# Diet Analysis of Wintering Waterfowl in the Southeastern United States in Relation to Ecoregion, Habitat, and Guild

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# ABSTRACT

Wintering waterfowl diet has been studied across North America to gain a better understanding of their foraging habits and feeding ecology. There is a need for a better understanding of waterfowl foraging based on ecoregion, guild, and habitats of wintering waterfowl, especially within the Mississippi Flyway. This study investigated the stomach content of wintering waterfowl in the Southeast United States, within the Mississippi Flyway region. The esophagus, proventriculus, and gizzard of each specimen were removed, dried, and sorted for statistical analysis. Multiple two-way ANOVAs were run to test the effects of ecoregion, habitat, and guild on total mass and diet mass in waterfowl. A difference between years was determined so separate analyses were conducted for each year. My results suggest that there was a significant difference in 2014 data for ecoregion by habitat within the Ridge and Valley ecoregion. Total diet composition results suggest that waterfowl consume different food components in each ecoregion. When analyzing guild diet composition, the results suggest that each guild consumes different types of food products, with the dabblers consuming the most agricultural products, divers consuming the most varied diet, and geese consuming the most grasses.

ACKNOWLEDGMENTS

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# LIST OF ABBREVIATIONS

ANOVA, Analysis of Variation

FWS, Fish and Wildlife Service

MAV, Mississippi Alluvial Valley

UTC, University of Tennessee at Chattanooga

WMA, Wildlife Management Area

# CHAPTER I

# INTRODUCTION

## *1.1 Mississippi Flyway*

The continent of North America is comprised of four major waterfowl flyways: Atlantic, Pacific, Central, and Mississippi. Each flyway is administratively established by a distinct flyway council, and the boundaries of the flyways were set due to early banding efforts showing waterfowl migration corridors during winter migration. (Mississippi Flyways and U.S. Fish and Wildlife Service 2016; Ducks Unlimited 2016). The Mississippi Flyway is used as a major corridor for winter migration by many species of waterfowl in North America. Many political entities fall within the Mississippi Flyway including: Alabama, Arkansas, Indiana, Illinois, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Ohio, Tennessee, and Wisconsin in the United States, as well as the Canadian provinces of Saskatchewan, Manitoba, and Ontario (Ducks Unlimited 2016). To properly manage the entire flyway, the Mississippi Flyway Council was organized in 1952 and consists of representatives from each state or province to coordinate the management of waterfowl and shorebirds; the Council provides a point of contact for the U.S. Fish and Wildlife Service (FWS) for the purpose of coordinating federal/state/provincial management activities, providing advice to the FWS on long and short-term migratory bird management needs of the flyway; this advice includes the establishment of harvest regulations so that the welfare of these resources can be properly safeguarded (Mississippi Flyways and U.S. Fish and Wildlife Service 2016; Ducks Unlimited 2016).

There are many different types of habitats for waterfowl that are suitable in the Mississippi Flyway such as bottomlands in the Mississippi Alluvial Valley (MAV) that during winter months hold millions of individuals. The MAV is the most important wintering area for waterfowl, especially mallards, in North America and also provides breeding and wintering habitat for large Wood Duck (*Aix sponsa*) populations (Baldassarre and Bolen 2006). The agriculture presence in the Mississippi Flyway also is a large food source for wintering waterfowl and provides feeding opportunities during winter migration. There are many species of waterfowl found within the Mississippi Flyway since there are an abundance and variety of food opportunities as well as multiple suitable habitats for each type of waterfowl. The Mallard Duck is the most common and harvested waterfowl in North America and the most common waterfowl seen in the Mississippi Flyway (Green and Krementz 2008). The Mississippi Flyway is an especially crucial habitat for waterfowl during winter migration.

### 1.2 *Wintering Waterfowl Habitat*

Understanding the habitats used by wintering waterfowl is important in understanding their diets and habitat requirements, especially during winter migration. Waterfowl use the Mississippi Flyway as a major corridor during winter migration, searching for suitable habitat as well as sources of food. Each year, seasonally flooded bottomland hardwoods provide suitable habitat for wintering waterfowl in the Mississippi Flyway as winter migration occurs (Delnicki et al. 1986). These areas provide habitat for wintering and nesting wood ducks, as well as the millions of dabbling and diving waterfowl during winter migration. The MAV is also a suitable area for waterfowl during winter migration due to the plethora of cultivated farmlands available for stopover (Stafford et al. 2006). Dabbler species, such as *Anas platyrhynchos* (Mallard Duck) and *Anas acuta* (Northern Pintails), use flooded agricultural fields as an important winter habitat, especially the flooded rice fields in Arkansas (Clark et al. 2014). Dabblers (especially Northern Pintails) generally select feeding habitats that provide the most abundance of food items in proportion to their availability (Clark et al. 2014; Drilling et al 2002). Almost all populations of *Branta canadaensis* (Canada Geese) have readily adapted to use of agricultural crops and this dominates their diets when agricultural crops are readily available in certain ecoregions (Mowbray et al 2002). The variety of food types and suitable habitats within the Mississippi Flyway makes it an ideal location for all waterfowl during winter and spring migration.

Waterfowl also rely on the natural habitats throughout the flyway to use as foraging and stopover sites during winter migration. Diver species, such as *Aythya Americana* (Redhead Ducks) and *Aythya collaris* (Ring-necked Ducks), can inhabit a wide variety of natural habitats such as swamps, backwaters, sloughs, and marshes, as well as use flooded agricultural areas as optimal habitat during winter months ( Clark et al. 2014; Roy et al. 2012). Wetlands have been drastically reduced over the years for industrialization, agricultural development, and flood control. More than 80% of bottomland wetlands have been destroyed and 50% of worldwide wetlands have been destroyed, showing importance and need for conservation with the remaining wetlands and natural habitats (Delnicki et al. 1986, Ma et al. 2009). Many studies have indicated that effectively managed wetlands can provide alternative or complementary habitats for waterbirds and mitigate the adverse effects of wetland loss and degradation (Ma et al. 2009). The habitat of waterfowl can tell us a lot about their diets and food requirements during migration and other important life history events.

1.3 *Waterfowl Foraging and Feeding Ecology*

A reliable assessment of the kind of foods consumed is essential in understanding waterfowl ecology and food availability in a region (Swanson et al. 1970). Food availability for waterfowl is determined by predicted models by waterfowl ecologists and food availability for waterfowl can be influenced by a range of factors including annual production or decomposition of plant and animal foods, competition for food with other wildlife, diet selectivity by foraging waterfowl, ice and snow cover over natural habitats, flooding depth and duration, disturbance by humans and natural predators, and photoperiodic cues triggering migration (Hagy et al. 2012a,b; Hagy et al. 2014; Newton 1998; Rees 1982; Schummer et al. 2010).

Growing waterfowl spend an average of 62% of daylight hours foraging and consuming food (Batt et al. 1992). The foods and feeding behavior of waterfowl are important aspects of their life history and represent an essential ingredient of habitat management (Baldassarre and Bolen 2006). Waterfowl have a varied diet based on the species and guild as well as having a different diet by habitat or geographic location throughout their lives. Young dabbling and diving ducks ingest invertebrates and other animals, and then change to a more plant-based diet as they age (Batt et al. 1992).

Waterfowl foraging ecology within the Mississippi Flyway can be compared by guilds. The diet of dabbling ducks generally includes agricultural grains or products, tubers of moist-soil plants, acorns, invertebrates, and vertebrates and use flooded agricultural fields and reservoirs as suitable habitat during the winter months (Clark et al. 2014; Drilling et al.2002; Smith et al. 1989). The most dominant dabbler species, Mallards, are opportunist and generalist feeders and have a very flexible diet, especially during winter months where food availability determines a majority of their diet (Drilling et al. 2002). More than 90% of energy requirements for nearly half the year are supplied by agricultural products, in which the main sources of energy are carbohydrates and acquiring fat from seed plants (Drilling et al. 2002). The diets of diving ducks consist mostly of tubers of moist-soil plants, invertebrates, as well as fish (Smith et al. 1989). Divers are known to occupy a variety of natural habitats and flooded agricultural fields and coastal areas, consuming aquatic vegetation and mollusks (Roy et al. 2012). Divers, like dabbler species, are omnivorous and almost feed exclusively in water or within flooded vegetation and generally consume benthic vegetation and benthic invertebrates (Roy et al. 2012; Woodin et al. 2002). Geese are almost strictly herbivores and their diet is composed of a wide variety of plant species including shoots of grasses, seeds, or agricultural products in the Mississippi Flyway (Mowbray et al. 2000; Mowbray et al. 2002; Smith et al. 1989).

