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# An Analysis of White-Tailed Deer, Odocoileus virginianus, Killed in Deer Vehicle Accidents on Bulloch County, GA Roadways

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# **An Analysis of White-Tailed Deer, *Odocoileus virginianus*, Killed in Deer Vehicle Accidents on Bulloch County, GA Roadways**

An Honors Thesis submitted in partial fulfillment of the requirements for the Honors in Department of Biology

By
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Under the mentorship of *Dr. Edward B. Mondor*

## ABSTRACT

White-tailed deer, *Odocoileus virginianus*, are native to Georgia. With over 1.2 million individuals in the state, White-tailed deer have been implicated in a large number of motor vehicle collisions (ca. 1 million) each year. It is unknown, however, if deer are more likely to be killed: 1) if they are of particular ages (or classes), and 2) in areas with specific road characteristics. We addressed these two questions by collecting the remains of 20 White-tailed deer killed in deer vehicle collisions ("deer vehicle accidents" - DVAs) in Bulloch County, GA. When a deer was located, the road characteristics were noted and the head was removed. In the lab, the lower jaw was excised so the deer could be aged by: 1) tooth eruption sequence and 2) cementum annuli aging of incisors. The proportion of deer in the study involved in a DVA that were one year and 7 months or younger was 0.55 using the tooth wear and replacement method. The proportion of deer in the study involved in a DVA that were one year or younger was 0.60 using the cementum annuli aging method. Deer were more likely to be killed on a 2-lane road, and on a paved road. It was not clear how speed limit, while significant, influenced DVAs. Signage should be posted on roads with a higher risk of a DVA to make drivers more aware of potential dangers.

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## Introduction

Anthropogenic factors are constantly changing the natural environment and, as a result, impacting wildlife (Rudolf & Rasmussen 2013). Human population growth has been a driving force of habitat fragmentation and habitat loss for many species; by altering the natural environment, community structure is ultimately impacted (Rudolf & Rasmussen 2013). As the human population grows, communities continually expand into wildlife habitats (Chen & Wu 2014, Liu et al. 2016). The creation of roadways, from this community growth, has a negative impact on wild animals because roads directly cause habitat fragmentation, resulting in habitat loss (Chen & Wu 2014).

In the United States, 1-2 million vehicles collide with mammals each year (Chen & Wu 2014). These accidents occur because animals must adapt to habitat fragmentation by crossing roads to travel between different patches (Chen & Wu 2014). Animals must adapt to the habitats they live in, putting them at increased risk of motor vehicle collisions (Sprem et. al 2013). Of all the animals affected by habitat fragmentation, large mammals appear to be the most affected, with deer being the most studied (Sprem et. al 2013).

White-tailed deer, *Odocoileus virginianus,* are increasing in number and causing significant problems in urban areas worldwide (McCance et al. 2015). Large populations tend to cause problems because of their negative ecological impact. For example, White-tailed deer are key herbivores (eating seeds, flowers, leaves, and sometimes certain bark) across much of America, which suppresses the regeneration of many tree species (Bradshaw & Waller 2016). Deer populations in forests across the country are experiencing historical highs, which is important considering much of the habitat in

Southeast North America is forest (McShea 2012).

Conversely, as White-tailed deer tend to be the largest herbivore in their ecological community; because of this, White-tailed deer are structurally important in shaping the plant community (such as spreading seeds through defecation) and supporting apex predators (McShea 2012). White-tailed deer have a positive economic and ecological impact in a specific community; the Department of Natural Resources (DNR) and other wildlife biologists have made a significant investment into trying to understand the role White-tailed deer play in the local community.

White-tailed deer were at one time almost completely extinct in the state of Georgia, but through wildlife management and preservation the state population now exceeds 1.2 million individuals (Georgia DNR 2004). Of the 37 million acres of land in Georgia, 24.8 million acres is forest (Georgia Forestry Commission 2011). Urbanization poses a very large threat to the forests in Georgia and can have a large impact on the wildlife (Georgia Forestry Commission 2011). Bulloch County has approximately 682.6 square miles of diverse rural land (Georgia Forestry Commission 2011). The number of deer in Bulloch county is not specifically known.

This increase in White-tailed deer populations directly affects humans because of the increase in vehicle collisions ("deer-vehicle-accidents - DVA"), which is costly to the vehicle owner and often deadly to the deer (Steiner et al. 2014). In fact, DVAs result in a 92% mortality rate for the deer (Conover et al. 1995) and cost vehicle owners in America over $1 billion per year (Conover 1997). Compared to vehicle collisions with other mammals, DVAs are reported more often because they cause more vehicle damage, making DVAs more economically costly and more likely to cause human injury (Steiner et al. 2014). The objective of this research is to determine if White-tailed deer, *O. virginianus*, are more likely to be killed in motor vehicle collisions in Bulloch County, Georgia: 1) if the deer are of particular ages (or age classes), and 2) based on specific road characteristics. This research will allow the Department of Natural Resources and Department of Transportation to identify high-risk areas in Bulloch County, and to reduce this risk by posting additional deer-crossing signs.

