turtle nest predation rates.

The majority of turtle nest depredation (55.08%) was during the first 3 day period of this study. Congdon et al (1983) found 47% of nest depredation occurred during the first 24 hours after deposition and 84% of nest predation occurred within the first 5 days. They also found that only 12% of predation occurred between day 6 and day 30 and no predation occurred after day 30 to hatching. This suggests that the longer amount of time a nest has after deposition, the better its chance of success. Shoreline predators may exploit island resources after shoreline areas have been depleted. The intervals between island visitations by shoreline predators may be the most productive time to nest. An islands distance from shore may increase the delay between predator visits thereby increasing the probability of success for nests located on more distal islands.

A total of 18 turtle hatchlings were trapped or observed on the Lake Tohopekaliga spoil islands from 2007-2009. Over half of the hatchlings (10) were found on Island 4, the distal island with 0% nest mortality. The remaining 8 hatchlings were found on 4 islands and 1 shoreline location. The majority of hatchlings (66%) were identified on distal islands. The hatchlings were from 5 species, Florida softshell turtle, peninsula cooter (*Pseudemys floridana peninsularis*), mud turtle (*Kinosternon bauri*), Florida snapping turtle (*Chelydra serpentina osceola*), and musk turtle (*Sternotherus odoratus*). Florida softshell turtle hatchlings were the most frequently trapped and observed species with 33% of the identifications (Shoger et al. 2009). The results of this study seem to parallel the hatchling capture locations.

Distal islands were the only habitat type with significantly higher survival (Figure 4-4). Distal islands for this experiment were ≥ 300 m from shore. Both mean number of nest survival days and survival curves were higher on distal island habitat than shoreline and proximal island nesting habitat. Shoreline locations and proximal islands (between 75 and 100 m from shore) were not significantly different from each other for either mean number of nest survival days or survival curves. These results suggest that near shore islands do not prohibit shoreline predator access and should not be anticipated to provide more productive turtle nesting habitat than the natural shoreline.

The majority of the differences in nesting habitat were based on a single island, Island 4 (Figure 4-5). Island 4 had both the most hatchling captures and the least nest predation. Island 4 had 100% survival. This was the only location with over 10% survival. The strong influence of this island on the survival estimates indicates additional characteristics, other than distance from shore, that play a role in predator

exclusion. This also indicates the need for additional research testing a higher number of island nesting locations and variables. Islands 4 and 22 were ≥ 300 m from shore with a permanent water barrier from the shoreline. However, Island 4 was unique in the large amount of open water surrounding the island. Island 22 had thick emergent vegetation growing the entire distance from shore to island. This thick vegetation may have formed floating mats and aided the foraging ability of nest predators such as raccoons. Island 4 had sparse emergent vegetation surrounding the island and areas of open water between the island and shore possibly creating a more functional barrier to intrepid mammalian predators. If a goal for spoil island creation is to promote a productive turtle population, spoil islands should be constructed ≥ 350 m from shore in relatively open water that is deep enough to maintain a permanent barrier to shoreline predators.

Several studies on ground duck nest productivity on created islands have indicated the need to control for mammalian nest predators. Giroux (1981) recommended islands be constructed ≥ 170 m from shore in areas with a water depth of 70 cm to discourage predator attraction. Lokemon and Woodward (1992) also recommended constructing islands ≥ 100 m from shore and conducting predator removal on islands when needed. Willms and Crawford (1989) indicated the need to implement direct predator control when space was not available to construct islands far enough from shore, particularly when dealing with semi-aquatic predators. Garmestani and Percival (2005) found that sea turtle nest depredations on barrier islands were substantially reduced when raccoons were removed from the islands. The nest success on Island 4 conforms to the recommendations for island construction by these studies.

The recommendation from this study to construct islands ≥ 350 m from shore may not be available to managers on smaller or deeper lakes. In these cases, direct control of mammalian predators may be needed either through trapping or electric fencing. Electric fencing, seasonally operated, could be installed on the islands or along sections of shoreline parallel to an island's location to discourage seasonal foraging and access to the island during the nesting season.

Red imported fire ants were found in several nest chambers during this study. Allen et al. (2004) reported that fire ants would enter nest chambers and attack turtle hatchlings shortly after pipping drastically reducing hatchling survival. The spoil islands in Lake Tohopekaliga have high densities of fire ants that when combined with the effects of nest predators on some of the islands, may act as potential population sinks. The population status and natural nesting success of turtle species on Lake Tohopekaliga has not been researched. The effect of the spoil islands on turtle production on the lake can not be identified without basic background ecology for these species. Future research should address these needs and continue to evaluate the effect of spoil island creation on freshwater turtle species.