1.4 *Waterfowl Diet Analysis*

Understanding the diet or guild of a certain waterfowl is important to better understand their feeding habits within a specific habitat or area. A common technique for analysis of waterfowl food habits is studying contents of the digestive system and it has been used for over a century to determine diet composition of specimen. The digestive system in waterfowl consists of the esophagus (crop), proventriculus, ventriculus or gizzard, and intestines (Baldasserre and Bolen 2006). Generally, diet analysis of waterfowl involves collecting specimens, removing food content from the digestive system, drying the contents, and then separating and classifying the contents (Baldasserre and Bolen 2006; Swanson et al. 1970; Swanson et al. 1974). Each component of the digestive system can be used to efficiently identify and categorize components of an individual's diet to better understand their foraging habits. Most diet analysis studies are statistically represented using aggregate percentages and volumes (Swanson et al. 1974). Many investigations have shown the use of the gizzard and esophagus for waterfowl diet analysis (Swanson et al. 1970, Swanson et al. 1974, McMahan 1970), as well as if there is bias in using certain parts of the digestive system. In some studies, (Swanson et al. 1970; Swanson et al. 1974; McMahan 1970; Delnicki et al. 1986) the esophageal content has been used rather than the gizzard due to the rapid digestion of food items by the gizzard and to remove bias any based on differences in degradation rates. Swanson et al. (1970) discussed bias associated with food analysis in waterfowl using the gizzards and suggested that to obtain reliable data one must 1) observe actively feeding waterfowl, 2) examine esophageal content only due to rapid degradation physically and chemically in the gizzard, and lastly 3) remove and preserve food items to avoid post-mortem digestion, which can occur rapidly.

### 1.5 *Expansion on Research*

Expanding knowledge of the diet composition of wintering waterfowl is critical, especially within the Mississippi Flyway. Despite multiple studies examining waterfowl foraging and diet analysis, there are few studies that use a large geographic region or have a substantial sample size. Previous studies such as Swanson et. al (1974) and Swanson et al. (1970) emphasized the value of using esophageal content instead of gizzard content to remove bias concerns. I decided to use both esophageal and gizzard content because I wanted to obtain as much food weight as I could to compare the waterfowl between ecoregions, habitats, and guilds. There is a need to increase understanding of waterfowl diet within specific ecoregions and to investigate habitat and guild differences within the ecoregions. It also is important to improve understanding of waterfowl diet by guild, ecoregion, and habitat. My research focuses on food utilization of waterfowl within the Mississippi Flyway, specifically by ecoregion to gain a better understand of waterfowl foraging.

### 1.6 *Research Questions*

This study was designed to examine waterfowl diet within the Mississippi flyway, as well as differences between ecoregion and guild diet composition. My research attempted to address three major questions: 1) Do waterfowl ingest the same amount of food in one ecoregion versus another? 2) Do waterfowl ingest the same amount of food in one habitat versus another? 3) Is there any difference in foraging between guilds of waterfowl, specifically dabblers, divers, and geese? Previous studies such as Swanson et al. (1974) and McMahan et al. (1970) have focused more on the food data and not the location, whether ecoregion or habitat. These studies focused on their food habits, and I wanted to investigate their food habits and how they relate to the ecoregion or habitat they were collected.

I hypothesized that ecoregions with a higher amount of agricultural habitat for waterfowl to forage would significantly increase the total amount of food material ingested by waterfowl compared to natural habitats in other ecoregions. This hypothesis was based on previous studies that investigated diet composition within a certain study site or specific location, showing a need for a broad approach to better understanding waterfowl diet by ecoregion, habitat, and guild. I also hypothesized that waterfowl in agricultural habitats would consume more total mass (including non-biological material) and more food mass compared to waterfowl collected at natural sites. Having higher food availability in agricultural regions, the waterfowl have an ideal habitat with water and food during migration. Lastly, I also hypothesized that each guild would have different foraging habits, foraging for different foods. dabblers would ingest a significantly higher amount of food materials compared to divers, disregarding geese for their larger size. Dabblers are generally known to be present in agricultural fields and use them as stopovers during winter migration, so this would give them a higher probability to have consumed more agricultural food.

CHAPTER II

STUDY AREA AND METHODS

2.1 *Study Area*

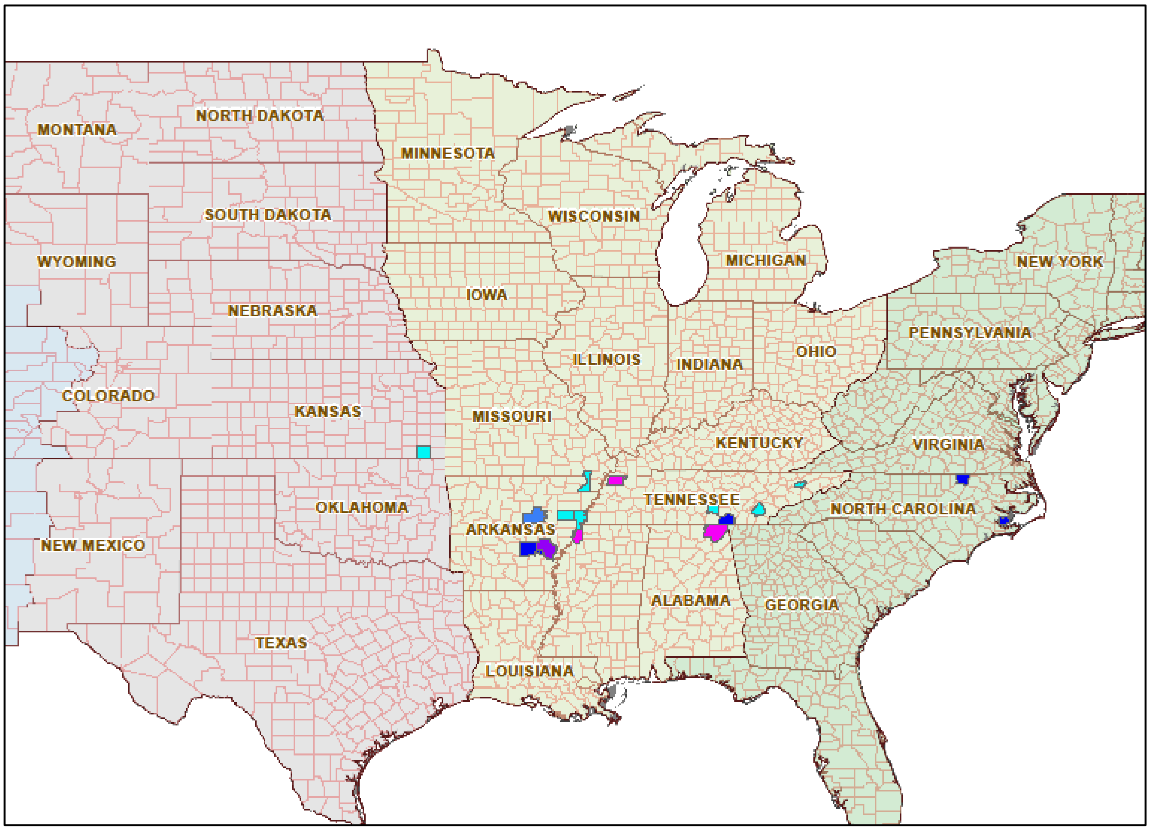


Figure 1 Sampling locations (counties) for this study. Samples in North Carolina and Kansas were later removed from the study because they fell outside the Mississippi Flyway (yellow area)

The study took place in the southeastern United States during the winter months of 2013 and 2014 (Figure 1). This region lies within the Mississippi Flyway, a region known to have a large winter waterfowl migration. Each of the states in the flyway and ecoregions offers multiple types of habitat for wintering waterfowl such as natural habitats like lakes and rivers, and extensive agricultural habitat, especially along the Mississippi River.  These multiple habitats offer a variety of food sources for waterfowl, making the flyway an ideal habitat for winter migration (Baldassarre and Bolen 2006, Wood et al. 2012).  There were five states included in this study: Tennessee, Arkansas, Mississippi, Missouri, and Alabama.

