

SEASONAL VARIATION IN SEX RATIOS AND SURVIVAL RATES OF WHITE-
TAILED DEER FAWNS

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SEASONAL VARIATION IN SEX RATIOS AND SURVIVAL RATES OF WHITE-
TAILED DEER FAWNS

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A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Degree of

Master of Science

Auburn, Alabama
May 11, 2006

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Sarah Therese Saalfeld

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Sarah Therese Saalfeld was born in Cincinnati, Ohio on July 13, 1982. She grew up in Northern Kentucky and graduated from Notre Dame Academy High School in Park Hills, Kentucky in 2000. Following this, she attended Thomas More College where she worked for three years at Thomas More College's Center for Ohio River Research and Education. Sarah graduated from Thomas More College summa cum laude with a Bachelor of Arts in Biology in 2003. She then began her graduate degree as a research assistant in Wildlife Sciences at Auburn University. Sarah finished her degree requirements for a Masters of Science in Wildlife Sciences in May, 2006.

THESIS ABSTRACT

SEASONAL VARIATION IN SEX RATIOS AND SURVIVAL RATES OF WHITE- TAILED DEER FAWNS

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Master of Science, May 11, 2006
(B.A., Thomas More College, 2003)

80 Typed Pages

Directed by Stephen S. Ditchkoff

The ability of a female to adjust the sex ratio of her offspring has been well documented in numerous mammalian species. However, few studies have deviated from focusing on maternal condition as the driving factor concerning sex ratio variation. In this study, we investigated how birth date influenced offspring sex ratios in a captive herd of white-tailed deer (*Odocoileus virginianus*) located in Michigan. Since it has been predicted that females will bias the sex ratio of her offspring in order to increase her lifetime fitness, we hypothesized that more males should be born earlier in the birthing season. Offspring born earlier will have more time for development and therefore have a greater potential for increased dominance and body size later in life, traits related to male reproductive success. In this study, we found that maternal condition did not influence offspring sex ratios, while birth date did. It was found that more males tended to be born during the second and fourth birthing periods, with females dominating the first, third and fifth birthing period. In addition, the mass of male fawns at six months decreased with

later birthing dates, a trend not as apparent in female fawns. This suggests that by varying offspring sex ratios, a female can improve her lifetime fitness by investing in the sex that will gain the greatest reproductive advantage by being born at certain times.

As humans continue to move from the urban epicenter, management of wildlife in these areas is becoming increasingly important. However, since wildlife residing in these areas are exposed to different stresses than their rural counterparts, they may exhibit behavioral or life history modifications, ultimately decreasing the effectiveness of management decisions. One life history characteristic that is important to understand before implementing management decisions is survival. In white-tailed deer, a great deal of natural mortality occurs within the first few months of life, and therefore has the potential to greatly influence population dynamics and management decisions. In this study, we determined the cause, timing, and factors influencing neonatal mortality of a suburban population of white-tailed deer in Alabama. We found a 67% mortality rate, with the leading causes of mortality being predation by coyotes (41.7%) and starvation due to abandonment (25%). We also found that survival rates were different between the two years of the study (23.5% in 2004 and 42.1% in 2005; with fawns born in 2005 being 1.49 more likely to survive than fawns born in 2004), were linearly related to time following birth (survival increasing by 1.36 with each additional week after birth), and were positively associated with mass at birth (survival increasing by 1.69 with each additional kg of birth mass). These mortality rates are greater than most rural populations, suggesting that population growth rates of white-tailed deer found in suburban areas may be limited by increased mortality rates early in life.

ACKNOWLEDGMENTS

I would especially like to thank my advisor, Stephen Ditchkoff, for his guidance and support during this project. I would also like to thank the other members of my committee, Stephen Dobson and Barry Grand, as well as John Ozoga and Mike Mitchell for their direction and assistance. I would like to thank all the faculty, staff, and fellow graduate students at the School of Forestry of Wildlife Sciences for their patience and help along the way and the funding for this project, which was provided by the Center for Forest Sustainability at Auburn University.

I would also like to give a special thanks to all those who helped with the field work for this study, especially David Saalfeld, Chad Newbolt, Jordan Smith, Chip Gibson, Vic Jackson, John Lewis, Buck Jolley, Will Underwood, Ashley Hand, Carrie Johnson, Thomas Harms, Dustin Rogers, Will Neighbors, Erin Holms, Chris Nix, Rachel DeFreese, Kyle Marable, and Lauren Bilodeaux. I would like to thank all landowners and Alabama Parks Division for allowing me to conduct this research on their property.

I would also like to express my sincere gratitude to my husband, David Saalfeld, for his constant support, patience, and love, without which, my dreams would not be as obtainable. I would also like to thank my family, especially my mom for being there to listen and encourage me through this undertaking and for instilling in me her strength to achieve my goals, my dad for his loving support and encouragement, and my sisters and brothers for their constant understanding, friendship, and support.

Style manual of journal used: Journal of Mammalogy

Computer software used: Microsoft Word 2002 (text and tables), SigmaPlot 8.0 (figures)

TABLE OF CONTENTS

LIST OF TABLES	xi
LIST OF FIGURES	xii
I. SEASONAL VARIATION IN SEX RATIOS PROVIDES DEVELOPMENTAL ADVANTAGES IN WHITE-TAILED DEER	
Abstract	1
Introduction	2
Materials and Methods	6
Results	8
Discussion	9
Literature Cited	15
Figures and Tables	22
II. SURVIVAL OF WHITE-TAILED DEER FAWNS IN A SUBURBAN POPULATION	
Abstract	28
Introduction	29
Material and Methods	31
Results	34
Discussion	36
Literature Cited	42

Figures and Tables.....49

APPENDICES

Appendix 1. Doe capture data in Auburn, Alabama during 2004 and 200558

Appendix 2. Fawn capture data in Auburn, Alabama for 2004 and 2005
using vaginal implant transmitters.....62

Appendix 3. Doe capture data in Camp Hill, Alabama during 200565

Appendix 4. Fawn capture data in Camp Hill, Alabama for 2005 using
vaginal implant transmitters.....66

Appendix 5. Fawn capture data in Auburn and Camp Hill, Alabama for
2004 and 2005 using spotlights and thermal imaging camera.....67

LIST OF TABLES

1. Causes of mortality of white-tailed deer fawns (2004-2005) during the initial 8 weeks of life in Auburn, Alabama.....49
2. Model results from known fate analysis of survival rates during the initial 8 weeks of life for white-tailed deer fawns in Auburn, Alabama from 2004-2005 50
3. Parameter estimates and likelihoods from known fate models of survival rates during the initial 8 weeks of life for white-tailed deer fawns in Auburn, Alabama from 2004-2005 52

LIST OF FIGURES

1. Frequency of white-tailed deer litters in relationship to birth date from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA22
2. Litter sex ratio of white-tailed deer offspring in relationship to birthdate from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA. Means with the same letters are not different ($P > 0.05$). Numbers correspond to sample sizes of litters in each time period24
3. Mass of 9-month old male and female white-tailed deer fawns born in relationship to birthdate from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA. Means with the same letters within an age class are not different ($P > 0.05$).....26
4. Survival of white-tailed deer fawns in Auburn, Alabama during the initial 8 weeks of life during 2004 and 200553
5. Survival rates of white-tailed deer fawns in Auburn, Alabama during the initial 8 weeks of life as predicted by birth mass and age during 2004 (A) and 2005 (B)55

I. SEASONAL VARIATION IN SEX RATIOS PROVIDES DEVELOPMENTAL ADVANTAGES IN WHITE-TAILED DEER

ABSTRACT

Since Trivers and Willard (1973) first proposed their hypothesis concerning the adaptive investment of a mother in the sex of her offspring, it has been at the forefront of scientific research concerning sex ratios with most subsequent studies focusing on maternal condition as a key contributor to variations in sex ratios. Another factor that could greatly influence sex ratios, although has been only infrequently examined in mammalian species, is birth date. We investigated how birth date influenced offspring sex ratios in white-tailed deer (*Odocoileus virginianus*). Since date of birth can greatly influence an individual's fitness and reproductive success we suggest that birth date may be an alternative strategy in determining offspring sex ratios. Since it has been predicted that females bias the sex ratio of their offspring in order to produce the sex that will most likely increase their lifetime reproductive fitness, we hypothesized that females will differentially produce male offspring earlier in the season. Offspring born earlier will have a head start in development and therefore have greater potential for increased body size and dominance later in life, traits which greatly influence male reproductive success. In this study, we found that maternal condition did not affect offspring sex ratio in a captive population of white-tailed deer in Michigan; however, birth date did. We found

that more males tended to be born during the second and fourth birthing periods, while more females were born during the first, third and fifth periods. In addition, we found that males born earlier in the season had greater mass the following spring than those born later, a trend that was not as dramatic in females. These results lend moderate support to our hypothesis that in mammals with polygynous mating systems females will tend to vary sex of offspring according to timing of birth and relative reproductive advantages gained by a particular sex being born at that time.

INTRODUCTION

The ability of a female to determine the sex of her offspring has been well documented in a number of mammalian species, including white-tailed deer (*Odocoileus virginianus*) (Verme and Ozoga 1981; Kojola and Eloranta 1989; Kucera 1991; Landete-Castillejos et al. 2001; Landete-Castillejos et al. 2004; Sheldon and West 2004). This allows females to enhance their lifetime fitness by producing the sex with the greatest potential reproductive value. Some factors shown to influence this selection include maternal age, condition, social status, and habitat quality. Trivers and Willard (1973) proposed that females of sexually dimorphic, polygynous species in good condition would benefit more from producing sons, because mother's condition would more strongly influence future reproductive success of sons than daughters. Conversely, females in poor condition would benefit most by producing daughters, since female offspring require less maternal investment and will likely reproduce regardless of maternal condition. Poor quality male offspring likely will not develop the physical characteristics necessary to compete successfully for females later in life. This

hypothesis is based on three assumptions: condition of offspring is correlated with condition of the mother after the parental investment period, condition of the young following the parental investment period will carry over to adulthood, and conditional advantages will differentially benefit male offspring in reproductive success. Since most ungulate species are polygynous, sexually dimorphic species which commonly exhibit the three assumptions (Hewison and Gaillard 1999), numerous studies have been conducted to test the Trivers-Willard hypothesis. In several of these studies, support for the Trivers-Willard hypothesis has been documented, where older or more dominant individuals gave birth to more males, and younger or subordinate females gave birth to more females (Landete-Castillejos et al. 2001; Landete-Castillejos et al. 2004; Sheldon and West 2004).

Despite the many findings that support Trivers and Willard (Landete-Castillejos et al. 2001; Landete-Castillejos et al. 2004; Sheldon and West 2004), numerous studies have reported data that seems to contradict their hypothesis. In a review of published papers on the genus *Odocoileus*, Verme (1983) found that more males were produced by younger females, females in poor condition, and females in areas of poor habitat quality. Similarly, Mendl et al. (1995) discovered that more female offspring were produced by dominant females in domestic pigs (*Sus scrofa*). These contradicting trends have been explained by alternative hypotheses for biased sex ratios including: the local resource competition hypothesis (Clark 1978), the advantaged daughter hypothesis (Hiraiwa-Hasegawa 1993), and the advantaged matriline hypothesis (Leimar 1996). According to the advantaged daughter and the advantaged matriline hypotheses, mothers are better able to influence the reproductive success of daughters rather than sons (eg. by

the transfer of rank and/or access to high quality resources). Therefore, these hypotheses propose that high quality females are more likely to produce females than males.

Conversely, the local resource competition hypothesis states that local resources rather than maternal condition drive biases in sex ratios. In matriarchal species, Clark (1978) proposed that females in good condition will produce more female offspring, whereas females in poor condition will invest more in male offspring. This is because female offspring normally establish home ranges that overlap their mother's home range, while males tend to disperse creating less competition for resources in the future.

