

**Determining whether tourist abundance and reproductive status
predispose golden-mantled ground squirrels (*Callospermophilus
lateralis*) to vehicular accidents**

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Abstract

Roads are a significant cause of biodiversity loss around the world, impacting wildlife by disrupting natural environment, changing abundance patterns of wildlife, and destroying habitat (Garrah et al. 2015). One of the most direct effects that roads have on animals is mortality from vehicular collision. Roads may be threatening to hibernating small mammals who rely on foraging because they may function as an ecological trap or an ecological sink (Ruiz-Capillas et al. 2015). This study examines roadkills in a known population of golden-mantled ground squirrels, *Callospermophilus lateralis*, (GMGS) at the Rocky Mountain Biological Laboratory (RMBL) in Gothic, CO in order to determine how timing and adult female reproductive phase predispose GMGS to vehicular collision. I hypothesize that (1) roadkill events involving GMGS peak in early to mid-July due to tourist abundance during the Wildflower Festival and late August due to pre-hibernation foraging and (2) reproducing adult female GMGS are more likely to be involved in a vehicular collision during their lactation stage due to peak energy demands. This study utilizes 25 years of GMGS life history and roadkill data (1995-2019) and two years of tourist data (2018 and 2019) from RMBL to compare roadkills and tourist abundance and to examine female reproductive stage when hit. There is a positive relationship between GMGS roadkill events and tourist counts. More reproductive GMGS were hit in their post-reproductive stage, and the majority of reproductive females were hit within a week of their litter emergence. It is clear that roads are a threat to the golden-mantled ground squirrel population at the Rocky Mountain Biological Laboratory site.

Introduction

More and more ecologists have begun to study the wide range of environmental effects of roads on different taxa within the past few decades (Lopez 2017, Schwatz et al. 2020). Roads are a significant cause of biodiversity loss around the world and have both direct and indirect negative effects on wildlife (Ruiz-Capillas et al. 2015, Kioko et al. 2015). The construction and existence of roads impact wildlife by disrupting natural environment, changing abundance patterns of wildlife, and destroying habitat (Ruiz-Capillas et al. 2015). Other indirect effects of roads relate to population dysconnectivity due to habitat fragmentation, alteration of animal behavior due to additional stimuli, and shortened lifespans in plant species due to road dust (Garrah et al. 2015, Lopez 2017). One of the most direct effects that roads have on animals is mortality from vehicular collisions.

Many studies that examine roadkill events have observed seasonal peaks. Seasonal peaks may be related to dispersal habits for different species and populations (Conard & Gipson 2006). These peaks may also correlate with emergence from hibernation, breeding, and migration patterns (Garrah et al. 2015). There is no consensus on whether there is a seasonal connection found between roadkill events and traffic abundance on roads.

Past ecological studies have determined that herpetofauna experience high levels of road mortality. For these amphibians and reptiles, roads are a threat because they are attractive places for foraging and thermoregulation (Garrah et al. 2015). Therefore, they have become the focus of worldwide conservation action due to their vulnerability to vehicular collision.

However, roads may be equally threatening to other animals, such as hibernating small mammals that live in townsites and rely on open areas for predator detection. Some small mammalian species tend to positively select habitat that are close to roads or transportation

infrastructure for foraging; in this way, roads may be functioning as an ecological trap, a habitat not well suited for survival and reproduction, or an ecological sink if the threat of vehicles is not recognized (Ruiz-Capillas et al. 2015). In fact, many roadkills have been recorded in areas with surrounding lush vegetation cover (Clevenger et al. 2003). Additionally, studies that have surveyed roads from a car have noticed high abundances of mammal and bird carcasses (Kioko et al. 2015, Smith-Patten & Patten 2008).

The golden-mantled ground squirrel (*Citellus lateralis*) (GMGS) is a common hibernating small mammal of the mountainous area of western United States. The GMGS population that resides in the Rocky Mountain Biological Laboratory (RMBL) site, located in Gothic, Colorado, has been studied for 30 years during their emergence months from May through September. The Rocky Mountain Biological Laboratory has many vehicles moving around the site every day of the summer season, including delivery trucks, personal cars, maintenance vehicles, research vans, and tourists' utility terrain vehicles. Tourist abundances throughout summer months heavily influence how much traffic is in the townsite.

Foraging behavior is very important for this species, and juveniles have been found to spend the largest portion of time foraging (James 2016). GMGS feed on fungi, leaves, seeds, flowers, bulbs, and fruit (McKeever 1964). Young animals increase their body weight rapidly early in the summer and then at a reduced rate until hibernation (McKeever 1964). For all golden-mantled ground squirrels, body mass must increase in the pre-hibernation phase of the summer in preparation for winter.

Adult female GMGS are a vital population demographic for stabilizing population growth and protecting against local extinction (Wells et al. 2019). Reproductive adult females experience a different pattern in foraging behavior throughout the summer due to their stages of

reproduction: gestation, lactation, post-reproduction/recovery, and pre-hibernation (McKeever 1964). These females have a 2.1-fold increase in food consumption during lactation when young are fully dependent on their mother for nutrition for up to 35 days (Kenagy et al. 1989). Though body weight does not vary significantly for the reproductive adult female, metabolism (rate of mass-specific oxygen consumption) and milk production both increase for the mother during this lactation period (Kenagy et al. 1989). Food intake is the major source for the added materials and work energy required for lactation, and more time spent foraging may lead to more interaction between the squirrels and human-developed areas such as roads (Kenagy et al. 1989). Lactating female GMGS may be more at risk of mortality from vehicular collision because of more pressure to forage and therefore more incentive to take risks foraging near roads and crossing roads.

Roadkill studies tend to identify anonymous individuals of several different species with little information about their life-history stage. By using a 25-year master data set containing information about the RMBL GMGS population life stage histories and causes of death, it is possible to determine what factors contribute to an increased risk of vehicular collision for a specific population of a small hibernating mammalian species. I hypothesized that (1) roadkill events involving GMGS peak in early to mid-July due to tourist abundance during the Wildflower Festival and late August due to pre-hibernation foraging and (2) reproducing adult female GMGS are more likely to be involved in a vehicular collision during their lactation stage due to peak energy demands. I predict that (1) I will observe a positive correlation between tourist abundance and adult GMGS roadkills and (2) the majority of reproducing adult female squirrels involved in a vehicular collision were killed before their litter emerged.