## Materials and Methods

White-tailed deer, *O. virginianus*, which had been involved in motor vehicle collisions in Bulloch County, GA were collected from public roadways. Notifications were posted on Facebook approximately twice a month over a two-year span, so a large number of people could notify myself or my advisor of recent DVAs. Once a deer was located, number of lanes (Appendix B), surface of the road, speed limit, and the GPS coordinates (Appendix D), were recorded. Pictures of each deer were taken. The head of the deer was removed using a machete and/or a large butcher knife. Safety equipment was used at all times; i.e., nitrile gloves, surgical mask, and safety goggles. Once removed, the head was placed in a large, black, plastic garbage bag and taken back to the lab.

In the lab, the deer head was taken out of the plastic bag in the fume-hood and placed on a large piece of cardboard so that no bodily fluids contaminated lab surfaces. Nitrile gloves, a surgical mask, and safety goggles were worn for protection while excising the lower jaw. A skinning knife was used to excise the lower jaw of the deer (i.e., slicing away any tissue or muscle connecting the mandible to the skull). After the mandible was detached from the skull, any additional tissue was removed using the skinning knife. Once most of the muscle and connective tissue had been removed from the jaw, it was placed in a slow cooker (“Crockpot”) (Model: SCCPVL600-R, Sunbeam Product, Jarden Consumer Solutions, Boca Raton, FL 3343) set on “Low” filled with soapy tap water. The mandible was left in the crockpot for approximately one week; adequate time to soften the tissue around the mandible and the teeth.

After this time period, the mandible was removed from the slow cooker and any soft tissue removed from the mandible. Free of any tissue, the mandible was then placed in a large beaker and covered with soapy water. The soap was used to draw out any remaining fat from the mandible. The mandible was left in this beaker for approximately 1 week. The mandible was then rinsed with ethyl alcohol to kill any bacteria that might be present. It is important to note that bleach and hydrogen peroxide were NOT used in this process because it can cause whitening of the teeth; these chemicals could alter the dentin rings analyzed in the tooth replacement and wear age-estimation procedure (Matson's Lab 2016). Also, bleach can cause histological damage to the teeth, which could alter the results of the cementum annuli aging procedure (Matson's Lab 2016). The mandible was then allowed to dry for approximately 3 days on paper towels in a fume-hood, to allow residual water to evaporate from the mandible. Each mandible was stored in a brown paper bag and both the mandible and the bag were labelled (i.e., double labeling). Each mandible was given a unique number based on when/where it was collected. Twenty mandibles were collected, prepared, and stored.

The first aging process was the tooth wear and replacement method. This method ages a deer's mandible based on the number of teeth, presence of dentin rings, thickness of the rings, and the teeth eruption sequence (Ivey et al 2002). The determined ages were not exact ages but, rather, age classes. The age classes were as follows: 6 months, 1 year 5 months, 1 ½ years, 1 year 7 months, 2 ½ years, 3 ½ years, 4 ½ years, and 5 ½ years or older (Table 1) (Appendix C).

To verify the accuracy of the tooth wear and replacement technique, another method was used: cementum annuli aging. Cementum annuli aging is based on the cyclic nature of cementum growth. The cementum growth within a White-tailed deer's tooth results in an annular pattern of rings (like tree rings) (Matson's Lab 2016). During winter an "annulus" is formed, which is a dark stain (Matson's Lab 2016). Light stains occur during the growth season, which is during spring and summer (Matson's Lab 2016). To prepare teeth for cementum annuli aging, an incisor (I1) was removed from each mandible and placed in a coin envelope labeled with a unique number assigned to the mandible (1-20). If the mandible was collected without an incisor, a molar was sent for analysis. After each mandible had one tooth extracted and placed in a coin envelope, a second tooth from each mandible was extracted and placed in a separate coin envelope. The second envelope for each mandible was labeled (21-40) depending on which mandible it was extracted from. Thus, two teeth were analyzed from each mandible. The second tooth directly assessed variability of the cementum annuli aging technique. After each of the mandibles had two teeth extracted, the coin envelopes were placed in a padded envelope and sent to Matson's Lab (Manhattan, MT 59741) for analysis.

For cementum annuli aging, a few key concepts must be understood: 1) Matson's Lab uses an assumed annual birthday of June 1st (deer aged zero years are assumed to turn one year of age, if they survive, on June 1st of the year they were killed), 2) Matson's Lab may have chosen to inspect a tooth instead of analyzing the cementum if the tooth showed evidence of root absorption, and 3) Some deer were given an age range based on the evidence the tooth presented (if a tooth showed evidence for an age range, the age that showed the most evidence was the determined age) (Appendix A).

### *Statistical Analysis*

Linear regression was used to compare the ages determined from the two teeth from each deer; Tooth 1 (1 through 20) versus Tooth 2 (21 through 40). A linear regression was conducted to determine the degree of association of the tooth wear and replacement model versus the cementum annuli aging model for each deer. In this analysis, for cementum annuli age, the ages for both teeth from each deer were averaged.

Two Chi-square tests were used to determine if there were significant differences in the age classes of deer killed in DVAs, as determined by tooth wear and replacement and cementum annuli aging.  Chi-square tests were also used to analyze the frequency of deer killed on roads with different number of lanes (two versus four lanes), surfaces (paved versus non-paved), and speed limits (35, 45, 50, 55 mph speed limit).

## Results

There was a significant relationship between the age determined for tooth one versus tooth two ($F_{1,18}$ = 110.91, P < 0.0001, $R^2$ = 0.86) (Figure 1). There was also a significant relationship between the age determined by tooth wear and replacement and cementum annuli aging ($\mathrm{F}_{1,18}$ = 16.20, P = 0.0008, $R^2$ = 0.47) (Figure 2).