While they differ, all of these hypotheses focus on maternal condition as the driving factor in offspring sex ratios of mammals. Another factor that should greatly influence reproductive potential of offspring and offspring sex ratios is birth date. In many sexually dimorphic species, it is believed that time at birth differentially affects the ability of a particular sex to reproduce during its first and subsequent years (Suttie 1983; Clutton-Brock et al. 1984; Kruuk et al. 1999; Festa-Bianchet et al. 2000). Therefore, biasing sex ratios of offspring according to birth date could increase a female's lifetime fitness. A number of avian species have been shown to vary sex ratios seasonally, including the northern goshawk (*Accipiter gentiles*: Byholm et al. 2002), European kestrel (*Falco tinnunculus*: Pen et al. 1999), common sandpiper (*Actitis hypoleucos*: Andersson et al. 2003), American kestrel (*F. sparverius*: Smallwood and Smallwood 1998; Griggio et al. 2002), spotted starling (*Sturnus unicolor*: Cordero et al. 2001), and little grassbirds (*Megalurus gramineus*: McIntosh et al. 2003). In their work with a nonmigratory population of American kestrels, Smallwood and Smallwood (1998) found more male-biased sex ratios earlier in the season as compared to later and proposed that

males that fledged earlier could find nest sites and defend territories better than males that fledged later. Griggio et al. (2002) found the same results in a migratory population of American kestrels, with more males born earlier in the season. Similarly, it was determined that the sex ratio variation could be due to acquisition of nest sites that were limited for this population. In contrast, competition for mates seemed the most likely explanation for male-biased sex ratios early in season in the common sandpiper, because males born earlier have an advantage in obtaining mates (Andersson et al. 2003). Although the explanations for these trends differ, they suggest that by varying offspring sex ratio by birth date, a mother can enhance her own future fitness. Smallwood and Smallwood (1998) coined this trend the “Early Bird Hypothesis” and predicted that the sex which gains the greatest advantage by hatching earlier is selected for in early conception dates in avian species.

The Early Bird Hypothesis (Smallwood and Smallwood 1998), however, has not been evaluated in mammals. While it has been demonstrated that older individuals tend to give birth earlier (Johns et al. 1977; Festa-Bianchet 1988; Christley et al. 2002) and offspring born earlier are more likely to survive due to increased food resources (Festa-Bianchet 1988; Singh et al. 1990; Festa-Bianchet et al. 1997; Côté and Festa-Bianchet 2001), the link to differential sex ratios based on birth date has not been well documented in mammalian species. We hypothesize that birth date is a driving factor in offspring sex ratios with females producing more male offspring earlier in the breeding season with increasing production of females as the season progresses. Because offspring born earlier should have a longer period of time to grow before their first

winter, more males should be produced at this time period because of the relative importance of size on future reproductive success in males and females.

MATERIALS AND METHODS

We analyzed data from the Cusino enclosure, a 252-ha enclosure located near Shingleton in Michigan's Upper Peninsula from 1973 through 1984 (excluding 1974). The enclosure consisted mainly of northern hardwoods, mixed hardwood-conifer stands, and pine plantation. Due to initial overbrowsing and subsequent condition decline, deer were supplementally fed *ad libitum* year-round with a pelleted ration beginning in 1972. Following this, deer were documented to be in good physical condition, even during winter months (Ozoga and Verme 1982). Initially (1972-1976), no deer were intentionally removed from the enclosure, however, to ensure a stable population, the number of individuals within the enclosure was maintained at approximately 40 individuals with the removal of most fawns and older individuals each year starting in 1977 (Ozoga and Verme 1982).

A complete population census was obtained annually in March by live-trapping deer and placing them in a holding pen. At this time, all deer were marked with numbered collars and weighed. In addition, adult does were X-rayed to determine stage of pregnancy and number of fetuses (Ozoga and Verme 1982). Age of fetuses was determined by comparing fetal radiograms with known-age fetal specimens (105 specimens ranging from 76-137 days old) determined by observed breeding dates (Ozoga and Verme 1985). Following this, birth dates were ascertained by using a 199-day gestation. Pregnancy in fawns was also monitored at this time. Since fetuses within

fawns would be too small to be detected on radiograms due to the late conception date, the presence of pregnancy in fawns was monitored through progesterone assay in peripheral plasma (Plotka et al. 1977).

Following the above procedures, deer were released back into a holding pen where they could be observed to confirm mother-fawn lineage from the previous year in some instances, as well as to document the dominance hierarchy among the deer. The dominance number assigned to each individual corresponded to the percentage of the herd that the individual dominated. All deer were released from the holding pen in late March or early April, and thereafter, observations were used to further elucidate behavioral patterns, social habits, birthing periods, rearing success, and sex of offspring. Fawns were captured and tagged whenever the opportunity arose and therefore most were already identified prior to the following March census. Those that were not tagged by the March census were identified and tagged for visual identification at this time (Ozoga and Verme 1982). All research was performed in a humane manner, followed ASM guidelines, and was approved by an institutional animal care and use committee.

In order to determine any possible role of birthdate on offspring sex ratio we analyzed data similar to Smallwood and Smallwood (1998). We subdivided fetuses into 10-day intervals for the range of birth dates observed in this study (May 13-July 25). Since not all groups had adequate sample sizes (Fig. 1) we pooled data of groups with samples sizes less than 10 litters. This resulted in the pooling of dates after June 22. We then tested whether sex ratios differed among these groups using repeated measures analysis of variance repeated among years with a compound symmetric covariance structure and birthing group nested within year as our error term (PROC MIXED: SAS

Institute 1999). In addition, to determine differences in physical condition by birth date between sexes, we tested if mass of fawns measured the following spring (March) differed among birthing groups (eg. birth date) within each sex using the same repeated measures analysis of variance. To test the validity of maternal-condition based hypotheses within this population, we investigated if any difference existed among maternal condition or age for females that produced sons or daughters using repeated measures analysis of variance repeated among years with a compound symmetric covariance structure. Although we were unable to account for repeatedly sampling females, we tested whether sex ratios among the different birthing periods differed from equality using a Pearson chi-square.

RESULTS

A total of 428 fawns from 251 litters were examined during the study: mean birth date was 4 June ($n = 230$; $SE = 0.63$ days), and mean number of fawns per doe was 1.85 ($n = 230$; $SE = 0.04$). The offspring sex ratio (50.4%) for the entire study did not differ from equality ($\chi^2 = 0.02$; $P = 0.880$). We detected a difference ($F_{4,58} = 2.86$; $P = 0.031$; Fig. 2) in the proportion of males born among time periods with a greater tendency of males being born in the second and fourth periods. We detected a greater proportion of males being born between June 12 - June 21 (70.4%) than between May 13 - May 22 (38.9%; $t_{58} = -2.30$; $P = 0.025$), June 2 - June 11 (46.5%; $t_{58} = -2.78$; $P = 0.007$), and June 22 - July 25 (38.9%; $t_{58} = 2.11$; $P = 0.040$). We also found a tendency for more males being born between May 23 - June 1 (58.0%) than between June 2 - June 11, however only approaching significance ($t_{58} = 1.78$; $P = 0.081$). We found no differences among

other time periods ($P > 0.050$). Additionally, we found that only the second birthing period had a sex ratio different than equality ($\chi^2 = 3.93$; $P = 0.047$).

Body mass of fawns when approximately 9 months of age decreased as birth date became later for males ($F_{4,31} = 5.11$; $P = 0.003$), but not for females ($F_{4,30} = 1.94$; $P = 0.130$; Fig. 3). We also did not detect any differences between body mass ($t_{57} = 1.60$; $P = 0.211$), dominance ($t_{56} = 0.00$; $P = 0.973$), or age ($t_{57} = 0.62$; $P = 0.434$) among mothers who produced either sons or daughters.

DISCUSSION

Our results support our hypothesis that birth date influences offspring sex ratios in white-tailed deer, suggesting benefits for females that adjust the sex ratio of their offspring. However, we found only moderate support for our hypothesis that more male offspring would be produced earlier in the birthing season as compared to females. Although we were unable to detect a significant difference in the sex ratios of the earliest time periods, we did find that more males tended to be born in the second time period resulting in a sex ratio different than parity. This same trend has been demonstrated in other studies on white-tailed deer where it was found that more male offspring were likely to be conceived earlier in the birthing season (S. S. Ditchkoff unpublished data; W. V. Underwood unpublished data). In ungulates, individuals that are born earlier have more time to grow and better food availability than late-born conspecifics (Festa-Bianchet 1988; Singh et al. 1990; Festa-Bianchet et al. 1997; Côté and Festa-Bianchet 2001). While an earlier birth could be beneficial to both sexes, fitness gain would potentially be greater for males than females in a sexually dimorphic,

polygynous species. Increases in body size and quality have been shown to strongly influence a male's initial reproductive success and lifetime fitness (Suttie 1983; Clutton-Brock et al. 1984; Kruuk et al. 1999; Festa-Bianchet et al. 2000). In addition, early births have also been shown to increase antler quality (Ozoga and Verme 1982; Schmidt et al. 2001; Gray et al. 2002), a trait which strongly affects dominance and ultimately reproductive success in ungulates (Clutton-Brock and Albon 1980; Bowyer 1986). Also, postweaning male fawns have a greater dietary protein requirement than females (Ullrey et al. 1967). Therefore, being born earlier would be most beneficial for males, since earlier born individuals have better food availability than late born individuals. Female fitness, however, is not as strongly influenced by this initial disadvantage in body size. Jorgenson et al. (1993) found that condition in female bighorn sheep (*Ovis canadensis*) did not have a major effect on age at first reproduction. However, they did detect a minimum mass for young ewes to begin reproduction. Variation in mass above this minimum, however, did not effect age at first reproduction. Therefore, adaptive investment of a mother in the sex of her offspring would potentially allow females to differentially produce the sex that would increase their lifetime fitness the most.

In white-tailed deer, most births normally occur within a short time period (e.g., several weeks). For example, 61% of litters in our population were born during a 15 day period (May 28-June 11). We expect that in species that have a much longer birthing period or multiple litters within a year, seasonal sex ratio biases would be more prominent. This is true in Virginia opossums (*Didelphis virginiana*: Wright et al. 1995), meadow voles (*Microtus pennsylvanicus*: Dobson and Myers 1989), and gray-tailed voles

(*Microtus canicaudus*: Bond et al. 2003), and this pattern has been termed the first-cohort advantage hypothesis (Wright et al. 1995). In Virginia opossums, females had more male-biased first litters than second litters possibly due to the increased reproductive fitness of males born earlier (Wright et al. 1995). Additionally, in meadow voles, more male-biased litters were born earlier in the season than later corresponding to a similar pattern in litter size, which also declined as the season progressed (Dobson and Myers 1989). On the other hand, Bond et al. (2003), when examining gray-tailed voles, found female-biased litters rather than male-biased litters early in the season. They hypothesized that this trend was seen since females almost always reproduce their first year, while most late-born males delay first breeding until the following spring. Additionally, they speculated that winter survival could also influence gray-tailed vole sex ratios, where males born later had greater survival through winter than females born at the same time. However, this does not discount the importance of seasonal sex-ratio variation in a species like white-tailed deer where births are highly synchronized. Our data demonstrate the relative importance of birth dates between sexes in white-tailed deer. Males born in the earliest time period had 18.1% greater mass the following spring at 9 months of age than males born in the last time period. Early-born females also tended to have greater mass the following spring than late-born individuals, but the difference between the groups was less (9.7%). Since our study was conducted on a supplementally-fed population, we suspect these differences to be less than in a natural population where food would be limited during the winter months. Although these data do not measure future fitness, they provide strong support for the hypothesis that birth

date differentially influences future fitness in males and females, as has been demonstrated with a number of avian species (Smallwood and Smallwood 1998; Pen et al. 1999; Cordero et al. 2001; Byholm et al. 2002; Griggio et al. 2002; Andersson et al. 2003; McIntosh et al. 2003). Despite this apparent trend, we did not detect a larger proportion of males born during the earliest time period. Although we are unsure of the specific reasoning for this, we suspect that early in the season resource availability may be unpredictable. While, giving birth early has advantages, it could also have disadvantages if food is unavailable or unpredictable at this time. Therefore, females may not invest in the more costly sex (i.e. males) if they may not be able to provide adequate nutrition for them. Additionally, low sample size during this time period ($n = 12$) could also prevent us from detecting this trend.