Methods

I used 25 years of RMBL golden-mantled ground squirrel data and two years of RMBL visitor center data from May through September in order to test my hypotheses. I searched for GMGS deaths caused by vehicular collision in complete, yearly master lists spanning from 1995-2019. I also searched for GMGS roadkill events in trap logs spanning from 2000-2018. For every roadkilled individual that was identified as a GMGS and had a listed date of death, I recorded one data point in my total count corresponding to which week of the season the death occurred. Week 1 was May 1 – May 7 and Week 18 was August 28 – September 3rd. For each individual that was identified by ear tag, I also recorded the age class (juvenile vs. adult) and sex (male vs. female). I also included individuals that were not ear tagged but were identified as a GMGS in a specific age class in my total counts.

I used 2018 and 2019 RMBL Visitor Center daily visitor counts spanning from June 8th – September 3rd and calculated average tourist abundance for each week of the season beginning on Week 6. Week 6 excludes counts from the first two days of the week, June 6th and 7th, either because the center was not open or because there are no records from these days, along with the previous days. Though I am using data from two years, these should approximate tourist trends over the period of the study.

In order to test hypothesis 1, I calculated how many roadkill events happened during each week of the season over the whole study period in total, for adults, for adult males, for adult females, and for juveniles. I used a linear regression model to compare the adult roadkill data per week to the tourist trends per week and tested the fit of that model. I did not compare juvenile data because all juvenile squirrels emerge after the gestation and lactation phases of the reproductive female, so it is not possible for them to encounter a road until later in the season.

In order to test hypothesis 2, for each ear tagged reproductive GMGS roadkill, I recorded date of roadkill event, date of her litter emergence, and how many days pre- or post-litter emergence the roadkill event occurred. I determined whether the female was in her gestation/lactation phase of summer or her post-reproduction/pre-hibernation phase of summer by looking at notes on the master lists and trap logs or by looking at whether the female died before or after her litter emergence if no reproductive phase was listed. If master list and trap log notes did not specify reproductive stage at death, females who died before litter emergence were listed as in their gestation/lactation phase and females who died after litter emergence were listed as in their post-reproduction/pre-hibernation phase.

Results

From May 1st through September 3rd of 1995 through 2019, there were 56 date-specific recorded GMGS roadkill events. Of these, nine were identified as adult males, 15 as adult females, and 32 as juveniles. Total roadkills, total adult roadkills, total adult male roadkills, and total adult female, non-reproductive and reproductive, roadkills summed for all 25 years each peaked in week 11 of the GMGS season, July 10th through July 16th (Figures 1-5). Total juvenile roadkills peaked in week 13, July 24th – July 30th (Figure 6).

The 2018 and 2019 RMBL Visitor Center data show that Week 11, July 10th through July 16th, was the peak of tourist activity in Gothic (Figure 7). Visitor Center data was only available starting from June 8th. County road, the main public road to RMBL, is closed in the winter due to snowpack and only reopens for the summer in mid-to-late May.

There is a positive relationship between tourist counts and GMGS roadkill events ($\beta=0.00399\pm0.00010$, $t=4.01$, $p=0.00204$, $R\text{-squared}=0.557$) (Figure 8). A similar relationship

was observed for adult GMGS roadkill events ($\beta=0.00285\pm0.00075$, $t=3.81$, $p=0.00291$, $R^2=0.529$), adult male GMGS roadkill events ($\beta=0.00124\pm0.00048$, $t=2.57$, $p=0.0263$, $R^2=0.318$), and adult female roadkill events ($\beta=0.00160\pm0.00041$, $t=3.93$, $p=0.00236$, $R^2=0.546$) (Figures 9-12).

There were nine reproductive adult females that were involved in a vehicular collision that had a specific date or reproductive stage recorded over 25 years (Table 1). All of these reproductive females had litters emerge by the Billy Barr Community Center (or older dining hall location), Oh-Be-Joyful, or the Coffee Lab/Town Hall, locations that are in proximity to County Road (Figure 13). Three of these females were in their gestation/lactation reproductive stage when hit (Figure 14). Of those females, two litters were lost (the litter was never seen above ground) and one litter emerged four days after the mother's roadkill event. The remaining six females were roadkilled after their litter had emerged (Figure 14). Four of these females were struck within a week of their litter emerging.

Discussion

Tourist Abundance

I hypothesized that roadkill events involving GMGS peak in early to mid-July due to tourist abundance during the Wildflower Festival and late August due to pre-hibernation foraging. GMGS roadkill events are most abundant in the 11th week of the season, from July 10th through July 16th, which corresponds to the week of peak tourism due to Wildflower season in the middle of July. GMGS roadkill events did not increase at the end of the summer for the overall population due to increased foraging demands.

This study provides strong evidence that there is a significant positive correlation between traffic volume and GMGS vehicular collisions: more squirrels are killed in weeks with high tourist visitation counts. There have been mixed findings about whether high traffic volume is a contributor to higher roadkill rates, but some studies have found a connection between roadkill events and traffic abundance for mammals (Conard & Gipson 2006, Seo et al. 2013). For mammals in particular, reproductive cycles and dispersal patterns also correspond to increased roadkill rates (Seo et al. 2013, Canova & Balestrieri 2018). In Italy, Roe Deer roadkill events peak during the time of highest dispersal rates, while wildboar roadkill events peak during mating season (Canova & Balestrieri 2018). Overall, this is not the case for the RMBL GMGS population. The mid-summer peak indicates that during May breeding and August dispersal, the low traffic volumes are a better indicator of roadkill rate. This may be because the number of tourists coming into RMBL changes drastically throughout the summer, and vehicles must be present in order for roadkill events to happen. It should be noted that for the adult males in the population, there was a less significant correlation between tourist abundance and roadkill rate; the influx of immigrants entering the population at the end of the summer may also have an impact on their vulnerability to vehicular collision.

Reproductive Female GMGS

More reproductive females were in a vehicular collision after their litter emerged, refuting hypothesis 2 that lactating females are most likely to die from a vehicular collision. GMGS reproductive females have peak energy demands during their lactation stage, which results in increased foraging (Kenagy et al. 1989). However, the results of this experiment show that more reproductive females were struck during their post-reproduction stage. In some

mammalian populations, lactating females also need to forcefully defend their territory, reducing their home range by 50% compared to non-reproductive females (Gilman et al. 2010). Overall, males tend to show greater amounts of wide-range exploratory behavior compared to females (Kenagy et al. 1989), so maybe when females' litters emerge and are not as dependent, post-reproductive females exhibit more exploratory behavior and consequently interact with more roads.