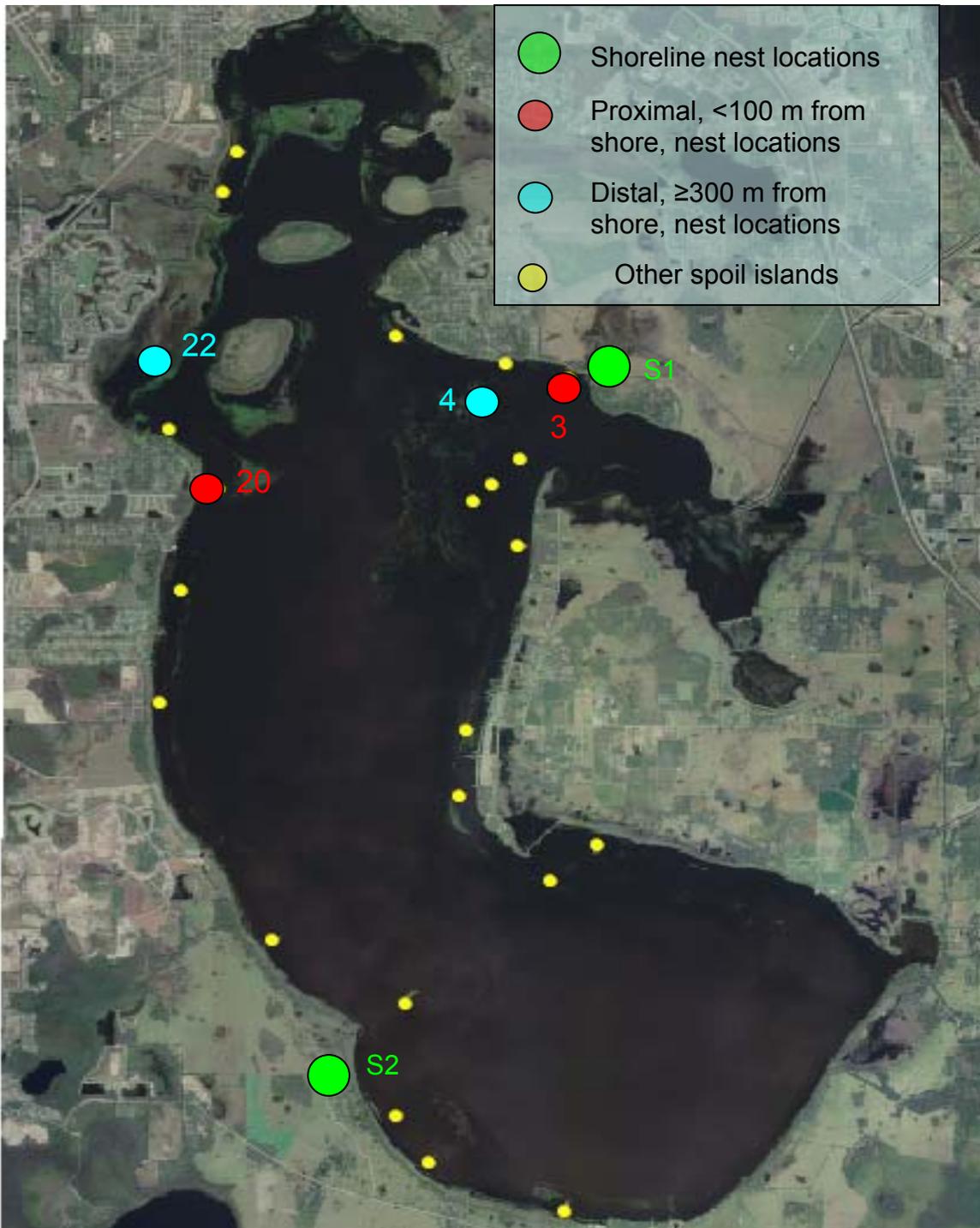


Figure 4-1. Location of turtle nesting sites on Lake Tohopekaliga



Figure 4-2. Artificial turtle nest construction showing ant trap surrounded by quail eggs.



A



B

Figure 4-3. Turtle nest depredation by raccoon showing A) the entire depredation site and B) a close-up of raccoon tracks. Uncovered nest cavity and depredated eggs are highlighted in red. Raccoon tracks are highlighted in orange.

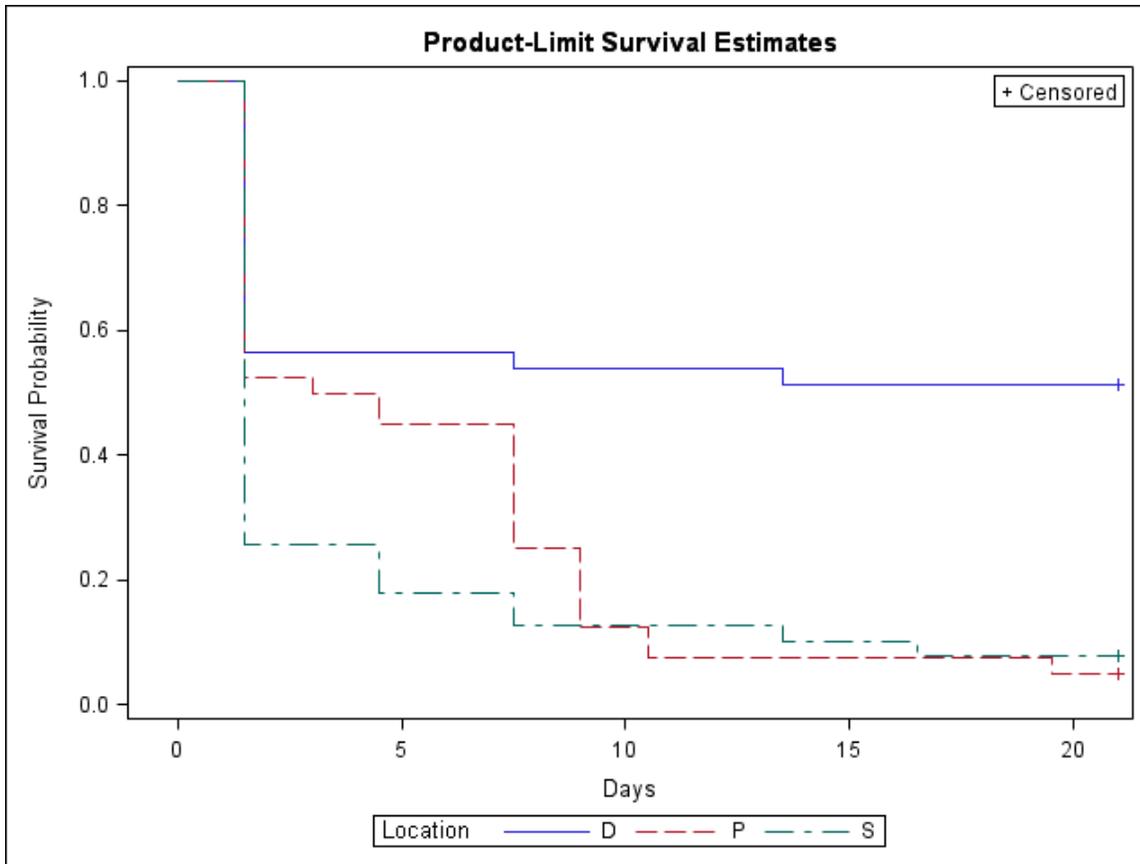


Figure 4-4. Turtle nest product-limit survival plot by location. D indicates distal Islands 4 and 22. P indicates proximal Islands 3 and 19. S indicates shoreline locations 1 and 2.