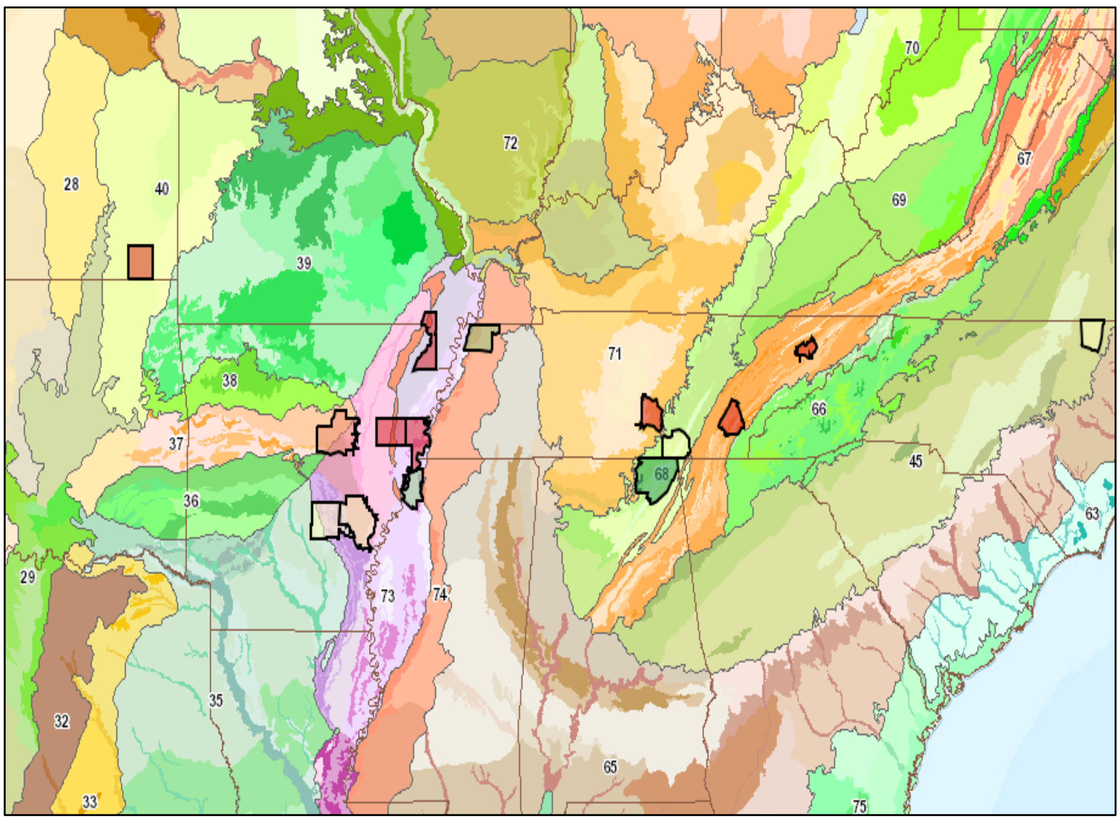


Figure 2 The ecoregions occupied by the study area and the study sites (counties) within different ecoregions: Ridge and Valley (67), Interior Plateau (71), Southwestern Appalachians (68), Mississippi Alluvial Plain (73), and Mississippi Loess Plains (74)

Ecoregions covered in this study (Figure 2) are the following: Ridge and Valley, Southwestern Appalachians, Mississippi Alluvial Plain.  Specimens were collected in

North Carolina and Kansas, but were removed from the study because they were located outside of the Mississippi flyway.

## 2.2 *Data Collection*

Waterfowl specimens obtained were taken by hunters across multiple states and ecoregions in the Mississippi Flyway. Some of the waterfowl were hunted in flooded agricultural fields with products such as rice, soybean, and corn. Many other hunters were in flooded timber or in natural habitats such as wetlands, lakes, rivers, or creeks.

To remove as much bias as possible, since the collection of data was done via hunting, all hunters were asked to give all of their waterfowl from a specific hunt. All waterfowl was accepted for this study, and those subfamilies collected included the groups *Anatini* (dabbling ducks), *Aythyini* (diving ducks), *Anserini* (geese), and *Rallidae* (rails, coots) (Wood et al. 2012). Many studies remove the family *Rallidae* from waterfowl studies due to their distant evolutionary relationship to that of geese and ducks, but their diets and foraging habits are similar to the ducks and geese in that specific area (Wood et al. 2012; Baldassarre and Bolen 2006). Each hunter was asked to give a description of the hunting area, county, general hunting location, surrounding vegetation type, and what specimens were killed or seen. The waterfowl specimens, along with the hunting information, were delivered and then transported to the University of Tennessee at Chattanooga within that day. Once in the laboratory, each specimen was dissected, removing the gizzard, stomach, and esophagus. Those organs were stored in freezers in the laboratory until their contents were removed. Previous studies such as Swanson et al.

(1974) used the esophageal content of waterfowl rather than the gizzard based upon previous studies of upland game birds. I decided to use the esophageal and gizzard content for this study as to include all ingested material.

Waterfowl were then categorized by type, sex, state, and given site codes based on their locality. This helped with organization as well as to differentiate between the two years of data when entering into a spreadsheet for statistical analysis. These specimens would remain frozen until the dissection phase of the study after data collection. The advantage of preserving the samples until dissection is the ability to preserve color and texture, which could be valuable when identifying stomach content material (Ward et al. 1970).

2.3 *Dissection*

Once the specimen collection was finished in January typically for each season, I began the diet analysis of each specimen. I removed the frozen gizzard, stomach, and esophagus and allowed them to thaw, allowing the removal of the contents from each of the digestive parts. Like previous dietary studies (Swanson et al. 1974; Dallinger et al. 1985), the dietary contents were then rinsed with water then dried in a drying oven at 55˚ Celsius over a period of three to five days until completely removed of moisture. The removal of moisture in the samples eliminated any excess water weight, allowing for an accurate way to quantify the total mass of the sample. Once the samples were dry, I separated the digestive content using a sieve and spatula and weighed each sample's components, giving me a diet mass and a total mass, which included the non-biological material.  I used a stereomicroscope to look for smaller seeds and material not easily visible (Ward et al. 1970).   I noticed while separating the samples, certain specimens had more non-biological material (e.g. rocks) than others, so this is why I recorded both diet mass and total mass.  Once the information was recorded, the samples were discarded as biohazard waste along with the carcasses and incinerated off-site.

### 2.4 *Data Analyses*

Once the specimens had been dissected and categorized, I entered all of the information into a spreadsheet using Microsoft Excel™.  From Excel, I took the habitat, ecoregion, and guild data for each specimen, along with the diet mass and total mass for each specimen, and transferred it into Sigma Stat Software™ for statistical analysis.  The diet data for each individual specimen were recorded and used to observe the overall comprehensive diet composition.  The independent variables for the study were ecoregion, habitat and guild.  The dependent variables were total mass of the diet contents and the diet mass, where the non-biological material is removed from the total mass.

Previous studies such as Swanson et al. (1974), Miller et al. (1987)  used percent occurrence and aggregate percent dry weight to summarize their data.  I performed  two-way ANOVAs, using the total mass and diet mass of each waterfowl specimen, to see if there are differences between years for the data.  I also tested ecoregion and habitat, ecoregion and guild, as well as guild and habitat relations to look at the main effects between the variables as well as any interactions.  If a significant difference was detected, a post-hoc Tukey's Test was run to test for significance. If the parameters for equal variance were violated, then a rank transformation of the data was performed. Once statistical analysis was complete, I analyzed the diet composition of each ecoregion and guild, grouping food categories in order to compare my results with previous work and to specifically investigate what waterfowl are consuming.

# CHAPTER III

# RESULTS

A total of 429 individuals were analyzed, 250 in 2013 and 179 in 2014. Each year the data were collected and accepted from hunters at random, causing an uneven number of ecoregions in each year as well as ecoregions with a few individuals. Data from any ecoregion with fewer than ten individuals were removed from the analysis. Before I combined the 2013 and 2014 data to make a larger and more robust data set, I ran two two-way ANOVAs to look for main effects or interaction effects of the year variable.