Of the reproductive females involved with vehicular collisions, more than half were killed within a week of her litter emerging. It is unclear whether this is due to higher traffic volume or whether this is due to time of litter emergence, since these two factors peak simultaneously in July. It is possible that maternal behavior around emergence time changes to wean her pups or to watch other females in the area. Factors that may pull a female away from her established territory and closer to roads during time of litter emergence include moving away from her pups during weaning to promote independence or looking around for other females or predators in the area. Home range of adult female GMGS is well understood (Jesmer et al. 2011), but in order to better understand the impact that reproductive status has on predisposition to vehicular collision, it is necessary to further study the home ranges of reproductive and nonreproductive females throughout the season.

Conclusion

This study examined roadkill events in a known population of golden-mantled ground squirrels at the Rocky Mountain Biological Laboratory. We do not fully understand the impacts that roads have on this population, but it is clear that roads are a direct threat to local GMGS and that mitigative solutions should be implemented. Successful mitigative methods in other areas

include signage, traffic calming measures, wildlife overpasses, culverts, and fencing (Garrah et. al. 2015).

Further investigation into what factors predispose reproductive females to vehicular collision is vital to ensure that this population is not at risk of local extinction. The methods of this study can also be used to study other populations of small mammals with long-term datasets that include relatedness, roadkill events, and adult-female reproductive stages. This research adds to the collection of literature determining to what extent human infrastructure negatively impacts wildlife.

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References

- Canova L & Balestrieri A. 2018. Long-term monitoring by roadkill counts of mammal populations living in intensively cultivated landscapes. *Biodiversity and Conservation*, 28(1):97-113.
- Clevenger AP, Chruszcz B, Gunson K. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. *Biological Conservation*, 109(1):15–26
- Conard JM & Gipson PS. 2006. Spatial and seasonal variation in wildlife–vehicle collisions. *Prairie Naturalist*, 38(4):251–260
- Garrah E, Danby RK, Eberhardt E, Cunningham GM, and Mitchell S. 2014. Hot Spots and Hot Times: Wildlife road mortality in a regional conservation corridor. *Environmental Management*, 56(4):874-889.
- Gilman RT, Mathews NE, Skinner BG, Julis VI, Frank ES, and Paul-Murphy J. 2010. Effects of maternal status on the movement and mortality of sterilized female white-tailed deer. *Journal of Wildlife Management*, 74(7):1484-1491.
- Grilo C., Koroleva E., Andrasik R., Bil M. and Gonzalez-Suarez M. 2020. Roadkill risk and population vulnerability in European birds and mammals. *Frontiers in Ecology and the Environment*.
- Jesmer BR, Van Vuran DH, Wilson JA, Kelt DA, and Johnson ML. 2011. Spatial organization in female golden-mantled ground squirrels. *American Midland Naturalist*, 165(1):162-168.
- Ha H & Shilling F. 2018. Modelling potential wildlife-vehicle collisions (WVC) locations using environmental factors and human population density: A case study from 3 state highways in Central California. *Ecological Informatics*, 43(1): 212-221.
- James F. 2016. Behavioral strategies of golden-mantled ground squirrels, *Callospermophilus lateralis*. Student Paper.
- Kenagy GT, Sharbaugh SM, & Nagy KA. 1989. Annual cycle of energy and time expenditure in a golden-mantled ground squirrel population. *Oecologia*, 78(2):269-282.
- Kenagy GT, Stevenson RD, Masman D. 1989. Energy requirements for lactation and postnatal growth in captive golden-mantled ground squirrels. *Physiological Zoology*, 62(2): 470-487.
- Kioko J, Kiffner C, Jenkins N, and Collinson WJ. 2015. Wildlife roadkill patterns on a major highway in Northern Tanzania. *African Zoology*, 50(1): 17-22.
- Lopez D. 2017. Effect of Road Dust Deposition on the Floral Lifespan of Scarlet gilia, *Ipomopsis aggregata*. Student Paper.

McKeever S. 1964. Biology of the Golden-Mantled Ground Squirrel. *Ecological Monographs* 34(4): 383-401.

Schwartz ALW, Shilling FM, & Perkins SE. 2020. The value of monitoring wildlife roadkill. *European Journal of Wildlife Research*, 66(1):1-12.

Seo C, Thorne JH, Choi T, Kwon H, & Park C. 2013. Disentangling roadkill: the influence of landscape and season on cumulative vertebrate mortality in South Korea. *Landscape and Ecological Engineering*. 11(1):87-99.

Smith-Patten BD & Patten MA. 2008. Diversity, Seasonality, and context of mammalian roadkills in the Southern Great Plains. *Environmental Management* 41(6):844-852

Wells CP, Wilson JA, Kelt DA, Van Vuren DH. 2019. Body mass as an estimate of female body condition in a hibernating small mammal. *Canadian Field-Naturalist* 133(1):34-42.

Figures and Tables

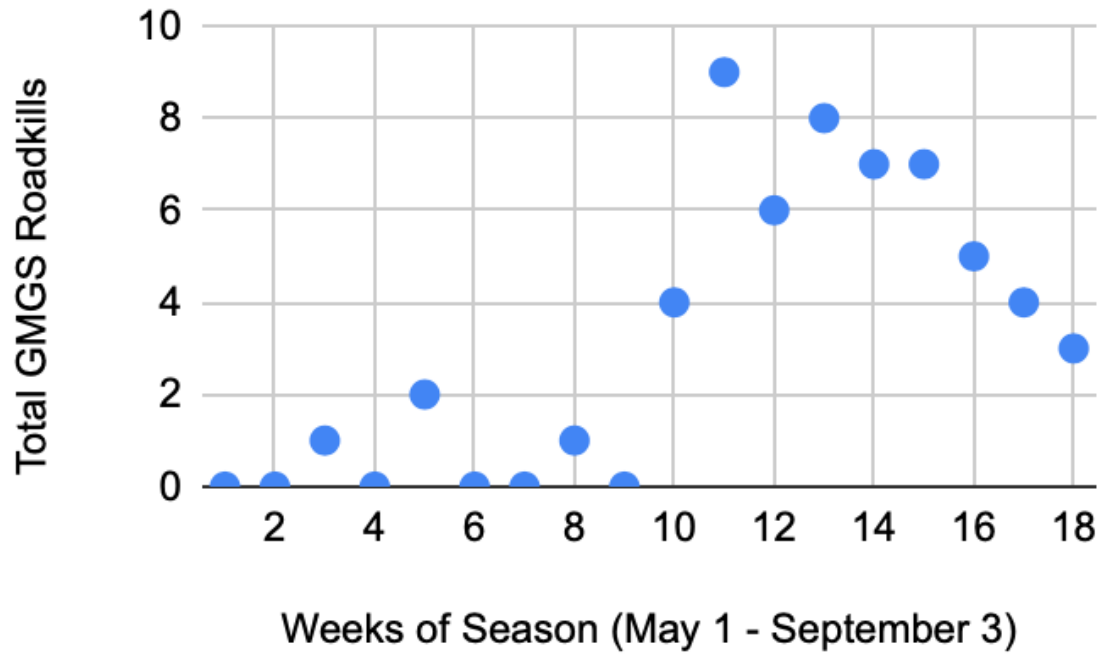


Figure 1: Total GMGS Roadkill Events per Week of Season (1995-2019)