There was a significant difference in the ages of deer involved in DVAs ($x_6^2$ =7.74, P = 0.2578) (Figure 3). Through the tooth wear and replacement method it was found that, in our sample, 55% of deer that were involved in a DVA were in age classes of 1 year and 7 months or younger. In our sample, 60% of deer involved in a DVA were found to be one year of age or younger through the cementum annuli aging method ($x_5^2$ = 12.30, P = 0.0309) (Figure 4).

More DVAs occurred on two-lane roads compared to that on four-lane roads, ($x_1^2$ = 19.79, P < 0.0001) (Figure 5). More DVAs occurred on paved roads compared to that on unpaved roads ($x_1^2$ = 19.79, P < 0.0001) (Figure 6). The effect of speed limit on DVA's was significant, though the trend was not clear ($x_3^2 = 11.22, P = 0.011$) (Figure 7)

## Discussion

The objective of this research was to determine if White-tailed deer, *O. virginianus*, were more likely to be killed in DVAs in Bulloch County, GA: 1) if the deer were of particular age classes, and 2) based on specific road characteristics. In this study, it was found that deer were more likely to be killed if they were younger, and more likely to be killed on roads that were paved and had two lanes. The relationship between speed limit and DVAs was not clear.

Two aging processes were used, tooth wear and replacement and cementum annuli aging. There was a significant relationship of deer age, as determined by the two methods. The tooth replacement and wear method, however, tended to age the deer a bit younger, while cementum annuli aging tended to age the deer a bit older. The tooth wear and replacement model is more subjective, relying heavily on the researcher's opinion, whereas cementum annuli aging is more objective, as it focuses on counting the cementum annuli. Although cementum annuli aging is more objective, it is only as good as the teeth that are used for the estimate. That is, to accurately age a tooth's cementum, the lab requests that an incisor is sent from each deer. Some deer that were involved in bad collisions, however, did not have front teeth and only molars could be sent to the lab. Molars cannot be age graded as accurately as incisors (Matson's Laboratory 2016).

The proportion of deer in this study that were found to be under the age of one was 0.60 using the cementum annuli aging method; whereas, the proportion of deer under the age of 1 year and 7 months was 0.55 using the tooth wear and replacement method. It was not possible to compare the exact ages using the two methods, as they utilize slightly different age classifications. Given the data collected in this study, though, it can be stated that younger deer were at a higher risk of a DVA as they were primarily under 2 years of age. In a similar study in Utah, of 397 deer involved in DVAs, 67% of them were under the age of 2 and a half years (Romin & Bissonette 1996).

The White-tailed deer collected in this study were found either on a two-lane or a four-lane road, with higher mortality on two-lane roads. Vehicle collisions are directly related to the width of the road on which they occur (Clevenger et al. 2003). A two-lane road is narrower than a four-lane road, leaving less room to maneuver to avoid an accident (Clevenger et al. 2003). The findings in this study match the findings of similar studies, a narrower road significantly increases the likelihood of a DVA (Clevenger et al. 2003).

Each deer was found on either a paved or unpaved road in Bulloch County, GA. Nineteen out of twenty deer were found to be on a paved road. This finding could not be compared to other studies because they have not studied this relationship. It is likely that road surface type may not have been studied because paved roads are the norm in the United States. Even in Georgia, unpaved roads are scarce.

Speed limits at each DVA site ranged from 35 to 55 mph. There was a significant difference in DVAs at different speed limits, but the trend was difficult to understand. The reason the trend was not clear is that only one DVA was recorded in a 50 mph zone. This speed limit, however, is much less frequent than are 45 mph or 55 mph zones. In general, when speed limit increases, the likelihood of a DVA will also increase (Meisingset et al. 2014). When the speed is increased the driver needs a longer amount of time to react, and the distance that the car needs to come to a stop will be greater (Meisingset et al. 2014).

It must be noted that deer were opportunistically collected in this study; deer were obtained when they were reported to my advisor or myself. As a result, it is quite likely that there was unequal sampling of roads with different characteristics (i.e., people often drive the same roads every day, and different people often use the same roads). Any conclusions of DVAs based on road characteristics in this study should be approached with extreme caution.  A more thorough investigation of this topic should be conducted in a systematic way, with equal effort being given to roads with different characteristics.

In conclusion, young deer were more likely to be killed on paved, two-lane roads. As the width of the road was determined to directly affect the occurrence of DVA's, additional animal crossing signs should be put on these roads to warn drivers of the increased risk (Clevenger et al. 2003). While speed limits in this study were significant, the trend was not clear. Other studies have found that speed limit directly affects the occurrence of a DVA. On roads with a higher speed limit, there should be additional animal crossing signs to warn the drivers traveling at a higher speed that there is an increased risk of colliding with an animal (Laurance et al. 2009). In the foreseeable future, habitat fragmentation and habitat loss will continue to increase, as will White-tailed deer populations.  As the potential for DVAs continues to increase, so does society's obligation to minimize these interactions.