## 3.1 *2013 and 2014 Year Comparison*

The total mass of the 2013 and 2014 specimens were used for the first two-way ANOVA, testing year by ecoregion. Results suggests that there is not a significant difference (P= 0.158), nor is there any main effects in regards to ecoregion (P=0.761). However, the ranked transformed diet mass results showed a significant difference in year (P=0.005). A Tukey's Test confirmed that the years are significantly different (P=0.028). Since the transformed data showed a significant difference between years with the diet mass, it was decided to separate years for both diet mass and total mass on any ANOVA that used the factor of ecoregion (Figs. 3 and 4). Figure 3 shows a lower mean in Ridge and Valley in 2013 than in 2014 and there is a higher mean diet mass in the Mississippi Alluvial Plains ecoregion in 2014. The Southwestern Appalachians were only represented in 2013. With this information, along with the ANOVA results showing a significant difference in diet mass, the 2013 and 2014 data was separated by year in regards to ecoregion.  There were no significant differences with the factors of habitat or guild between years.

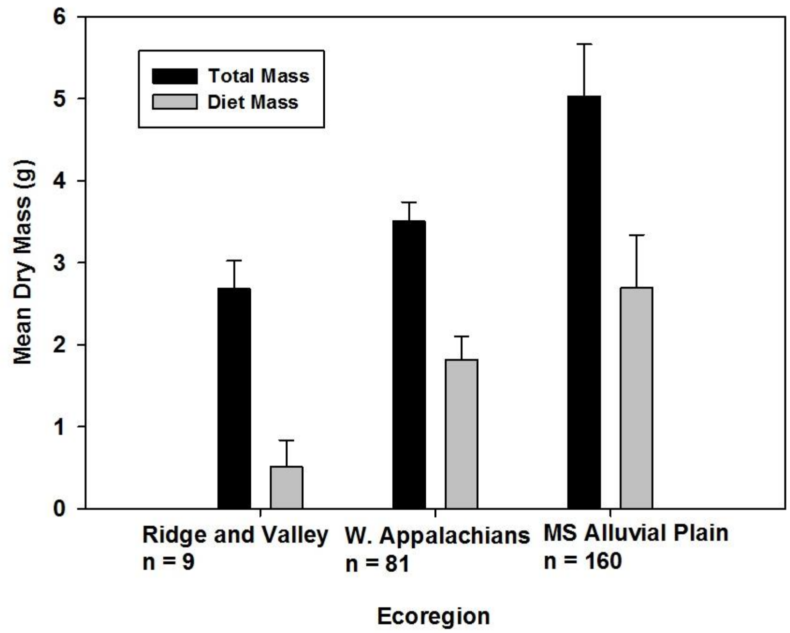


Figure 3 Mean digestive mass (+SE) of total mass and diet mass for three ecoregions in 2013

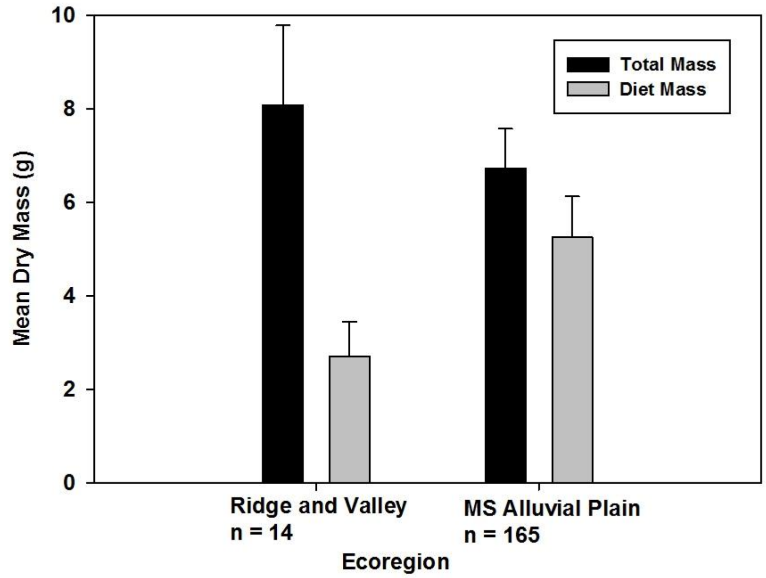


Figure 4 Mean digestive mass (+SE) of total mass and diet mass for two ecoregions in 2014

3.2 *Ecoregion by Habitat*

The variables of ecoregions and habitat were tested using a two-way ANOVA with the 2013 total mass data and results suggested that there were no main effects or significant differences for ecoregion (P=0.138) by habitat (P=0.931) when using the total mass. The diet mass data was then used with the same variables in another two-way ANOVA. There were no main effects found between ecoregion (P=0.537) and habitat (P=0.691) in 2013 using the diet mass data.

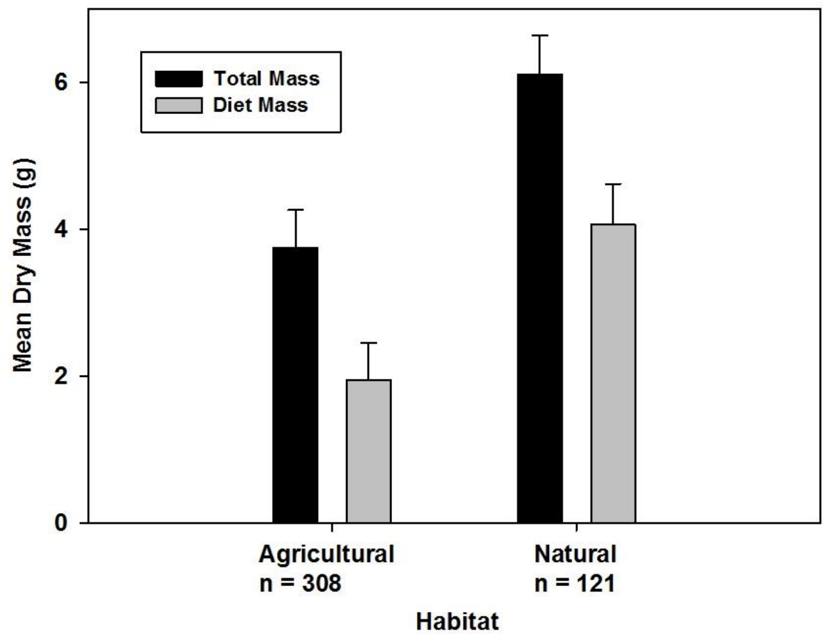


Figure 5 Mean digestive mass (+SE) of total mass and diet mass for agricultural habitats and natural habitats

The 2014 total mass data was used to test for main effects between ecoregions and habitat variables. The results from the ANOVA suggest that there is a significant habitat difference (P=0.005) but not with ecoregions (P=0.947). A Tukey's Test showed a significant difference (P=0.048) as well. The 2014 diet mass data was then used to test for main effects using a two-way ANOVA with ecoregions and habitat. ANOVA results showed no difference in ecoregion (P=0.115) and a significant difference in habitat (P<0.001). The ANOVA was able to test for interactions between ecoregion and habitat, showing that there is a significant interaction (P=0.008) between the two variables. The Tukey Test investigated the comparison between the ecoregions and the habitats within showed that there was a significant difference in habitats within the Ridge and Valley ecoregion. Figure 5 shows a higher mean total and diet mass of waterfowl in natural areas over agricultural areas and the Ridge and Valley ecoregion shows that waterfowl are consuming more total and diet mass in the natural areas. There were no significant differences within the Mississippi Alluvial Plain ecoregion in terms of habitat, nor were there habitat differences within the Southwestern Appalachians due to the absence of specimens in 2014.

### 3.3 *Ecoregion by Guild*

The variables ecoregion and guild were tested for main effected in a two-way ANOVA using the 2013 total mass and diet mass. The results of the total mass ANOVA showed no main effects or significant differences between ecoregion (0.312) and guild (P=0.165). Diet mass data was also used to look for main effects between both variables and there was also no significant differences found between ecoregion (P=0.391) or guild (P=0.559).

When using the 2014 total mass data, the ANOVA showed a slight significance in guild (P=0.043) and no significance in ecoregion (P=0.953). A Tukey's Test compared the guilds total mass data and showed no significant differences in geese vs. divers (P=0.088), geese vs. dabblers (P=0.320), or dabblers vs. divers (P=0.462). However, when analyzing the 2014 diet mass data with the same variables, there were no main effects or significant differences between guild (P=0.297) and ecoregion (P=0.781). When looking at the overall data for both 2013 and 2014 (Figure 6), the geese consumed the most total mass. Once the non-biological material was removed from analysis, there were no longer any significant differences between the three guilds In terms of diet mass.