Another interesting trend seen in our data was that more males were additionally born later in the season. This trend was also seen in American kestrels, where more male-biased broods were born later in the season, although low sample size precluded statistical analysis (Smallwood and Smallwood 1998). Giving birth late in the season increases the likelihood of producing smaller, disadvantaged offspring of either sex. In elk (*Cervus elaphus nelsoni*: Smith and Anderson 1998), red deer (*C. elaphus*: Clutton-Brock et al. 1987), and moose (*Alces alces*: Keech et al. 2000) offspring of either sex that were late-born had decreased survival and reproduction. We propose that the best strategy for a mother that conceives late may be to produce the dispersing sex. According to the local resource competition hypothesis (Clark 1978), a mother improves her fitness, as well as that of previous and future offspring that reside within her home range by producing the dispersing sex, which reduces competition for resources. Our

data support this hypothesis since both males and females born late in the birthing season had low mass the following spring compared to offspring born early. Despite this trend, we were unable to detect a greater proportion of males produced in last time period, possibly due to the low sample size (9 litters).

Although our data do not provide an explanation for the mechanism controlling sex ratio variations, there have been numerous hypotheses developed in order to explain this phenomenon (see Clutton-Brock and Iason 1986; see Krackow 1995). These hypotheses focus on three main mechanisms that could potentially control sex ratio variation: fetal reabsorption, differential utilization of X and Y carrying sperm, and variation in hormonal or chemical concentrations at or near implantation. Although it has been found that fetal reabsorption may be a very important way some mammalian species such as rodents control sex ratios, this mechanism is not believed to be the main mechanism in all mammalian species (James 1996). In springbok (*Antidorcas marsupialis*), Krüger et al. (2004) found that fetal mortality did not explain sex ratio variation since very few females were found with reabsorbed fetuses. In addition, since the mean number of fawns per doe in our study was 1.85, fetal reabsorption is not a likely explanation for the observed sex ratio biases. Therefore, we believe that differential utilization of X and Y sperm or differences in hormonal or chemical concentrations around the time of implantation appear to be the most likely mechanisms controlling seasonal sex ratio variation in this species. Variation in glucose (Cameron 2004) and hormonal levels (James 1996), which influence development of male and female offspring, vary throughout the reproductive cycle, potentially influencing offspring sex ratios in relation to conception dates. In addition, adult males might also control sex ratio

variation by producing Y-chromosome biased ejaculates. However, DeYoung et al. (2004) did not find this in white-tailed deer. More research is needed in order to fully understand the mechanisms controlling variations in sex ratios.

Altering sex ratios according to birth date is an overlooked but perhaps very important tactic for increasing lifetime fitness of white-tailed deer and other polygynous mammals. Although this is not the first documented evidence of male-biased sex ratios early in the birthing season in ungulates (Clutton-Brock et al. 1982; Kohlmann 1999) or large sexually dimorphic mammals (Coulson and Hickling 1961; Stirling 1971), we believe our data provides a better explanation for this phenomenon than has previously been proposed. Although there are numerous factors that influence sex ratios and timing of birth, it appears that timing of birth was the main cause of variation in sex ratios in the population we studied. Although our data were collected from a captive herd of white-tailed deer, we assume that they are representative of a natural population and expect that some of the trends we have seen to be more dramatic in a natural population. This seasonal variation would be most beneficial in species where reproductive success is correlated with initial body mass and therefore birth date of a particular sex. This initial advantage for one sex may be based on a variety of life history traits that differentially affect one sex more than the other such as in sexually dimorphic, polygynous species that exhibit sex-biased competition for mates or territories.

LITERATURE CITED

- Andersson, M., J. Wallander, L. Oring, E. Akst, J. M. Reed, and R. C. Fleischer. 2003. Adaptive seasonal trend in brood sex ratio: test in two sister species with contrasting breeding systems. *Journal of Evolutionary Biology* 16:510-515.
- Bond, M. L., J. O. Wolff, and S. Krackow. 2003. Recruitment sex ratios in gray-tailed voles (*Microtus canicaudus*) in response to density, sex ratio and season. *Canadian Journal of Zoology* 81:1306-1311.
- Bowyer, R. T. 1986. Antler characteristics as related to social-status of male southern mule deer. *Southwestern Naturalist* 31:289-298.
- Byholm, P., J. E. Brommer, and P. Saurola. 2002. Scale and seasonal sex-ratio trends in northern goshawk *Accipiter gentilis* broods. *Journal of Avian Biology* 33:399-406.
- Cameron, E. Z. 2004. Facultative adjustment of mammalian sex ratios in support of the Trivers-Willard hypothesis: evidence for a mechanism. *Proceedings of the Royal Society of London B: Biological Sciences* 271:1723-1728.
- Christley, R. M., K. L. Morgan, T. D. H. Parkin, and N. P. French. 2002. Factors related to the risk of neonatal mortality, birth-weight and serum immunoglobulin concentration in lambs in the UK. *Preventive Veterinary Medicine* 57:209-226.
- Clark, A. B. 1978. Sex ratio and local resource competition in a prosimian primate. *Science* 201:163-165.
- Clutton-Brock, T. H., and S. D. Albon. 1980. Antlers, body size and breeding group size in the Cervidae. *Nature* 285:565-567.

- Clutton-Brock, T. H., S. D. Albon, and F. E. Guinness. 1984. Maternal dominance, breeding success and birth sex ratios in red deer. *Nature* 308:358-360.
- Clutton-Brock, T. H., F. E. Guinness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. University of Chicago Press, Chicago.
- Clutton-Brock, T. H., and G. R. Iason. 1986. Sex ratio variation in mammals. *The Quarterly Review of Biology* 61:339-374.
- Clutton-Brock, T. H., M. Major, S. D. Albon, and F. E. Guinness. 1987. Early development and population dynamics in red deer. I. Density-dependent effects on juvenile survival. *Journal of Animal Ecology* 56:53-67.
- Cordero, P. J., J. Viñuela, J. M. Aparicio, and J. P. Veiga. 2001. Seasonal variation in sex ratio and sexual egg dimorphism favouring daughters in first clutches of the spotless starling. *Journal of Evolutionary Biology* 14:829-834.
- Côté, S. D., and M. Festa-Bianchet. 2001. Birthdate, mass and survival in mountain goat kids: effects of maternal characteristics and forage quality. *Oecologia* 127:230-238.
- Coulson, J. C., and G. Hickling. 1961. Variation in the secondary sex-ratio of the grey seal *Halichoerus grypus* (Fab.) during the breeding season. *Nature* 190:281.
- DeYoung, R. W., et al. 2004. Do *Odocoileus virginianus* males produce Y-chromosome-biased ejaculates? Implications for adaptive sex ratio theories. *Journal of Mammalogy* 85:768-773.
- Dobson, F. S., and P. Myers. 1989. The seasonal decline in the litter size of meadow voles. *Journal of Mammalogy* 70:142-152.

- Festa-Bianchet, M. 1988. Birthdate and survival in bighorn lambs (*Ovis canadensis*).
Journal of Zoology 214:653-661.
- Festa-Bianchet, M., J. T. Jorgenson, C. H. Bérubé, C. Portier, and W. D. Wishart. 1997.
Body mass and survival of bighorn sheep. Canadian Journal of Zoology 75:1372-
1379.
- Festa-Bianchet, M., J. T. Jorgenson, and D. Réale. 2000. Early development, adult mass,
and reproductive success in bighorn sheep. Behavioral Ecology 11:633-639.
- Gray, W. N., II, S. S. Ditchkoff, M. K. Causey, and C. W. Cook. 2002. The yearling
disadvantage in Alabama deer: effect of birth date on development. Proceedings
of the Annual Conference of the Southeastern Association of Fish and Wildlife
Agencies 56:255-264.
- Griggio, M., F. Hamerstrom, R. N. Rosenfield, and G. Tavecchia. 2002. Seasonal
variation in sex ratio of fledgling American kestrels: a long term study. Wilson
Bulletin 114:474-478.
- Hewison, A. J. M., and J. M. Gaillard. 1999. Successful sons or advantaged daughters?
The Trivers-Willard model and sex-biased maternal investment in ungulates.
Trends in Ecology and Evolution 14:229-234.
- Hiraiwa-Hasegawa, M. 1993. Skewed birth sex ratios in primates: should high ranking
mothers have daughters or sons? Trends in ecology and evolution 8:395-400.
- James, W. 1996. Evidence that mammalian sex ratios at birth are partially controlled by
parental hormone levels at the time of conception. Journal of Theoretical Biology
180:271-286.

- Johns, P. E., R. Baccus, M. N. Manlove, J. Pinder, III, and M. H. Smith. 1977. Reproductive patterns, productivity and genetic variability in adjacent white-tailed deer populations. Proceedings of the annual conference Southeastern Association of Fish and Wildlife Agencies 31:167-172.
- Jorgenson, J. T., M. Festa-Bianchet, M. Lucherini, and W. D. Wishart. 1993. Effects of body size, population density, and maternal characteristics on age at first reproduction in bighorn ewes. Canadian Journal of Zoology 71:2509-2517.
- Keech, M. A., R. T. Bowyer, J. M. V. Hoef, R. D. Boertje, B. W. Dale, and T. R. Stephenson. 2000. Life-history consequences of maternal condition in Alaskan moose. Journal of Wildlife Management 64:450-462.
- Kohlmann, S. G. 1999. Adaptive fetal sex allocation in elk: evidence and implications. Journal of Wildlife Management 63:1109-1117.
- Kojola, I., and E. Eloranta. 1989. Influences of maternal body weight, age and parity on sex ratio in semidomesticated reindeer (*Rangifer t. tarandus*). Evolution 43:1331-1336.
- Krackow, S. 1995. Potential mechanisms for sex ratio adjustment in mammals and birds. Biological Reviews 70:225-241.
- Krüger, O., A. N. Radford, C. Anderson, and R. Liverside. 2004. Successful sons or superior daughters: sex-ratio variation in springbok. Proceedings of the Royal Society of London B: Biological Sciences 272:375-381.
- Kruuk, L. E. B., T. H. Clutton-Brock, K. E. Rose, and F. E. Guinness. 1999. Early determinants of lifetime reproductive success differ between the sexes in red deer.

- Proceedings of the Royal Society of London. Series B: Biological Sciences
266:1655-1661.
- Kucera, T. E. 1991. Adaptive variation in sex ratios of offspring in nutritionally stressed mule deer. *Journal of Mammalogy* 72:745-749.
- Landete-Castillejos, T., A. Garcia, S. Langton, I. Inglis, L. Gallego, and J. Garde. 2001. Opposing offspring sex ratio variations with increasing age and weight in mouflon mothers (*Ovis musimon*). *Acta Veterinaria Hungarica* 49:257-268.
- Landete-Castillejos, T., C. Gortázar, J. Vicente, Y. Fierro, A. Garcia, and L. Gallego. 2004. Age-related foetal sex ratio bias in Iberian red deer (*Cervus elaphus hispanicus*): are male calves too expensive for growing mothers? *Behavioral Ecology and Sociobiology* 56:1-8.
- Leimar, O. 1996. Life-history analysis of the Trivers and Willard sex-ratio problem. *Behavioral Ecology* 7:316-325.
- McIntosh, R. R., R. Kats, M. Berg, J. Komdeur, and M. A. Elgar. 2003. Breeding ecology and bias in offspring sex ratio in little grassbirds (*Megalurus gramineus*). *Australian Journal of Zoology* 51:505-514.
- Mendl, M., A. J. Zanella, D. M. Broom, and C. T. Whittemore. 1995. Maternal social status and birth sex ratio in domestic pigs: an analysis of mechanisms. *Animal Behaviour* 50:1361-1370.
- Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. *Journal of Wildlife Management* 46:281-301.