**Table 1.** Tooth wear and replacement aging criteria

| Expected age: | Characteristics of teeth: |
|---|---|
| 6 months old | ● Only first molar is present |
| 1 year and 5 months | ● All molars and temporary premolars are in place<br>● The third premolar, has three cusps and they are highly worn |
| 1 year and 6 months | ● At least one temporary premolar has been shed<br>● A permanent molar is erupting (bicuspid) |
| 1 year and 7 months | ● All premolars are present and are showing slight staining<br>● Third molar has little to no dentine line on the crest |
| 2 years and 6 months | ● Slight dentine line on third molar<br>● Dentine and enamel are equal on the lingual crest of the first molar, but narrower on the second and third molar |
| 3 years and 6 months | ● Premolars show considerable wear<br>● Third premolar cusp is warn giving it a smooth or cupped appearance<br>● Dentine is wider than enamel on first molar, equal on the second molar, and narrower on the third molar |
| 4 years and 6 months | ● All the premolars are severely worn<br>● Dentine is wider than enamel on the first and second premolar, but equal on the third.<br>● The first molars secondary crest is worn but slightly raised |
| 5 years and 6 months | ● Dentine is wider than enamel on all the molars<br>● The first molar's secondary crest is worn but still visible on both cusps |

Adapted from: Ivey, T. L., & Ruth, C. (2002). Deer hunter's guide for aging and jawbone removal. *South Carolina State Documents Depository*. Available from: http://www.dnr.sc.gov/wildlife/deer/pdf/deerjaw.pdf.

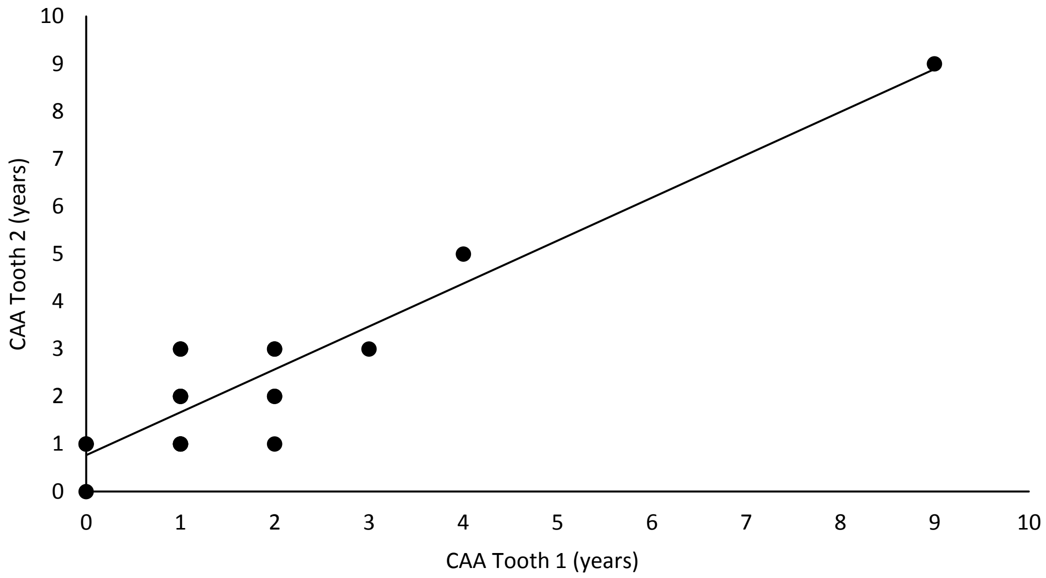

Figure 1. Comparison of ages as determined by cementum annuli aging (CAA) tooth one versus tooth two, taken from the same individual.

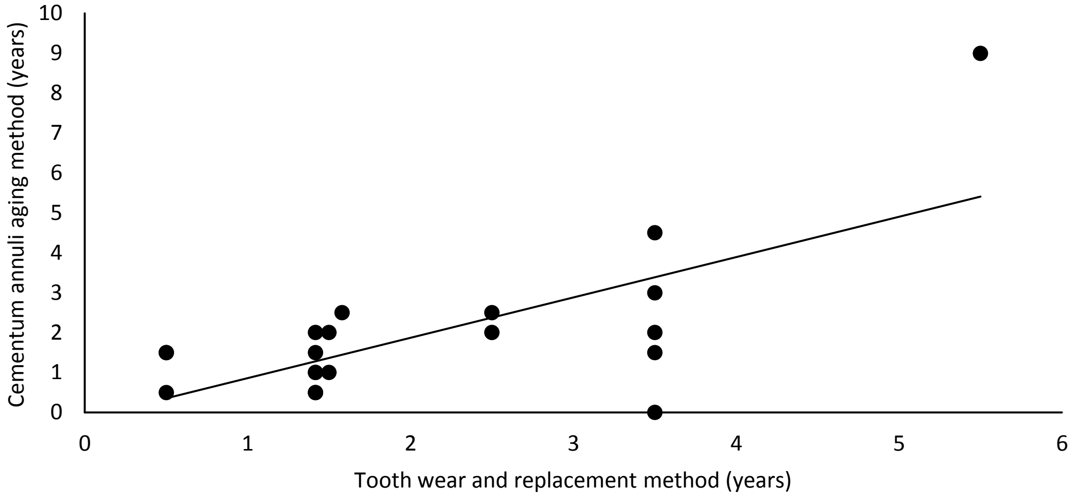

Figure 2. Comparison of ages as determined by the tooth wear and replacement versus the cementum annuli aging methods

