AN ABSTRACT OF THE THESIS OF

Nathan P. Pamplin for the degree of Master of Science in Wildlife Science presented on April 8, 2003.

Title: Ecology of Columbian Black-Tailed Deer Fawns in Western Oregon.

Abstract approved Signature redacted for privacy.
Richard A. Schmitz

Little is known about Columbian black-tailed deer (*Odocoileus hemionus columbianus*) because of their elusive nature and the logistical difficulty of studying them in densely forested and mountainous terrain. The Oregon Department of Fish and Wildlife has identified fawn survival as an important gap in the current knowledge of demography and their understanding of an apparent population decline.

We used vaginal-implant transmitters to locate birth sites and capture newborn Columbian black-tailed deer fawns in the Umpqua National Forest in western Oregon. We used modified Clover traps to capture deer during the winter and early spring of 2000 and 2001. Vaginal-implant transmitters were inserted into 36 adult does in 2000 and 32 adult does in 2001. We identified a total of 42 birth sites within our study area using this technique and we captured 23 fawns which we monitored daily throughout the summer.

We modeled birth site selection by examining both site-specific variables and characteristics that describe habitat structure across a nested, hierarchical range of four circular areas. We used logistic regression to compare 42 birth sites with 80

random sites. The model that explained the most variation included the amount of edge and the average slope within 1,000 m of the birth site.

We radiocollared 23 fawns from 2000 and 2001; 19 were captured at the birth site, which was identified using the vaginal-implant transmitter, and 4 were captured opportunistically. Fawns were located at least every other day and we assessed habitat selection using selection ratios. Fawns used open and shelterwood patches more than their availability in the study area. Timber habitats were used most by fawns, but were used less than available.

Survival was monitored daily from the fawns estimated date of birth to 76 days. The Kaplan-Meier survival estimate for 76 days was 44% (95% confidence interval=23-66%). We fitted our survival data to the Weibull distribution and took an information-theoretic approach to construct *a priori* models using fawn capture morphometrics and habitat variables within a 600 m and 1,000 m radius of the capture site. The model that best explained fawn survival time was the amount of roads within a 1,000 m radius of the capture site. A higher road density within fawn summer range increases fawn survival time by likely minimizing predator density due to vehicular disturbance.

Ecology of Columbian Black-Tailed Deer Fawns in Western Oregon

by
Nathan P. Pamplin

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APPROVED:

Signature redacted for privacy.

Major professor, representing Wildlife Science

Signature redacted for privacy.

Head of the Department of Fisheries and Wildlife

Signature redacted for privacy.

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Nathan P. Pamplin, Author

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CONTRIBUTION OF AUTHORS

Drs. Richard A. Schmitz and DeWaine H. Jackson assisted with the design and analysis of this research. Dr. Richard A. Schmitz assisted with the writing of the manuscripts. We will be submitting Chapter 1 to the Journal of Wildlife Management, Chapter 2 to the Canadian Journal of Zoology, and Chapter 3 to the Wildlife Society Bulletin.

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INTRODUCTION

The Oregon Department of Fish and Wildlife (ODFW) conducts annual spotlight counts from ground vehicles to monitor Columbian black-tailed deer (CBTD; *Odocoileus hemionus columbianus*) population trends in western Oregon. The counts have dropped from 5,014 in 1996, to 2,885 in 1997, and to 2,560 deer spotted in 1998 (ODFW 1996-1998). It is unknown whether or not the observed decrease was an actual population decline or due to reduced silvicultural activity along transect routes, which resulted in better concealment for deer. A complete picture of CBTD demography is needed by ODFW for quantitative assessment of population dynamics. Fawn survival was identified by ODFW as an important gap in their current knowledge of demography.

Survival of neonate ungulates has largely been ignored by researchers because of the difficulty in locating birth sites. Researchers typically have captured neonates with several techniques including: observing parturient does (Ozoga et al. 1982, Whittaker and Lindzey 1999); observing a doe tending her newborn fawn (Nelson and Woolf 1987); actively searching for fawns in known fawning areas (Steigers and Flinders 1980, Hamlin et al. 1984, Riley and Dood 1984, Nelson and Woolf 1987, Ballard et al. 1999); and opportunistically spotting fawns while performing other tasks (Bowyer et al. 1998). Garrott and Bartmann (1984) used a surgically implanted vaginal transmitter to locate birth sites but had limited success due to severe trauma caused to the doe when the transmitter was expelled. Bowman and Jacobson (1998) used a vaginal-implant transmitter (VIT) that did not involve sutures in 16 white-tailed deer (*O. virginianus*) and suggested that the use of VIT were safe for does.

We used VIT to locate birth sites and capture neonate CBTD in the Umpqua National Forest in Oregon. In Chapter 1, we present our research on birth site selection of CBTD. Birth sites identified by the VIT were compared with random sites across a range of spatial scales; variables measured from the birth site itself out to 1,000 m away. We were interested in determining which factor(s) best explained the variation within each scale and we were interested in determining which scale best explains birth site selection. In Chapter 2, we present habitat selection and survival of the radiocollared newborn fawns during their first 10 weeks of life. We used parametric survival modeling to examine which measures of fawn morphometrics and forest habitat structure best predict survival time. In Chapter 3, we evaluate the performance and effectiveness of using VIT as a technique to locate birth sites.

Chapter 1

Birth site selection of Columbian black-tailed deer in western Oregon

Nathan P. Pamplin, Richard A. Schmitz, and DeWaine H. Jackson

INTRODUCTION

There is a likely trade-off in habitat selection for female ungulates between the increased forage requirement brought on by lactation and the risk of predation to the neonate (Geist 1981, Bowyer et al. 1998, Mysterud and Østbye 1999). The selection of parturition locations by pregnant females may increase the chance of survival in their offspring. Deer neonates (*Odocoileus* spp.) are not moved far from their birth sites in the first month post-partum and doe areas of habitat use are reduced from the home-range used throughout the year (Ozoga et al. 1982). Therefore, the neonates' first few weeks of habitat use are generally determined by parturition site selection by does.

Parturition locations for deer that successfully reproduce include good forage, water, gentle slopes, and cover, all in close proximity (Witmer et al. 1985). Loft et al. (1984) noted that parturition sites were associated with riparian zones. Cover provides refuge from inclement weather (Witmer et. al 1985, Bowyer et al. 1998) and predators (Parkinson 1982). Parkinson (1982) showed that wild does held in captivity would not nurse their fawns unless adequate cover was provided.

Previous investigations of selection of ungulate parturition locations involved monitoring female behavior as parturition neared or as the female returned to their offspring for nursing (Hines 1975, Bowyer et al. 1999, Barten et al. 2001). These studies were limited in spatial effect to studying the immediate area around the birth site. They also may be biased because observers may be searching for birth sites in habitats where the concealment cover of the habitat type favor the researchers' ability to observe parturient females.

Lactating does forage over a wide area, while fawns need concealment in a small area. Therefore, habitat selection of parturition across a range of spatial scales should be modeled simultaneously. By modeling habitat selection in this manner, we can understand the relative importance of the different parturition site characteristics at each spatial scale.

In this study, we used vaginal-implant transmitters (VIT) inserted into adult doe Columbian black-tailed deer (*O. hemionus columbianus*) in western Oregon to more precisely identify the location of birth sites in 2000 and 2001. In order to identify key attributes of habitat structure, we modeled birth site selection by examining both site-specific variables and variables that describe habitat structure and topography across a nested, hierarchical range of spatial scales.

STUDY AREA

The 23,016 ha study area was located in the Umpqua National Forest on the west slope of the Cascade Mountains in southern Oregon. The area receives approximately 150 cm of precipitation annually. The most common conifer was Douglas fir (*Pseudotsuga menziesii*) and other conifers in the region include ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and incense-cedar (*Calocedrus decurrens*). Primary understory shrubs include Pacific rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), and western serviceberry (*Amelanchier alnifolia*). The elevation of the study area ranged from 580 m to 1,830 m. Most of this region consists of steep ridges interspersed with flat areas.

Different forest seral stages exist in the study area as a result of silvicultural practices. The majority of the study area consisted of mature second-growth or old-growth forest (73%). There were also clear-cuts (5%), regeneration stands (18%), and shelterwood units (4%) dispersed throughout the region. The average size of the three types of younger seral stages was 15 ha.

METHODS

We used modified Clover traps (McCullough 1975) to capture adult (> 2 years) female Columbian black-tailed deer from February to May, 2000 and 2001. Because yearling pregnancy rates are low (85%), we inserted vaginal-implant transmitters (VIT; SirTrack Limited, NZ; Bowman and Jacobson 1998) into adult does which had a higher probability of being pregnant (≥93%; Thomas 1983). Doe age was determined using tooth eruption (Severinghaus 1949). The VIT were set with a 2 hour motion-sensor transmitter delay. To maintain sampling independence, we did not re-implant does in 2001 that were captured in 2000. We also fitted each doe with a radiocollar with a 5 hour motion-sensor mortality delay (Model 500-56A, Telonics, Mesa, AZ). All animal handling procedures were approved by the Institutional Animal Care and Use Committee of Oregon State University, Corvallis, OR, USA.

Does were located using aerial telemetry from a fixed-wing aircraft before and during the fawning season. These locations were used to delineate a year-specific study area boundary in a geographic information system (GIS; ArcView, ESRI, Redlands, CA). Each boundary was a 1 km buffer of a minimum convex polygon of the winter and spring adult doe aerial locations. We selected 40 random points for each field season to describe the available habitat.

From the first week of June through the middle of July, we attempted to check on the status of each VIT 3 times per day from the ground to determine if it was expelled. Once a VIT signal indicated that it was expelled, we located the VIT and recorded the Universal Transverse Mercator coordinates using United States Geographical Survey 7.5-minute topographic maps. We assumed the birth site was the location of the expelled VIT. We measured horizontal concealment cover of a bedded and standing deer using a 2 m cover pole (Griffith and Youtie 1988) and measured vertical canopy cover using a spherical densiometer (Lemmon 1957). All measurements recorded at birth sites were also recorded at random sites.