- Ozoga, J. J., and L. J. Verme. 1985. Determining fetus age in live white-tailed does by x-ray. *Journal of Wildlife Management* 49:372-374.
- Pen, I., F. J. Weissing, and S. Daan. 1999. Seasonal sex ratio trend in the European kestrel: an evolutionarily stable strategy analysis. *The American Naturalist* 153:384-397.
- Plotka, E. D., U. S. Seal, L. J. Verme, and J. J. Ozoga. 1977. Reproductive steroids in the white-tailed deer (*Odocoileus virginianus borealis*). II. Progesterone and estrogen levels in peripheral plasma during pregnancy. *Biology of reproduction* 17:78-83.
- SAS Institute. 1999. SAS/STAT software: the logistic procedure, version 8. SAS Institute, Inc., Cary, North Carolina.
- Schmidt, K. T., A. Stien, S. D. Albon, and F. E. Guinness. 2001. Antler length of yearling red deer is determined by population density, weather and early life-history. *Oecologia* 127:191-197.
- Sheldon, B. C., and S. A. West. 2004. Maternal dominance, maternal condition, and offspring sex ratio in ungulate mammals. *The American Naturalist* 163:40-54.
- Singh, D. K., H. R. Mishra, and C. S. P. Singh. 1990. Genetic and non-genetic factors affecting pre-weaning survivability in kids. *Animal Production* 51:559-564.
- Smallwood, P. D., and J. A. Smallwood. 1998. Seasonal shifts in sex ratios of fledgling American kestrels (*Falco sparverius paulus*): the Early Bird Hypothesis. *Evolutionary Ecology* 12:839-853.
- Smith, B. L., and S. H. Anderson. 1998. Juvenile Survival and Population Regulation of the Jackson Elk Herd. *Journal of Wildlife Management* 62:1036-1045.

- Stirling, I. 1971. Variation in sex ratio of newborn Weddell seals during the pupping season. *Journal of Mammalogy* 52:842-844.
- Suttie, J. M. 1983. Body size: dominance relationships in red deer stag calves. *Animal Behaviour* 31:610-611.
- Trivers, R. L., and D. E. Willard. 1973. Natural selection of parental ability to vary the sex ratio of offspring. *Science* 179:90-92.
- Ullrey, D. E., W. G. Youatt, H. E. Johnson, L. D. Fay, and B. L. Bradley. 1967. Protein requirement of white-tailed deer fawns. *Journal of Wildlife Management* 31:679-685.
- Verme, L. J. 1983. Sex ratio variation in *Odocoileus*: a critical review. *Journal of Wildlife Management* 47:573-582.
- Verme, L. J., and J. J. Ozoga. 1981. Sex ratio of white-tailed deer and the estrus cycle. *Journal of Wildlife Management* 45:710-715.
- Wright, D. D., J. T. Ryser, and R. A. Kiltie. 1995. First-cohort advantage hypothesis: a new twist on facultative sex ratio adjustment. *American Naturalist* 145:133-145.

Figure 1. Frequency of white-tailed deer litters in relationship to birth date from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA.

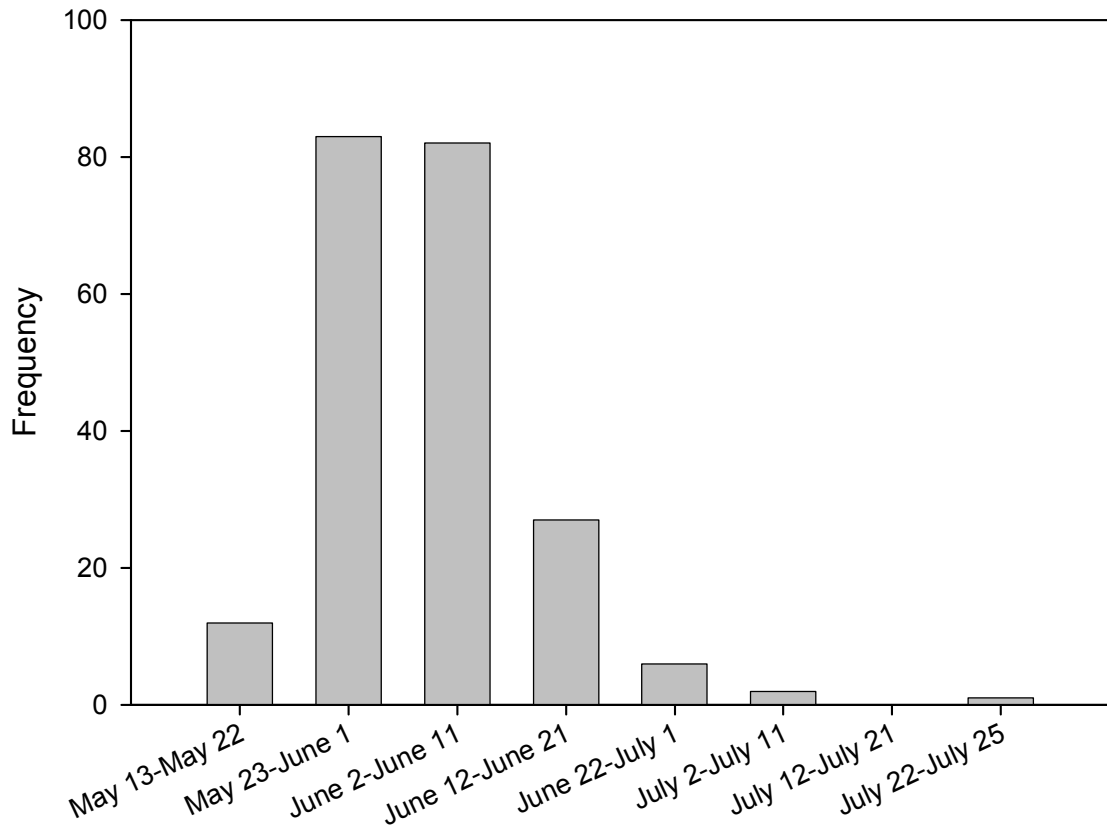


Figure 2. Litter sex ratio of white-tailed deer offspring in relationship to birthdate from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA. Means with the same letters are not different ($P > 0.05$). Numbers correspond to sample sizes of litters in each time period.

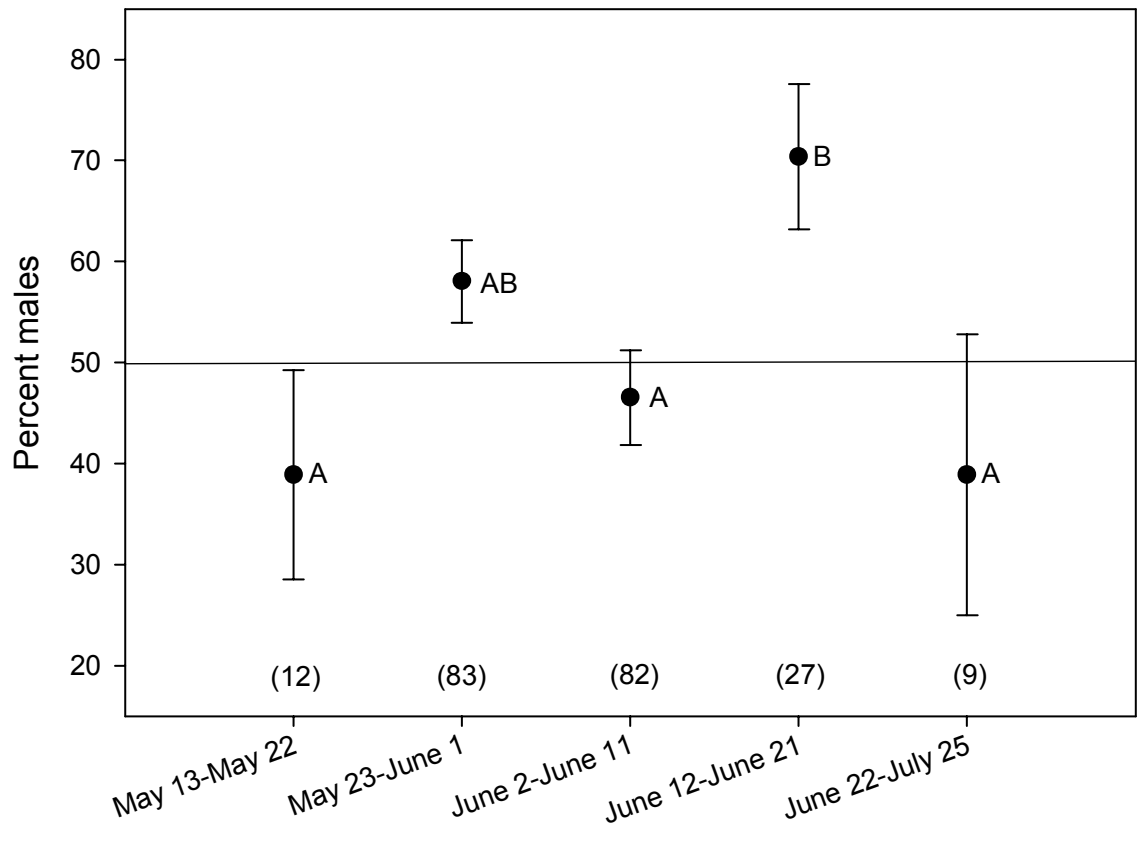
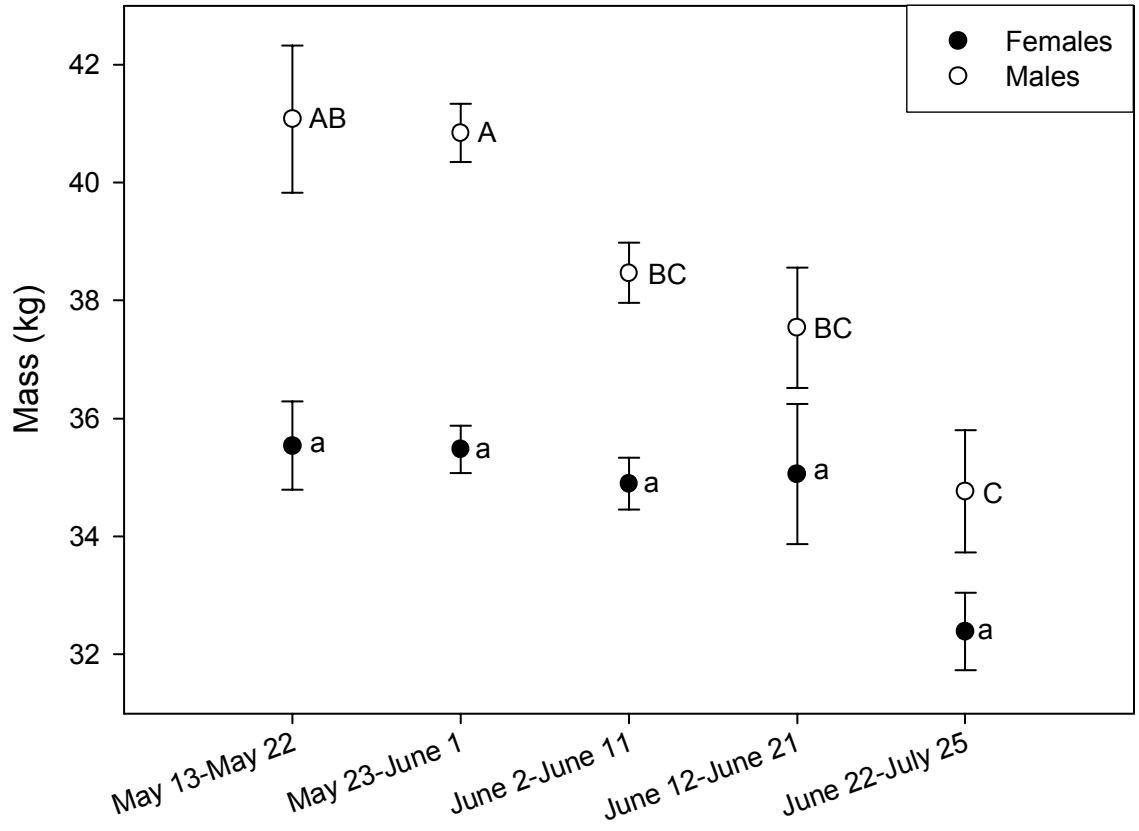


Figure 3. Mass of 9-month old male and female white-tailed deer fawns born in relationship to birthdate from 1973-1984 (excluding 1974) at the Cusino deer research facility, Michigan, USA. Means with the same letters within an age class are not different ($P > 0.05$).