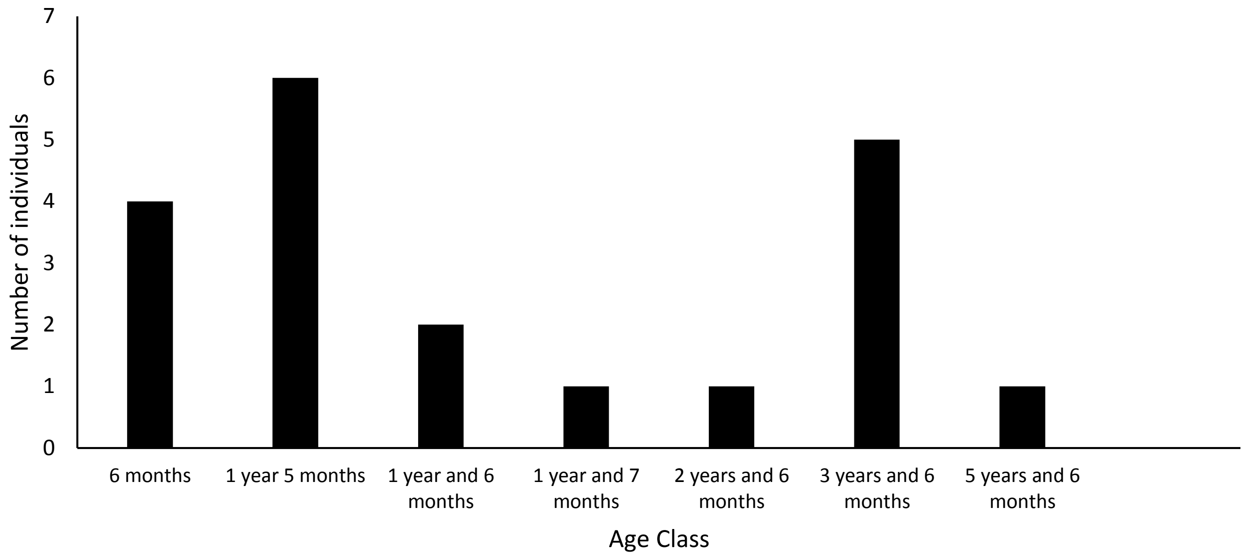

Figure 3. Numbers of individuals of different ages as determined by the tooth wear and replacement method

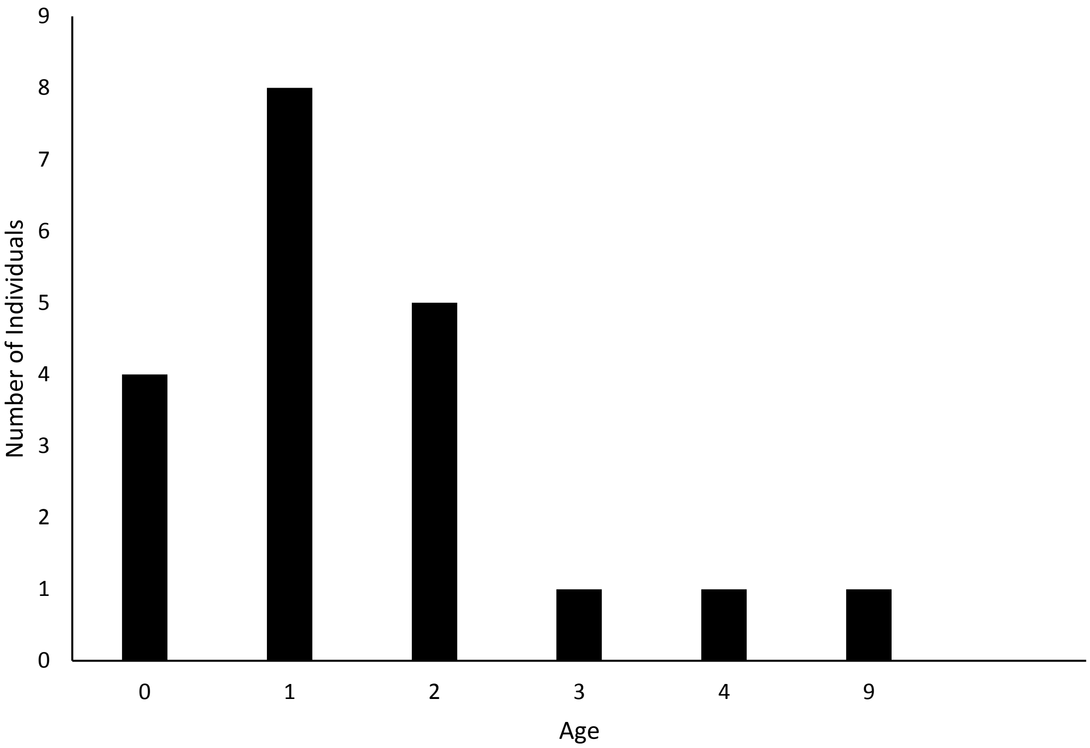

Figure 4. Numbers of individuals of different ages as determined by the cementum annuli aging method