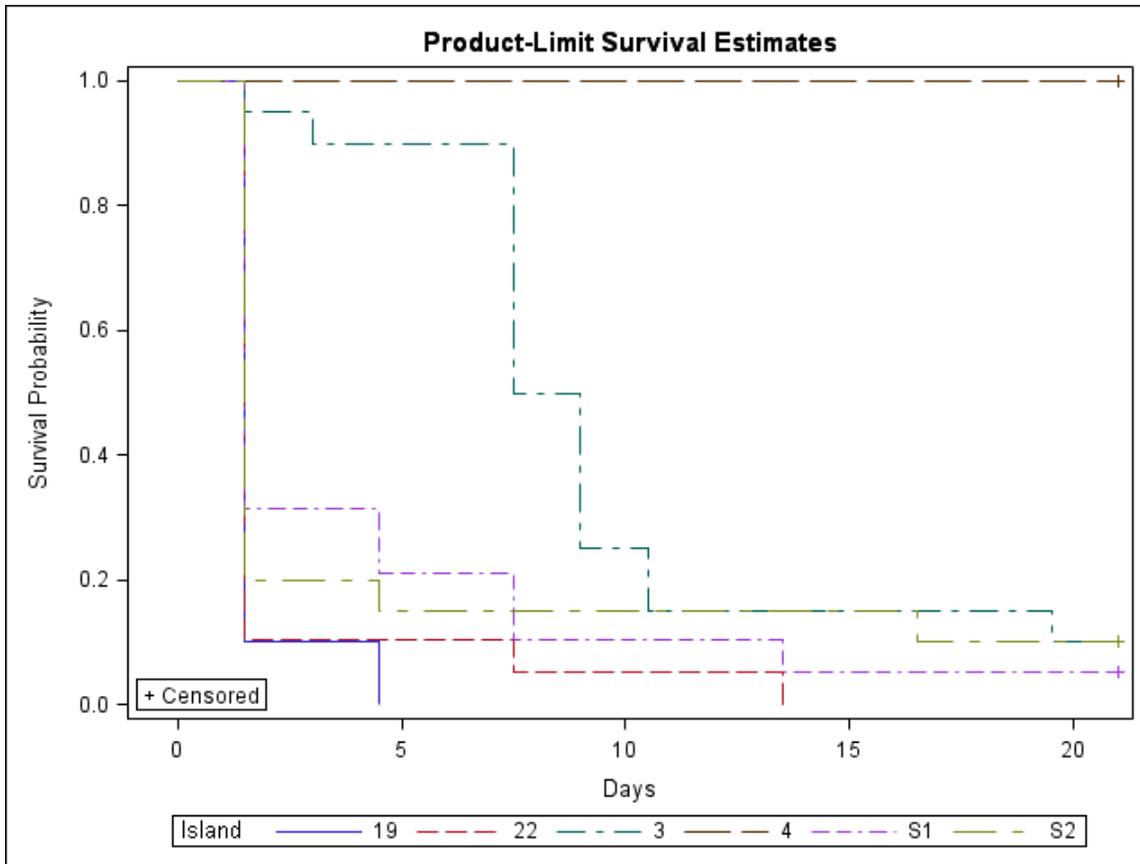


Figure 4-5. Turtle nest product-limit survival plot by site.

CHAPTER 5 CONCLUSION

The results of this study may be used to direct the construction and management of future in-lake spoil island projects throughout the state of Florida. It is important to recognize that the use of in-lake spoil islands by wildlife is largely unknown and studies on in-lake spoil islands outside of Lake Tohopekaliga are lacking. Even so, these results could be cautiously applied in other lake systems due to the widespread nature of the species in question and the multiple geomorphic (island construction, location, grazing pressure) and biotic (floral and faunal) variables being considered.

The era of avian-centric spoil island creation and research is over. Currently, there is a paucity of data on the uses of created spoil island habitat by non-avian species and the effects these habitats may have on other wildlife. This study looked into the use of spoil islands by a more diverse group of species than traditionally examined. The composition of local shoreline populations, distance of an island from shore, and island vegetation characteristics were all found to be important in determining the extent of island usage by small mammals and fire ants. Predator occurrence was not associated with total number of small mammals trapped indicating additional prey sources on the islands in addition to rodents. The location of spoil islands in the lake was important in determining marsh rice rat occupancy. The rats were only found in a few areas of the lake, while hispid cotton rats were much more widespread. The marsh rice rat is a semi-aquatic rodent that should not have had any difficulty colonizing the spoil islands. The lack of colonization may signify that marsh rice rat shoreline populations were probably smaller or non-existent in the areas adjacent to un-colonized spoil islands. Island size was also a factor for marsh rice rat

occupancy having occupancy inversely related to island size. Hispid cotton rats were the most commonly and widespread small mammal captured on the Lake Tohopekaliga spoil islands. Cotton rat occupancy was influenced mainly by vegetation structure with higher occupancy rates found in less diverse and thicker vegetated patches.

Occupancy on the spoil islands for the cotton rat was also found inversely related to distance from shore. It was found that occupancy greatly decreases between islands 80 m to 200 m from shore. House mice have only colonized a single island sufficiently to allow occupancy modeling. Detection probability for the house mouse was closely tied to mean ambient air temperature with higher detection probability during hotter days. The house mouse is a non-native species with the potential to exist in very dense populations. Future colonization of more spoil islands should be expected and monitored for any effects on native wildlife.

Fire ants were found on all spoil islands in Lake Tohopekaliga. I expected the high density of fire ant mounds to have a profound effect on wildlife species, but no direct effects on occupancy of small mammals or numbers of ground dwelling species trapped were observed. The effects of fire ants on ground nesting species remain unclear. We detected fire ants in 6 of the constructed turtle nests before hatching and 3 of 7 natural alligator nests. Fire ant predation combined with high nest mortality rates on proximal, and some distal, islands could render the spoil islands a population sink for some ground nesting species. I did not assess the relative differences in predation rates between shoreline and island habitats for avian species, but it would be reasonable and prudent to assume that predation pressures affecting turtle nests would also affect other ground nesting animals.

This was the first study to begin to assess the productivity of spoil islands for nesting turtle species. Survival rates for ground nesting birds has been heavily researched on spoil islands. Most of these studies focused on predation rates by mammalian and avian predators. None of the studies I found looked into egg and chick predation by snakes and none reported quantifiable data on the effects of fire ants on ground nesters. Spoil island predation rates on turtle nests only differed from shoreline locations on distal islands, influenced predominantly by a single island. These results indicate that the majority of spoil islands in Lake Tohopekaliga offer no additional protection from mammalian predation, and may function as population sinks. With the recent concern over turtle populations in Florida and the implementation of a highly restricted harvest, the role of spoil islands in turtle ecology on freshwater lakes should be a priority of future research. Avian use of spoil islands will always be a high priority and avifauna may be the major beneficiaries of spoil island creation, but the use of spoil islands by other species is undeniable and an important part in the ecology of these novel ecosystems.

Spoil island creation should be a goal driven exercise. Different animal guilds and species have been shown to favor different island types. Only by identifying the species assemblage desired on an island before creation, can construction and management plans expect to succeed in attracting the desired species. Available literature and species ecologies should be referenced when designing and managing islands for desired outcomes. Future island construction projects should seek to incorporate experimental framework into the design, construction, and management of spoil islands. By doing so, researchers and managers can apply adaptive management techniques on

the islands and gain quantifiable knowledge on the uses of islands in relation to construction methods and habitat characteristics. This information will help to increase the usefulness of constructed islands for wildlife and help bridge the gap from the art of island making to the science of island construction.

Spoil islands will continue to be used for spoil retention projects into the foreseeable future. These islands have been shown to have considerable value to wildlife and likely will play a larger role in the future as native habitat dwindles forcing species to utilize novel habitats. The dependence shown by some species of waterbirds, and possibly other guilds, on spoil islands for nesting habitat is likely to increase in the future. Increased research into the full ecology of spoil islands and the reliance of wildlife on these islands will be especially important to anticipate possible climate change effects on the longevity and use of spoil islands into the future.

APPENDIX A
SMALL MAMMAL SPECIES LIST

Table A-1. Species list of small mammals captured on the study islands and small mammal predators included in the predator index.