II. SURVIVAL OF WHITE-TAILED DEER FAWNS IN A SUBURBAN POPULATION

ABSTRACT

As humans continue to move further from the urban epicenter, management of wildlife populations in urban/suburban areas is becoming increasingly important. Because wildlife residing in these areas are exposed to different stresses, they may not exhibit the same behavior and life history characteristics as their rural counterparts. Therefore, in order to properly manage these species, it may be necessary to relearn important life history characteristics, such as survival, that influence management decisions. In white-tailed deer (*Odocoileus virginianus*), a great deal of natural mortality occurs within the first few months of life and has the potential to greatly influence population growth. Therefore, understanding neonatal mortality in this species is important when implementing management decisions. Although numerous studies have determined the causes and timing of death of neonatal white-tailed deer fawns, none have focused on urban/suburban populations. In this study, we determined causes and timing of deaths of neonatal white-tailed deer in a suburban area of Alabama in 2004 and 2005, estimated survival rates, and determined factors that influenced survival for the initial 8 weeks of life. We found a 67% mortality rate during the two year study, with the leading causes of mortality being predation by coyotes (41.7%) and starvation due to

abandonment (25%). Survival rates were different between the two years of the study (23.5% in 2004 and 42.1% in 2005) with fawns born in 2005 being 1.49 times more likely to survive than fawns born in 2004. Additionally, we found that survival rates were linearly related to time following birth and increased by a factor of 1.36 for each week following birth. Survival rates were also associated positively with mass at birth and increased by a factor of 1.77 for each additional kilogram of birth mass. Most studies with rural populations have reported fawn survival rates greater than those reported here, suggesting that population growth rates of high density white-tailed deer populations, such as those found in suburban areas, may be limited by increased mortality rates early in life.

INTRODUCTION

As humans continue to move further from the urban epicenter, wildlife-human conflicts have been increasing. Once a suitable habitat for only a few species, suburban areas are now designed in such a way that allows wildlife to live along side human populations. By creating larger lots and maintaining native vegetation between houses, suburban areas are now able to support wildlife populations that were never able to reside in these areas in the past. Because of this, management of wildlife populations residing in these areas is becoming increasingly important. White-tailed deer is a particular species causing much concern due to overabundant populations and increased wildlife-human conflicts (e.g. vehicular accidents and foraging of landscapes). These management concerns, however, may be hard to address for populations living in these areas. It has been suggested that because wildlife residing in urban areas are exposed to

different stresses than their rural counterparts, behavior and life history characteristics may be altered in order to alleviate the stress encountered in these new environments (Ditchkoff et al. 2006). It has been shown that wildlife residing in urban areas may be forced to modify or experience changes in movements, diet, reproduction, health, and survival rates (see Ditchkoff et al. 2006). Since most wildlife management decisions in urban areas are concerned with wildlife-human conflicts and decreasing populations, understanding behavior and life history characteristics related to conflicts (eg. movements and diet) and population growth (eg. survival and reproduction) are essential for effective control. However, currently most management recommendations for wildlife are based on knowledge obtained from rural populations. If wildlife populations living in urban/suburban areas are displaying differences in behavior or life history characteristics essential to management decisions, management recommendations may be inaccurate and ineffective. In order to effectively manage species in these areas, detailed knowledge must be obtained concerning these behaviors and life history characteristics in urban/suburban populations.

One very important factor that influences population growth and ultimately management decisions is survival. In white-tailed deer, a great amount of natural mortality occurs during the first few months of life. Although numerous studies on white-tailed deer fawn survival have been conducted (Cook et al. 1971; Garner et al. 1976; Carroll and Brown 1977; Bartush and Lewis 1981; Epstein et al. 1983; Epstein et al. 1985; Huegel et al. 1985; Nelson and Woolf 1987; Kunkel and Mech 1994; Sams et al. 1996; Long et al. 1998; Ballard et al. 1999; Ricca et al. 2002; Vreeland et al. 2004), none have focused on urban/suburban populations. However, it has been shown that

wildlife residing in urban/suburban areas are exposed to different predation and mortality risks such as vehicular traffic (Forman and Alexander 1998; Koenig et al. 2002) and predation by domestic animals (Koenig et al. 2002; Gillies and Clout 2003; Lepczyk et al. 2003). These additional mortality risks have the potential to alter survival rates and population growth, factors essential for management decisions. In a study on white-tailed deer in Missouri, it was found that adult mortality rates were similar between urban/suburban areas and forested/agricultural areas, however, the causes of mortality were different with vehicular accidents replacing hunting mortality in urban areas (Hansen and Beringer 2003). In addition, it was found that deer-vehicular collision was the greatest cause of adult white-tailed deer mortality in Chicago, Illinois (Etter et al. 2002). Despite the large impacts such differences in mortality risks can have on management, decisions are still being based on knowledge obtained from rural areas. In this study, we examined the cause and timing of death of neonatal white-tailed deer fawns in a suburban area in Alabama, estimated survival rates, and determined the potential factors that influence survival of fawns in this area.

MATERIALS AND METHODS

Our study site was located in a suburban area of Auburn, Alabama in Lee County. It consisted of a cluster of suburban developments with 0.4-2.0 ha lots, which maintained much of the native vegetation and wooded areas between houses, suitable for wildlife corridors. In addition, we also examined deer from Chewacla State Park, in Auburn, Alabama, a 281.3 ha tract of land, surrounded by these suburban developments. This study area was intersected with low density two-lane suburban/city streets and bordered

by a major interstate (I-85) with high-speed traffic. Deer on this site regularly crossed roads and lived in close proximity to human habitation.

Between March and August in 2004 and 2005, 46 female white-tailed deer were captured and fitted with vaginal implant transmitters (Models M3950 and M3930 Advanced Telemetry Systems, Insanti, Michigan). Captured deer were anesthetized using an intramuscular injection of telazol (2.25 ml/45.36 kg) and xylazine (2 ml/45.36 kg), administered with dart guns over areas baited with whole corn. While anesthetized, a vaginal implant transmitter was inserted approximately 15-20 cm into the vaginal canal, with the silicone wings pressed firmly against the cervix (Carstensen et al. 2003). These transmitters were specifically designed to be expelled during the birth process and emit a signal when the temperature of the transmitter changed from 34°C to 30°C (Bowman and Jacobson 1998). Age of the doe was also determined from annuli in the cementum of the first incisor (Matson's Laboratory Milltown, MT, USA: Low and Cowan 1963; Gilbert 1966).

Does were monitored approximately every 8 hours beginning in July through August. During the peak fawning period (throughout August) does were monitored more extensively in order to locate fawns soon after birth. Once a transmitter was expelled, we waited at least 4 hours after the pulse rate switched to locate the birth site through hand-held telemetry. If the fawn had moved from the birth site, we expanded the search area to a 200-300m radius around the birth site as described by Carstensen et al. (2003). In addition, we also used a thermal imaging camera (Thermal-Eye 250D, L-3 Communications Infrared Products, Dallas Texas, USA) to help locate fawns moved from the birth site. Once located, each newborn fawn was captured by hand. Each fawn

was weighed in a cloth bag that was rubbed in dirt prior to each new capture to minimize scent transfer. In addition, an expandable radio collar (Model M4210 Advanced Telemetry Systems, Insanti, Minnesota, USA: Diefenbach et al. 2003) was affixed to each fawn allowing us to monitor survival for approximately 6-12 months. These collars were designed to give a signal if activity was undetected for 6 hours and included a coding system allowing us to determine the exact time motion ceased.

Following release, each fawn was located at least once per day. In cases of mortality, cause of death was ascertained. In cases of predation, predators were distinguished by comparison of location and description of remains, hair found at site and bite marks (Cook et al. 1971; White 1973; Garner et al. 1976). When we could not determine conclusively that predation was the cause of death, but evidence suggested predation (eg. found only collar with bite marks or near predator scat or time exceeded 24 hours following death and scavenging could not be eliminated as possibility), it was classified as possible predation. If the cause of death could not be determined in the field, necropsies were performed. Emaciation was identified similar to Sams et al. (1996) by severe atrophy of adipose tissue, absence of gastrointestinal contents, and presence of meconium in lower intestines. If cause of death was unable to be determined by these procedures it was classified as unknown.

Survival analysis was performed with a known fate model in program MARK version 4.2 (White and Burnham 1999). Weekly survival rates starting from the date of birth were used to determine the best model explaining survival rates in this population. We modeled survival rates for the initial 8 weeks of life (56 days), the approximate time weaning will begin. Eighteen models were developed to be tested including time

following birth (i.e. survival rates are different among the 8 weeks following birth), a linear time trend (i.e. survival rates for each week following week are related in a linear trend over time), and individual covariates: year (coded: 2004 = 1; 2005 = 0), mass of fawn at birth, sex of fawn (coded: male = 1; female = 0), birthdate, and age of mother (divided into 2 groups; coded: $\leq 2.5 = 0$ and $> 2.5 = 1$). We used Akaike's Information Criterion corrected for small size (AICc) to select the best models and determined parameter estimates, likelihoods, and standard errors from the estimates given by MARK. In order to test the goodness of fit of the most general model, we used Hosmer and Lemeshow goodness of fit statistic (PROC LOGISTIC, SAS Institute 1999). In addition, we used a *t*-test to test for differences in birth date and birth mass between years. We used a chi-square to test for differences in survival rates between years. We also tested for differences in mother's condition (i.e. age and chest girth) among fawns that lived, were abandoned, and died of all other causes with an analysis of variance.

RESULTS

We implanted 46 does in 2004 and 2005 with vaginal implant transmitters, of which 28 resulted in the successful captures of fawns. Unsuccessful captures from transmitters resulted from premature expulsion of transmitter ($n = 9$), transmitter failure ($n = 2$; one of which was replaced), transmitter malfunction ($n = 1$), failure to locate fawns after birth ($n = 1$), and implantation of infertile or post parturition does ($n = 6$).

We captured a total of 36 fawns, 17 in 2004 and 19 in 2005. Mean birth date in 2004 was later ($t_{34} = -2.64$; $P = 0.012$; 15 August) than in 2005 (4 August), however mean birth mass did not differ ($t_{34} = 0.14$; $P = 0.893$) between years (2.50 kg in 2004 and

2.53 kg in 2005). The overall survival rate for the first 8 weeks of life was 33.3%. Although the survival rate in 2005 (42.1%) tended to be greater than 2004 (23.5%), it was not significant ($X^2 = 1.39$; $P = 0.238$). During both years, greater mortality rates occurred immediately following birth with fewer mortalities occurring as the fawns aged (Figure 1). The most common cause of mortality during both years (41.7%) was predation by coyotes, followed by starvation due to abandonment (25.0%), possible predation (20.8%), and accidents and unknown causes (<13.0%; Table 1). When comparing maternal condition among fawns with different fates, we did not detect any differences ($P > 0.050$) in age or chest girth of mothers for fawns abandoned (age = 3.83, chest girth = 832.50), fawns that died of all other causes (age = 3.33, chest girth = 809.72), and fawns that survived (age = 3.58, chest girth = 845.83).

From the known fate analysis the best model ($\Delta AICc = 0.00$, $AICw = 0.43$) from the suite of models considered was the additive model of the linear time trend, mass, and year (Table 2), suggesting that the change in weekly survival was linearly related and varied between years and between masses at an equal rate (Figure 2). The second best model ($\Delta AICc = 0.61$, $AICw = 0.31$), the additive model of the linear time trend and mass, also has considerable strength of evidence as a good model. Therefore, parameter likelihoods and estimates were determined. The parameter likelihoods illustrated that the linear time trend (0.92), mass (0.81), and year (0.58) were the most important parameters to be included in the best model (Table 3). From the top model it was determined that survival each week following birth increased by a factor of 1.36 (95% CI = 0.08-2.63). Additionally, survival increased by 1.69 with each additional kg of birth weight (95% CI = 0.07-3.31) and fawns born in 2005 were 1.49 times more likely to survive than fawns

born in 2004 (95% CI = -0.11-3.09). Models containing the variables age of the mother, birth date, sex, and time following birth did not explain a significant proportion of variation in survival rates (Table 2). Similarly, parameter likelihoods also indicated that age of the mother (0.00), birthdate (0.00), sex of fawn (0.00) and time following birth (0.01) were not likely to be included in the best model. The Hosmer-Lemeshow goodness of fit statistic ($\hat{c} = 0.714$) indicated that the most general model fit the data well.