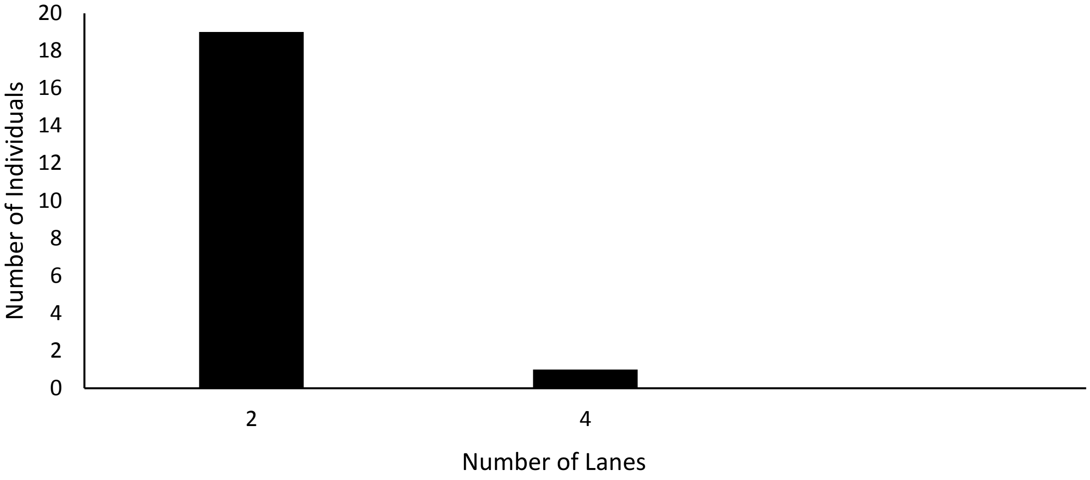

Figure 5. Numbers of individuals found on two and four lane roads

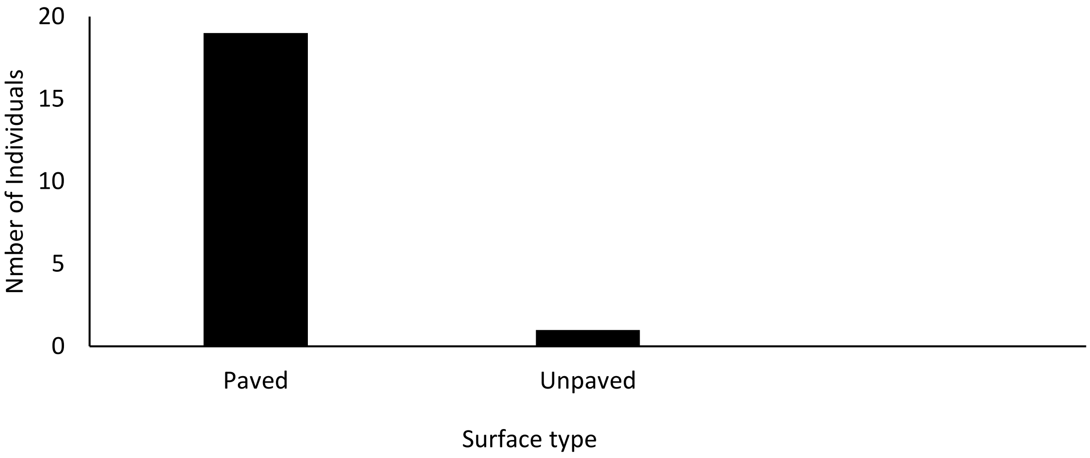

Figure 6. Numbers of individuals found on paved and unpaved roads

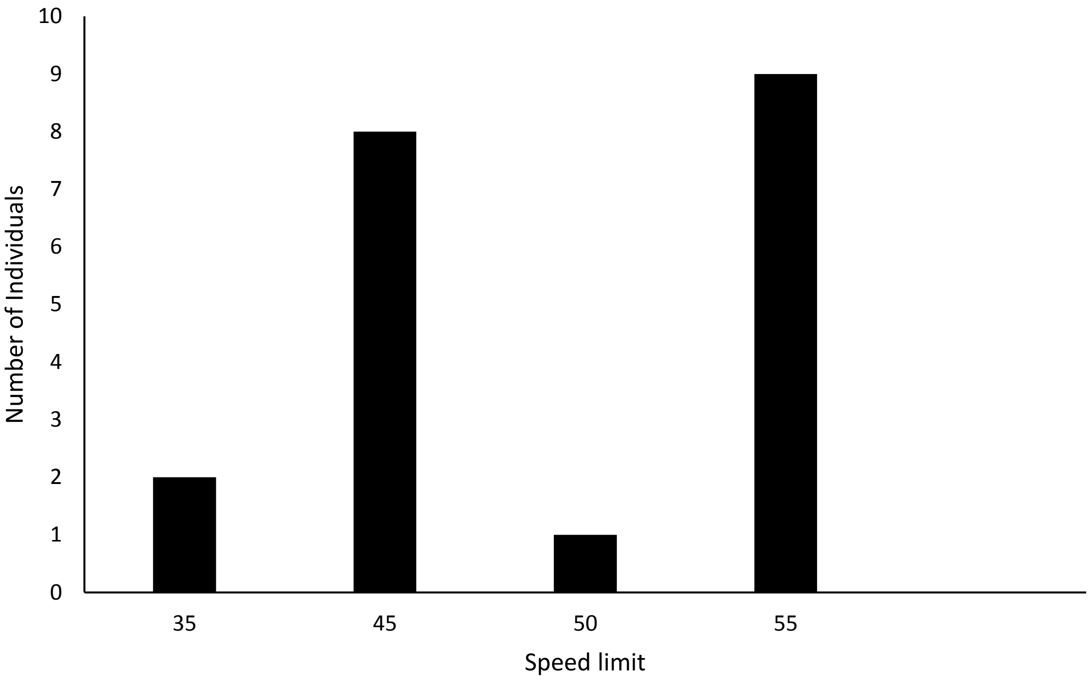

Figure 7. Numbers of individuals found on roads with different speed limits

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# Appendix A:

## Matson’s Lab cementum annuli aging data

| Date | Non standard tooth | Serial | Tooth ID | Age | CC* | Age Range | Aging notes** |
|---|---|---|---|---|---|---|---|
| November | | 1 | D1 | 0 | A | | IN |
| January | | 2 | D2 | 2 | A | | |
| February | | 3 | D3 | 0 | A | | |
| February | | 4 | D4 | 0 | A | | BR |
| March | | 5 | D5 | 2 | B | 1-2 | BR |
| June | l1 & LC | 6 | D6 | 1 | | | BR |
| June | | 7 | D7 | 9 | A | | |
| June | | 8 | D8 | 1 | A | | |
| June | | 9 | D9 | 4 | A | | |
| July | | 10 | D10 | 2 | B | 2-3 | AH |
| July | | 11 | D11 | 2 | B | 2-3 | |
| August | | 12 | D12 | 1 | B | 1-2 | |
| August | | 13 | D13 | 2 | A | | |
| September | M3 | 14 | D14 | 1 | A | | IN |
| November | PM3 | 15 | D15 | 1 | A | | IN |
| December | | 16 | D16 | 1 | B | 1-2 | |
| January | M2 | 17 | D17 | 1 | A | | IN |
| February | | 18 | D18 | 3 | A | | BR |
| February | | 19 | D19 | 1 | A | | |
| March | | 20 | D20 | 0 | A | | |
| November | l3 | 21 | D21 | 1 | A | | |
| January | l2 | 22 | D22 | 3 | A | | |
| February | LC | 23 | D23 | 1 | A | | IN |
| February | LC | 24 | D24 | 1 | A | | IN |
| March | l2 | 25 | D25 | 2 | B | 1-2 | |
| June | | 26 | D26 | 3 | A | | BR |
| June | l2 | 27 | D27 | 9 | A | | |
| June | l2 | 28 | D28 | 1 | A | | |
| June | l2 | 29 | D29 | 5 | A | | |
| July | I2 | 30 | D30 | 3 | B | 2-3 | |
| July | l2 | 31 | D31 | 2 | A | | |
| August | PM1 | 32 | D32 | 3 | A | | |
| August | M2 | 33 | D33 | 1 | A | | IN |
| September | M1 | 34 | D34 | 2 | A | | |
| November | PM3 | 35 | D35 | 2 | B | 2-3 | BR AH |
| December | I2 | 36 | D36 | 2 | A | | |
| January | M2 | 37 | D37 | 1 | A | | IN |
| February | l2 | 38 | D38 | 3 | A | | |
| February | I2 | 39 | D39 | 1 | B | 1-2 | |
| March | l3 | 40 | D40 | 0 | A | | IN |

* A- reliability ages indicate that the cementum characteristics of the tooth section very nearly match those of the standardized cementum aging model for the species and tooth type.  B- reliability ages there is histological evidence to support the result, and the correct age is expected to be within the range given.

**IN-Aged by inspection, without aging, BR-Broken with missing cementum, AH-Abnormal histology, usually removal of tooth tissue

## Appendix B:

## Road characteristics for each DVA location

| Deer # | Number of Lanes | Paved or Unpaved | Speed Limit |
|---|---|---|---|
| 1 | 2 | Paved | 55mph |
| 2 | 2 | Paved | 55 mph |
| 3 | 2 | Paved | 45 mph |
| 4 | 2 | Paved | 55 mph |
| 5 | 2 | Paved | 35mph |
| 6 | 2 | Paved | 55 mph |
| 7 | 2 | Paved | 45 mph |
| 8 | 2 | Paved | 45 mph |
| 9 | 2 | Paved | 55 mph |
| 10 | 2 | Paved | 45 mph |
| 11 | 2 | Not Paved, dirt road | 35 mph |
| 12 | 2 | Paved | 55 mph |
| 13 | 4 | Paved | 50 mph |
| 14 | 2 | Paved | 45 mph |
| 15 | 2 | Paved | 55mph |
| 16 | 2 | Paved | 55mph |
| 17 | 2 | Paved | 55mph |
| 18 | 2 | Paved | 45mph |
| 19 | 2 | Paved | 45 mph |
| 20 | 2 | Paved | 45mph |