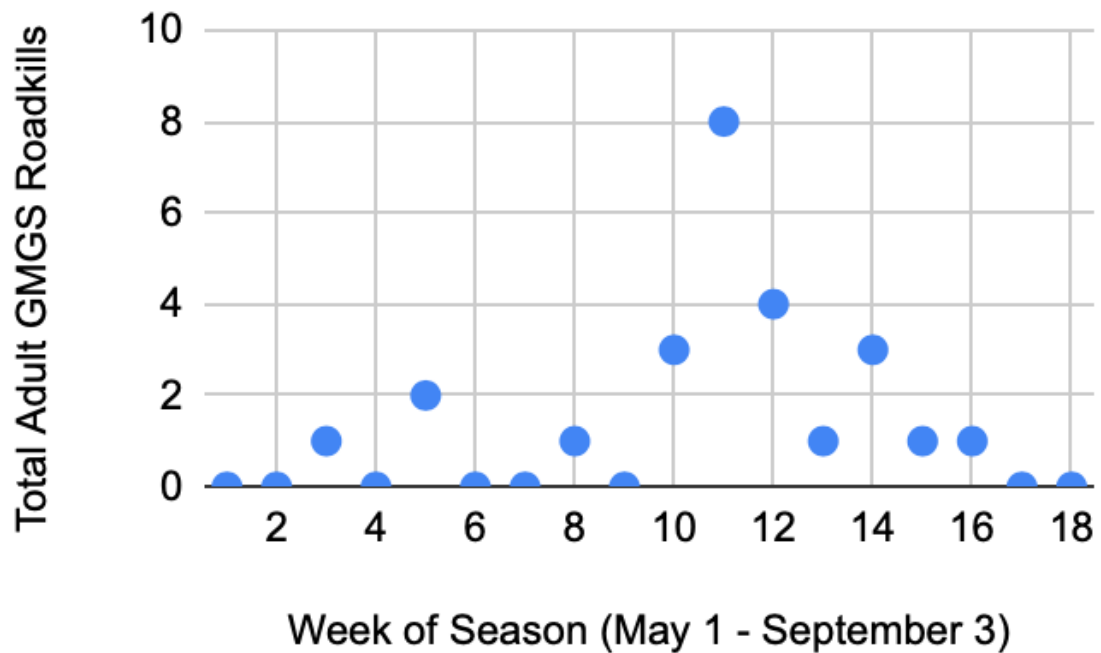


Figure 2: Total Adult GMGS Roadkill Events per Week of Season (1995-2019)

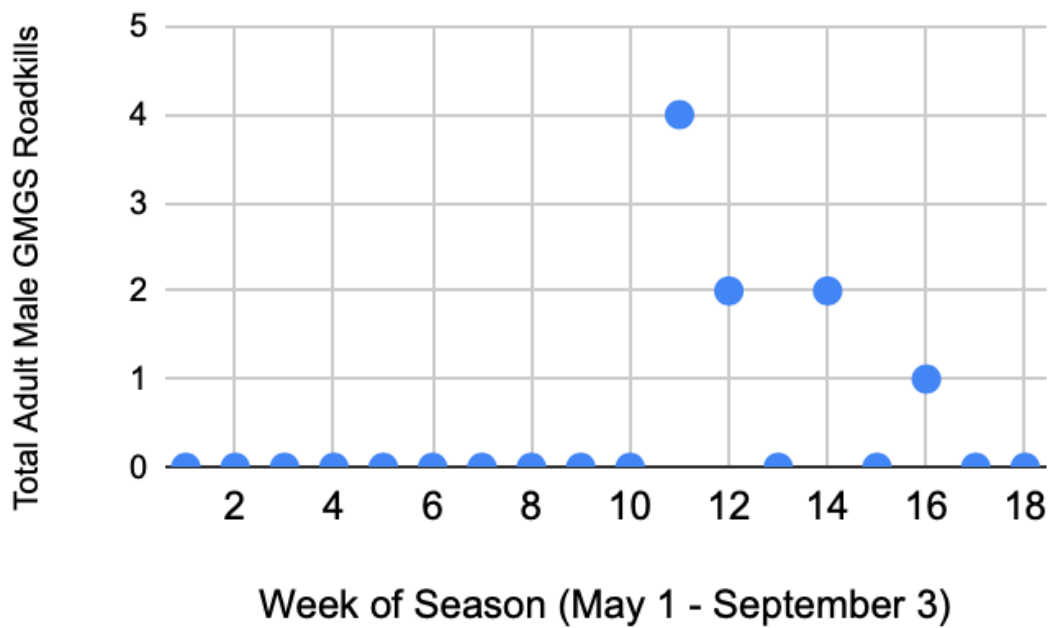


Figure 3: Total Adult Male GMGS Roadkill Events per Week of Season (1995-2019)