DISCUSSION

Numerous studies have determined cause and timing of mortalities of white-tailed deer fawns across the United States (Cook et al. 1971; Garner et al. 1976; Carroll and Brown 1977; Bartush and Lewis 1981; Epstein et al. 1983; Epstein et al. 1985; Huegel et al. 1985; Nelson and Woolf 1987; Kunkel and Mech 1994; Sams et al. 1996; Long et al. 1998; Ballard et al. 1999; Ricca et al. 2002; Vreeland et al. 2004). However, no studies have examined survival of white-tailed deer fawns in urban/suburban areas. The mortality rate of suburban white-tailed deer fawns detected in our study was 66.7%. This rate is greater than the mean rate of neonatal mortality among temperate ungulates (45%) as calculated by Linnell et al. (1995). In addition, among studies of white-tailed deer, neonatal mortality rates ranged from 23.6%-90.0%, with a mean mortality rate of 54.8%. Additionally, 69% of these studies resulted in mortality rates lower than the rate observed in this study. The high neonatal mortality rate observed in this study could be attributed to sampling biases of other studies. Since most previous studies on neonatal survival of white-tailed deer captured fawns with foot searches or doe behavior, most fawns were a few days to weeks old at time of capture. Therefore, mortality occurring within the first

few days of life went undetected and could have resulted in lower rates of mortality. In our study, 50.0% of mortalities occurred in the first week of life. Therefore, in order to accurately measure survival rates, it is critical that fawns are captured as early as possible or analyses account for staggered entry of individuals (Pollock et al. 1989).

We also attribute the high mortality rate we detected to a high predation rate on this population. We detected a predation rate of 41.7%-62.5%, of which, 100% was attributed to coyotes. Other studies have found similar coyote predation rates (>50.0% predation rate, of which >50% attributed to coyotes) of neonatal white-tailed deer in various geographic regions, including Oklahoma (Garner et al. 1976), Iowa (Huegel et al. 1985), Illinois (Nelson and Woolf 1987), and Texas (Cook et al. 1971; Carroll and Brown 1977). We suspect that the high rate of predation was due to efficient detection of bedded fawns in the typical open landscape of the suburban area. Coyotes are visual hunters and therefore, it has been suggested that increased predation on neonatal white-tailed deer fawns by coyotes is associated with sparse vegetative cover (Garner et al. 1976; Carroll and Brown 1977; Huegel et al. 1985; Nelson and Woolf 1987; Long et al. 1998). This effect would be most evident within the first 30 days of life since fawns are bedded at this time and therefore rely on camouflage to avoid predation (Huegel et al. 1985). The manicured lawns and landscaped yards in suburban areas would complement the search strategies employed by coyotes.

The timing of the birthing season in this population could also contribute to increased predation. In Alabama, the birthing season is much later than most other populations of white-tailed deer, occurring from late July to early September (Gray et al. 2002). This birthing season coincides with the greatest hunting population of coyotes

since predispersal coyote pups are hunting independently at this time (Harrison and Harrison 1984; Harrison et al. 1991). In one of the few studies done on food habits of coyotes in Alabama, Hoerath (1990) found that in fall (September-November) white-tailed deer fawns were the most abundant (23.9%) and frequent (33.1%) food source found in coyote scat. In addition, fawns were also an important food source in summer (June-August), third in abundance (15.0%) and frequency (27.5%) only to lagomorphs (*Sylvilagus floridanus* and *S. aquaticus*) and cotton rats (*Sigmodon hispidus*). This suggests that white-tailed deer fawns in Alabama are an important food source to coyotes during the months where fawns are the most vulnerable.

The second major cause of mortality in this population (25.0%) was starvation due to abandonment. This cause, while relatively high (46.2%) in the first year, was absent in the second. Although abandonment could be due to disturbance of the birth site or scent transfer while handling fawns, all precautions were taken in order to minimize these effects, including waiting a minimum of four hours after birth to collar fawns, wearing non-scented latex gloves, minimizing handling time to less than 10 minutes, minimizing the number of handlers to one or two, and minimizing disturbance to the birth site. The methods and researchers handling fawns did not change between years. Therefore, we believe that abandonment was not due to disturbance during the handling process. In addition, in a study done on the effects of handling techniques on the rate of abandonment, Carstensen Powell et al. (2005) found that increased scent transfer, increased handling time, time of capture and increased handling stress did not affect the rate of abandonment in a free-ranging herd of white-tailed deer in Minnesota. Therefore, they suggest that removing data on fawns suspected of handling-induced abandonment is

unwarranted. One possible explanation for increased abandonment in 2004 is low food availability as indicated by monthly rainfall. In 2004, the total rainfall for March and April (2.24 cm and 11.23 cm) was much lower than in 2005 (26.29 cm and 17.68 cm). In addition, in 2004 the cumulative rainfall from March through September remained below normal with the mean departure being 17 cm below normal, as compared to 5 cm greater than normal in 2005. It has been shown that in years of poor nutritional availability that white-tailed deer does were more likely to abandon fawns or fawns were more likely to die of malnutrition (Verme 1962; Murphy and Coates 1966; Langenau and Lerg 1976). From the known fate model, year was an important factor in predicting survival for this population. It was estimated that fawns born in 2005 were 1.49 times more likely to survive than fawns born in 2004.

Other causes of mortality in this population were due to accidents and unknown reasons. These, however, did not account for the majority of the deaths. Vehicular accidents have been found to be a major cause of mortality of adult white-tailed deer living in urban/suburban areas (66% of mortality: Etter et al. 2002; 73% of mortality: Hansen and Beringer 2003). We had anticipated higher rates of mortality due to vehicular traffic, but it is possible that the sedentary nature of fawns early in life may have resulted in fawns only infrequently crossing roads. During the first three weeks of life fawns are active only 8%-15% of the time, traveling less than 100m in the first week, and less than 200m by the third (Jackson et al. 1972). By the fourth-eighth week, however, fawns are active 15%-20% of the time, and by 4 months they are as active as adults (Jackson et al. 1972). These data suggest that mortality of fawns due to vehicular traffic should increase with age, however, since we monitored survival for the initial 8

weeks of life, we may not have observed the time period at which fawns are most vulnerable to this mortality risk.

Neonatal fawns exhibit greater vulnerability to mortality early in life. In numerous studies on white-tailed deer it has been shown that mortality rates of younger fawns are greater than that of older fawns (Cook et al. 1971; Garner et al. 1976; Nelson and Mech 1986; Long et al. 1998; Ricca et al. 2002; Vreeland et al. 2004). In this study, we found that neonatal survival was linearly associated with time following birth and increased by a factor of 1.36 with each additional week after birth. Other studies have found similar results with greatest mortality rates occurring within the first week of life (Ricca et al. 2002; Vreeland et al. 2004). Since the leading causes of mortality for this population were abandonment and predation, these results suggest that fawns are more susceptible to these causes of mortality earlier in life.

It has been shown that mass at birth can also have substantial impacts on survival, with lighter neonatal white-tailed deer having higher mortality than heavier individuals (Verme 1962, 1977; Nelson and Woolf 1987; Kunkel and Mech 1994; Vreeland et al. 2004). Mass at birth was an important factor in our population predicting survival rates. We found that survival rates increased 1.69 times with each additional kg of birth mass (as predicted by known fate model). In a study done in Pennsylvania on white-tailed deer fawns, Vreeland et al. (2004) found similar results in that fawns were 2.14 times more likely to survive with each additional kg of weight at capture.

Other factors that could potentially influence fawn survival include age of the mother, birthdate, and sex of the fawn. It has been suggested that fawn mortality rates are negatively related to the mother's age since birth weight tends to be associated

positively with maternal age and older individuals tend to defend and protect their young better than younger individuals (Smith 1987; Mech and McRoberts 1990). Additionally, fawns survival may be negatively related to date of birth. Since older mothers or mothers in better condition tend to give birth earlier (Johns et al. 1977; Festa-Bianchet 1988; Berger 1992; Christley et al. 2002), and survival of fawns increases as maternal condition and age increases (Verme 1962; Murphy and Coates 1966; Langenau and Lerg 1976; McGinnes and Downing 1977; Rognum et al. 1983; Smith 1987; Mech and McRoberts 1990), survival may be predicted by date of birth. Activity patterns of male and female fawns also differ, with males being more active, potentially leading to increased predation rates of male fawns (Jackson et al. 1972). Despite the potential influence on fawn survival, maternal age, birthdate, and sex of the fawn were not found to be important factors explaining fawn mortality rates in this population.

As humans continue to move away from the urban epicenter into suburban areas, management of suburban wildlife will become increasingly important. However, species living in these areas are exposed to different stresses and can potentially alter behavior and life history characteristics to mitigate this stress. Therefore, basing management decisions of urban wildlife on rural populations may be inaccurate and could potentially lead to ineffective results (Ditchkoff et al. 2006). One important life history characteristic to understand when managing a species is survival. Changes in survival rates and causes of survival have profound impacts on management and control decisions of urban wildlife such as white-tailed deer. In this study, we found that urban populations of white-tailed deer may exhibit greater rates of neonatal mortality than rural areas due to increased predator efficiency. This change in survival rates could have

profound impacts on urban populations and may help decrease population growth rates in these areas. It has been suggested that suburban populations of white-tailed deer tend to have smaller home ranges and subsequently higher densities than rural areas due to increased food availability (Porter et al. 2004). However, if mortality rates are higher in these areas, population growth may be limited even though food availability is high. Understanding these processes and other life history characteristics of urban populations will aid in the attempt to control and manage these species effectively.

LITERATURE CITED

- Ballard, W. B., H. A. Whitlaw, S. J. Young, R. A. Jenkins, and G. J. Forbes. 1999. Predation and survival of white-tailed deer fawns in northcentral New Brunswick. *Journal of Wildlife Management* 63:574-579.
- Bartush, W. S., and J. C. Lewis. 1981. Mortality of white-tailed deer fawns in the Wichita Mountains. *Proceedings of the Oklahoma Academy of Science* 61:23-27.
- Berger, J. 1992. Facilitation of reproductive synchrony by gestation adjustment in gregarious mammals: a new hypothesis. *Ecology* 73:323-329.
- Bowman, J. L., and H. A. Jacobson. 1998. An improved vaginal-implant transmitter for locating white-tailed deer birth sites and fawns. *Wildlife Society Bulletin* 26:295-298.
- Carroll, B. K., and D. L. Brown. 1977. Factors affecting neonatal fawn survival in southern-central Texas. *Journal of Wildlife Management* 41:63-69.

- Carstensen, M., G. D. DelGiudice, and B. A. Sampson. 2003. Using doe behavior and vaginal-implant transmitters to capture neonate white-tailed deer in north-central Minnesota. *Wildlife Society Bulletin* 31:634-641.
- Carstensen Powell, M., G. D. DelGiudice, and B. A. Sampson. 2005. Low risk of marking-induced abandonment in free-ranging white-tailed deer neonates. *Wildlife Society Bulletin* 33:643-655.
- Christley, R. M., K. L. Morgan, T. D. H. Parkin, and N. P. French. 2002. Factors related to the risk of neonatal mortality, birth-weight and serum immunoglobulin concentration in lambs in the UK. *Preventive Veterinary Medicine* 57:209-226.
- Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. *Journal of Wildlife Management* 35:47-56.
- Diefenbach, D. R., C. O. Kochanny, J. K. Vreeland, and B. D. Wallingford. 2003. Evaluation of an expandable, breakaway radiocollar for white-tailed deer fawns. *Wildlife Society Bulletin* 31:756-761.
- Ditchkoff, S. S., S. T. Saalfeld, and C. J. Gibson. 2006. Animal behavior in urban ecosystems: modifications due to human-induced stress. *Urban Ecosystems* 9:5-12.
- Epstein, M. B., G. A. Feldhamer, and R. L. Joyner. 1983. Predation on white-tailed deer fawns by bobcats, foxes, and alligators: predator assessment. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 37:161-172.

- Epstein, M. B., G. A. Feldhamer, R. L. Joyner, R. J. Hamilton, and W. G. Moore. 1985. Home range and mortality of white-tailed deer fawns in coastal South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39:373-379.
- Etter, D. R., et al. 2002. Survival and movements of white-tailed deer in suburban Chicago, Illinois. Journal of Wildlife Management 66:500-510.
- Festa-Bianchet, M. 1988. Birthdate and survival in bighorn lambs (*Ovis canadensis*). Journal of Zoology 214:653-661.
- Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.
- Garner, G. W., J. A. Morrison, and J. C. Lewis. 1976. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:493-506.
- Gilbert, F. F. 1966. Aging white-tailed deer by annuli in the cementum of the first incisor. Journal of Wildlife Management 30:200-202.
- Gillies, C., and M. Clout. 2003. The prey of domestic cats (*Felis catus*) in two suburbs of Auckland City, New Zealand. Journal of Zoology 259:309-315.
- Gray, W. N., II, S. S. Ditchkoff, M. K. Causey, and C. W. Cook. 2002. The yearling disadvantage in Alabama deer: effect of birth date on development. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 56:255-264.