Small Mammals	
Common Name	Scientific Name
Cotton mouse	<i>Peromyscus leucopus</i>
Eastern woodrat	<i>Neotoma stephensi</i>
Hispid cotton rat	<i>Sigmodon hispidus</i>
Marsh rice rat	<i>Oryzomys palustris</i>
House mouse	<i>Mus musculus</i>
Southern Least Shrew	<i>Blarina carolinensis</i>
Small Mammal Predators	
Common Name	Scientific Name
American alligator	<i>Alligator mississippiensis</i>
Black racer	<i>Coluber constrictor</i>
Florida cottonmouth	<i>Agkistrodon piscivorus contanti</i>
Yellow rat snake	<i>Elaphe obsoleta quadrivittata</i>
Crested caracara	<i>Caracara cheriway</i>
Northern harrier	<i>Circus cyaneus</i>
Red-shouldered hawk	<i>Buteo lineatus</i>
Great horned owl	<i>Bubo virginianus</i>
Barn owl	<i>Tyto alba</i>
Bobcat	<i>Lynx rufus</i>
Coyote	<i>Canis latrans</i>

APPENDIX B
OCCUPANCY MODELS

The model selected for inference was highlighted in yellow. Global models used to assess goodness of fit are highlighted in blue. The top 5 AIC ranked models are presented for each species. The model is followed by AIC rank, change in AIC between models, AIC weight, and the number of model parameters. Seasonal models include the X^2 statistic, p-value for the statistic, and estimated \hat{c} . When QAIC was used, an extra parameter was added to the number of model parameters listed for the estimation of \hat{c} . Covariates presented below are (.)=constant, (G)=presence of grazing, (C)=method of construction, (D)=distance from shore, (LL)=lake location, (season)=4 day monthly trapping season, (C/O)=trap covered or uncovered directly by vegetation, (VH)=# of height categories in 5m radius of trap, (Temp)=average daily temperature.

Table B-1. Occupancy models for small mammal species.

Top Models for the Hispid Cotton Rat

Multi-Season Full Study Model

Model	AIC	Δ AIC	AICw	# Par
psi(VH), gamma(LL), p(.)	1937.62	0	0.33	6
psi(VH), gamma(.), p(.)	1937.72	0.1	0.3139	3
psi(LL), gamma(.), p(.)	1939.59	1.97	0.1232	6
psi(.), gamma(.), p(.)	1939.65	2.03	0.1196	3
psi(.), gamma(LL), p(.)	1941.02	3.4	0.0603	6

Single-Season Seasonal Models

April

Model	AIC	Δ AIC	AICw	# par.	X2 Stat	X2 p	\hat{c}
psi(D), p(VH)	353.29	0	0.3067	2	0.965	0.5724	0.8598
psi(D), p(.)	353.35	0.06	0.2976	2			
psi(D+C+G+VH), p(VH)	354.7	1.41	0.1515	5			
psi(D+G+VH), p(VH)	355.28	1.99	0.1134	4			
psi(D+C+G+LL+RIFA+VH), p(VH+Temp+C/O)	357.01	3.72	0.0477	12	0.9622	0.5614	0.8622

Table B-1. Continued

June

Model	AIC	Δ AIC	AICw	# par.	X2 Stat	X2 p	\hat{C}
psi(D+C+G+LL+RIFA+IS+VH), p(VH+Temp+C/O)	213.04	0	0.9844	13	2.3386	0.2837	1.0985
psi(D+C+G+LL+VH), p(.)	224.22	11.18	0.0037	9			
psi(D), p(VH)	224.48	11.44	0.0032	2			
psi(D), p(Temp)	225.57	12.53	0.0019	2			
psi(D), p(.)	225.68	12.64	0.0018	2			

November

Model	AIC	Δ AIC	AICw	# par.	X2 Stat	X2 p	\hat{C}
psi(D), p(.)	68.24	0	0.3705	2	1.7556	0.4785	0.4659
psi(D+C+VH), p(.)	69.56	1.32	0.1915	4			
psi(D+C), p(.)	69.7	1.46	0.1785	3			
psi(D+VH), p(.)	70.03	1.79	0.1514	3			
psi(C.), p(.)	74.39	6.15	0.0171	2			
.....							
psi(D+C+G+LL+RIFA+IS+VH), p(VH+Temp+C/O)	82.17	13.93	0.0003	13	2.2532	0.4316	0.6481

January

Model	AIC	Δ AIC	AICw	# par.	X2 Stat	X2 p	\hat{C}
psi(D), p(Temp)	115.13	0	0.17	2	1.3728	0.5964	0.4308
psi(D), p(VH)	115.22	0.09	0.1625	2			
psi(D), p(.)	115.84	0.71	0.1192	2			
psi(D), p(VH+Temp)	116.02	0.89	0.1089	3			
psi(D+C+G), p(.)	116.64	1.51	0.0799	4			
.....							
psi(D+C+G+LL+RIFA+IS+VH), p(VH+Temp+C/O)	117.36	2.23	0.0557	13	1.1972	0.5305	0.5255

Top Models for the Marsh Rice Rat

Multi-Season Full Study Model

Model	AIC	Δ AIC	AICw	# Par
psi(LL), gamma(.), p(.)	475.94	0	0.492	6
psi(C+LL), gamma(.), p(.)	476.89	0.95	0.306	7
psi(C+G+LL), gamma(.), p(.)	478.89	2.95	0.1126	8
psi(D+C+G+LL+IS), gamma(.), p(.)	480.01	4.07	0.0643	10
psi(LL), gamma(LL), p(.)	481.94	6	0.0245	9

Table B-1. Continued

Seasonal Model

March

Model	QAIC	Δ AIC	AICw	# par.	X2 Stat	X2 p	\hat{C}
psi(LL+IS), p(.)	83.28	0	0.5683	7	3.0859	0.0699	1.7224
psi(LL), p(.)	85.82	2.54	0.1596	6			
psi(IS), p(.)	86.71	3.43	0.1023	3			
psi(D+C+G+LL+RIFA+IS+VH), p(VH+Temp+C/O)	86.92	3.64	0.0921	14	2.8182	0.1009	1.6168
psi(.), p(.)	89.27	5.99	0.0284	3			

Top Models for the House Mouse

Multi-Season Full Study Model

Model	AIC	Δ AIC	AICw	# par
psi(.), gamma(.), p(C/O+Temp)	300.41	0	0.2525	4
psi(VH), gamma(.), p(C/O+Temp)	300.41	0	0.2525	4
psi(.), gamma(.), p(C/O+VH)	300.95	0.54	0.1927	4
psi(.), gamma(.), p(C/O+VH+Temp)	301.14	0.73	0.1753	5
psi(.), gamma(.), p(C/O)	303.52	3.11	0.0533	3

APPENDIX C WILDLIFE USE OF SPOIL ISLANDS: A LITERATURE REVIEW

Restoration of aquatic habitat and improvements to shipping channels creates large amounts of left over material termed spoil. Dredge spoil has traditionally been stored in off site, upland locations where possible. In coastal waters, spoil has been used to form islands for future spoil retention. Between the mid-19th century and 2004, over 2000 spoil islands were constructed in Atlantic and Gulf coast estuaries (Yozzo et al. 2004). The majority of U.S. coastal dredging took place during the 1920's construction of the Intracoastal Waterway along the Atlantic and Gulf coasts (Parnell et al. 1986). Freshwater in-lake spoil island creation has recently begun to gain favor with lake managers due to the increased costs of spoil transport to off-site locations and the lack of accessibility to those locations. This literature review found 20 studies on coastal spoil island use and 13 studies on inland spoil island use. The following is an overview of the current state of knowledge on wildlife usage of created spoil islands in North America.

Wildlife Use of Coastal Islands

Shorebird, Gull, Tern, and Waterbird Use of Coastal Spoil Islands

Spoil islands can be particularly attractive to nesting terns, gulls, shorebirds, and waterbirds. The islands, particularly when young, are sparsely vegetated and composed of sandy materials similar to natural beach nesting areas. The majority of coastal spoil island research has been on the use of spoil islands by these avian species.