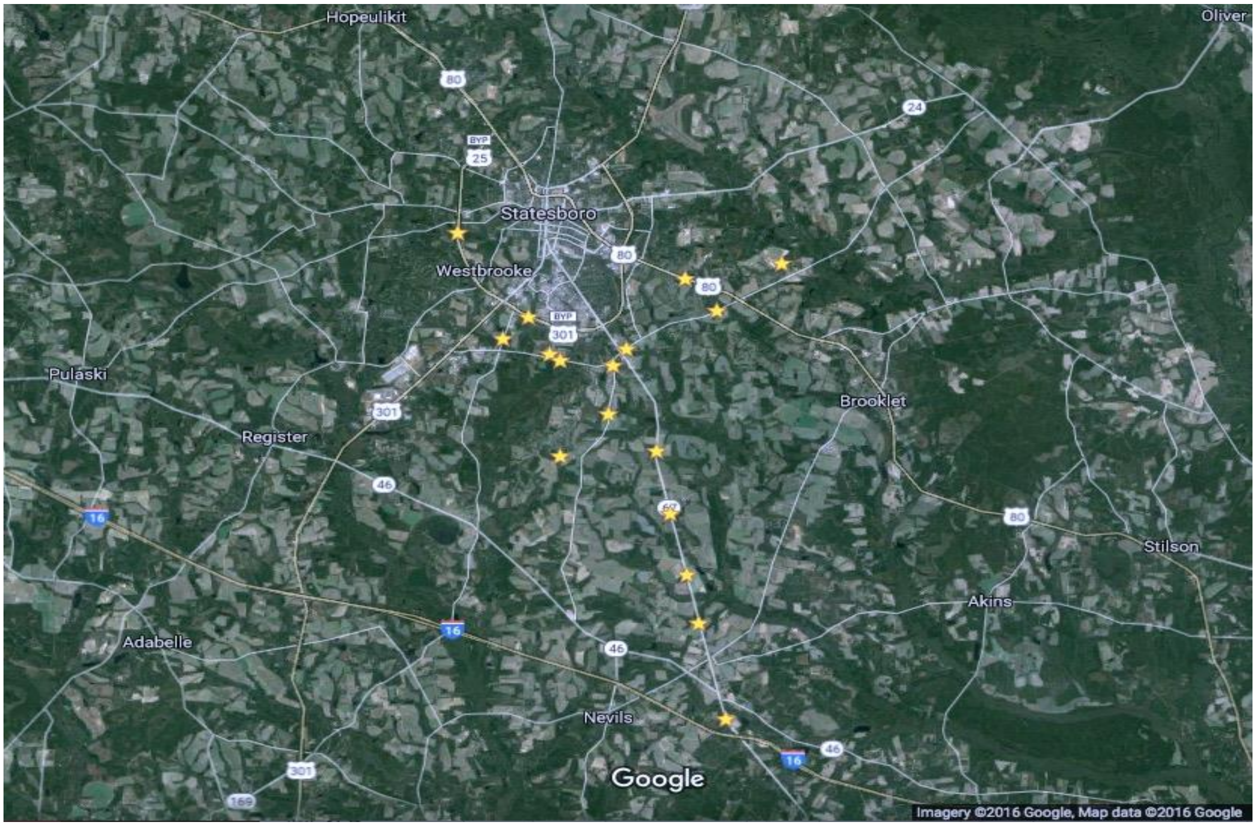
Appendix C:

Age assigned to each individual using the tooth wear and replacement method

| Deer # | Eruption Sequence |
|---|---|
| 1 | 6 months |
| 2 | 1 year 7 months |
| 3 | 1 year 5 months |
| 4 | 1 year 5 months |
| 5 | 1 year 6 months |
| 6 | 1 year 5 months |
| 7 | 5 years and 6 months |
| 8 | 1 year 5 months |
| 9 | 3 years and 6 months |
| 10 | 2 years and 6 months |
| 11 | 2 years and 6 months |
| 12 | 3 years and 6 months |
| 13 | 1 year 5 months |
| 14 | 6 months |
| 15 | 6 months |
| 16 | 3 years and 6 months |
| 17 | 1 year 5 months |
| 18 | 3 years and 6 months |
| 19 | 1 year and 6 months |
| 20 | 3 years and 6 months |

# Appendix D:

## Map of GPS coordinates of deer collected



*Note there are only 17 locations marked, but multiple deer were collected from the same location

# University Honors Program Thesis/Capstone Project Proposal Form

**Deadlines**

Proposal form is due by the following date one full year prior to graduation:
**Fall Graduates:** December 1st
**Spring/Summer Graduates:** May 1st
Final draft is due by the following date during the semester of graduation:
**Fall Graduates:** November 1st
**Spring/Summer Graduates:** April 1st

### General Student Information

Name: **Mackenzie Payne** Eagle ID: **900813481**

Expected graduation date: Fall [✓ **Spring**] Summer **2017**

Major: **Biology** Minor (if applicable): **Chemistry, Business**

P.O. Box: ______________________ Local Phone: **(702) 400-3933**

### Thesis/Capstone Project Information

Title: An Analysis of White-Tailed Deer, *Odocoileus virginianus*, Killed in Deer Vehicle Accidents on Bulloch County, GA Roadways

Faculty Mentor: **Dr. Edward Mondor** Faculty PO Box: 8042-1

**Requirements:**

- Separately attach a Thesis/Capstone Project Proposal (follow the format of your department)
- Submit final draft by the appropriate deadline listed above
- Present at the Honors Research Symposium

Student Signature: ______________________________
Date: ____________________

Faculty Mentor Signature: ________________________
Date: ____________________

## OFFICE USE ONLY

Term Received: ____________________ Term Completed: ______________________

Approved: ______________________________________________

**Please mail completed application to Box 8130 or drop off at the Eidson House.**