- Hansen, L. P., and J. Beringer. 2003. Survival of rural and urban white-tailed deer in Missouri. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 57:326-336.
- Harrison, D. J., and J. A. Harrison. 1984. Foods of adult Maine coyotes and their known-aged pups. *Journal of Wildlife Management* 48:922-926.
- Harrison, D. J., J. A. Harrison, and M. O'Donoghue. 1991. Predispersal movements of coyote (*Canis latrans*) pups in eastern Maine. *Journal of Mammalogy* 72:756-763.
- Hoerath, J. D. 1990. Influences of coyotes on game animals as monitored by fecal analysis. Master of Science, Auburn University, Auburn.
- Huegel, C. N., R. B. Dahlgren, and H. L. Gladfelter. 1985. Mortality of white-tailed deer fawns in south-central Iowa. *Journal of Wildlife Management* 49:377-380.
- Jackson, R. M., M. White, and F. F. Knowlton. 1972. Activity patterns of young white-tailed deer fawns in south Texas. *Ecology* 53:262-270.
- Johns, P. E., R. Baccus, M. N. Manlove, J. Pinder, III, and M. H. Smith. 1977. Reproductive patterns, productivity and genetic variability in adjacent white-tailed deer populations. *Proceedings of the annual conference Southeastern Association of Fish and Wildlife Agencies* 31:167-172.
- Koenig, J., R. Shine, and G. Shea. 2002. The dangers of life in the city: patterns of activity, injury and mortality in suburban lizards (*Tiliqua scincoides*). *Journal of Herpetology* 36:62-68.
- Kunkel, K. E., and L. D. Mech. 1994. Wolf and bear predation on white-tailed deer fawns in northeastern Minnesota. *Canadian Journal of Zoology* 72:1557-1565.

- Langenau, E. E., Jr, and J. M. Lerg. 1976. The effects of winter nutritional stress on maternal and neonatal behavior in penned white-tailed deer. *Applied Animal Ethology* 2:207-223.
- Lepczyk, C. A., A. G. Mertig, and J. Liu. 2003. Landowners and cat predation across rural-to-urban landscapes. *Biological Conservation* 115:191-201.
- Linnell, J. D. C., R. Aanes, and R. Andersen. 1995. Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. *Wildlife Biology* 1:209-223.
- Long, R. A., A. F. J. O'Connell, and D. J. Harrison. 1998. Mortality and survival of white-tailed deer *Odocoileus virginianus* fawns on a north Atlantic coastal island. *Wildlife Biology* 4:237-247.
- Low, W. A., and I. M. Cowan. 1963. Age determination of deer by annular structure of dental cementum. *Journal of Wildlife Management* 27:466-471.
- McGinnes, B. S., and R. L. Downing. 1977. Factors affecting the peak of white-tailed deer fawning in Virginia. *Journal of Wildlife Management* 41:715-719.
- Mech, L. D., and R. E. McRoberts. 1990. Survival of white-tailed deer fawns in relation to maternal age. *Journal of Mammalogy* 71:465-467.
- Murphy, D. A., and J. A. Coates. 1966. Effects of dietary protein on deer. *Transactions of the North American Wildlife and Natural Resources Conference* 31:129-139.
- Nelson, M. E., and L. D. Mech. 1986. Mortality of white-tailed deer in northeastern Minnesota. *Journal of Wildlife Management* 50:691-698.
- Nelson, T. A., and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illinois. *Journal of Wildlife Management* 51:326-329.

- Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. *Journal of Wildlife Management* 53:7-15.
- Porter, W. F., H. B. Underwood, and J. L. Woodard. 2004. Movement behavior, dispersal, and the potential for localized management of deer in a suburban environment. *Journal of Wildlife Management* 68:247-256.
- Ricca, M. A., R. G. Anthony, D. H. Jackson, and S. A. Wolfe. 2002. Survival of Columbian white-tailed deer in western Oregon. *Journal of Wildlife Management* 66:1255-1266.
- Rognmo, A., K. A. Markussen, E. Jacobsen, H. J. Grav, and A. S. Blix. 1983. Effects of improved nutrition in pregnant reindeer on milk quality, calf birth weight, growth, and mortality. *Rangifer* 3:10-18.
- Sams, M. G., R. L. Lochmiller, C. W. Q. Jr., D. M. L. Jr., and M. E. Payton. 1996. Physiological correlates of neonatal mortality in an overpopulated herd of white-tailed deer. *Journal of Mammalogy* 77:179-190.
- SAS Institute. 1999. SAS/STAT software: the logistic procedure, version 8. SAS Institute, Inc., Cary, North Carolina.
- Smith, W. P. 1987. Maternal defense in Columbian white-tailed deer: when is it worth it? *The American Naturalist* 130:310-316.
- Verme, L. J. 1962. Mortality of white-tailed deer fawns in relation to nutrition. *Proceedings of the National White-tailed Deer Disease Symposium* 1:15-38.
- Verme, L. J. 1977. Assessment of natal mortality in upper Michigan deer. *Journal of Wildlife Management* 41:700-708.

- Vreeland, J. K., D. R. Diefenbach, and B. D. Wallingford. 2004. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. *Wildlife Society Bulletin* 32:542-553.
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46:S120-139.
- White, M. 1973. Description of remains of deer fawns killed by coyotes. *Journal of Mammalogy* 54:291-293.

Table 1. Causes of mortality of white-tailed deer fawns (2004-2005) during the initial 8 weeks of life in Auburn, Alabama.

Cause of Mortality	2004		2005	
	%	N	%	N
Predation	38.5	5	45.5	5
Possible Predation	7.7	1	36.4	4
Abandonment	46.2	6	-----	--
Accident ^a	-----	--	9.1	1
Unknown	7.7	1	9.1	1

^a Fawn fell in hole soon after birth and could not escape.

Table 2. Model results from known fate analysis of survival rates during the initial 8 weeks of life for white-tailed deer fawns in Auburn, Alabama from 2004-2005.

Model	No. Parameters	$\Delta AICc^a$	AICw ^b
S (linear time trend + year + mass) ^c	4	0.00	0.43
S (linear time trend + mass)	3	0.61	0.31
S (linear time trend + year)	3	2.93	0.10
S (linear time trend)	2	3.25	0.08
S (year + mass)	3	5.06	0.03
S (mass)	2	6.77	0.01
S (year*mass) ^d	4	6.85	0.01
S (time + year + mass)	10	9.42	0.00
S (time + mass)	9	9.59	0.00
S (year)	2	9.60	0.00
S (.) ^e	1	11.12	0.00
S (time)	8	11.80	0.00
S (time + year)	9	11.85	0.00
S (sex of fawn)	2	12.50	0.00
S (birthdate)	2	12.93	0.00

Table 2. Continued.

Model	No. Parameters	ΔAICc^a	AICw^b
S (age of mother)	2	13.14	0.00
S (time + age of mother)	9	14.02	0.00
S (time*year) ^f	16	19.83	0.00

^a Difference between model's Akaike's Information Criteria, corrected for small sample size and the lowest AICc value

^b AICc relative weight attributed to model

^c Model of additive effects of linear time trend, year, and mass

^d Model of additive effects of year and mass and the interaction

^e Model of no effects on survival

^f Numerical convergence not reached

Table 3. Parameter estimates and likelihoods from known fate models of survival rates during the initial 8 weeks of life for white-tailed deer fawns in Auburn, Alabama from 2004-2005.

Explanatory Variable	Parameter Likelihood ^a	Parameter Estimate ^b	SE ^c	Parameter Estimate From Top Model	SE From Top Model
Intercept	1.00	0.73	0.22	0.67	0.41
Linear time trend	0.92	0.29	0.01	0.30	0.12
Mass	0.81	0.43	0.22	0.53	0.25
Year	0.58	-0.23	0.17	-0.40	0.24
Age of mother	0.00	0.00	0.00	-----	-----
Birthdate	0.00	0.00	0.00	-----	-----
Sex of fawn	0.00	0.00	0.00	-----	-----
Time	0.01	-----	-----	-----	-----

^a AICc weights summed across all candidate models that include a given variable

^b Weighted averages (based on model AICc weight) from all candidate models

^c Based on unconditional variances over the suite of models considered

Figure 1. Survival of white-tailed deer fawns in Auburn, Alabama during the initial 8 weeks of life during 2004 and 2005.

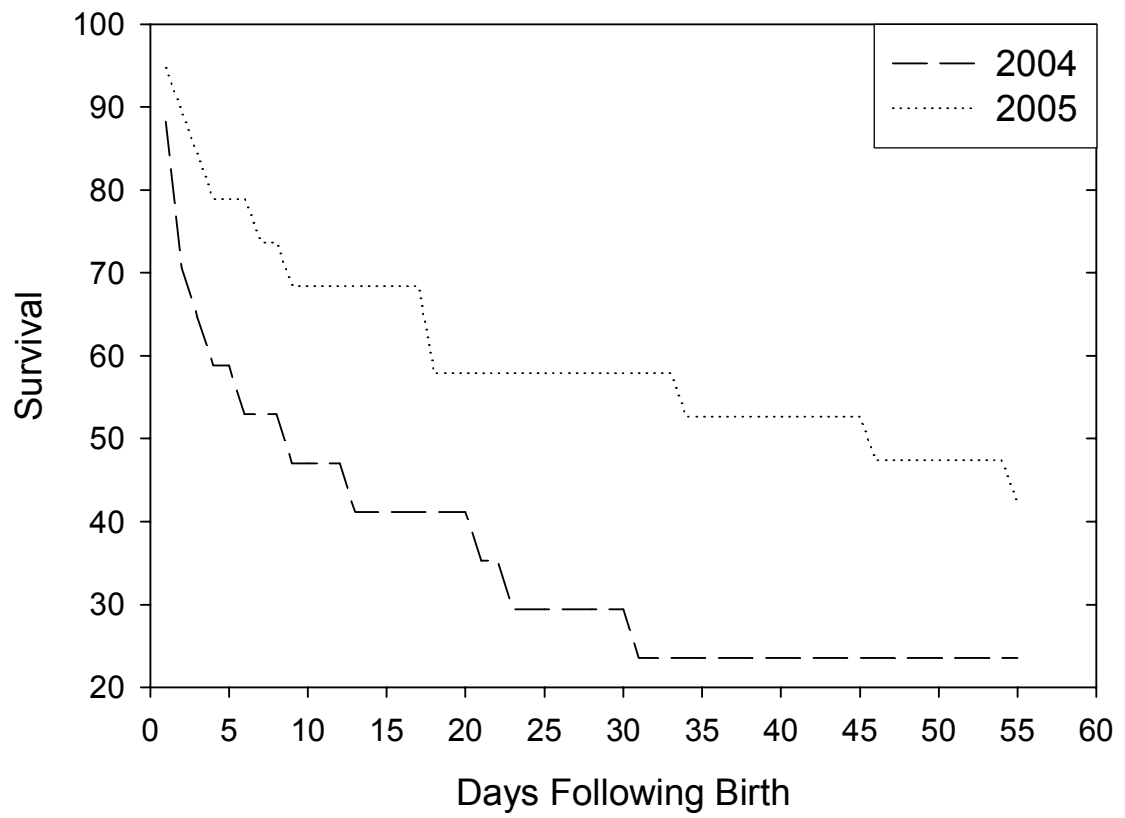
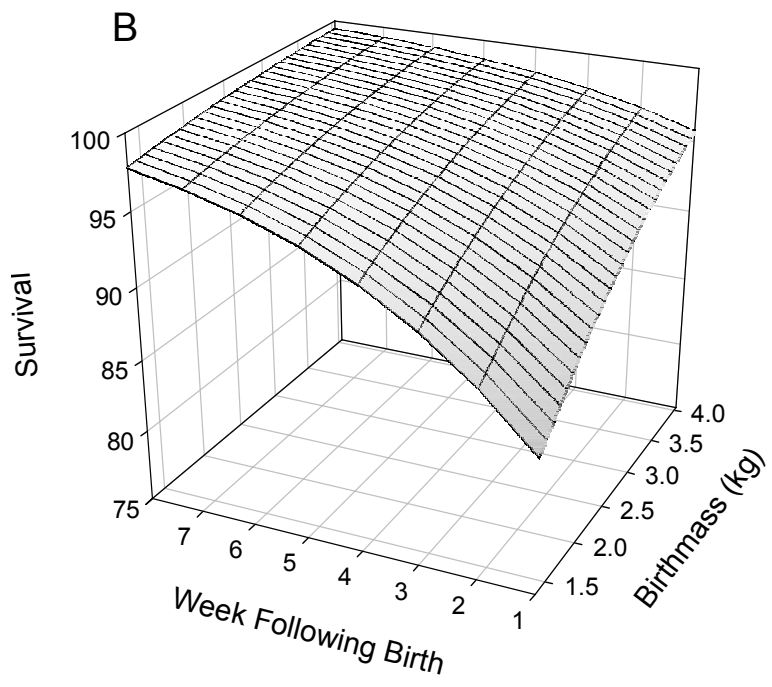
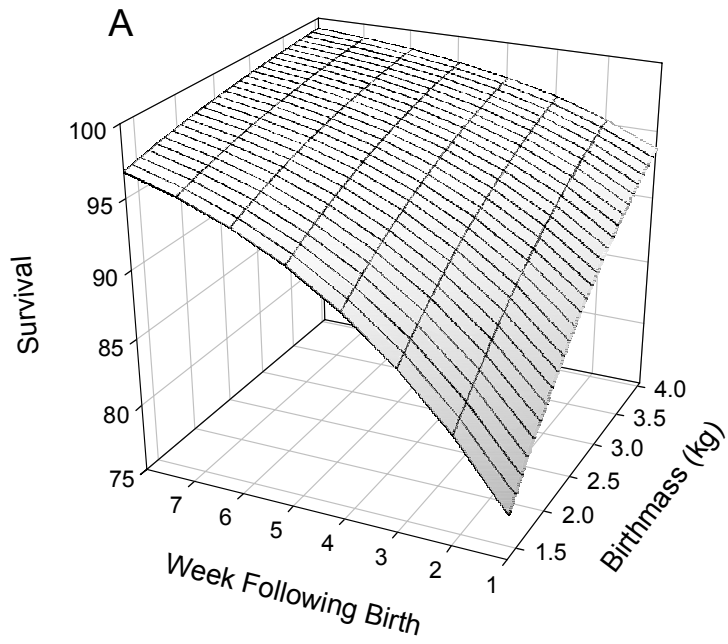