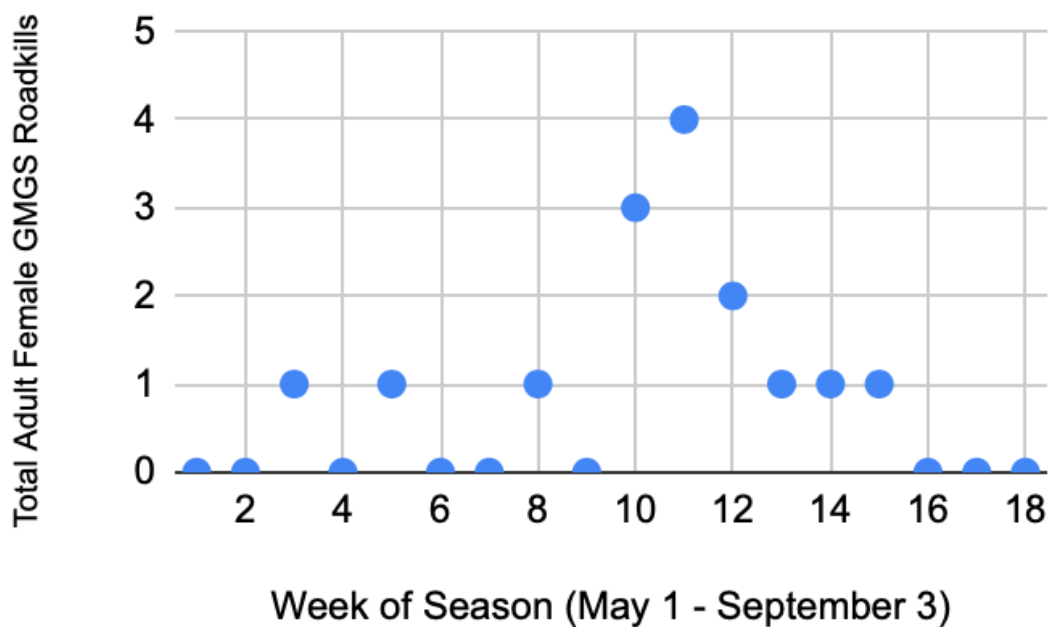


Figure 4: Total Adult Female GMGS Roadkill Events per Week of Season (1995-2019)

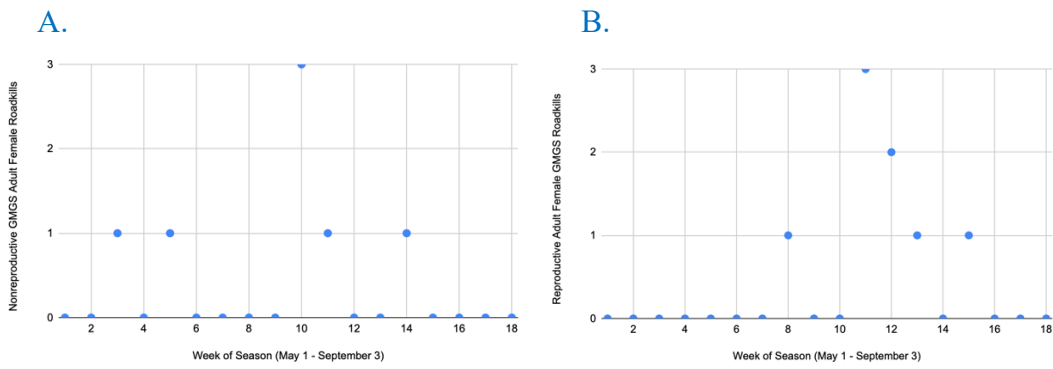


Figure 5: Nonreproductive (A) vs. Reproductive (B) Adult Female GMGS Roadkill Events

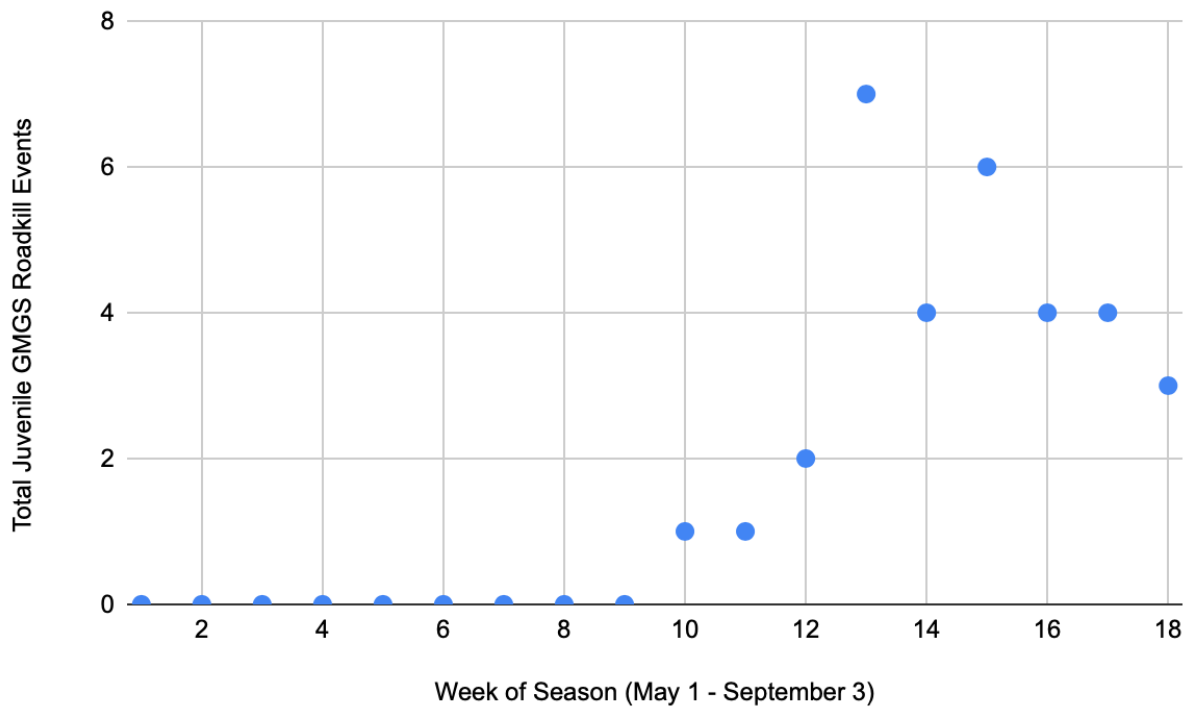


Figure 6: Total Juvenile GMGS Roadkill Events per Week of Season (1995-2019)