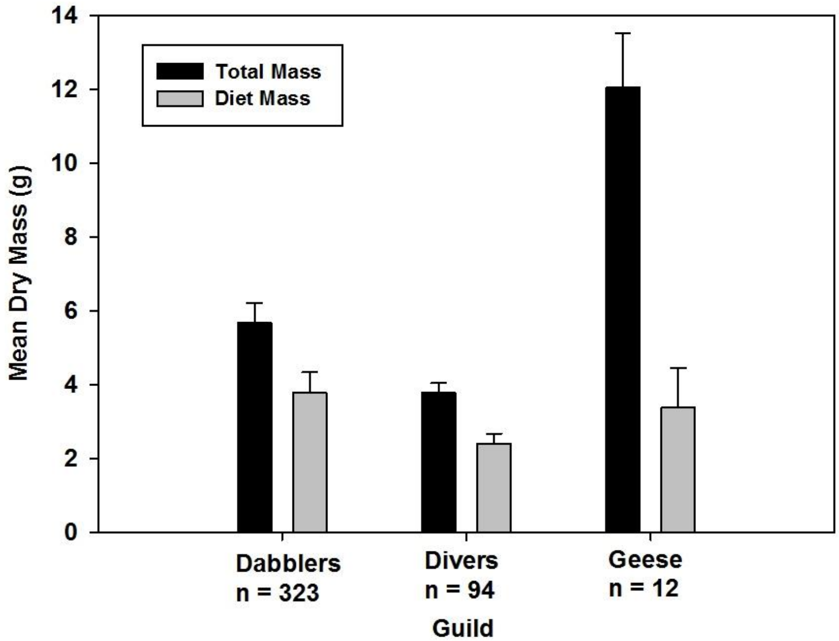


Figure 6 Mean digestive mass (+SE) of total mass and diet mass for dabblers, divers, and geese

3.4 *2013 and 2014 Combined Guild by Habitat*

The final group of tests looked at the factors of guild and habitat in terms of the total mass and the diet mass. Both 2013 and 2014 years' data were combined for these tests since preliminary ANOVA testing showed that there is not a significant year difference in guild or habitat, just ecoregion. The total mass of both years' data was used to test for main effects between guild and habitat and there was a significant difference in guild (P=0.005) and no significant difference in habitat (P=0.092). There was an interaction ran between guild and habitat but there was no significant interaction between the two factors (P=0.219). A Tukey's Test compared the factor of guild and found significant differences between geese and divers (P=0.003), geese and dabblers (P=0.007), and no significant differences between the dabblers and divers (P=0.600).

The combined diet mass data from both years were also used to investigate main effects between guild and habitat using a two-way ANOVA. There were no significant differences or main effects found between guild (P=0.824) or habitat (P=0.982). There were also no interactions between habitat and. Guild (P=0.255). When analyzing the guilds (Figure 6), the diet mass of each guild is similar once non-biological material is removed from the total mass.

### 3.5 *Total Diet Composition by Ecoregion*

The overall diet of the waterfowl in each ecoregion was then analyzed similar to previous studies (Swanson et al. 1970; Swanson et al. 1974), as well as looking at year differences. Ecoregions had to be treated separately due to the ANOVA results showing a significant difference between years. Due to digestion of some of the plant matter, I was not able to identify plants to a higher classification so they were grouped into broad categories.

#### 3.5.1 *Ridge and Valley Ecoregion Diet Composition*

When looking at the 2013 Ridge and Valley ecoregion in Figure 7, a majority of the waterfowl diet (excluding non-biological material) was seeds and arboreal content as well as a small amount of invertebrates. When looking at the 2014 Ridge and Valley data in Figure 8, there is a difference in overall diet components between the years. There was less non-biological material consumed in 2014 than in 2013. A larger percentage of the waterfowl from 2014 in the Ridge and Valley consumed arboreal (leaves and acorns) material as well as grasses.  There was also a higher percentage of invertebrates consumed in 2014 than in 2013.

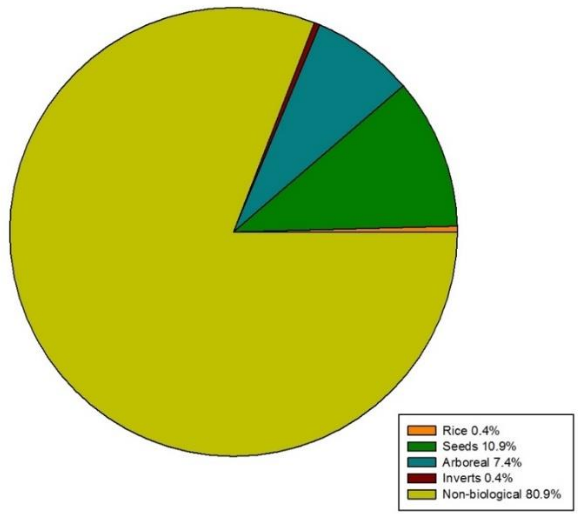


Figure 7 Total diet composition of wintering waterfowl in the Ridge and Valley ecoregion in 2013

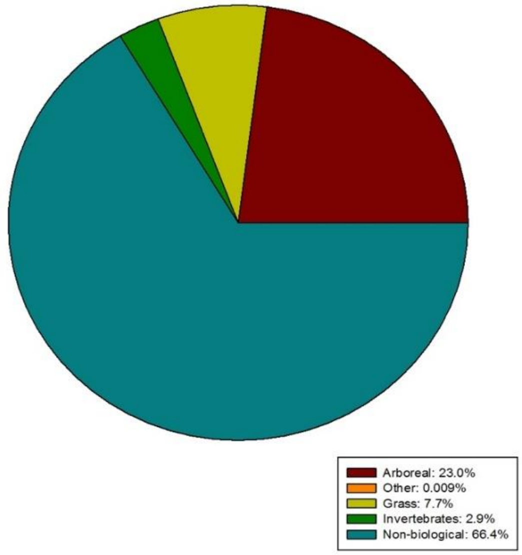


Figure 8 Total diet composition of wintering waterfowl in the Ridge and Valley ecoregion in 2014

3.5.2 *Southwestern Appalachians Ecoregion Diet Composition*

The Southwestern Appalachians Ecoregion data (Figure 9) was only represented in 2014. Waterfowl in this ecoregion consumed a large variety of food in their diet and consumed less non-biological material than in the Ridge and Valley and also a higher amount of seeds and agricultural products such as corn and soybean. Waterfowl in this ecoregion consumed a higher percentage of invertebrates compared to the Ridge and Valley and Mississippi Alluvial Plains.

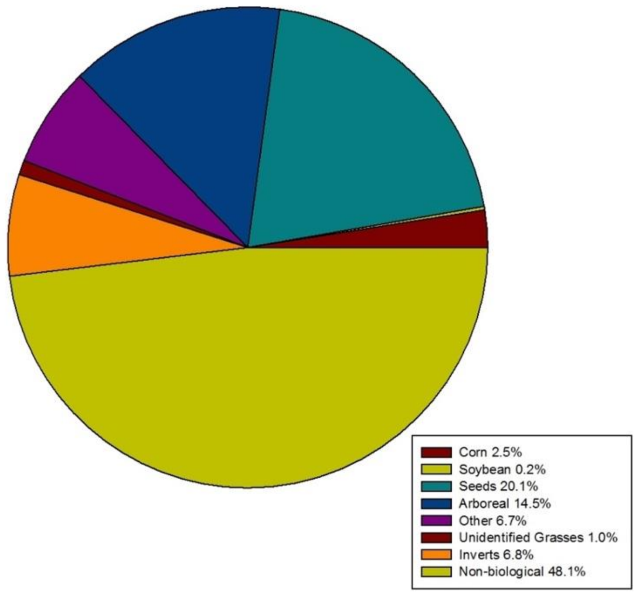


Figure 9 Total diet composition of waterfowl in the Southwestern Appalachians ecoregion in 2013

3.5.3 *Mississippi Alluvial Plain Ecoregion Diet Composition*

Waterfowl from the Mississippi Alluvial Plain Ecoregion were studied in both 2013 (Figure 10) and 2014 (Figure 11). In 2013, less than half of the materials ingested were non-biological and a large percent of their diet was rice (30.6%). In 2014, a similar trend can be seen except for a relatively low non-biological material mass compared to other years and other ecoregions. A significantly higher amount of rice (60.2%) was consumed by waterfowl in 2014 in the Mississippi Alluvial Plains compared to other waterfowl in other ecoregions and also consumed the most agricultural products out of every ecoregion and year.