We used 1993 1 m digital orthophotoquads and a 30 m 1999 Landsat Thematic Mapper image to delineate a habitat map based on forest structure in the GIS. Forest structure was described by 6 categories: open; regeneration; shelterwood; timber; water; and miscellaneous (Figure 1.1). The open forest structure category included recent clear-cuts and meadows. The regeneration category consisted of a dense monoculture of pole trees with little understory. The shelterwood structure category consisted of harvested units where mature seed trees

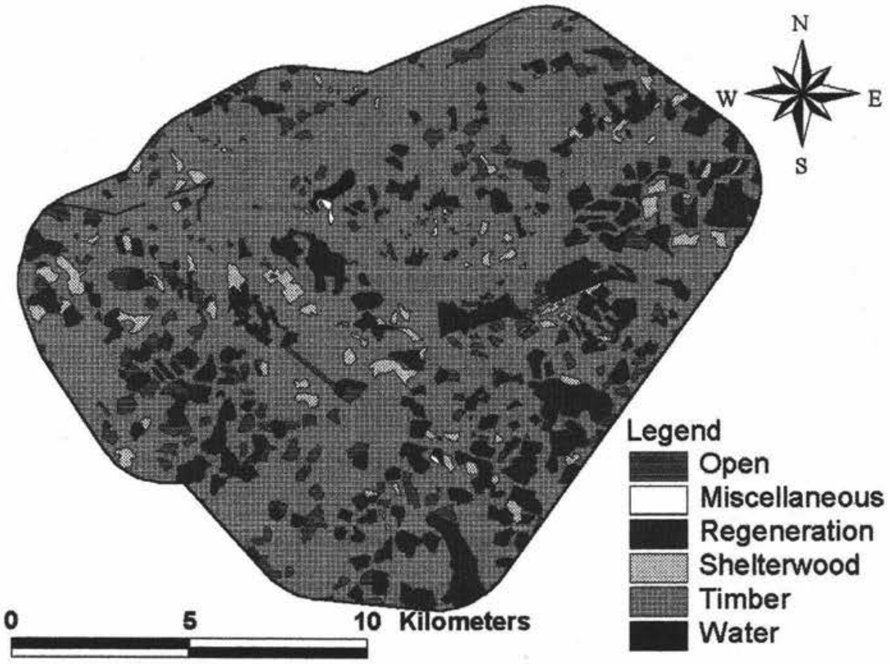

Figure 1.1. The study area habitat map was based on forest structure and was divided into 6 categories: miscellaneous (MI); open (OP); regeneration (RE); shelterwood (SH); timber (TI); and water (WA).

were left evenly spaced throughout the unit. The timber category was composed of old-growth and mature second-growth. The timber category was continuous across the study area and was a matrix in which the other categories were imbedded as patches of other land use. The water category consisted of man-made ponds for the hydroelectric water diversion projects in the area and did not include the associated canal systems or natural streams. The final category, miscellaneous, consisted of large rock outcroppings and a US Forest Service ranger station. The combined area of the water and miscellaneous forest structure categories totaled less than 1% of the study region. The forest structure map was ground-truthed on foot and by vehicle in the fall of 2001.

Geographic information system data layers for elevation, road networks, streams, and forest structure were used to calculate metrics for each birth and random site. This included: the distance to road (m), streams (m), and edge of nearest forest patch (m); topographic slope (degrees); aspect (which was sine and cosine transformed for northing and easting, respectively); elevation (m); and forest structure type for the exact locations of the birth and random sites. We also examined landscape metrics calculated within 4 circular areas (Figure 1.2) of increasing size around each birth and random site that were superimposed over the data layers for forest structure, elevation, road networks, and streams. This allowed us to standardize measurements across the 4 areas. The 4 circular areas corresponded to: sub-stand; stand; home-range; and landscape (Bissonette et al. 1997). The sub-stand area was calculated using a 30 m radius, which yielded a 0.3 ha area. This radius was selected because it was the pixel size of our digital elevation model and satellite imagery and represented the smallest resolution of the data. The stand area was calculated using a 219 m radius, which yielded a 15 ha area. The stand area was the mean individual patch size of the pooled open, regeneration, and shelterwood patches. The home-range radius was 600 m, which yielded a 113 ha area. It was the radius that gives the area of our average summer adult doe home-range. The average home-range was based on a minimum convex polygon (Mohr 1947) of spring and summer locations from 8 does during 2000 and

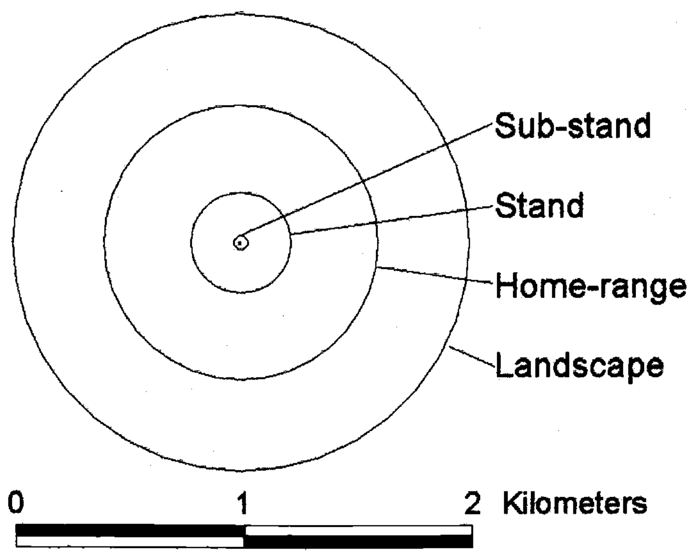

Figure 1.2. A schematic of the four circular buffer distances around each birth and random site from which landscape metrics were derived: sub-stand (30 m); stand (219 m); home-range (600 m); and landscape (1,000 m).

2001. The landscape area was calculated using a 1,000 m radius with an area of 314 ha.

Within each circular area in the GIS, we calculated the average slope (degrees), the greatest difference in elevation (m), the amount of streams (m), the amount of open, driveable roads (m), and the percent of non-timber patches (the proportion of open, regeneration, shelterwood, water, and miscellaneous forest structure types). We used the Patch Analyst extension (Rempel 2000) within the

GIS to determine the amount of edge (m) between adjacent forest patches, the number of forest patches, the average patch size (ha), and the patch size standard deviation within each circular area.

An information-theoretic approach (Burnham and Anderson 1998) was used to develop *a priori* models to examine birth site selection. We were interested in determining which variables best explained the selection at each scale of area around the birth site and which factors best explained the variability in birth site selection, among all circular areas and point-specific variables. Therefore, we constructed 5 model suites. The first 4 suites contained the identical model structure (21 models) applied to each of the 4 circular areas (sub-stand, stand, home-range, and landscape areas). The fifth list of models (137 models) included the 84 models from the first 4 suites, and models that included site-specific variables.

We used logistic regression (PROC LOGISTIC, SAS Institute 1997) with birth sites (coded 1) and random sites (coded 0) to model birth site selection. We used the Akaike Information Criterion (AIC; Akaike 1973) corrected for small samples (AIC_c; Burnham and Anderson 1998) to identify the model(s) with the best fit to the data. Models within 2 ΔAIC_c values of the top model as ranked by AIC_c were considered competing models (Burnham and Anderson 1998).

We assessed the relative importance of variables within each circular area and how each variable responded across spatial scales. First, a subset of the model list was selected of only the models that were in the upper 95% of the summed

Akaike weights. The model list Akaike weights were then re-normalized so that they would sum to 1. We then summed across the re-normalized Akaike weights of models that contained a particular variable (Burnham and Anderson 1998) and repeated this for each of the 9 variables that were in the model suite.

Inter-annual variation in birth site selection was examined by using the same 5 model lists and re-applying them for the birth sites (random sites excluded) with year 2000 (coded 0) and with year 2001 (coded 1).

RESULTS

We captured 36 adult does in 2000 and 32 in 2001. We identified 25 birth sites in 2000 and 17 in 2001 within our study area (Figure 1.3). The VIT were usually found lying off to the side of a small scratched-out bed site, typically under shrubs on level ground. Some VIT (19%) that were not found on scratched-out birth sites, were located on deer trails, and presumably had fallen out because of dilation of the vaginal canal as the doe neared parturition. We included these in our sample because we would either find the newborn fawn close by (< 25 m) or we knew from ground telemetry that the doe was staying close to the location of the VIT while we were in the area.

Vaginal-implant transmitters were recovered in 4 of the 5 forest structure types (excluding water; Figure 1.4). In contrast, all 5 of the forest structure types were represented in the random locations. Based on the proportion of occurrence in each forest structure category for VIT and random sites, at least 1 of the forest

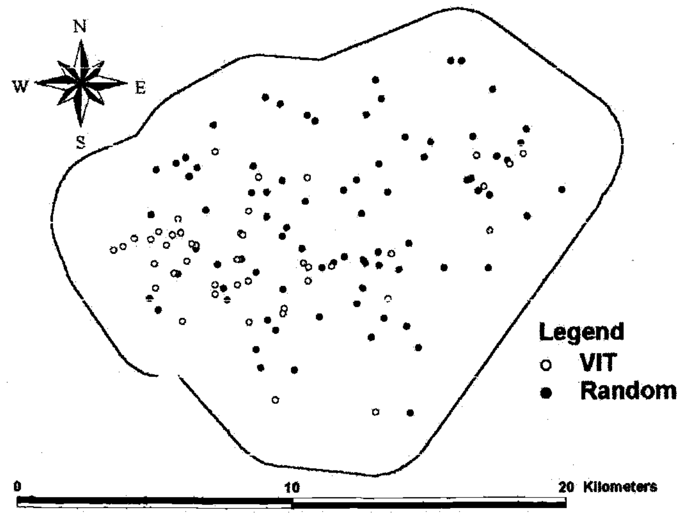

Figure 1.3. The locations of vaginal implant transmitters (VIT; n=42) and random (n=80) sites for 2000 and 2001 within the study area, Umpqua National Forest, Oregon.

structure types was used disproportionately (χ^2=19.103, 4 d.f., p-value < 0.001). The open forest structure category accounted for 12% of the VIT and only accounted for 3% of the random sites. The regeneration forest structure category accounted for 24% of the VIT while was only observed in 15% of the random sites. Timber was the most used forest structure category (60%) for birth sites, but was used less than available (76% occurrence in the random sites).