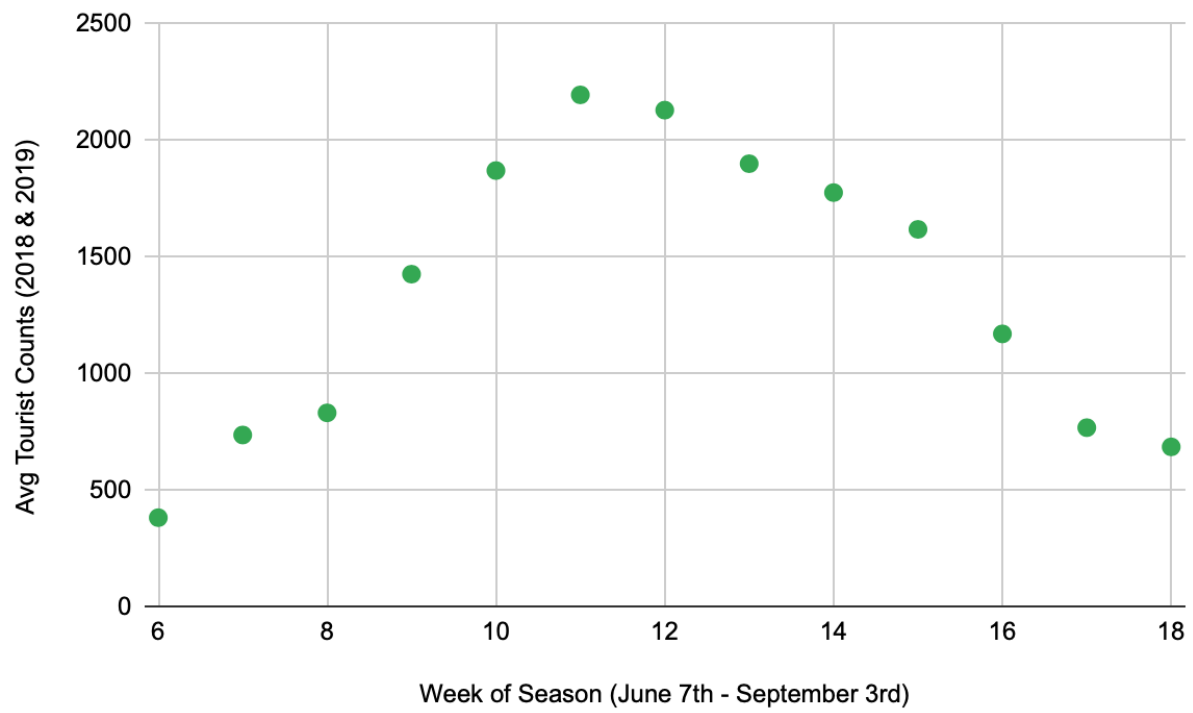


Figure 7: Average Tourist Counts during 2018 and 2019 from RMBL Visitor Center



Figure 8: Linear Model of Total Roadkill Events as a Function of Tourist Counts

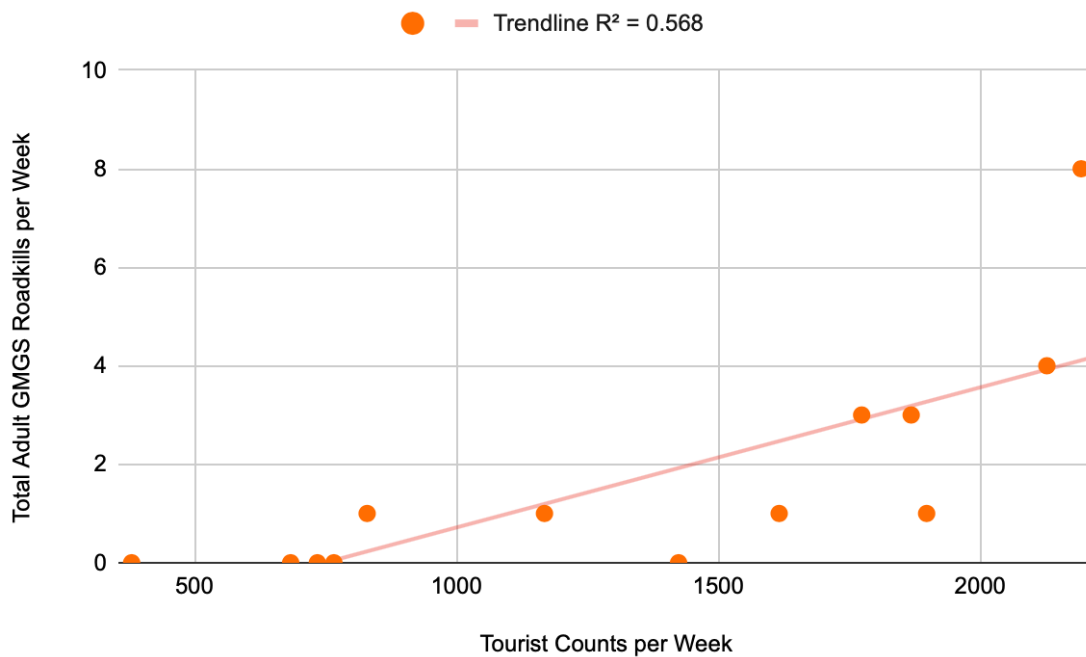


Figure 9: Linear Model of Adult Roadkill Events as a function of Tourist Counts

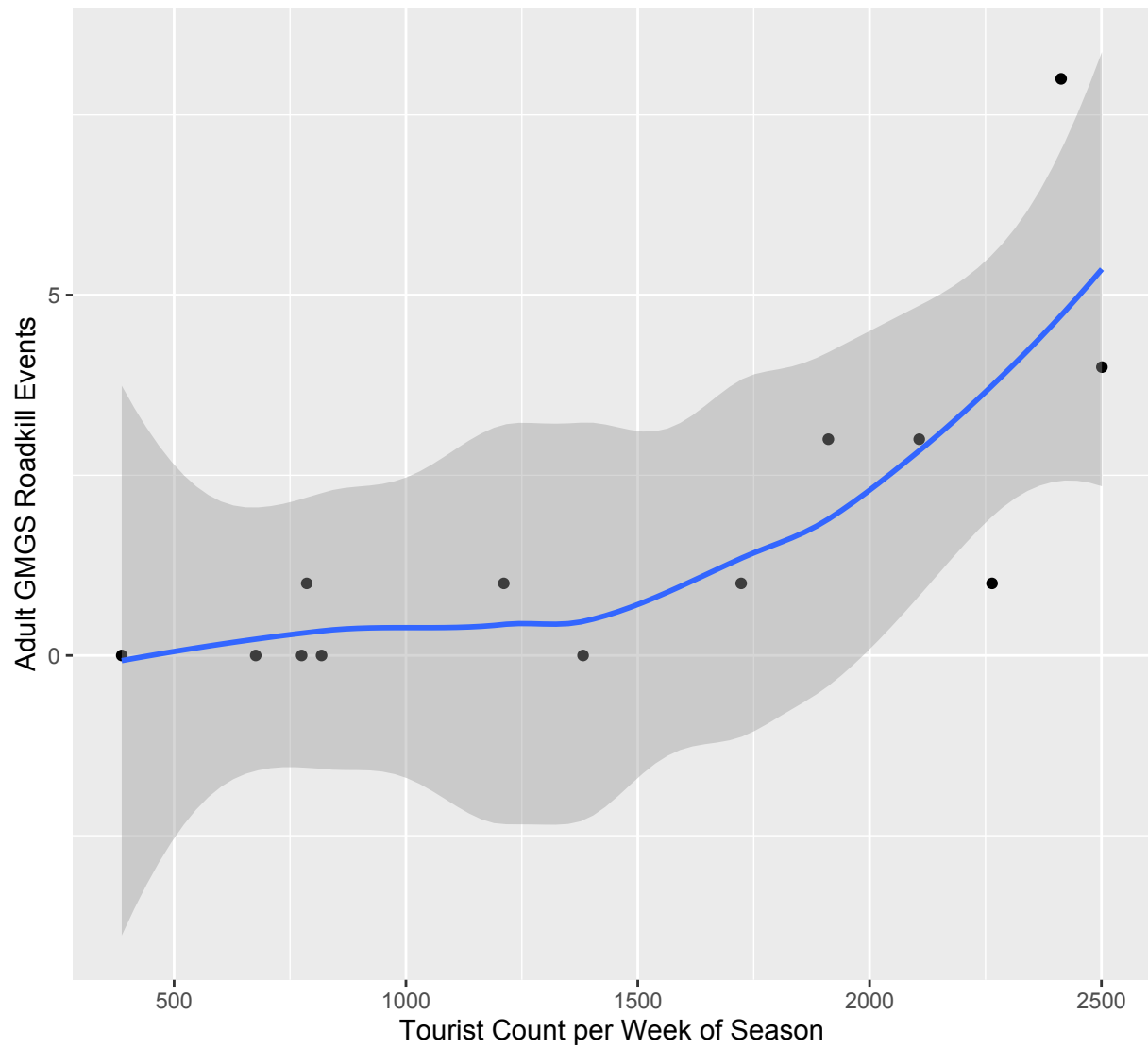