Spoil islands have been proposed to benefit piping plovers (*Charadrius melodus*, Cohen et al. 2008). They found that plovers preferred island habitats over barrier island

beaches when tide levels were low. They suggested that created sand flats could help to mitigate beach habitat loss. Western snowy plover (*Charadrius alexandrinus nivosus*) use of created islands in Southern California was studied by Powell and Collier (2000). They found that these islands were used for nesting and foraging and resting for overwintering snowy plovers. The plovers were found to prefer an island with finer, siltier substrate than other island with coarser substrate. They also selected for nesting sites with low amounts of cover, but located nests in areas of greater cover than random sites. The authors hypothesized that the silty substrate allowed easier plant colonization than coarse sand and shell islands creating the preferred amount of cover for nesting snowy plovers. Killdeer (*Charadrius vociferus*) and American avocet (*Recurvirostra americana*) were also found nesting on this island. Powell and Collier mentioned the possibility of these nesting islands resulting in population sinks. The islands may be highly attractive to the plovers but they may facilitate low reproductive rates, ultimately harming the population. Large islands for low nest densities with adequate cover for nests and chicks, but sparse enough to discourage predators were suggested for optimal use by nesting snowy plovers.

American oystercatchers (*Haematopus palliatus*) were observed nesting on spoil islands by Toland (1992). He studied oystercatcher nesting on spoil islands in the Indian River Lagoon, near Vero Beach, FL. The spoil islands studied ranged in size from 0.2 ha to 1.2 ha. Eleven nests were found between 1986 through 1990. Oystercatchers were observed nesting on forested islands with some success; both nests fledged at least 1 young. The nests on islands with typical nesting substrate, sand/shell, fledged chicks from only 3 of 9 nests. Toland hypothesized that the use of

these forested islands was in response to human encroachment on traditional beach nesting areas. The lack of success on the more traditional substrate was a result of increased human recreational activity on the islands.

Black skimmers (*Rynchops niger*) have benefited from spoil island creation (Erwin 1977, Erwin et al. 2003). Black skimmer populations along the Atlantic coast were found to heavily use spoil islands for nesting. The shift from natural barrier islands to spoil islands was postulated to be caused by increased human disturbance on the natural islands. Erwin et al. (2003) found that confined disposal facilities, diked spoil islands, often had higher and steeper slopes leading to increased vegetation succession. Vegetation succession lead to decreased use of the spoil islands by black skimmers. Management was recommended to maintain bare substrate preferred by skimmers and terns. Black skimmers, least and gull-billed tern spoil island usage in the Atchafalaya Delta, Louisiana was studied by Mallach and Leberg (1999). The authors reported on nesting use in relation to island substrate. Spoil islands are typically composed of fine sediments or a sand/shell mix. They found that terns had higher egg hatch rates and better nest concealment on shell substrates. In addition, shell substrates reduced and retarded vegetation colonization of spoil islands increasing the usefulness to nesting terns and skimmers. The authors suggested supplemental shell deposits on spoil islands to increase the attractiveness to nesting waterbirds and combat vegetation colonization.

Gull-billed terns (*Sterna nilotica*), common terns (*Sterna hirundo*), Caspian terns (*Sterna caspia*), and least terns (*Sterna antillarum*) have all been reported to benefit from spoil island creation. Molina and Erwin (2006) reported on gull-billed tern use of

coastal islands in Maryland. Vegetation succession was one of the largest threats facing tern populations relying on spoil island nesting areas. During the 1990's, the Hampton Roads Bridge Tunnel, a spoil island, was the largest common tern nesting colony in Virginia (Erwin et al. 2003). Caspian tern populations along the Pacific coast and Southeastern shoreline heavily used spoil islands managed for sparse vegetation and kept predator free. Caspian terns in Florida and Alabama only nested on spoil islands in 2000 and were hypothesized to prefer nesting on spoil islands in the southeast by Wires and Cuthbert (2000). Least terns were studied on spoil islands ranging from 7-10 ha in Georgia by Krogh and Schweitzer (1999). Spoil island habitat was found to be not as preferable to least terns as natural beach habitat but the islands were less likely to flood. This was the first study to report predation of ground nests on spoil islands by red imported fire ants (*Solenopsis invicta*). Over 70% of least terns nested on spoil islands in North Carolina and similar results were observed in Texas (Jackson and Jackson 1985). Spoil islands have become critical to the maintenance of tern populations in many areas of the country. Royal and Sandwich terns were also observed nesting on spoil islands by Jackson and Jackson (1985). The San Francisco Bay Estuary contained large colonies of breeding Caspian and Forster's Terns (*Sterna forsteri*), and California Gulls (*Larus californicus*). These species heavily nested on spoil islands with 59% of Forster's terns, 46% of Caspian terns, and 4 of 7 California Gull colonies were all on salt pond created islands (Strong et al. 2004). The authors stated that the preservation of flat, minimally vegetated islands with a low potential for flooding and disturbance, and a wide angle of view were critical to maintaining gull and tern populations in the San Francisco Bay Estuary.

Herring gull (*Larus argentatus*) use of spoil piles in a salt marsh for nesting was reported on by Burger and Shisler (1978). Herring gull nests on spoil piles were taller than normal nests with larger clutches and bigger eggs. Chicks from the spoil pile nests had higher fledging success than other areas in the marsh. They found that spoil piles were not sub-optimal nesting habitat for herring gulls as they were the driest areas in the marsh, staying above mean tide.

Landin and Soots (1978) provided a national report on the use of spoil islands by colonially nesting birds. Nationwide, over 37 colonially nesting species and 46 non-colonial nesting species used spoil islands for nesting. Up to 92% of colonially nesting species found in an area nested on spoil islands. Large islands (>8 ha) were used less often probably due to the year-round presence of mammalian nest predators. Diked islands were found to be more resistant to erosion and beneficial for feeding and loafing birds, but detrimental to nesting species. The authors found extensive use of the islands for migrating, over-wintering, and permanent avian species as well. They stated that the higher the human population and encroachment into natural breeding areas, the larger the percentage of birds nesting on spoil islands. Parnell et al. (1986) reported that 190 species have been seen on spoil islands in North Carolina since 1971. Forty-three of those nested on islands. They found that around 50% of avian species in coastal North Carolina utilized spoil islands and around 33% of those species nested on the islands. The islands in North Carolina were especially important for ground nesting colonial waterbirds and wading birds. In 1983, 63% of all wading bird colonies and 76% of all ground nesting waterbird colonies were found on spoil islands. In addition to waterbirds, they reported that American oystercatcher and willet (*Catoptrophorus*

semipalmatus) nesting densities on upland spoil islands could become very high. Erwin and Beck (2007) reported on avian usage of 3 large (from 456-1,050 ha) spoil retention facilities in the Chesapeake Bay. These spoil retention facilities were only partially upland spoil area or contained smaller spoil islands within diked spoil holding cells. These islands were heavily used by many bird guilds with over 224 species found on 1 of the islands, Craney Island. Least and common terns nested on the islands although reported hatching failure was almost total during 2003 and 2004. The authors cited predation as the main cause of nest failure on these large islands, and without control, the productivity of these islands may decline.