Figure 2. Survival rates of white-tailed deer fawns in Auburn, Alabama during the initial 8 weeks of life as predicted by birth mass and age during 2004 (A) and 2005 (B).



APPENDICES

Appendix 1. Doe capture data in Auburn, Alabama during 2004 and 2005.

Doe ID	Date		Capture		Fawns
	Captured	Year	Location	Transmitter Fate	Caught
1	March 24	2004	Gentry	premature expulsion	0
2	March 29	2004	Gentry	premature expulsion	0
3	April 2	2004	Gentry	premature expulsion	0
4	April 19	2004	Hammond	premature expulsion	0
5	April 28	2004	Boecklen	not pregnant	0
6	May 3	2004	Gentry	successful	2
7	May 5	2004	Boecklen	successful	1
8	May 12	2004	Hammond	successful	2
9	May 17	2004	Hammond	not pregnant	0
10	May 23	2004	Hammond	successful	1
11	May 26	2004	Gentry	successful	1
12	June 4	2004	Gentry	successful	1
13	June 11	2004	Chewacla	successful	2
14	June 18	2004	Chewacla	successful	1
15	June 19	2004	Chewacla	successful	1

Appendix 1. Continued.

Doe ID	Date		Capture		Fawns
	Captured	Year	Location	Transmitter Fate	Caught
16	July 11	2004	Chewacla	not pregnant	0
17	July 13	2004	Robin Rd	successful	1
18	July 23	2004	Angarano	not pregnant	0
19	August 1	2004	Whippoorwill	successful	1
20	August 6	2004	Whippoorwill	successful	2
21	August 8	2004	Chewacla	not pregnant	0
22	August 13	2004	Angarano	failure to locate fawns	0
23	August 23	2004	Ogletree Rd	successful	1
24	March 1	2005	Gentry	successful	1
25	March 8	2005	Chewacla	successful	2
26	March 13	2005	Chewacla	premature expulsion	0
27	March 18	2005	Boecklen	successful	1
28	April 4	2005	Angarano	successful	2
29	April 7	2005	Whippoorwill	successful	1
30	April 18	2005	Chewacla	successful	1

Appendix 1. Continued

Doe ID	Date		Capture		Fawns
	Captured	Year	Location	Transmitter Fate	Caught
31	April 20	2005	Chewacla	successful	1
32	April 22	2005	Angarano	transmitter failure	0
33	May 3	2005	Ogletree Rd	premature expulsion	0
34	May 6	2005	Chewacla	not pregnant	0
35	May 22	2005	Chewacla	successful	1
36	June 4	2005	Whippoorwill	transmitter malfunction	0
37	June 4	2005	Gentry	successful	1
38	June 12	2005	Chewacla	premature expulsion	0
39	June 17	2005	Chewacla	premature expulsion	0
40	June 28	2005	Angarano	premature expulsion	0
41	July 5	2005	Angarano	successful	1
42	July 9	2005	Gentry	successful	2
43	July 11	2005	Glover	successful	1
44	July 16	2005	Glover	successful	2
45	July 19	2005	Angarano	successful	1

Appendix 1. Continued

	Date		Capture		Fawns
Doe ID	Captured	Year	Location	Transmitter Fate	Caught
46	July 29	2005	Ogletree Rd	successful	1

Appendix 2. Fawn capture data in Auburn, Alabama for 2004 and 2005 using vaginal implant transmitters.

Fawn ID	Mother ID	Birth Date	Birth Location	Sex	Date of Death	Cause of Death
F3	12	Jul-30-04	Whippoorwill	F	Aug-30-04	Predation
F4	17	Aug-05-04	Whippoorwill	F	Aug-09-04	Unknown
F5	10	Aug-05-04	Whippoorwill	F	Aug-28-04	Predation
F6	13	Aug-08-04	Chewacla	M	Aug-11-04	Abandoned
F7	13	Aug-08-04	Chewacla	F	-----	Survived
F8	20	Aug-09-04	Chewacla	F	Aug-11-04	Abandoned
F9	20	Aug-09-04	Chewacla	F	Aug-11-04	Abandoned
F10	14	Aug-10-04	Chewacla	M	Aug-16-04	Possible Predation
F11	19	Aug-13-04	Whippoorwill	M	Aug-22-04	Predation
F12	7	Aug-18-04	Whippoorwill	F	-----	Survived
F13	8	Aug-18-04	Whippoorwill	M	Aug-31-04	Predation
F14	8	Aug-18-04	Whippoorwill	M	-----	Survived
F15	11	Aug-19-04	Whippoorwill	M	Aug-20-04	Abandoned
F16	6	Aug-22-04	Whippoorwill	F	Aug-24-04	Abandoned

Appendix 2. Continued.

Fawn ID	Mother ID	Birth Date	Birth Location	Sex	Date of Death	Cause of Death
F17	6	Aug-22-04	Whippoorwill	F	Aug-23-04	Abandoned
F18	23	Aug-28-04	Twin Creeks	F	Sep-18-04	Predation
F19	15	Sep-03-04	Chewacla	F	-----	Survived
F20	29	Jul-14-05	Whippoorwill	F	-----	Survived
F21	44	Jul-19-05	Glover	F	Jul-24-05	Possible Predation
F22	44	Jul-19-05	Glover	F	Aug-23-05	Predation
F24	42	Jul-23-05	Whippoorwill	F	-----	Survived
F25	42	Jul-23-05	Whippoorwill	M	Aug-11-05	Predation
F27	45	Jul-26-05	Angarano	M	Aug-05-05	Unknown
F30	25	Jul-31-05	Outing Club	F	-----	Survived
F31	25	Jul-31-05	Outing Club	F	Aug-19-05	Predation
F33	28	Jul-31-05	Springwood	M	Aug-08-05	Possible Predation
F34	28	Jul-31-05	Springwood	F	-----	Survived
F36	27	Aug-06-05	Whippoorwill	M	-----	Survived
F37	24	Aug-09-05	Whippoorwill	F	Aug-10-05	Predation

Appendix 2. Continued

Fawn ID	Mother ID	Birth Date	Birth Location	Sex	Date of Death	Cause of Death
F38	37	Aug-11-05	Whippoorwill	M	Aug-14-05	Predation
F41	31	Aug-14-05	Whippoorwill	F	-----	Survived
F42	30	Aug-15-05	Chewacla	F	Aug-17-05	Accident
F47	43	Aug-21-05	Grove Hill	F	Oct-15-05	Possible Predation
F49	35	Aug-25-05	Angarano	F	Oct-10-05	Possible Predation
F50	46	Aug-26-05	Ogletree	M	-----	Survived
F52	41	Sep-01-05	Springwood	M	-----	Survived

Appendix 3. Doe capture data in Camp Hill, Alabama during 2005.

	Date			Fawns
Doe ID	Captured	Year	Transmitter Fate	Caught
200	March 10	2005	transmitter failure	0
201	March 20	2005	failure to locate fawns	0
203	May 10	2005	successful	2
204	May 16	2005	successful	1
205	May 23	2005	successful	2
206	May 28	2005	successful	1
207	June 7	2005	successful	1
208	June 14	2005	not pregnant	0
209	June 14	2005	premature expulsion	0
210	June 16	2005	successful	2

Appendix 4. Fawn capture data in Camp Hill, Alabama for 2005 using vaginal implant transmitters.

Fawn ID	Mother ID	Birth Date	Sex	Date of Death	Cause of Death
F100	206	Jul-27-05	M	Jul-31-05	Predation
F101	205	Jul-29-05	F	Aug-18-05	Predation
F102	205	Jul-29-05	M	-----	Survived
F103	203	Aug-03-05	M	Oct-2-05	Predation
F104	203	Aug-03-05	M	Aug-14-05	Predation
F105	210	Aug-08-05	F	Aug-13-05	Predation
F106	210	Aug-08-05	M	Aug-10-05	Predation
F107	207	Aug-09-05	M	Aug-14-05	Predation
F109	204	Aug-22-05	M	-----	Survived

Appendix 5. Fawn capture data in Auburn and Camp Hill, Alabama for 2004 and 2005 using spotlights and thermal imaging camera.

Fawn ID	Hoof Growth	Capture Date	Capture Location	Sex	Date of Death	Cause of Death
F1	0.0	Jul-19-04	Chewacla	M	Aug-22-04	Predation
F2	0.0	Jul-19-04	Chewacla	M	-----	Survived
F23	----	Jul-22-05	Chewacla	M	Aug-09-05	Predation
F26	4.0	Jul-23-05	Whippoorwill	M	-----	Survived
F28	1.0	Jul-28-05	Robin Rd	F	Aug-06-05	Predation
F29	5.0	Jul-30-05	Robin Rd	M	-----	Survived
F32	3.0	Jul-31-05	Whippoorwill	F	Oct-23-05	Predation
F35	6.0	Aug-04-05	Angarano	M	Oct-11-05	Possible Predation
F39	5.0	Aug-13-05	Whippoorwill	M	Aug-23-05	Predation
F40	6.0	Aug-13-05	Whippoorwill	M	-----	Survived
F43	7.0	Aug-16-05	Whippoorwill	M	Aug-17-05	Hit by Car
F44	8.0	Aug-19-05	Whippoorwill	F	Aug-24-05	Possible Predation
F45	7.0	Aug-19-05	Whippoorwill	M	Oct-22-05	Domestic Dog
F48	5.0	Aug-25-05	Springwood	M	-----	Survived

Appendix 5. Continued.

Fawn ID	Hoof Growth	Capture Date	Capture Location	Sex	Date of Death	Cause of Death
F51	5.0	Aug-28-05	Chewacla	F	Sep-06-05	Predation
F108	5.0	Aug-15-05	Camp Hill	F	-----	Survived