Figure 10: Linear Model with 95% CI of Adult Roadkill Events as a function of Tourist Counts

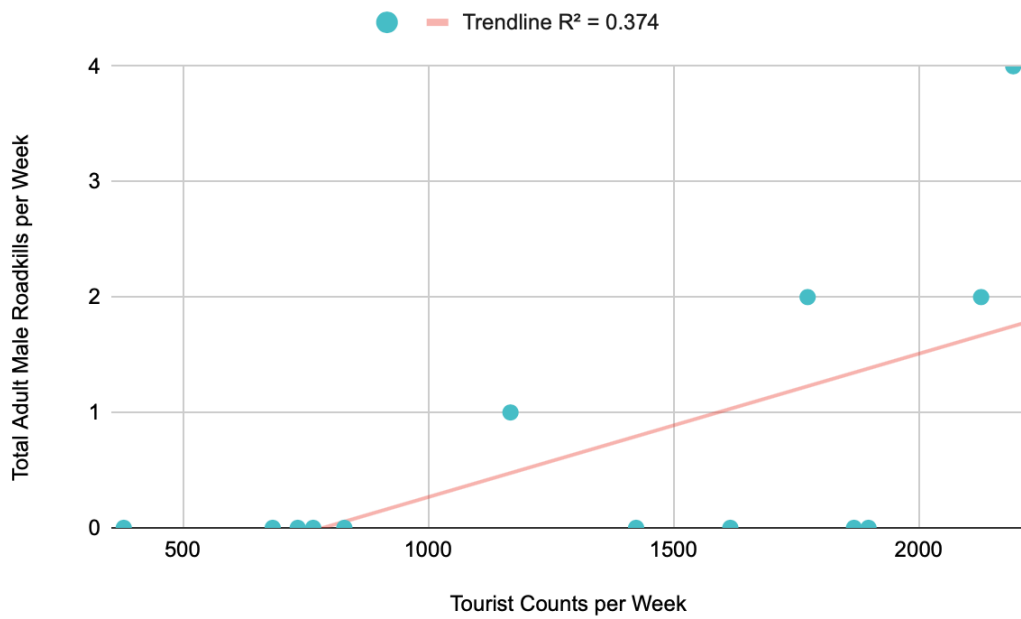


Figure 11: Linear Model of Adult Male Roadkill Events as a function of Tourist Counts

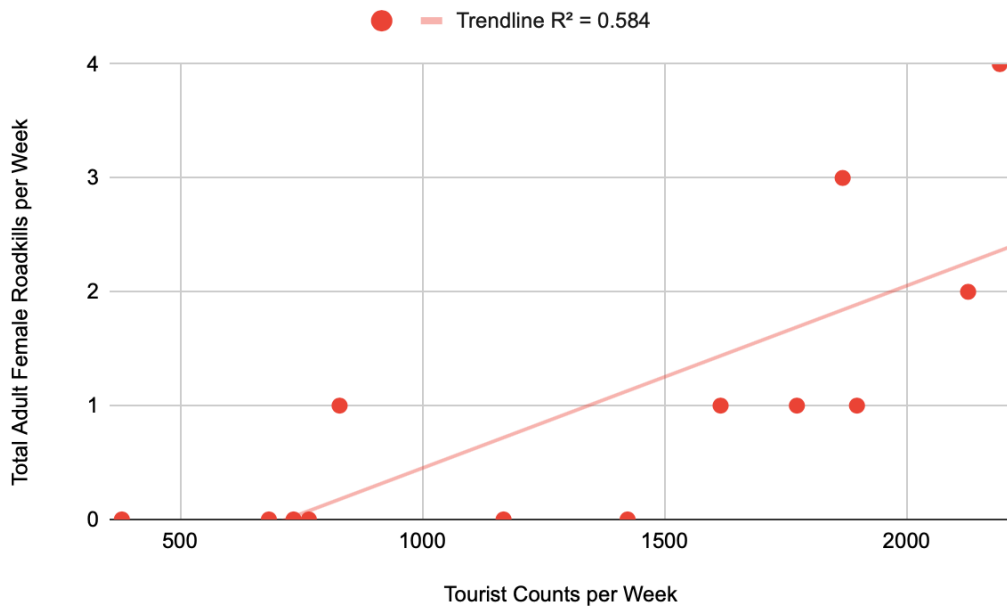


Figure 12: Linear Model of Adult Female Roadkill Events as a function of Tourist Counts