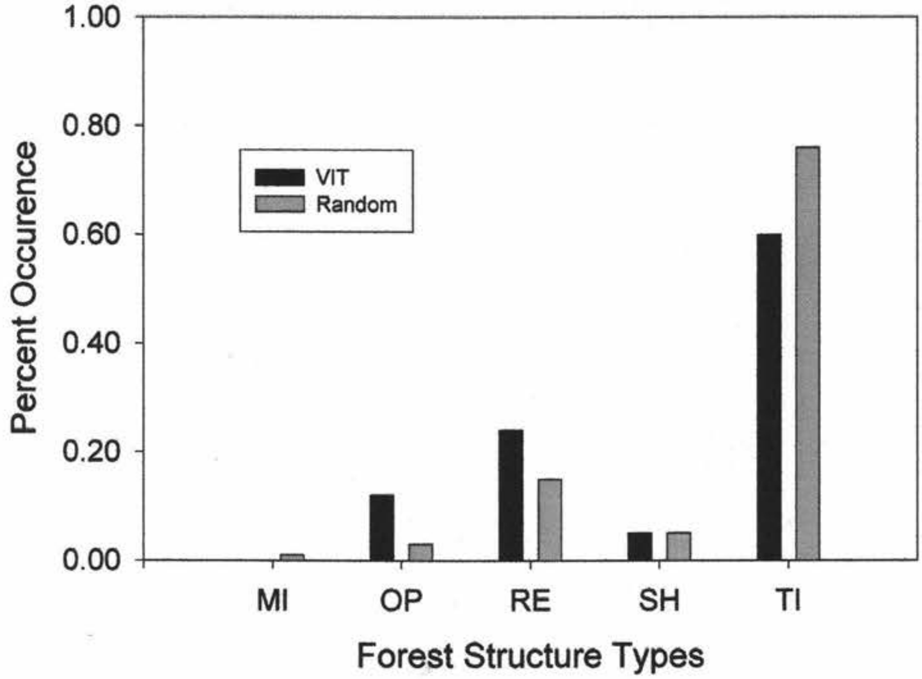

Figure 1.4. The proportion of habitats observed for parturition sites (n=42) from the vaginal implant transmiter (VIT) and the proportion of habitats expected based on random sites (n=80). Habitats are based on the following forest structure types: miscellaneous (MI); open (OP); regeneration (RE); shelterwood (SH); and timber (TI); summers of 2000 and 2001, Umpqua National Forest, Oregon.

We modeled the same *a priori* model structure for each of our hierarchical circular areas around the birth site (Table 1.1). There were 3 competing models (within 2 ΔAIC_c) for the sub-stand area (0.3 ha): the average slope combined with the amount of non-timber; the average slope; and the average slope combined with amount of roads. The best model for the stand area (15 ha) was the average slope combined with the amount of edge. There were 4 competing models (within 2

Table 1.1. The competing models (< 2.0 ΔAICc) for each of the 4 model suites of birth site selection. Subscript notation: substand ($_{SS}$); stand ($_{ST}$); home range ($_{HR}$); and landscape ($_{LS}$). $^{\Psi}$: the variable was not significant (95% confidence interval included zero). Data gathered from the summers of 2000 and 2001, Umpqua National Forest, Oregon. K=number of parameters and w_i=Akaike weight for the model.

SUB-STAND SUITE

Rank	Model Structure	K	AICc	ΔAICc	w_i
1	$Slope_{SS}$ + Amount $Non\text{-}timber_{SS}^{\Psi}$	3	152.537	0.000	0.24
2	$Slope_{SS}$	2	153.425	0.889	0.15
3	$Slope_{SS}$ + $Roads_{SS}^{\Psi}$	3	153.614	1.078	0.14
13	Null	1	159.126	6.589	0.01

STAND SUITE

Rank	Model Structure	K	AICc	ΔAICc	w_i
1	$Slope_{ST}$ + $Edge_{ST}$	3	149.074	0.000	0.31
18	Null	1	159.126	10.052	0.00

HOME-RANGE SUITE

Rank	Model Structure	K	AICc	ΔAICc	w_i
1	$Slope_{HR}$ + $Edge_{HR}$	3	145.985	0.000	0.23
2	$Slope_{HR}$ + Amount $Non\text{-}timber_{HR}$ + $Streams_{HR}^{\Psi}$	4	146.454	0.469	0.18
3	Amount $Non\text{-}timber_{HR}$ + Number of $patches_{HR}^{\Psi}$	3	147.217	1.232	0.13
4	$Slope_{HR}$ + Amount $Non\text{-}timber_{HR}$	3	147.252	1.267	0.12
18	Null	1	159.126	13.141	0.00

LANDSCAPE SUITE

Rank	Model Structure	K	AICc	ΔAICc	w_i
1	$Edge_{LS}$ + $Slope_{LS}^{\Psi}$	3	140.272	0.000	0.48
2	$Edge_{LS}$	2	142.191	1.817	0.19
20	Null	1	159.126	18.651	0.00

ΔAIC_c) for the home-range area (113 ha): the average slope combined with the amount of edge; the amount of non-timber combined with the average slope and the amount of streams; the amount of non-timber combined with the number of patches; and the amount of non-timber combined with the average slope. There were 2 competing models (within 2 ΔAIC_c) for the landscape area (314 ha): the amount of edge combined with the average slope; and the amount of edge.

The first 4 model suites contained the same model structure applied to 4 increasingly larger circular areas. The relative importance of each variable within each model suite was assessed by summing the weights for each individual factor (Table 1.2; Burnham and Anderson 1998). The average slope was the dominant variable in the models for the sub-stand, stand, and home-range area. The average slope within the area decreased in importance as the circular area increased in size, while the amount of edge generally increased in importance with increasing buffer size, and was the most important variable within the landscape area model suite.

Our fifth model suite included all of the models from the nested, circular area approach and models containing site-specific variables to examine which scale best explained birth site selection. The overall best model based on the lowest ΔAIC_c values were the 2 best performing landscape circular area models. The Akaike weights were 0.40 for the model that included the amount of edge within landscape circular area plus the average slope of the landscape circular area and 0.16 for the model amount of edge within the landscape circular area (Figure 1.5).

Table 1.2. A table showing the relative importance of variables for each of the four hierarchical buffered scales. Values were based on the summed re-normalized Akaike weights of models that contained a particular variable. The value of the most important variable within each scale is in bold. Data gathered in the summers of 2000 and 2001, Umpqua National Forest, Oregon.

Variable Name	Sub-Stand	Stand	Home-Range	Landscape
Average Slope	**0.91**	**0.71**	**0.63**	0.60
Amount of Edge	0.06	0.47	0.39	**0.85**
Amount of Non-timber	0.43	0.16	0.61	0.08
Amount of Streams	0.16	0.11	0.32	0.23
Difference in Elevation	0.14	0.16	0.10	0.00
Number of Patches	0.02	0.12	0.19	0.00
Amount of Roads	0.15	0.03	0.05	0.00
Mean Patch Size	0.00	0.13	0.05	0.00
Patch Size Standard Dev.	0.02	0.03	0.05	0.00

We compared the 2 years of birth site data (n=25 for 2000; n=17 for 2001) using the same model structures as we used to compare birth sites with random sites. In the fifth model suite, when all the models were ranked together, there were 15 competing models (within 2 ΔAIC_c), and 1 of these models included the null. Therefore, there was insufficient evidence of between year differences in birth site selection.

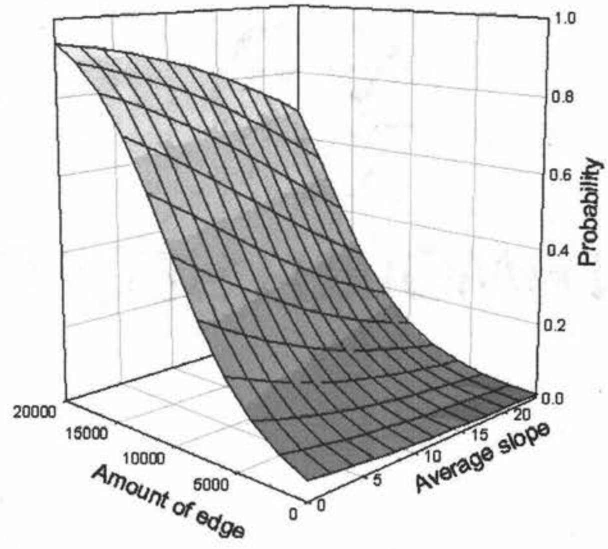

Figure 1.5. The response surface of the best overall model: y=1/(1+exp(-(-2.9643) – (0.000283)*(Amount of edge within the landscape circular area [meters]) – (-0.0810)*(Average slope of the landscape circular area [degrees])). The values of edge and slope were generated from the range of data observed from both birth and random sites. Data gathered in the summers of 2000 and 2001, Umpqua National Forest, Oregon.

DISCUSSION

It is difficult to assess at which scale an animal perceives its environment and resource selection may vary depending on the scale at which it is analyzed (Bond et al. 2002). We used a hierarchical scale approach to examine how adult doe Columbian black-tailed deer perceive their environment when selecting their birth sites. In our study, birth sites were more associated with measures of habitat structure on a large spatial scale (a circular area with a 1,000 m radius from the site). Animals are perceived to not respond to scales beyond their home-range (except with migration and dispersal) and therefore the landscape scale may be difficult to interpret (Bissonnette et al. 1997). However, the resource selection response at the landscape scale may put constraints on selection at finer scales (Bissonnette et al. 1997), and therefore limit the available areas for an animal to establish its home-range, find quality foraging sites, and in this case, select parturition locations. We believe that there could be innumerable potential fine-scale parturition sites available to does in our study area, but the overall environmental context of the region around the birth site is critical. This environmental context was measured in our study by the amount of forest edge and the average slope of the region around the birth site up to 1,000 m away. Other variables that potentially drive resource selection at this scale that we did not address may include the density of other parturient adult does, the distribution of other deer and their home-ranges, and the distribution of predators.