Recommendations for islands constructed for nesting shorebirds, terns, and skimmers were given by Lewis and Lewis (1978), Erwin et al. (2003), and Golder et al. (2008). Islands isolated from shore were preferred by terns due to a lack of predators. Golder et al. recommended at least 2 km of open water at mean low tide with a deep channel and tidal flow to reduce predation and human visitation. Undiked islands were recommended to provide the more coarse substrate preferred by terns. Islands should be between 2 and 20 ha with a gentle slope and a 1 to 3 m rise in elevation. Vegetation succession greatly reduced the use of islands for nesting, particularly once the herb-shrub stage took over. Vegetation management was the largest determinant of productive nesting success where predators were excluded. Vegetation management for open, sandy shorelines by mechanical removal or addition of new spoil would increase nesting areas for these guilds.

Other Avian Guild Usage of Coastal Spoil Islands

Waterfowl use of coastal spoil islands has received much less attention than use by gulls, terns, shorebirds, and other waterbirds. However, the mottled duck (*Anas*

fulvigula) in Florida is a non-migratory species that was found to breed on spoil islands along the Atlantic Coast in the Indian River Lagoon by Stieglitz and Wilson (1968). They found heavy use of spoil islands by the ducks as well as laughing gulls (*Larus atricilla*), black skimmers, willets, and blue jays (*Cyanocitta cristata*). The authors identified the lack of mammalian predators as the primary reason for mottled duck nesting on the spoil islands. The authors cited human encroachment, invasive plant species, and erosion as limiting factors to spoil island use by mottled ducks. Parnell et al. (1986) also reported waterfowl use of coastal spoil islands in North Carolina. The authors reported American black ducks (*Anas rubripes*), gadwalls (*Anas strepera*), and blue-winged teal (*Anas discors*) utilized salt marsh growing on these islands. American white pelicans (*Pelecanus erythrorhynchos*) were shown to use and greatly benefit from spoil island creation in the Mississippi Delta (Yozzo et al. 2004). Brown pelicans (*Pelecanus occidentalis*) and wading birds were reported using spoil islands along the Atlantic coast by Erwin et al. (2003). These species used the islands after vegetation succession forced out nesting terns. Erwin and Beck (2007) reported that a pair of Virginia rail (*Rallus limicola*) and around 25 pairs of the rare coastal plain swamp sparrow (*Melospiza Georgiana nigrescens*) were found on the large spoil island, Hart-Miller Island, in the Chesapeake Bay, Maryland.

Mammal Use of Coastal Spoil Islands

Mammal use of coastal spoil islands has focused solely on avian nest predation effects. This is partly due to the placement and design of coastal islands to limit mammalian colonization and the traditional narrow focus of wildlife uses for spoil islands. Raccoon (*Procyon lotor*) was the most common nest predator found on coastal spoil islands (Landin and Soots 1978, Krogh and Schweitzer 1999, Erwin et al. 2003,

Erwin and Beck 2007). Red fox (*Vulpes vulpes*, Landin and Soots 1978, Erwin et al 2003, Erwin and Beck 2007), feral dogs (*Canis familiaris*) and cats (*Felis catus*)(Landian and Soots 1978, Krogh and Schweitzer 1999, Erwin and Beck 2007) were the second most commonly identified mammalian predators. Other predators observed on the islands in smaller numbers were coyote (*Canis latrans*, Landin and Soots 1978, Krogh and Schweitzer 1999), Norway rat (*Rattus norvegicus*, Erwin et al. 2003), and river otter (*Lutra canadensis*, Erwin and Beck 2007). Almost no attention has been paid to non-predatory mammals using coastal spoil islands. Stieglitz and Wilson (1968) observed marsh rabbits (*Sylvilagus palustris*) on 2 spoil islands near Merrit Island, FL. The lack of information on rodent and other small mammal species on coastal islands should be addressed by future research.

Herpetofaunal Use of Coastal Spoil Islands

There have been no studies conducted, to my knowledge, on herpetofaunal use of coastal spoil islands. It is reasonable to assume that the American crocodile (*Crocodylus acutus*) may utilize spoil islands in southern Florida. Nesting sea turtles may use spoil islands along the coast of southeastern states. Snake and salt marsh turtle species may also utilize spoil islands close to occupied shoreline habitats or in estuaries. Water snakes (*Nerodia* spp.) and diamondback terrapins (*Malaclemys terrapin*) were observed on spoil islands in the Indian River Lagoon in Florida by Stieglitz and Wilson (1968). The use of coastal spoil islands by these species and there effects on other wildlife should be determined in the future.

Wildlife Use of Inland Spoil Islands

Shorebird, Gull, and Tern Use of Inland Spoil Islands

Studies on avian use of inland spoil islands are less numerous than those on coastal island use, but have indicated use by many species. Interior populations of gulls and terns, including the endangered interior least tern (*Sterna antillarum athalassos*) have been shown to utilize inland spoil islands.

American avocets have benefited from the creation of waterfowl nesting islands in the prairie pothole region of the U.S. and Canada. Dahl et al (2003) studied avocets nesting on created islands in North Dakota. The islands used in this study were ≥ 90 m from shore and between 0.1 and 0.6 ha in size. They found avocet nest densities higher on larger islands (>3 ha) and islands with beaches. The beaches on some islands may have indicated shallow water foraging areas surrounding the islands. Avocets typically forage in shallow water areas and nest nearby. Shallow wetlands were found to support larger islands with beaches due to the water depth. Piping plover, spotted sandpiper (*Actitis macularia*), Wilson's phalarope (*Phalaropus tricolor*), marbled godwit (*Limosa fedoa*), and killdeer were also found nesting on the islands.

Scharf (1981) found both common terns (*Sterna hirundo*) and ring-billed gulls (*Larus delawarensis*) nesting in the St. Mary's River in Michigan. Many of the nesting islands experienced heavy erosion due to dredge spoil deposition in alternate sites. Scharf found that islands composed of sand with shoreline stabilization were less likely to erode. Gull nesting was also hampered by thick vegetation on the islands. Gull-billed tern nesting was reported on spoil islands in Maryland by Molina and Erwin (2006). Spoil islands were found both helpful and harmful for the Maryland tern population. Terns had turned to nesting on human-created islands when natural

habitats were lost. Erosion and submergence of nesting islands coupled with vegetation succession were partly responsible for the extirpation of gull-billed terns from parts of Maryland. Vegetation succession on spoil islands nesting areas in particular, was cited as a main threat to reproductive success.