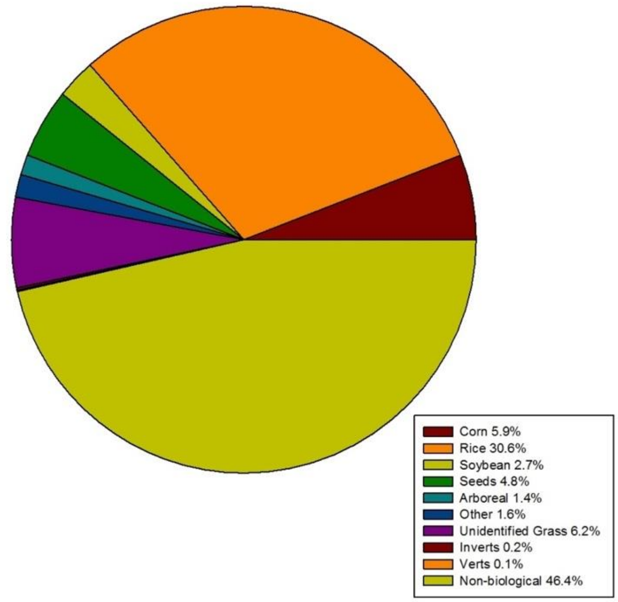


Figure 10 Total diet composition of waterfowl in the Mississippi Alluvial Plains ecoregion in 2013

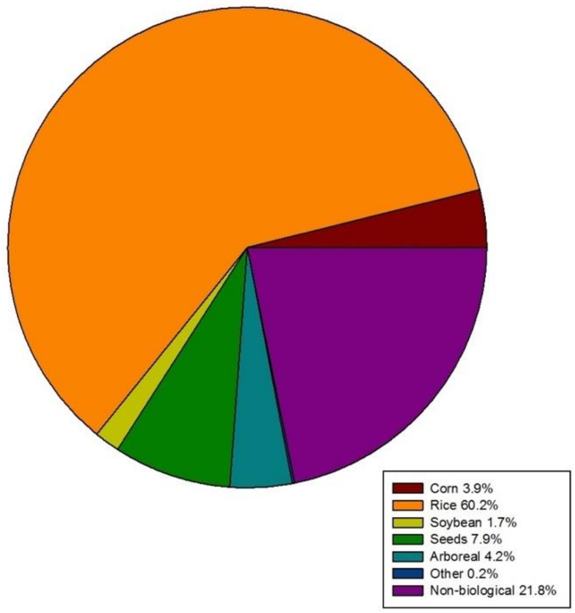


Figure 11 Total diet composition of waterfowl in the Mississippi Alluvial Plains ecoregion in 2014

## 3.6 *Total Diet Composition by Guild*

### 3.6.1 *Dabblers*

Of the three guilds examined, dabblers consumed the least amount of non-biological material (Figure 12). They also consumed a much higher amount of agricultural products than other guilds, especially rice and corn. A majority of dabblers diet is the consumption of rice.

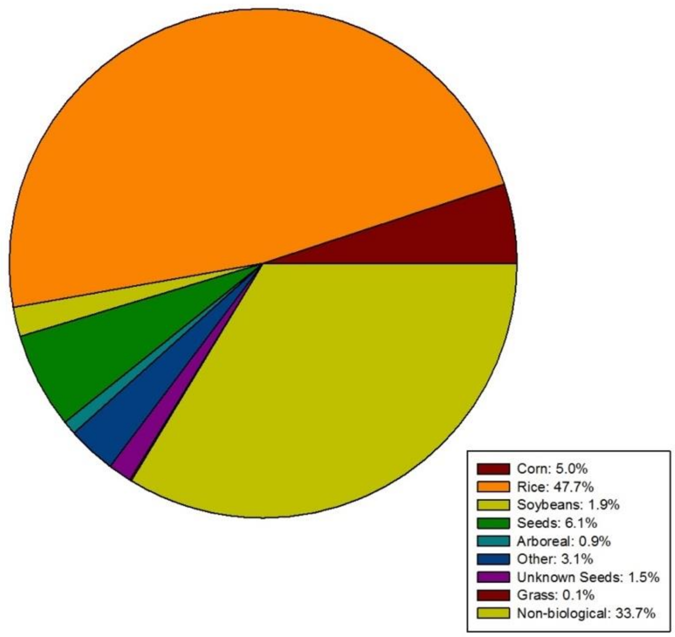


Figure 12 Combined total diet composition of dabbling waterfowl in the Ridge and Valley, Southwestern Appalachians, and Mississippi Alluvial Plains

### 3.6.2 *Divers*

Divers had the most varied diet of the three guilds, and consumed the second highest amount of non-biological material (Figure 13). This was expected due to divers generally being bottom feeders and remove sand and rocks from the soil and sediments when obtaining food. Divers also consumed the highest amount of arboreal content such as leaves and acorns as well as consuming the highest amount of invertebrates and vertebrates over geese and dabblers.

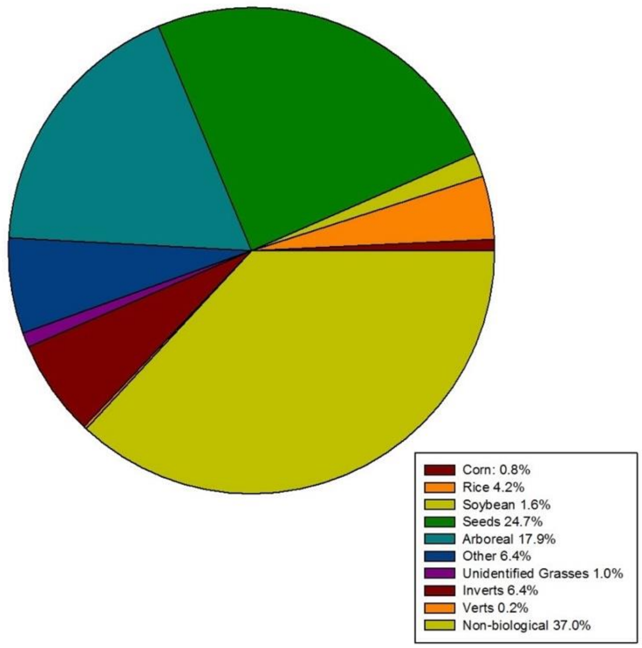


Figure 13 Combined total diet composition of diving waterfowl in the Ridge and Valley, Southwestern Appalachians, and Mississippi Alluvial Plains

### 3.6.3 *Geese*

Geese overall consumed the most non-biological material compared to divers and dabblers (Figure 14). Geese also consumed a larger amount of grasses than the dabblers and divers which had a more varied diet compared to the geese. Geese also consumed a small amount of agricultural products such as soybean and rice.

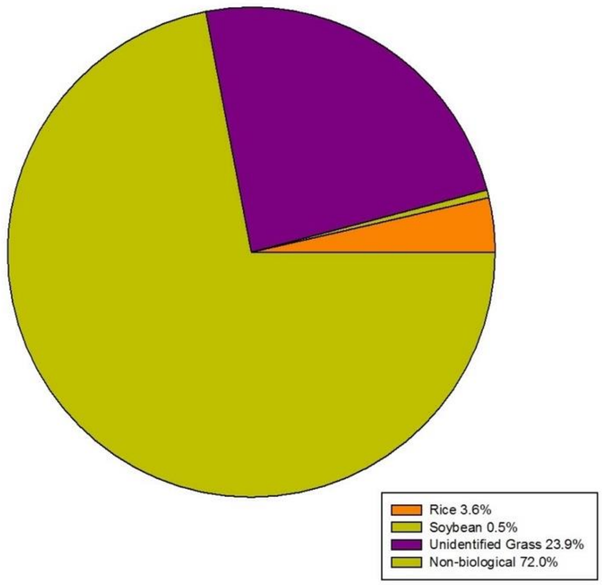


Figure 14 Combined total diet composition of geese in the Ridge and Valley, Southwestern Appalachians, and Mississippi Alluvial Plains

# CHAPTER IV

# DISCUSSION

## *4.1 Interpretation of Statistical Results*

### *4.1.1 Year Differences*

Overall, there were no significant effects of habitat or ecoregion when analyzing the diet mass of the waterfowl in 2013; however, in 2014 there were significant differences in total mass and diet mass between habitats in the Ridge and Valley ecoregion. These year differences were largely due to the different in sample sizes for each year as well as possible weather between years. Another reason for the difference between years could be due to 2013 having all three ecoregions represented and 2014 only representing two of the ecoregions represented in the study.