The 3 most dominant variables common to the 4 circular areas used in our hierarchical approach were the average slope, the amount of edge, and the amount of non-timber. As the area around the birth site increases, the average slope decreases in relative importance, and the amount of edge increases in relative importance. The predominance of the amount of edge and the amount of non-timber (i.e., early seral forest) both imply the need for does to readily seek forage. Lactation is a large energy drain on female ungulates (Sadlier 1980) and they must frequently forage in order to meet this increased nutritional demand. It is difficult to interpret the importance of average slope. It could be that parturient does are selecting less steep slopes because of ease of movement or that does are selecting less steep slopes because more logging has occurred on less rugged terrain, and thus more early seral forest was present. The decline in the importance of slope with increasing area is probably due to the fact that the larger areas will likely contain diverse and rugged terrain, and the average slope at these coarser scales becomes similar between birth and random sites.

In the literature addressing ungulate parturition site selection, much of the analysis was based on site-specific environmental variables. Many of our models that included site-specific variables outperformed the null and had variables that were significant. However, these models did not perform nearly as well as models that included variables from larger spatial scales. If we ignore all of the variables derived from the hierarchical spatial scale approach, we had 3 top competing models which were: site-specific slope combined with distance to edge; the concealment cover of a bedded deer combined with the concealment cover of a standing deer; and the site-specific slope. Thirty-eight models from the hierarchical spatial scale approach explained the data better or as good as the 3 listed above, and if a hierarchical approach had not been used, a completely different and weaker inference to the data may have been drawn from only the site-specific measures.

MANAGEMENT IMPLICATIONS

The results of this study demonstrate that flatter slopes, the amount of non-timber, and the amount of edge are strongly associated with birth site selection by adult doe Columbian black-tailed deer. This can be best explained using measures of habitat structure up to 1 km from the birth site. Two early seral stages (open and regeneration) were used disproportionately by does as birth sites and these patches will not be maintained or replaced elsewhere in the area because of the lack of disturbance from decreased timber harvest and increased fire suppression on public lands. Not only do Columbian black-tailed deer use these early seral patches for birth sites, but they also are selecting for habitats at a larger scale that have high edge density and a greater proportion of early seral forest. Under the current disturbance regime, early seral stages will mature and edge density will decline. We do not know how adult parturient does will respond to this potential decline in parturition site habitat, and we suggest further monitoring and research.

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Chapter 2

Survival and habitat selection of Columbian black-tailed deer fawns in western Oregon

Nathan P. Pamplin, Richard A. Schmitz, and DeWaine H. Jackson

INTRODUCTION

Fawns, and in particular neonates (< 10 days old [Bowyer et al. 1998]), represent one of the most critical life-history stages in deer (Jackson et al. 1972). Nearly all black-tailed deer (*Odocoileus hemionus columbianus*) and mule deer (*O. h. hemionus*) populations have a greater mortality rate in fawns than in adults (Connolly 1981). Predation of fawns can be high, even when the population is nutritionally healthy (Hamlin et al. 1984). Summer is the period of highest fawn mortality (Ballard et al. 1999), followed by mortality in late-winter/early-spring (Hines 1975). It is important for wildlife managers to understand fawn mortality for effective population management (Nelson and Woolf 1987, Ballard et al. 1999).

Researchers studying different ungulate populations have identified factors that are associated with variability in neonate survival. Neonate birth weight is associated with survival in deer (Verme 1977, Sams et al. 1996). Birth weight is a reflection of the nutritional state of the mother, fetal maturity, and disease (Gustafson et al. 1998). The birth date can also be an important predictor of survival, particularly if there is birth synchronization in order to swamp predators with neonates (Rutberg 1987). Whittaker and Lindzey (1999) found that parturition date was a good predictor of fawn survival in mule deer and that mule deer benefited from being born later than sympatric white-tailed deer (*O. virginianus*) by being among a greater pulse of fawns. Predator swamping by synchronized fawning has also been shown in pronghorn (*Antilocapra americana*; Gregg et al. 2001). The deer neonatal response to remain motionless when disturbed (alarm bradycardia) is reduced 2 weeks post-partum (Jacobsen 1979). After two weeks, fawn mortality by predators may increase because the neonate will flush rather than hide (Nelson and Woolf 1987).

The resource selection by parturient does may also have important consequences for the survival of their fawns. Does need to balance the increased forage requirement brought on by lactation and, at the same time, select habitats that provide for concealment and predator avoidance for the neonate (Bowyer et al. 1998). Bowyer et al. (1998) reported that black-tailed deer neonates were encountered in habitats with variable cover and sites with grasses, sedges, and forbs. Riley and Dood (1984) found that mule deer fawns used thick cover and mid-slopes as a strategy to avoid predation by coyotes (*Canis latrans*), which typically use ridge tops or valley floors.

In comparison to other members of the genus *Odocoileus*, little is known about Columbian black-tailed deer habitat selection, demographics, and population dynamics because of their elusive nature and the logistical difficulty of studying them in densely forested and mountainous terrain. In this study, we captured newborn Columbian black-tailed deer fawns and monitored their survival and habitat use during their first 10 weeks of life. We used parametric survival modeling to examine which measures of fawn morphometrics and forest habitat structure best predict survival time.

STUDY AREA

The study area was located in the Umpqua National Forest on the west slope of the Cascade Mountains in southern Oregon. The elevation ranged from 580 m to 1,830 m. which was predominately steep ridges interspersed by large, flat areas. The area receives approximately 150 cm of precipitation annually. The most prevalent conifer was Douglas fir (*Pseudotsuga menziesii*); other conifers in the region included ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and incense-cedar (*Calocedrus decurrens*). The most common understory shrubs included Pacific rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), and western serviceberry (*Amelanchier alnifolia*). Potential predators of deer in the region included mountain lion (*Felis concolor*), coyote (*Canis latrans*), black bear (*Ursus americanus*), and bobcat (*Lynx rufus*).

METHODS

We inserted vaginal-implant transmitters (VIT; Bowman and Jacobson 1998), set with a 2 hour motion sensor delay, into adult does to allow us to locate birth sites in 2000 and 2001. Adult does were captured using modified Clover traps (McCullough 1975) baited with alfalfa in the winter and with salt in the spring. Does were also fitted with radiocollars and were located weekly by radio telemetry from a fixed-wing aircraft during the winter and spring and then monitored daily throughout the fawning season.

When we detected that an implant was expelled, we approached the birth site and searched for the neonate. We also opportunistically spotted fawns while driving roads. When a fawn was located, we wore latex gloves during handling to avoid transfer of human scent (Livezey 1990). Fawns were sexed and then weighed using a sling scale. We fitted fawns with 105 g break-away radiocollars (Telonics, Inc., Mesa, AZ) which were programmed with a 5 hour motion-sensor mortality delay. If twins were present at the capture site, both neonates received collars. However, to ensure independent observations, we randomly selected only one fawn for subsequent data analyses. Fawns captured at the birth site were assigned a birth date as the day the VIT was expelled. We determined the birth date for fawns captured opportunistically by hoof eruption (Haugen and Speake 1958). Total handling time was $\leq$ 5 minutes and all animal handling procedures were approved by the Institutional Animal Care and Use Committee of Oregon State University, Corvallis, OR.

Fawns were located at least every other day, but not more than once per day, by triangulation (White and Garrott 1990) from a handheld Yagi antennae and receiver. The Universal Transverse Mercator coordinates were estimated for each location from a minimum of 3 bearings using program Locate II (Nams 1990). Locations with an error ellipse of area greater than 3 ha were censored. Coordinates were also recorded from a United States Geological Survey 7.5 minute quadrangle map when we directly sighted a fawn. If a fawn could not be located from the ground, it was located from a fixed-wing aircraft using radio telemetry.

We delineated a habitat map based on forest structure using 1993 1 m digital orthophotoquads and a 1999 Landsat Thematic Mapper satellite image within a geographic information system (GIS; ArcView, Environmental Systems Research Institute, Redlands, CA). The boundary of the habitat map was drawn from a minimum convex polygon of the winter and spring adult doe locations and then buffered by 2 km in a GIS. We classified habitat using 6 categories: open, regeneration, shelterwood, timber, water, and miscellaneous. The open habitat type consisted of meadows and clear-cut units. The regeneration habitat type were stands of dense, immature pole trees with little understory vegetation. The shelterwood habitat type were silvicultural units that had been logged, but with mature seed trees left behind and evenly spaced throughout the unit. The timber category consisted of old-growth and mature second-growth forest and comprised the majority of the study area. The water habitat type represented man-made holding ponds for hydroelectric water diversion projects in the area, but they did not include the associated hydroelectric canal system or natural streams. The miscellaneous category contained large rock outcroppings and a United States Forest Service ranger station. Both the water and miscellaneous habitat classifications totaled less than 1% of the total study area.

Fawn locations were displayed on our habitat map and forest structure categories were assigned to each location in a GIS. Following Manly et al. (1993) methods for when all available resource units are known within the study area, we assessed fawn habitat use by calculating selection ratios. The ratio was based on the total number of locations (n=393) for all fawns (n=22) using the equation:

$$\hat{w}_i = u_{i+} / (\pi_i u_{++}) \qquad (2.1)$$

where u_{i+} is the number of type i resource units used by all fawns; π_i is the proportion of the available resource for 1 to I habitat types; and u_{++} is the total number of resource units used by all fawns (Manly et al. 1993). Manly et al. (1993) recommends this technique for ratio estimation versus using an average of each individual fawn habitat selection ratio because ratios of totals have less bias and variance than using the average of ratios. The variance of the ratio was estimated using the equation:

$$\mathrm{var}(\hat{w}_i) = \{\sum_{j=1}^{n} u_{ij}/\pi_i - w_i u_{+j})^2 /(n-1)\}\{n / u_{++}^2\} \qquad (2.2)$$

where u_{ij} is the number of type i resource units used by fawn j; and u_{+j} is the total number of units used by fawn j (Manly et al. 1993). Bonferroni confidence intervals were assigned using the equation:

$$\hat{w}_i \pm z_{\alpha/(2I)} \mathrm{se}(\hat{w}_i) \qquad (2.3)$$

where α is adjusted by twice the total number of habitat categories (I; Manly et al. 1993). If the confidence interval of the selection ratio includes 1, then we interpreted that the use of resources was equivalent to available resources. If the ratio was above 1 (and did not include 1 in the confidence interval), then we concluded that fawns used that forest structure category more than what was available and if the ratio were lower than 1 (and did not include 1 in the confidence interval), then we concluded that fawns used that category less than what was available. We did not include capture locations and mortality locations in our habitat selection analysis, and we right censored all locations after 76 days of life (Pollock et al. 1989).