Spear et al. (2007) studied least tern nesting success on Andrews Island, a 312 ha spoil island in the Turtle River, Brunswick, GA. Least terns nested on an 8 ha, managed patch on the south-western corner of the island. They studied the effects of different management practices on tern nesting success from 1993-1998, alternating management yearly. Management included pre-nesting season vegetation disking and electric fencing for predator exclusion. Increased management activities resulted in increased nest survival and 21-day survival rate. They hypothesized that managing for least tern nesting sites would also benefit Wilson's plover (*Charadrius wilsonia*), piping plover, American oystercatcher, and black skimmer. Least tern nesting was also studied on spoil islands and other human created habitats in central Nebraska. Interior least terns were first found using spoil islands in central Nebraska in 1949. Jenniges and Plettner (2008) found that 90% of least tern nests in NE were on human created habitats, sandpits and spoil islands created for least tern and piping plover nesting. Sandpits were favored over spoil islands by nesting least terns. Successful fledging was only reported from islands where vegetation was physically cleared to create bare nesting substrate.

Recommendations on island construction for terns center on vegetation management, erosion control, and prevention of predator and human disturbances. These recommendations were similar to those for coastal islands. The lack of tern, gull,

and shorebird use of spoil islands in Lake Tohopekaliga, FL was attributed to heavily vegetated islands, ease of access by mammalian predators, and an abundant raptor population (Shoger et al. 2009). Scharf (1981) recommended constructing islands with heavier sandy material and diking the spoil to prevent erosion. Brush removal and fire were recommended to manage vegetation succession and maintain tern nesting habitat.

Waterfowl Use of Inland Spoil Islands

Island creation to increase waterfowl production has been a focus in the prairie pothole region of the U. S. and Canada. Hammond and Mann (1956) reported on waterfowl use of constructed islands in North Dakota and across the prairie pothole states. They attributed the high use of island habitat to the high ratio of land-water edge, close proximity of food, water, loafing sites, and good nesting cover. They found that Canada geese (*Branta canadensis*), and gadwalls, with mallards (*Anas platyrhynchos*) and Northern pintails (*Anas acuta*) to a lesser extent, had the greatest chances of attaining island nesting densities higher than in normal habitat. They found high nest densities on islands isolated from the shoreline and predators by open water from 0.3 to 1.0 acres in size. These islands supported nest densities between 20 and 80 nests/acre. Isolation of the islands from the mainland by an open water barrier was a key determinant to heavy use by waterfowl. Several hundred feet of isolation with water ≥ 12 inches deep was recommended as sufficient to dissuade predators. The need to control island erosion to extend island life was also mentioned.

Nesting success by Canada geese and mallards was studied by Johnson et al. (1978) on islands in North Dakota. The islands were small in size, averaging 0.003 ha, and constructed in prairie wetlands. Mallard nesting success was greater on islands

(57%) than in associated upland habitats (12%). Canada goose and redhead ducks (*Aythya americana*) were also found on the spoil islands. Most of this increased nesting success was attributed to predator exclusion from the islands.

Giroux (1981) studied waterfowl use of created islands in Alberta, Canada. He found that mallard, lesser scaup (*Aythya affinis*), and gadwall were the most common ducks nesting on the islands. Northern pintail, blue-winged teal, green-winged teal (*Anas crecca*), cinnamon teal (*Anas cyanoptera*), northern shovler (*Anas clypeata*), American widgeon (*Anas americana*), redhead, white-winged scoter (*Melanitta fusca*), and ruddy duck (*Oxyura jamaicensis*) were also observed nesting on the islands. Nesting densities were found positively correlated with an island's distance from shore with closer islands having densities of 33.7 nests/ha and farther islands having densities at 46.8 nests/ha. Nesting success was also positively correlated with island distance from shore. 57% of failed nests were the result of depredation by mammalian predators. Mammalian predation was probably responsible for the positive correlation between distance from shore and nest success. The author reported that smaller islands located farther from shore with more vegetative cover were the most productive waterfowl nesting islands.

Seven waterfowl species were found to nest on constructed islands in North Dakota by Wilms and Crawford (1989). Over 90% of the nesting was by mallards, gadwalls, and blue-winged teal. Other species nesting on the islands included lesser scaup, northern pintail, green-winged teal, and northern shoveler. Nest densities were found highly correlated with the existence of an open water barrier surrounding the island. The open water barrier was especially important for mallard and gadwall

nesting. Nest densities were greatest on islands ≥ 335 m from shore, surrounded by 150-200 m of open water, and covered in good vegetative nesting cover.

Mottled ducks established 5 nests on spoil island in Lake Tohopekaliga, FL (Shoger et al. 2009). The nest fate was only determined on a single nest, which failed. It was assumed that a high abundance of nest predators in the area was responsible for the lack of nesting and low productivity on the islands. Mottled ducks were also observed feeding on vegetation in the center of a low-relief island on numerous occasions. Vegetation in the center of this island remains close to the water table year-round due to the low elevation possibly providing succulent vegetation favored by foraging mottled ducks. Mallard, ruddy ducks, ring-necked ducks (*Aythya collaris*), and wood ducks (*Aix sponsa*) were also observed using the wetted island for foraging and loafing.

Several studies have given recommendations for construction of spoil islands for optimal waterfowl nesting success. Most recommendations seek to maximize deterrence from mammalian predators. Islands constructed far from shore in water deep enough to prevent drying out and force wildlife to swim to the islands, and surrounded by an open water barrier were consistent recommendations. Johnson et al. (1978) recommended constructing islands far from shore in water ≥ 0.3 m with a low-profile. Giroux (1981) suggested island sizes of around 0.1 ha constructed ≥ 170 m from shore with good vegetative cover. He also advised that islands should be aligned with prevailing winds to reduce erosion and prolong the life of the island. Wilms and Crawford (1989) recommended constructing islands far from shore with an open water barrier between the shoreline. They found that an open water barrier was not a

complete deterrent to mammalian predators and recommended predator control when needed. Lokemon and Woodward (1992) recommended islands be constructed at least 100 m from shore, planted with nesting cover and removed of predators for optimal use by ducks. They also suggested that saline lakes with a high density of peripheral wetlands were ideal locations for creation of waterfowl nesting islands.

Other Avian Guild Usage of Inland Spoil Islands

Other avian guilds have benefited from inland spoil island creation. Landin and Newling (1987) reported over 85 species utilizing a 20 acre spoil island in Virginia. Species observed on the island were migratory shorebirds, Canada geese, American bald eagles (*Haliaeetus leucocephalus*), and numerous waterfowl species. The island became less useful to many species as erosion and subsidence took hold over a 10 year period.

Hulon et al. (1998) reported 24 species utilizing 2 spoil islands in Lake Jackson, Osceola County, FL. Of those species, 5 were listed as species of special concern in Florida and 2, the whooping crane (*Grus americana*) and wood stork (*Mycteria americana*) were listed as federally endangered species. Wild turkey (*Meleagris gallopavo*), a game species, was observed using the peninsular spoil island and on the second more distal island only when the lake level was drawdown. They observed shore and wading birds using open shoreline habitat. Raptors were common on the islands. Hulon et al. postulated that an abundant rodent population drew the raptors to the islands.

Shoger et al. (2009) reported 85 avian species utilizing 13 spoil islands in Lake Tohopekaliga, Osceola County, FL. Five of the birds were listed as species of special concern, 2 were federally threatened species, the Florida sandhill crane (*Grus*

Canadensis pratensis) and crested caracara (*Caracara cheriway*), and 2 were federally endangered species, the wood stork and snail kite (*Rostrhamus sociabilis*).