### *4.1.2 Comparisons with Other Studies*

Previous studies (Swanson et al. 1974, Swanson et al. 1974, McMahan et al. 1970) used aggregate percentages and volumetric percentages to assess the foods consumed by waterfowl, as well as using esophageal content for analysis. These studies were able to gain a better understanding of waterfowl diets within a specific site, but not a broad geographic region looking at habitat differences between species or guilds. These studies also obtained specimens after observing foraging and I obtained specimens without observation. I did not observe actively feeding waterfowl before capture since I am looking at relationships between their food contents and their habitat, ecoregion, and guild differences; if I were to observe feeding before capture of the specimens then that would lead to bias in the analysis since I would already know what foods the waterfowl would be consuming. These studies used aggregate percentages and volumetric measurements to quantify stomach content, but since I used the stomach content to find ecoregion, habitat, and guild differences, the ANOVA was the better analysis procedure. Previous studies, such as Euliss et al. (1991), had results similar to this study, where statistical analysis using ANOVAs showed year differences as well as showing differences in total diet composition between different guilds and waterfowl species. The total mass of the waterfowl in terms of ecoregion showed to have no significant difference. The ANOVAs and post hoc testing confirmed year differences in diet mass, leading me to separate the data between years to better display the data. The previous studies mentioned above had significant findings of waterfowl stomach analysis, and along with my study we can have a better understanding of the waterfowl diet components, and now ecoregion, habitat, and guild-specific understanding.

### 4.2 *Diet Composition Comparisons*

When comparing my results with other studies, I noticed a difference in overall diet composition between studies. McMahan et al. (1970) analyzed Redhead (diver), Lesser Scaup (diver) and Northern Pintail (dabbler) stomach content and showed that Pintails and Redheads consumed a greater volume of plant foods and Lesser Scaup had a more evenly distributed overall diet with more animal material consumed. In comparison, the guilds from my study showed similar results, where divers consumed more animals than divers. Also the dabblers had a higher amount of plant material consumed in my study (especially agricultural products) compared to the Pintail data from McMahan et al (1970). Other studies such as Swanson et al. (1970) studied stomach analysis during April-June and they saw a high percentage of animal material in the esophagus which differed from my wintering waterfowl results. Another study during April-June, Swanson et al. (1974), showed a high amount of animal food items in dabblers. Again my results showed dabblers having a higher plant based diet. My results showed waterfowl having variable diets between guilds, especially divers having consumed a larger variety of foods as compared to dabblers and geese.

### 4.2.1 Ecoregion, Habitat, and Guild

The relationship between ecoregion and habitat significantly differed between years. The specimens from 2013 did not have any significant differences in ecoregion or habitat; However, in 2014, there was a significant difference between habitats. Furthermore, diet mass showed a significant interaction between ecoregion and habitat. These data reveal a significant difference in habitat in the Ridge and Valley ecoregion but no habitat differences within the Mississippi Alluvial Plains. This result is reasonable due to the overwhelming amount of cultivated farmland in the MAV (Mississippi Alluvial Valley) (Stafford et al. 2006), making this area predominately one type of habitat. When analyzing the ecoregion by guild, there were no significant differences in

2013 or 2014. This shows that there are no significant guild differences based on ecoregion foe either year.

Habitat and guild had a significant difference when the total mass was analyzed, showing that geese were different from dabblers and divers. Once the non-biological material was removed from analysis, there was no significant difference in waterfowl diet mass based on ecoregion, habitat, or guild. The difference in guild was between geese and the other two categories of dabblers and divers. Geese generally inhabit agricultural fields during wintering months, consuming grasses and agricultural products; dabblers and divers can also be found in flooded agricultural fields, but have a wide variety of habitat locations and a more wide variety of food options (Clark et al. 2014; Drilling et al. 2002; Mowbray et al. 2000; Mowbray et al. 2002; Roy et al. 2012; Woodin et al. 2002). This significant difference was due to the large amount of non-biological material consumed by geese compared to dabblers and divers as well as having a larger digestive system and overall larger body size compared to other guilds analyzed. The dabblers and divers ingested a similar amount of food, but their diet composition differed. Dabblers and divers are both historically omnivorous (Clark et al. 2014; Woodin et al. 2002), consuming similar foods and are similar in size in comparison to geese.

### *4.3 Interpretation of Waterfowl Diet Composition by Ecoregion*

The diet composition of the three ecoregions showed differing diets when looking at individual diet components. The waterfowl in the Mississippi Alluvial Plain consumed a higher amount of agricultural foods than the other ecoregions in both years. This is to be expected due to the large amount of agricultural cultivation along the Mississippi River, giving the waterfowl a readily available food source and water source during winter migration. Waterfowl in the Ridge and Valley ecoregion consumed the highest amount of non-biological material as well as a high amount of arboreal material and seeds. There is not as large of an agricultural presence in the Ridge and Valley as seen in the Mississippi Alluvial Plain, so the waterfowl diet would be expected to be composed of arboreal material and plant material. In the Southwestern Appalachians ecoregion, two thirds of their diet was non-biological and the other large component of their diet composition was arboreal material. The Southwestern Appalachians had a more even diet distribution, including multiple types of agricultural products, plant products, as well as invertebrates. This showed that there is a variety of food sources and food availability options for the waterfowl in this ecoregion and that there is no specific diet trend.

## *4.4 Interpretation of Waterfowl Diet Composition by Guild*

### 4.4.1 *Geese*

One of the largest statistical differences found between guilds was the difference in total mass between the geese and the dabblers and divers. Geese are almost strictly herbivores, so they would not be expected to have as wide of a variety of food products found compared to dabblers and divers (Mowbray et al. 2000; Mowbray et al. 2002). The geese are able to store more food in their larger digestive tract, so they had a larger total mass than the other guilds. Once the non-biological material was removed, their overall diet mass was similar to that of the divers and dabblers. Each guild had a different diet composition overall and the geese had the most basic diet compared to the other guilds. Literature on Canada Geese and Snow Geese (*Chen caerulescens*) show that they are almost entirely vegetarian and herbivorous, consuming a wide variety of plants including agricultural plants as well as grasses and other easily digestible carbohydrate rich plants (Mowbray et al. 2000; Mowbray et al. 2002). Previous studies showed that Snow Geese eat different plant parts in different habitats and that in a rice dominated region they mostly consume green shoots and leaves, including grasses and forbs; but geese in an area with a large presence of corn agriculture ingested mostly corn (81%) and sorghum (Mowbray et al. 2000). Canada Geese in previous studies consumed a large amount of agricultural products as well as 20-30% of their diet was comprised of green vegetation. Comprised mostly of non-biological material and grasses, the geese in my study did not ingest as much of a variety as other guilds. Like previous studies (Mowbray et al. 2000; Mowbray et al. 2002), some geese did contain agricultural products when shot in an area with rice, corn, or soybeans present but mostly ingested green vegetation including grasses.

### 4.4.2 *Dabblers*

Literature on dabblers in the Mississippi Flyway discusses how dabblers are omnivorous; consuming a wide variety of food products from plants to invertebrates depends on time of year, precipitation, and location (Clark et al. 2014; Drilling et al. 2002). Previous research on dabbler species such as Mallards has shown that a majority of their diet is comprised of agricultural products during the winter months and winter migration; esophageal studies in Arkansas and West Mississippi showed 47-49% of Mallard diet as agricultural products (Delnicki et al. 1986; Drilling et al. 2002). These results from previous studies within the Mississippi flyway had similar results, showing nearly half of dabbler diets being comprised of agricultural products. Dabblers in my study ingested a large amount of agricultural products, as well as multiple plants, seeds, vertebrates, and invertebrates. Dabbler species such as the Northern Pintail are well known to be found in the Arkansas Grand Prairie during wintering months, due to the heavy agricultural presents and the importance for food availability (Clark et al. 2014; Smith et al. 1989). Pintail data from my study showed heavy use of agricultural areas as a source of food during the wintering months.