Survival was monitored daily from the estimated birth date to 76 days. When a radiocollar indicated that a fawn had died, we approached the carcass as quickly as possible to determine the cause of death (O'Gara 1978, Steigers and Flinders 1980, Wade and Bowns 1984). We estimated survival rates using the Kaplan-Meier product-limit estimator (Kaplan and Meier 1958). We used the Cox and Oates (1984) estimate of variance in our calculations of 95% confidence curves.

We modeled survival using the SAS procedure LIFEREG (SAS Institute 1997) by fitting a Weibull distribution to the data. We used an information-theoretic approach as our model selection strategy to list 61 *a priori* models which were then ranked by the small sample size bias corrected form of Akaike's Information Criterion (AIC_c; Akaike 1973, Burnham and Anderson 1998). Models within two ΔAIC_c values were considered competing models (Burnham and Anderson 1998). Covariates (Table 2.1) included capture weight, sex, study year, capture method (either at birth site or opportunistically), and the estimated date of birth (Julian days). We also used the quadratic of date of birth to determine if fawns born at either the tails or within the main pulse of the fawning distribution influenced survival as seen with pronghorns (Gregg et al. 2001). Fawn movement

Table 2.1. List of variables and units used in modeling survival of fawns from estimated birth date to 76 days, summers of 2000 and 2001, Umpqua National Forest, OR. Subscripts: $_{LS}$ = variable calculated from a circular area of 1,000 m radius from capture site, $_{HR}$ = variable calculated from a circular area of 600 m radius from capture site.

Variable Name	Units
Weight	kg
Sex	1 for male, 0 for female
Estimated date of birth	days
Estimated date of birth squared	$days^2$
Study year	0 for 2000, 1 for 2001
Capture technique	1 birth site, 0 opportunistic
Maximum distance	m
Distance to censor	m
$Edge_{LS}$	m
$Slope_{LS}$	degrees
$Streams_{LS}$	m
Amount $non\text{-}timber_{LS}$	proportion
$Roads_{LS}$	m
$Slope_{HR}$	degrees
$Edge_{HR}$	m
Amount $non\text{-}timber_{HR}$	proportion
$Streams_{HR}$	m

covariates included the distance from the capture site to where it was censored (called distance to censor) and the maximum distance from where we located a fawn to its capture site, both of which were calculated in a GIS.

We also included covariates based on the habitat around the capture site. Chapter 1 identified that the habitat around birth sites within a radius of 1,000 m best explained birth site selection. We used the variables from the top competing models found in Chapter 1 from the 2 largest scales: the home-range circular area (radius equal to 600 m from the capture site) and the landscape circular area (radius equal to 1,000 m from the capture site). These variables included: the amount of edge (between 2 forest structure patches) and the average slope at the landscape circular area; the amount of edge (between adjacent habitat patches), the average slope, the amount of non-timber (the proportion of area of habitat patches that did not include the timber category), and the amount of streams of the home-range circular area. We also included variables at this scale for the amount of streams, the amount of non-timber, and the amount of roads within the landscape circular area because that scale provided the best explanation from the birth site modeling in Chapter 1. Because opportunistic fawns were not captured at the birth site, values for these variables were calculated based on their capture coordinates. We knew the age of opportunistically captured fawns based on hoof eruption and assumed that these fawns were in close proximity to their actual birth site.

We also examined the relative variable importance by comparing the sum of the re-normalized Akaike weights of models (only included the models in the upper 95% of the model suite) that contained a variable of interest (Burnham and Anderson 1998).

RESULTS

We captured 23 fawns; 10 in 2000 and 13 in 2001. Nineteen of the fawns were captured at the birth site and 4 were captured opportunistically. The average neonate weight at capture was 3.01 kg (SE=0.15). The average weight for male neonates was 3.40 kg (SE=0.19, n=13) and was 2.68 kg (SE=0.19, n=10) for females. We used Welch's 2-sample t-test (Ramsey and Schafer 1997) to compare differences in weight by sex and found that males were significantly larger than females (t-statistic=2.71, d.f.=20, P<0.01).

We analyzed resource selection by comparing the proportion of each forest structure category used for the total sample of fawns to the proportion of the forest structure type within the boundary of our study area (Figure 2.1). Both open and shelterwood patches were used more than their availability (ratios significantly greater than 1.0; Table 2.2). Open habitat had selection ratios which were high,

Table 2.2. Selection ratios (Manly et al. 1993) of forest structure categories used by fawns and 95% confidence intervals, summers of 2000 and 2001, Umpqua National Forest, OR.

Forest Structure	Ratio (w_i)	Lower 95% CI	Upper 95% CI
Open	12.89	10.98	14.80
Regeneration	1.13	0.92	1.35
Shelterwood	1.81	1.19	2.42
Timber	0.91	0.87	0.96

suggesting a strong selection by fawns. Timber was used significantly less than available, but was the most used habitat type by the fawns. Use by fawns of regeneration patches was not significantly different from 1.0.

Nine fawns survived 76 days and most mortality was attributed to predation (Table 2.3). The Kaplan-Meier survival estimate at 76 days was 44% (95% confidence interval=23-66%; Figure 2.2). Two fawns lost their collars and were right censored at 19 and 23 days. We were able to positively identify the predator species in 5 of the 9 predator-caused mortalities, which included bobcat, coyote,

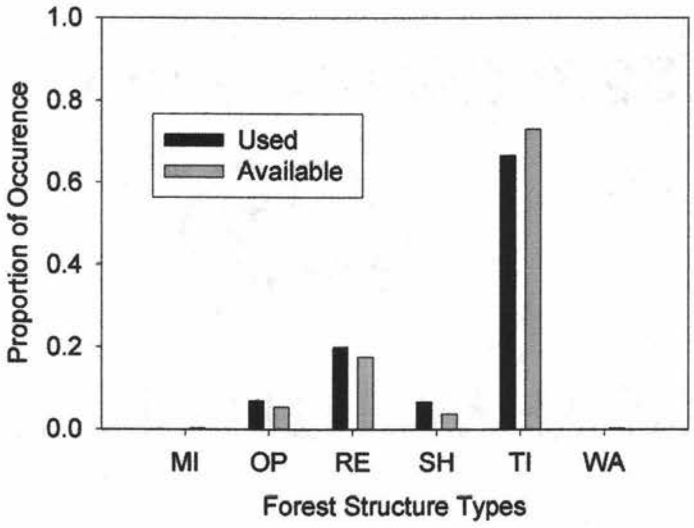

Figure 2.1. Proportions of habitats used by fawns from locations (n=393) and proportions of available habitats, summers of 2000 and 2001,Umpqua National Forest, OR. Habitats are based on the following forest structure types: miscellaneous (MI); open (OP); regeneration (RE); shelterwood (SH); and timber (TI).

Table 2.3. Summary of fates for fawns (n=23) over 76 days, summers of 2000 and 2001, Umpqua National Forest, OR.

Fate	Number of fawns
Predation Total	9
Bobcat	2
Coyote	1
Bear	1
Unidentified	5
Drowned	1
Entrapment	1
Runt	1
Lost collar before 76 days	2
Alive at t=76	9

and black bear. Although, we did not identify a cougar kill of a fawn in our study area, we did see cougar kills of fawns outside of our study area and we had numerous adult does killed by cougars within our study area. We had 1 fawn that died within 1 day of birth, and she was surmised to be a runt, weighing 1.3 kg. The fawn only moved 10 m from the birth site before expiring, and while abandonment cannot be ruled out, it had rained overnight and may have died from exposure and being underweight. We also had a fawn that died because it had fallen into a rotted-out stump at 3 days old and could not climb out (entrapment). Another fawn

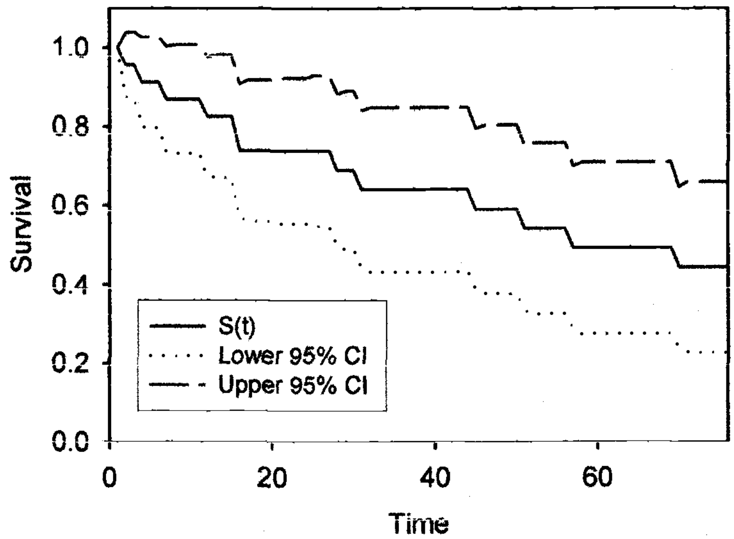

Figure 2.2. Kaplan-Meier survivorship curve of fawns (n=23) from estimated birth date to 76 days of life and associated 95% confidence interval curves. $S(t_{76})$=0.44 (95% CI=0.23-0.66), summers of 2000 and 2001,Umpqua National Forest, OR.

was discovered in 1 of the man-made water holding ponds over 5 km from his last known location.