Wading birds were highly associated with islands grazed by cattle. This association may have been prey related, with anurans and fish attracted to the high nutrient waters around the islands or due to the lack of a willow (*Salix* spp.) fringe on the grazed island. Common moorhen (*Gallinula chloropus*), limpkin (*Aramus guarauna*), sandhill crane, boat-tailed grackle (*Quiscalus major*), red-winged blackbird (*Agelaius phoeniceus*), least bittern (*Ixobrychus exilis*), were all found nesting on spoil islands in Lake Tohopekaliga. The majority of avian nesting was by the 2 passerine species, the boat-tailed grackle and red-winged blackbird.

Mammal Use of Inland Spoil Islands

Most research on spoil islands has been avian-centric only including mammal occurrence in discussions on nest predation or as qualitative observations. Most observations of predator species on inland spoil islands were of semi-aquatic mesopredators. The most frequently reported species being the raccoon (Landin and Newling 1987, Wilms and Crawford 1989, Johnson et al. 1978, Hulon et al. 1998, Shoger et al. 2009). The raccoon was of particular concern due to its adaptability to multiple habitats, ability to swim long distances, and its ability to devastate ground nesting species. Mink (*Mustela vison*) was a primary predator of nesting waterfowl and nests by Wilms and Crawford (1989) and Johnson et al. (1978). Other mammalian predators identified more infrequently on spoil islands were red fox (Johnson et al. 1978), grey fox (*Urocyon cinereoargenteus*, Hulon et al. 1998), coyote (Giroux 1981, Shoger et al. 2009), bobcat (*Lynx rufus*, Hulon et al. 1998, Shoger et al. 2009), badger (*Taxidea taxus*, Giroux 1981), striped skunk (*Mephitis mephitis*, Giroux 1981), opossum

(*Didelphis virginiana*, Shoger et al. 2009), nine-banded armadillo (*Dasypus novemcinctus*, Hulon et al. 1998), and North American river otter (Hulon et al. 1998, Shoger et al. 2009). These predator species were probably less important on many islands than raccoon and mink, due to their less aquatic nature and subsequently lessened ability to reach more distally located islands. River otters are highly aquatic but mainly prey on fish and crustaceans, rarely taking terrestrial vertebrate prey.

The use of inland spoil islands by mammals other than nest predators has been rarely studied. Landin and Newling (1987) observed four mammal species on Windmill Point, a 20 acre spoil island in the James River, VA. Marsh rice rats (*Oryzomys palustris*), raccoons, muskrats (*Ondatra zibethicus*), and mice were utilizing the island soon after construction but observations decreased within 10 years due to island erosion and subsidence, much the same as the avian species mentioned earlier. Studies by Hulon et al. (1998) and Shoger et al. (2009) specifically focused research on mammal use of in-lake spoil islands in Florida. Hulon et al. (1998) found 6 small mammal species and 2 game species in addition to the predators mentioned earlier. Shoger et al. (2009) found 7 small mammal species, white-tailed deer (*Odocoileus virginianus*), and domesticated cows on the spoil islands in addition to the aforementioned predator species. Marsh rice rats were reported to be the most abundant small mammal species on the islands by Hulon et al. (1998). Hispid cotton rats (*Sigmodon hispidus*) were the most commonly trapped and widespread species on the islands by Shoger et al. (2009). Marsh rice rats island occupancy was related to lake location of the island indicating the importance of a strong shoreline population for colonizing islands. Hispid cotton rat occupancy was related mainly to vegetative habitat

characteristics and less an islands distance to the nearest shoreline. Both white-tailed deer and wild pigs (*Sus scrofa*) were observed using the peninsular island and the more distal island during lake level drawdowns. White-tailed deer were found on multiple spoil islands in Lake Tohopekaliga, FL by Shoger et al. (2009). The deer were capable of swimming to even the most remote islands in the lake, but the importance of the islands to deer was assumed minimal.

Herpetofaunal Use of Inland Spoil Islands

The use of spoil islands by herpetofaunal species has been extremely poorly studied. The only 2 studies I found were both from Osceola County, FL and reported on wildlife use on in-lake spoil islands.

Hulon et al (1998) captured 8 anuran species on the 2 spoil islands in Lake Jackson. A single salamander species, the greater siren (*Siren lacertian*), was also captured utilizing the islands. Shoger et al. (2009) also found numerous amphibian species using spoil islands in Lake Tohopekaliga, Osceola County, FL, including 6 anuran species and 2 salamander species. Tadpoles were found around the wetted fringe of several islands indicating breeding by anuran species. Southern leopard frogs (*Rana sphenoccephala*) had higher occupancy rates on islands grazed by cattle and on islands left in rough heaps of dredged spoil instead of graded smooth.

Hulon et al. (1998) found a total of 18 reptile species on the Lake Jackson islands, including 11 snake species, 4 turtle species, and 3 lizard species. Two of those species are specially protected. The American alligator (*Alligator mississippiensis*) was listed as a species of special concern in Florida and the Eastern indigo snake (*Drymarchon corais couperi*) was a federally threatened species. American alligator, banded water snake (*Nerodia fasciata*), eastern mud snake (*Farancia abacura*

abacura), Florida softshell turtle (*Apalone ferox*), peninsula cooter (*Pseudemys floridana peninsularis*), common musk turtle (*Sternotherus odoratus*), and ground skink (*Scincella lateralis*) reproduced on the Lake Jackson spoil islands. Shoger et al. (2009) found a total of 19 reptile species on the Lake Tohopekaliga islands, including 10 snake species, 6 turtle species, and 2 lizard species. American alligator, all 6 turtle species, and several snake species reproduced on the islands. Snake species were found associated with islands left in rough heaps of spoil as opposed to islands smoothed by heavy machinery. At least 1 alligator nest and the majority of turtle nests found had been depredated.

Conclusion

Yozzo et al. (2004) gave general recommendations for the creation of spoil islands, both coastal and inland. They suggested that wildlife diversity could be maximized by creating and fostering heterogeneous habitat. Colonization from shoreline species, such as rodents, should be expected. Trees and shrubs should rapidly colonize most islands and provide canopy nesting opportunities for species. In all, creating and maintaining a diverse array of insular habitat should provide maximal wildlife usage of spoil islands. The spoil islands created as a result of dredging activities are new, novel ecosystems with potentially both helpful and harmful effects on wildlife. The relatively recent surge in interest for the development of non-coastal, in-lake spoil islands needs to be met with an increase in research to determine the potential impacts these islands have on wildlife.

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BIOGRAPHICAL SKETCH

Bradley Shoger was born in 1981 in Indianapolis, Indiana. Brad attended Indiana University and received a Bachelor of Science in public affairs in 2003, majoring in environmental management with a minor in biology. He then gained field experience in wildlife and habitat management in both Idaho and Florida. After a year of working for the Florida Fish and Wildlife Cooperative Research Unit, Brad was accepted into the Master of Science in wildlife ecology and conservation program at the University of Florida. Brad's research interests include wildlife and habitat restoration on private lands and the conservation of mammalian predators.