### 4.4.3 *Divers*

Diver species are well known to winter in swamps, backwater areas, or flooded riverplains as well as being omnivorous, consuming a wide variety of plants and animals (Roy et al. 2012). Previous studies investigating the diver species of Redhead Ducks showed diet being dominated by submerged vegetation (Woodin et al. 2002). The diver species in my study consumed a large variety of food types including agricultural products, but their composition skewed towards arboreal and other submerged plants and animals. A study in South Carolina (Roy et al. 2012) showed Ring-necked Duck's diet being made up of 62% plant and 38% animal, snowing a utilization of aquatic plants and in my study the diver guild showed a utilization for plants, but also consumed animals as well. This information is similar to literature on diver species as having a wide variety of food products consumed as well as consuming submerged vegetation. The divers in my study had a significantly different diet from the other guilds due to the wide variety of plants and animals found within the ingested contents.

Each guild consumed some form of agricultural product so it can be shown that waterfowl of all types use agricultural fields as a food source as well as using natural habitats to forage for plants, seeds, invertebrates, and invertebrates. Even though the total mass and diet mass analyses did not show significant differences between ecoregions, there is a difference in the composition of the waterfowl diet within that ecoregion. Their diet composition is based on the food availability within that ecoregion and the amount of that food consumed by the individuals in that guild or ecoregion. This information shows how varied waterfowl guild diets can be and that their foraging habits depend on the ecoregion and habitat they inhabit and that they are able to adapt their diets based on food availability. Even though the total food mass or diet mass may not be significantly different, their total diet composition is different between ecoregions.

### 4.5 *Acknowledgement of Potential Biases*

The collection and handling of the specimens and digestive content is an integral part of a scientific study. For my study, a concern I had was obtaining the waterfowl from hunters and guides in a timely manner in order to prevent digestion of the food material, especially in the gizzard. Swanson et al. (1970) performed analyses on Blue-Winged Teal, analyzing waterfowl diets and differing digestion rates and found that the gizzard rapidly degraded food in comparison to the esophagus. Briggs et al. (1985)

studied waterfowl food habits in Australia and they noticed a difference in digestion as well, citing the importance of invertebrates in waterfowl diet and that the gizzard analysis did not give a good representation of that food source. Even though a small amount of food material could have been lost to digestion, the specimens were immediately frozen when obtained in order to preserve the specimens and prevent further digestion. Another potential confounding variable is that my study did not allow for observation of the waterfowl foraging before they were shot. Many studies, like Swanson et al. (1974), observed their specimens to make sure there was adequate food for analysis. This method seemed more biased as the researchers were selectively picking their study specimens, whereas this study involves a more random sampling approach.

Previous studies, such as Swanson et al. 1970, have expressed concerns of bias in regards to the use of the gizzard for waterfowl diet analysis due to the rapid digestion of soft bodied invertebrates and other soft plant matter. Most of these studies opted for an esophageal study, but I wanted to gather as much data as possible to better understand the diet of waterfowl in the Mississippi Flyway and removing the esophagus, proventriculus, and gizzard was the best way to obtain that goal.

### 4.6 *Management Implications*

The foods and feeding behavior of waterfowl are important aspects of their life history and represent an essential ingredient of habitat management (Baldassasre and Bolen 2006). Most waterfowl are known to have a varying diet and different guilds were shown to have different overall diet compositions in this study. A study such as this could be important for waterfowl management in WMAs, agricultural fields, and public or private natural habitats. Previous studies (e.g. Swanson et al. 1974, Swanson et al. 1970 and McMahan et al. 1970), performed diet analysis using a smaller study area as well as a smaller sample size. The implications of this study, having a large sample size and large study area, give wildlife managers information on waterfowl diet analysis and total diet composition by ecoregion, habitat, and guild. This can better help wildlife managers to improve upon habitat management in areas that are lacking in food availability, giving them a general understanding of what a certain waterfowl consumes in that ecoregion and habitat. The results from 2014, where a habitat difference in the Ridge and Valley ecoregion was detected, could be usable information for managers to implement habitat improvements based on which lands are better utilized by waterfowl in that area. Having a suitable habitat and sufficient food availability is essential to waterfowl management and it is important to maintain these habitats for a healthy population in the Mississippi Flyway, especially during winter migration.

Current waterfowl management practices involve using crops such as corn, grains, rice, and soybeans to provide food for waterfowl on private and public lands (Smith et al. 1989). Some of these agricultural fields are also flooded, giving the opportunity perfect habitat and food availability for waterfowl. The results from the diet composition of the waterfowl can be used along with these management practices to determine what products would be best in the specific area. These crops are relatively cheap, easy, and quick to grow to improve the habitat for waterfowl.

A scientific study such as this not only benefits waterfowl and governmental agencies that specialize in waterfowl management, but it also benefits waterfowl hunters who are interested in waterfowl conservation and to maintain good populations of waterfowl in their ecoregion. A hunter is an integral part to waterfowl management due to the funding of wildlife management projects through organizations such as Delta Waterfowl or Ducks Unlimited Inc., as well as through the purchase of federal and state waterfowl stamps which gives the proceeds to acquire and protect wetland habitats (Fish and Wildlife Service 2014). All waterfowl specimens for my study were collected by hunters, who also shared a passion for waterfowl conservation. In a previous study, Adams et al. (2006), the results showed that waterfowlers hunted to be close to nature and one of the factors that prevented them from hunting was the loss of habitat. These individuals have time and money invested into providing suitable waterfowl habitat. The results from this study can be very useful to a waterfowler who is creating suitable habitat, showing them what food sources are best in that ecoregion. As an avid waterfowler, I can use these data to better implement our waterfowl management practices, creating different types of food sources based on the diet composition of the waterfowl from the ecoregion I hunt. The relationship and cooperation between hunters and wildlife managers is crucial for waterfowl management and working together, waterfowlers can have a more successful hunt and more importantly waterfowl can thrive in every ecoregion of the Mississippi Flyway.

# CHAPTER V

# CONCLUSION

This study addressed the lack of a large scale diet analysis over multiple ecoregions within the Mississippi Flyway, using waterfowl diet analysis as a measure to gain better understanding about waterfowl foraging. Overall this study showed that there were no significant differences in ecoregion but there were differences in habitat in 2014 within the Ridge and Valley and Southwestern Appalachians ecoregions. Statistical analysis showed a difference in ecoregion and habitat, but when analyzed closely the Ridge and Valley and Southwestern Appalachians ecoregions had a difference in habitat, showing a greater utilization of natural areas for foraging and the Mississippi Alluvial Plains did not have any habitat differences.. The waterfowl in the Ridge and Valley were utilizing the natural habitats more than the agricultural lands. In terms of a more specific overall diet composition, waterfowl in each ecoregion had various diets and each guild had differing diet components. Although these values are only used for these specific ecoregions, the information can be used along with future studies to gain a better understanding of diet composition of waterfowl in the Mississippi Flyway.

## 5.1 *Future Work*

To expand upon my research on wintering waterfowl I would like to analyze the diet of each individual, identifying the food to family which would give us a better understanding of the diet of wintering waterfowl in specific ecoregions and habitats. The more specific the food identification would not only help wildlife management areas with waterfowl conservation, but also help sportsman in the specific ecoregion or habitat. With this knowledge and better understanding of waterfowl diet, we could cultivate better habitats for waterfowl in the Mississippi Flyway.

For future studies, I would suggest obtaining a body weight of each individual and perform a study comparing the body weight of the waterfowl to the contents of its diet. This could give researchers more information in regards to the individual's condition or fitness and whether certain food types present yield a larger individual. I think it would also be beneficial to increase the number of ecoregions across the Mississippi Flyway, having more data and a larger area to describe the entire flyway by ecoregion. My research showed ecoregion differences by year and eventually a pattern of waterfowl diet could be detected to better understand wintering waterfowl foraging throughout the Mississippi Flyway.

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# VITA

Justin Andrew Walley was born in Memphis, Tennessee to Drs. Donald and Glenda Walley, and grew up outside of Memphis in Eads, Tennessee. He attended Briarcrest Christian High School where he graduated with honors in 2009. He then attended the University of Tennessee at Chattanooga where he graduated *cum laude* in 2013 with a Bachelor of Science in Biology. He decided to continue his education in the fall of 2013 at UTC to pursue his Master of Science degree in Environmental Science. He completed his thesis researching foraging waterfowl of the southeast under Dr. David Aborn and was also a Graduate Teaching Assistant for Biology and Environmental Science labs during his time at UTC. Justin also worked with Dr. Thomas Wilson on the long term Team Salamander study throughout his tenure at UTC. Justin graduated with a Master of Science degree in Environmental Sciences in August of 2016. His research interests included waterfowl ecology and foraging, avian conservation, as well as reptile amphibian home ranges.