We modeled survival using fawn morphometrics, capture site landscape metrics, and movement variables. The best model in our suite (Table 2.4) was the amount of roads within a 1,000 m of the point of capture and there were no competing models (within 2.0 ΔAIC_c values of the top model). The null model was ranked 13 among the other models and was 6.123 ΔAIC_c values below the top model. The sign of the coefficient of roads indicated that the increasing concentration of roads within 1,000 m of the capture site increased the probability

Table 2.4. Thirteen of the 61 survival models fitted using the Weibull distribution, summers of 2000 and 2001, Umpqua National Forest, OR. K=number of parameters and w_i=Akaike weight. Subscripts: $_{LS}$ = variable calculated from a circular area of 1,000 m radius from capture site and $_{HR}$ = variable calculated from a circular area of 600 m radius from capture site.

Model Structure	K	AIC_c	ΔAIC_c	w_I
$Roads_{LS}$	3	62.467	0.000	0.293
$Roads_{LS}$ + Date of Birth (DOB) + DOB^2	5	64.691	2.224	0.096
$Roads_{LS}$ +Weight	4	64.706	2.239	0.096
$Roads_{LS}$ + DOB	4	65.214	2.747	0.074
$Slope_{LS}$ + DOB + DOB^2	5	65.915	3.448	0.052
$Slope_{LS}$ + Study Year	4	66.116	3.649	0.047
$Slope_{LS}$	3	66.527	4.060	0.038
$Slope_{HR}$	3	66.707	4.240	0.035
$Slope_{LS}$ + Distance max	4	67.926	5.459	0.019
Sex	3	68.081	5.614	0.018
$Slope_{LS}$ + Distance to censor	4	68.396	5.929	0.015
Sex + DOB + DOB^2	5	68.555	6.088	0.014
Null	2	68.590	6.123	0.014

of survival (Table 2.5) and that survival drops precipitously in regions with low road density (Figure 2.3). The scale parameter was 1.0383 indicating that the hazard function decreased over time (Allison 1995). We were interested to determine if the presence of roads within the landscape circular area was associated with the amount of edge and amount of non-timber. We used PROC CORR in SAS (SAS Institute 1997) to determine if the amount of non-timber and the amount of edge within the landscape circular area were correlated with the amount of roads since roads were typically constructed to facilitate silvicultural operations. The Pearson correlation coefficient was 0.19 (P=0.38) between the amount of roads

Table 2.5. Coefficients and standard errors of our top survival model fitted to the Weibull distribution for survival of fawns (n=23) from estimated date of birth to 76 days, summers of 2000 and 2001 in the Umpqua National Forest, OR.

Variable	Coefficient	Standard Error
Intercept	2.2240	0.7799
Road density within the landscape area	0.0050	0.0002
Scale	1.0383	0.2660

and the amount of edge within the landscape circular area and was 0.02 (P=0.93) between the amount of roads and the amount of non-timber within the landscape circular area; thus neither are correlated with roads.

The relative importance of variables (based on the sum of re-normalized Akaike weights of models that included the variable of interest) was assessed and the amount of roads at the landscape scale scored highest, followed by the estimated date of birth (Table 2.6). The sign of the coefficient for models containing the variable for the estimated date of birth was positive indicating that fawns born later in the spring had a higher probability of survival, although this coefficient was never significant (95% confidence interval includes 0).

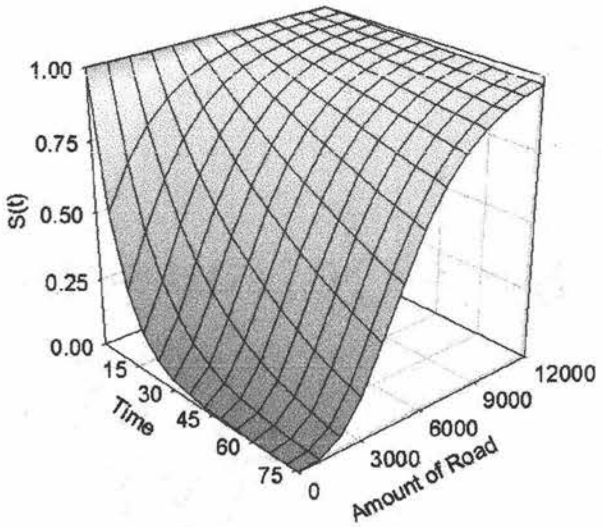

Figure 2.3. Response surface of the top survival model fitted to a Weibull distribution: $S_i(t)=\exp\{-[t_1 e^{-(2.2240+0.005(\text{Amount road at landscape scale})}]^\wedge(1/1.0383)\}$, summers of 2000 and 2001, Umpqua National Forest, OR. Values of time are from 1 to 76 days and the amount of road within a 1,000 m radius of capture site ranged from 0 to 12,000 m.

DISCUSSION

Our study suggests that more roads within 1,000 m of the capture site of neonates are associated with higher fawn survival. We modeled survival of fawns using capture morphometrics, date of birth, distances moved from the capture site, and variables that measured the habitat and topography at large spatial scales around the capture site. Road density may be an important predictor of fawn survival in a way that we did not characterize in this study. The increased vegetation alongside roads due to more light reaching the forest floor and more

Table 2.6. Relative variable importance in our fawn survival model suite. The score is the sum of the re-normalized Akaike weights of models in the upper 95% of the model suite (31 of 61 models) that contained the variable of interest. Only variables with values greater than 5% are reported. Survival data gathered in 2000 and 2001 in the Umpqua National Forest, OR.

Variable	Score
Roads within landscape area	0.59
Estimated date of birth	0.27
Estimated date of birth squared	0.17
Average slope within the landscape buffer	0.17
Weight	0.13
Study year	0.07

moisture due to road drainage (Forman and Alexander 1998) could provide a unique habitat feature that benefits fawns by either increasing the forage base or the concealment cover.

Road density may also be an important predictor of fawn survival because of the predator response to the presence of roads. Bobcats have been shown to avoid habitats in close proximity of roads (Lovallo and Anderson 1996). Predators may also avoid roads because of hunting pressure (Brody and Pelton 1989). There was one highway that bisected the study area, but the majority of all of the other roads in the study area were gravel. Traffic was light on all of these roads (excluding the highway) during the spring and summer, with the researchers for this study comprising the majority of the traffic. Because we were locating fawns from the ground, it may have benefited fawns captured within a heavily roaded area because that area experienced more traffic disturbance because of our intensive efforts trying to locate the fawn via triangulation. Therefore, our presence may have influenced fawn survival in this study by influencing the presence of predators in the region. Fawns that were captured in low road density areas lived in habitats that received less disturbance from us and potentially had higher levels of predators than high road density areas.

Riley and Dood (1984) reported that fawns selected habitat with dense vegetative cover while Bowyer et al. (1998) concluded that the forage quality and abundance were important aspects of habitat selection by a Columbian black-tailed doe and her neonate. Our results of the early, more open seral stage forest being used more by fawns than their availability supports the Bowyer et al. (1998) conclusion.

We had 1 fawn die because of drowning, and another died when it fell into a hole and could not climb out at 3 days old. Although these deaths on the surface appear rare, Hamlin et al. (1984) had a mule deer fawn accidentally die when it fell into a mud-hole and Steigers and Flinders (1980) saw multiple mule deer fawns that were born on islands and drowned as they attempted to cross rivers. We believe that accidental deaths may be an important, yet often overlooked, component of fawn mortality.

MANAGEMENT IMPLICATIONS

We encourage researchers to more thoroughly examine the effect of roads on the survival of Columbian black-tailed deer fawns. Our results indicated that roads within the landscape circular area (1,000 m radius of capture site) were a good predictor of fawn survival and outperformed traditional measures of fawn morphometrics, date of birth, and movement. We do not know the mechanism for why this was the case. The presence of roads may have a direct, positive relationship with the survival and presence of fawns, and/or a negative relationship with the survival and presence of predators.

Columbian black-tailed deer fawns used open and shelterwood units more than their availability and used timber less than what was available in our study area. Currently, public land managers in western Oregon have decreased the rate of timber harvest and maintain a policy of large-scale fire suppression. This minimizes the disturbance regime in the forest, which would otherwise maintain and promote new patches of open stands. The fawn habitat selection response to the decline in early seral stage forest over time is unknown but warrants further investigation.

Researchers typically have captured neonates for habitat and survival studies by using several techniques including: observing parturient does (Ozoga et al. 1982, Whittaker and Lindzey 1999); observing a doe tending her fawn (Nelson and Woolf 1987); actively searching for fawns in known fawning areas (Steigers and Flinders 1980, Hamlin et al. 1984, Riley and Dood 1984, Nelson and Woolf

1987, Ballard et al. 1999); and opportunistically spotting fawns while performing other tasks (Bowyer et al. 1998). The vaginal-implant transmitter was instrumental for us to obtain an adequate sample size as other fawn capture techniques would be problematic in the dense vegetation and rugged terrain of western Oregon. We had 2 fawns of our 21 fawns captured at the birth site die within 3 days of life ($S_{t=3}$=90 %). We strongly encourage researchers to capture neonates at the birth site to avoid overestimating summer fawn survival by excluding mortalities that occur within the first few days of life.

ACKNOWLEDGMENTS

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Chapter 3

Evaluation of vaginal-implant transmitters to locate birth sites and neonates of Columbian black-tailed deer in western Oregon

Nathan P. Pamplin, Richard A. Schmitz, and DeWaine H. Jackson

INTRODUCTION

The Oregon Department of Fish and Wildlife (ODFW) conducts annual spotlight counts from ground vehicles to monitor Columbian black-tailed deer (CBTD; *Odocoileus hemionus columbianus*) population trends in western Oregon. The counts have dropped from 5,014 in 1996, to 2,885 in 1997, and to 2,560 deer spotted in 1998 (ODFW 1996-1998). It is unknown whether or not the observed decrease was an actual population decline or due to reduced silvicultural activity along transect routes which resulted in better concealment for deer. ODFW needs to assemble a complete picture of CBTD demography for quantitative assessment of population dynamics. ODFW identified fawn survival as an important gap in their current knowledge of demography.