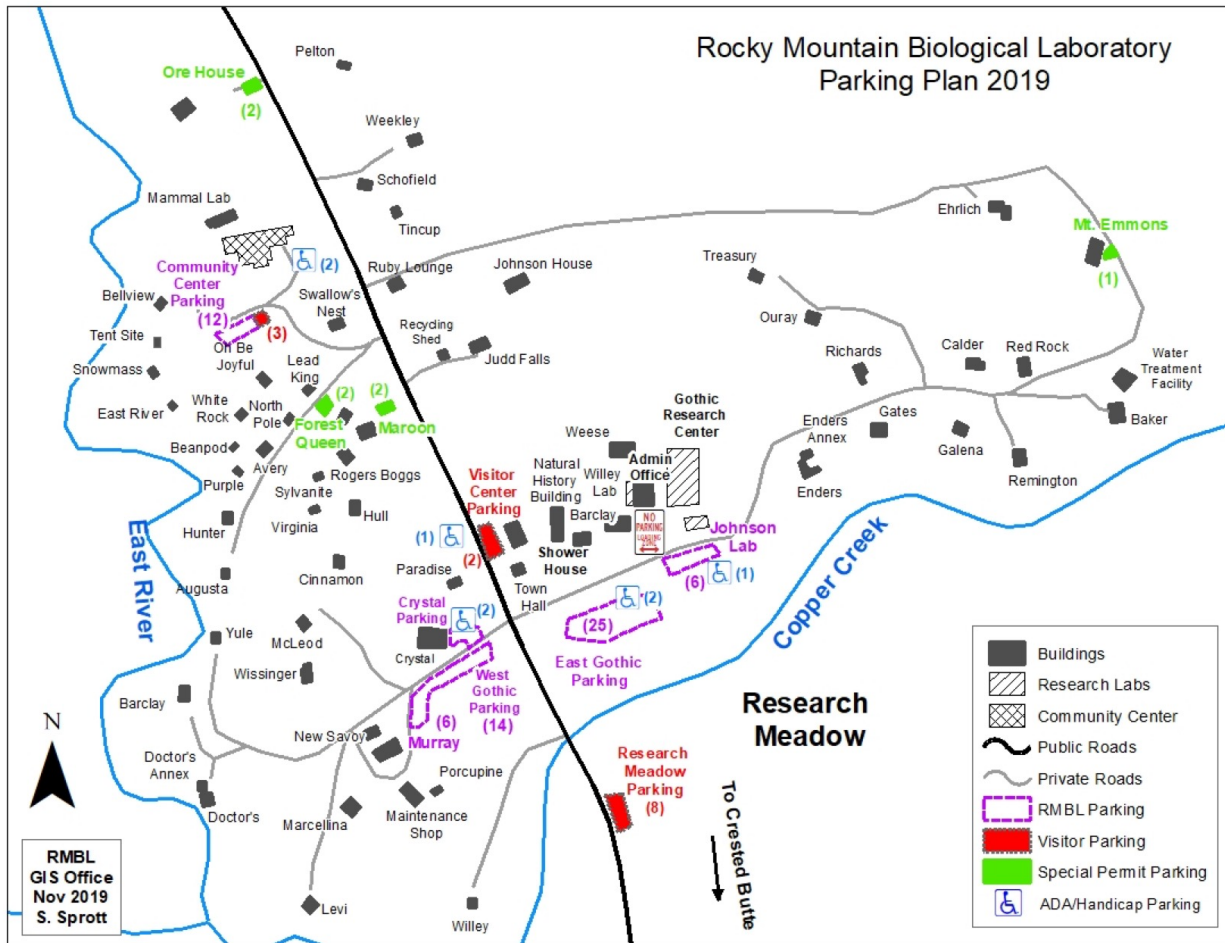


Figure 13: Map of GMGS Project Site in Gothic, CO

Table 1: Female GMGS Roadkill and Reproductive Information

Female GMGS	Year	Roadkill Date	Roadkill Location	Litter Emergence Date	Litter Emergence Location	Reproductive Stage
599/600	1997	na	na	July 11	na	Post-Reproductive
926/928	1998	July 17	na	July 23	Dining Hall	Gestation/Lactation
590/591	2003	July 13	CC Bridge	na	na	Gestation/Lactation
430/431	2003	July 25	Ruby	June 29	Oh-Be-Joyful	Post-Reproductive
503/815	2010	July 17	Town Hall	July 10	Town Hall	Post-Reproductive
766/851	2011	July 10	Ore House	na	na	Gestation/Lactation
666/105	2018	June 25	Ruby	June 21	Oh-Be-Joyful	Post-Reproductive
242/913	2019	July 16	billy barr Community Center	July 15	billy barr Community Center	Post-Reproductive
37/58	2019	August 7	billy barr Community Center	July 31	billy barr Community Center	Post-Reproductive

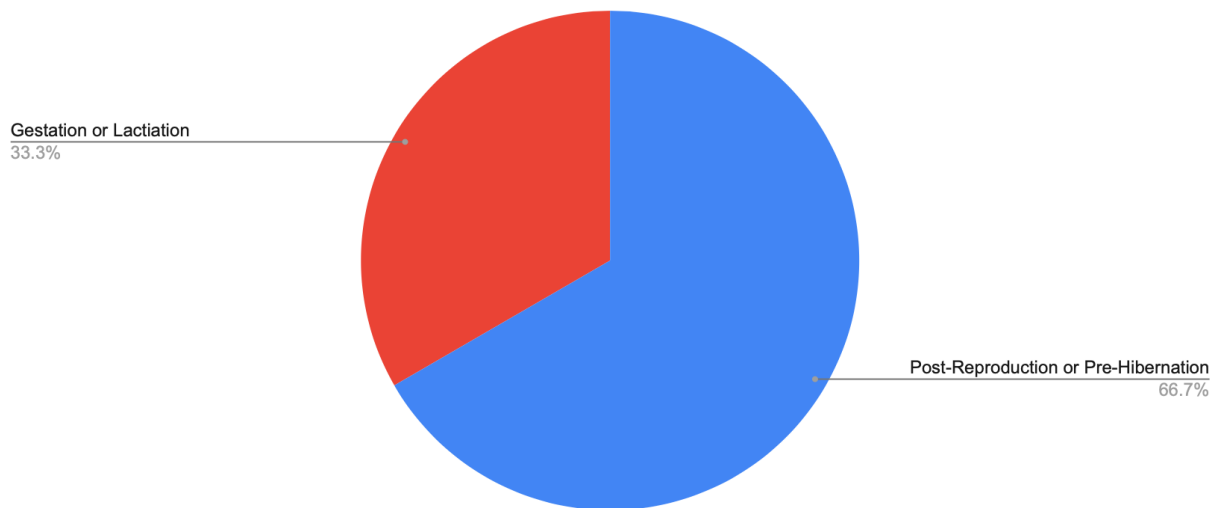


Figure 14: Percentage of Reproductive Adult Female GMGS in Each Reproductive Phase during Vehicular Collision