Survival of neonate ungulates has been largely ignored by researchers because of the difficulty in locating birth sites. Typically, neonates are captured and radiomarked by observing behavior of pregnant females as they reach parturition (White et al. 1972, Steigers and Flinders 1980, Bowyer et al. 1999, Gregg et al. 2001). Ground searches near suspected fawning areas (Bowyer et al. 1998) or opportunistic captures, such as spotting neonates while driving roads or while performing other study duties (Bowyer et al. 1998, Bowyer et al. 1999) also allow researchers to radiomark neonates. Garrott and Bartmann (1984) used a surgically implanted vaginal transmitter to locate birth sites but had limited success due to severe trauma caused to the doe when the transmitter was expelled.

Bowman and Jacobson (1998) used a vaginal-implant transmitter (VIT) that did not involve sutures in 16 white-tailed deer (*O. virginianus*) and suggested that the use of VIT were safe for does.

We used VIT to locate birth sites and capture neonate CBTD in the Umpqua National Forest in Oregon. Because CBTD live in habitat that provides thick concealment cover, reliance on observation of parturient does alone would have been inadequate. We present an evaluation of the performance and usefulness of VIT to locate birth sites and newborn fawns. The use of VIT also enabled us to determine the approximate time of day of birth, the distribution of birth dates during the fawning season, and the habitat selection of a parturient doe.

STUDY AREA

Our study area was located in the Umpqua National Forest, which is on the west slope of the Cascade Mountains in southern Oregon. The 23,016 ha study area centered around the Toketee Ranger Station, administered by the United States Forest Service (USFS). This area was selected because it is known to be a historical summer range for CBTD. ODFW has also used this area for previous adult CBTD survival studies and our birth site and fawn survival information would complement other ongoing research projects. We defined the study area boundary by drawing a minimum convex polygon around aerial winter and spring doe locations, and then buffered by 2 km in a geographic information system (GIS; ArcView, Environmental Systems Research Institute, Redlands, CA).

The forest in the area is both compositionally and structurally diverse. The most common conifer is Douglas fir (*Pseudotsuga menziesii*). Other conifers in the region include ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and incense-cedar (*Calocedrus decurrens*). Primary understory shrubs include Pacific rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), and western serviceberry (*Amelanchier alnifolia*). While much of the Umpqua National Forest in this area is mature timber, the area is dotted with numerous silvicultural units averaging 15 ha in size and composed of clear-cuts, regeneration, and shelterwood stands. The elevation of the study area ranges from 580 m to 1,830 m and receives approximately 150 cm of precipitation annually.

METHODS

We used modified Clover traps (McCullough 1975) baited with alfalfa hay from February to April and baited with salt in May to capture adult does. Captured does were physically restrained with 2 people and blindfolded to minimize stress (Beringer et al. 1996). Deer age was determined by tooth eruption (Severinghaus 1949). We only included adult does (>2.5 years) in our sample because of the higher percentage of pregnancy and we wanted to minimize the chance of implanting a non-pregnant doe. Thomas (1983) found on Vancouver Island that the pregnancy rate for CBTD was 0% in fawns (0.5 years), 85% in yearlings (1.5 years) and >93% in adults.

We wanted to verify, post-release, if the adult does that we had implanted were pregnant. We drew 10 ml of blood from the jugular vein, which was later centrifuged and 2 ml of serum was extracted and frozen. The serum sample was analyzed for progesterone (P4) to determine pregnancy (Weber and Wolfe 1982, Wood et al. 1986); sample analyses were processed by the Reproductive Endocrine Laboratory, Department of Biomedical Sciences, College of Veterinary Medicine, Oregon State University, Corvallis, OR. In 2001, we also collected serum from yearlings and from recaptured does that were implanted in the previous year.

Does were fitted with radiocollars (Model 500-56A, Telonics, Mesa, AZ) and ear-tagged. A 18.9 g VIT (SirTrack Limited, NZ) was lubricated with Chlorhexidine and inserted into the vaginal canal with a PVC applicator (Figure 3.1) with the antennae pointing posteriorly (Figure 3.2). The applicator had 2 tubes; the outer 1.9 cm (3/4 inch) PVC pipe was 13.5 cm long that joined a "T" connection, which was drilled to allow a longer 30 cm rubber tube to slide inside it. The flexible VIT arms were folded inside the PVC applicator with the VIT antennae threaded into the inner tube. When loaded, the inner tube was pushed back the length of the folded VIT. The arms of the VIT were aligned parallel with the "T" PVC connection so that we could know the position of the arms within the applicator. We inserted the VIT so that the arms were horizontal within the doe and until the "T" connection came into contact with the labia. Once the applicator was inserted, the inner tube was pushed slightly forward until the wings were clear of the outer PVC pipe. The outer PVC tube was then pulled out of the vaginal

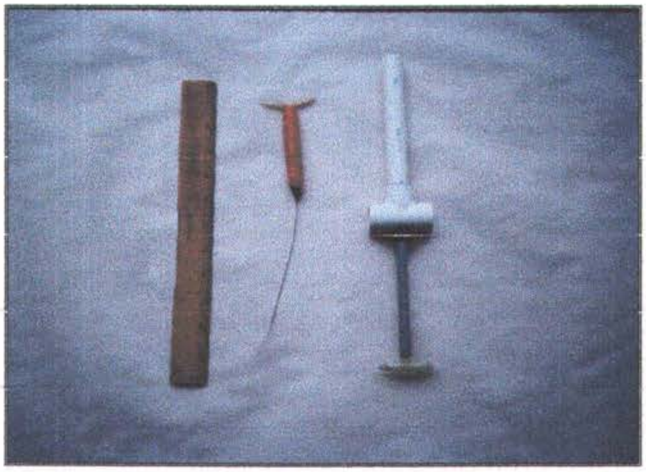

Figure 3.1. Photograph showing vaginal-implant transmitter (center) and applicator (right). Ruler is 30.5 cm (1 foot).

canal while the inner tube was held motionless to keep the VIT in place. The VIT was then completely inserted and the applicator was pulled away, unthreading the antennae which remained outside the vaginal canal.

In the 2000 field season, the VIT was designed to begin transmitting after it was motionless for 2 hours, indicating that it was expelled. In the 2001 field season, we modified the VIT so that it would continuously transmit a signal beat every 3 seconds, and then transmitted at a more rapid rate of 1 beat per second after it was motionless for 2 hours. Doe response to the implant was generally calm or with some slight kicking. Trapping efforts ceased at least 2 weeks before fawning was predicted to begin to minimize potential birth complications associated with

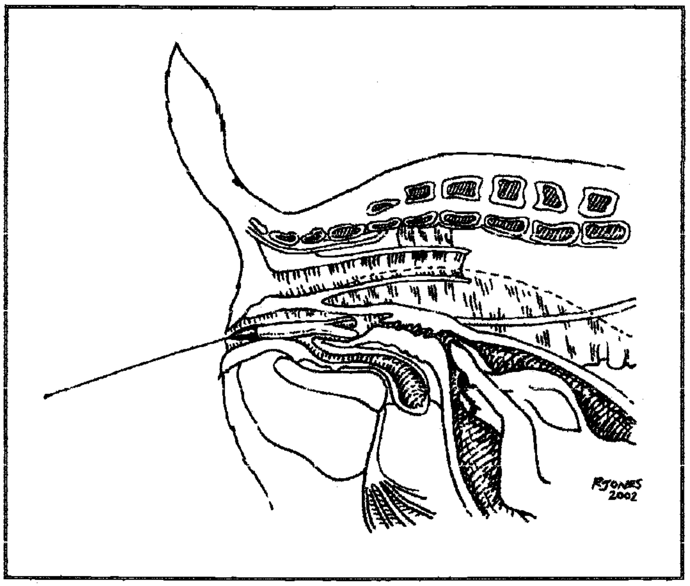

Figure 3.2. Drawing showing the placement of the vaginal-implant transmitter *in situ*. (Figure drawn by R. Jones, 2002.)

stress from handling. All animal handling procedures were approved by the Institutional Animal Use and Care Committee at Oregon State University, Corvallis, OR.

We checked VIT signals daily with TR-2 receivers (Telonics, Mesa, AZ) at the start of the year 2000 fawning season. About mid-fawning of 2000 and throughout all of the fawning season in 2001, we checked the status of the VIT 3 times per day. Once the VIT signal indicated that it was expelled, we attempted to locate it using 1 to 6 people. The expelled VIT was used as a starting point for our search for a fawn. Once we located a fawn, we sexed, weighed, and fitted the fawn with an expandable break-away collar (Model 305-56A, Telonics, Mesa, AZ) that had a 5.5 hour mortality sensor. Surgical gloves were worn to help prevent the transfer of human scent onto the fawn to avoid abandonment (Livezey 1990). After handling the fawn, we immediately left the area and did not actively look for a twin. However, if a twin was located incidentally, then it was also radiocollared.

RESULTS

Trapping

Thirty-six adult does were implanted with VIT in 2000 and 32 in 2001 for a total of 68 VIT. We intentionally did not re-implant does in 2001 that were included in our 2000 sample; therefore, our 2 sample sizes were independent. We had 657 trap nights (i.e., a trap night is 1 trap open 1 night) in 2000 and 838 trap nights in 2001. We increased our trap effort in 2001, especially in the spring using salt, because we had experienced good success with trapping during that time period in 2000. In 2000, we had 237 trap nights in May using salt while in 2001 we had 527 trap nights in May.

VIT performance

Out of the 36 VIT implanted in 2000, 25 worked as designed and identified birth sites within our study area boundary. The remaining 11 VIT were accounted for as follows: 3 were found on birth sites outside our study area; 2 were retrieved in the fall; 4 does died before they gave birth (3 due to predation, the other had fallen off a cliff); and 2 VIT whose status was unknown. One of the unknown fate VIT was in a doe that died in the fall, but the VIT was never found. Therefore, 1 VIT in 2000 may have either still been implanted in the doe and she was not pregnant or the VIT was expelled and failed. One of the 2 VIT found in the fall was on a birth site well outside our study area and we may have missed the VIT coming out in the spring with our aerial flights. The other VIT that was found in the fall was not located on either a birth site or deer trail and we are uncertain as to what happened to this particular VIT.

Out of the 32 VIT implanted in 2001, 17 were associated with birth sites within the study area. The remaining 15 VIT were accounted for as follows: 2 were found on birth sites outside the study area; 2 were expelled prematurely; 4 does died before they gave birth; and 7 VIT failed prior to parturition. The 7 failed VIT were all implanted during our winter trapping, and presumably the batteries did not have sufficient charge to last until fawning as was originally calculated. One of the 7 failed VIT was coincidentally found and returned to us by a utility worker. One of our VIT, not included in the failure category, was in a rapid signal mode while still in a doe for over 2 weeks before it was eventually expelled. We were able to identify the birth site, but were unsure about the exact date of birth. We primarily relied on aerial telemetry to determine when this particular VIT was separate from the doe. The cause of death for 3 of the 4 does in 2001 that died before fawning was capture myopathy (Berlinger et al. 1996). It was unseasonably warm during our spring capture efforts, and does already stressed from being handled in the trap, with the addition of heat exhaustion, probably caused their deaths.

Out of the 25 birth sites in 2000, 19 of the VIT were directly located on scratched-out birth sites and in 2001, 17 of the 18 VIT were found on scratched-out birth sites. The other VIT were usually located on deer trails adjacent to birth sites. Presumably, the doe was nearing parturition and as the vaginal canal dilated, the VIT slid out. The mean distance between the location of the expelled VIT and the doe capture sites was 1,737.23 m (n=43; SE=337.05).

Birth date distribution

The mean birth date for 2000 was 14 June (n=25), and for 2001 was 16 June (n=18). The combined mean from both years was 14 June. Fawning ranged from 29 May to 8 July in 2000 and from 8 June to 16 July in 2001 (Figure 3.3).

In 2000, we did not know the status of the VIT while inside the does. When we could not hear a signal from a VIT, it meant that either the VIT was still implanted and working as designed, or that the VIT had been expelled and that we were not getting close enough to detect a signal. We flew almost weekly to check the VIT status. Six of the VIT were assigned birth dates as the date they were detected from the air and the exact date of birth between the 2 flights was not known. We improved signal detection in 2000 as we learned how close we needed to be to detect the VIT. Also, as the field season progressed, we were more familiar with each doe's general location and we had identified better locations for checking VIT status as fawning progressed. In 2001, the modified VIT operated much like a mortality signal in a radiocollar, so we knew if the VIT was still implanted or if it was expelled.

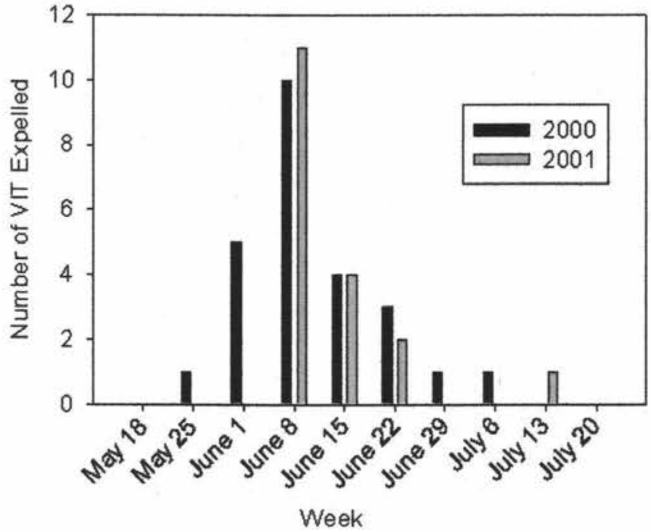

Figure 3.3. Number of vaginal-implant transmitters (VIT) expelled each week during the fawning season for 2000 and 2001, Umpqua National Forest, Oregon.

By checking the VIT multiple times per day, we were able to more precisely detect the time of day that the birth had occurred. We were able to successfully do this for 9 times in 2000 and for 15 times in 2001. Our VIT checks occurred in three time frames: 6-9 am, 12-2 pm, and 5-7 pm and births were classified as over-night, mid-day, and afternoon, respectively. For 2000, 78% of the does gave birth over-night and 22% gave birth mid-day. For 2001, 53% were over-night, 7% were mid-day, and 40% were afternoon births.

Serum progesterone and pregnancy

Wood et al. (1986) reported success with progesterone analysis in mule deer to identify pregnancy. They found that there is a reliable dichotomy between pregnant and non-pregnant mule deer (values lower than 2.0 ng/ml were not pregnant), but that the progesterone analysis for pregnant and non-pregnant white-tailed deer yielded overlapping results in the 1.0 to 2.0 ng/ml range, but otherwise could be diagnostic. We could not find in the literature any progesterone levels reported for CBTD.

Progesterone levels (ng/ml) in does in our study ranged from 1.79 to 7.14 in 2000 (n=35) and from 1.97 to 6.41 in 2001 (n=32; Figure 3.4). One doe in 2000 that received a VIT did not have blood drawn, but was determined to be pregnant from palpation. Yearlings in 2001 ranged from 0.23 to 4.56 ng/ml (n=6) and recaptured 2000 does in 2001 ranged from 1.48 to 8.19 ng/ml (n=4). Of the 2 does that received VIT, which had progesterone values less than 2.0 ng/ml, 1 was pregnant and we captured her fawn, and the other died before giving birth and the status of her pregnancy could not be determined because the carcass was scavenged. All of our other does that received VIT were pregnant based on Wood et al. (1986) mule deer values. Pregnancy status was not verified for the yearlings caught in 2001 and for the adult does used in 2000 that were recaptured in 2001.

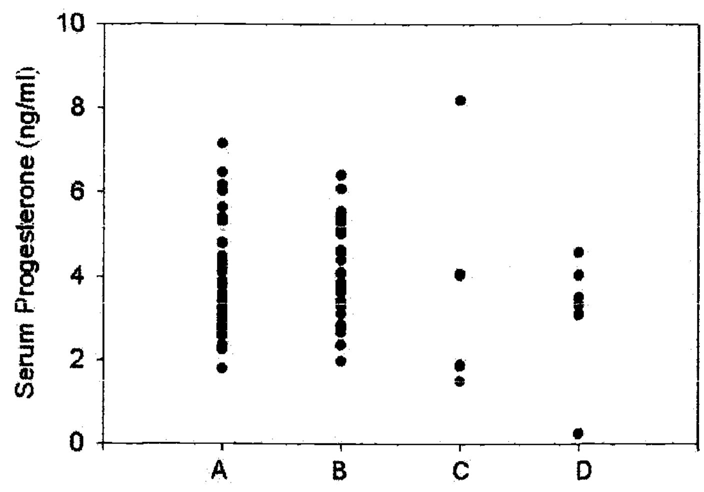

Figure 3.4. Serum progesterone (ng/ml) results for 2000 adult does (A; n=35), 2001 adult does (B; n=32), 2001 recapture of 2000 adult does (C; n=4), and 2001 yearlings (D; n=6); Umpqua National Forest, Oregon.

Doe fate

Doe radiocollar mortality signals were monitored weekly from time of capture until May and then daily from May until the third week of September. One doe in 2000 died during the winter after she fell off a cliff. Three does in 2000 were preyed upon during the fawning time period, and their deaths did not appear to be related to the presence of the VIT or associated with our handling. No does died during the fawning time period in 2001. Of both study years, only 1 doe died during the summer as a result of poaching. We lost 3 pre-parturient does to capture myopathy in 2001 (Beringer et al. 1996). These 3 does all died during our spring trapping efforts when it was unseasonably warm, which increased stress on these does. Our results suggest that using VIT does not affect the survival of implanted does.

Capturing neonates

In 2000, we found 11 fawns at the birth site. We found 7 singletons and we found 2 sets of twins. In 2001, we found 11 singleton fawns at their birth sites. The success of finding a neonate at the birth site in our study area was 44% in 2000 (the number of fawns found divided by the number of identified birth sites) and 61% in 2001. This increase can largely be attributed to 2 things: the VIT signal modification made in 2001 so that we knew the status of the VIT while in the doe; and checking the VIT status at least 3 times per day throughout the fawning season.

DISCUSSION

Overall, the VIT performed well and was a useful tool enabling us to locate birth sites and radiomark neonate CBTD. The rugged terrain and the dense vegetation in western Oregon are not conducive to locating fawns opportunistically or from observing parturient doe behavior in order to find neonates. The VIT allowed us to capture fawns that other sampling techniques would potentially miss. For instance, 2 fawns were found dead upon our arrival at the birth site, 1 fawn died within 24 hours because it was a runt (it was less than 50% of the average fawn weight), and another fawn died with 3 days of birth because it became entrapped in a hollowed-out stump.

Locating birth sites promptly and capturing neonates was a very laborious process, despite using technology to identify the birth site. We were operating 7 days per week for 6 weeks and often 16 hours per day in order to check the status of VIT 3 times per day. We used from 1 to 6 personnel, including volunteers, while in the field. Because of the size of the study area, we assigned personnel into 3 vehicles to cover deer ranging over the 23,000 ha study area. At the same time as listening for the status of VIT and trying to locate does, fawns were being captured and monitored, and the habitat of birth and random sites were being studied.

We were initially concerned about the handling of does while implanting a VIT and debated on whether to use tranquilizers. We recommend that researchers manually restrain deer within the trap because the does did not respond with reactions greater than general discomfort. In our opinion, the reaction of does to implanting VIT does not warrant the use of tranquilizers, which would only complicate the handling process and increase the handling time.

We were also concerned about how early in the winter we should begin trapping. We wanted to balance having enough time to capture does, without implanting VIT too early to cause the battery life to run out before fawning or to have the VIT be absorbed by vaginal tissue (Bowman and Jacobson 1998). We felt that trapping up to 4 months from the peak of fawning was adequate. We were able to surpass our target of 30 does for each field season and the battery life problems we had in 2001 were due to poor batteries and not due to miscalculations of battery life. We found no tissue on the VIT indicating that they had been absorbed and then torn out during parturition.

Our results from the serum progesterone analysis indicate that for CBTD there was some overlap between pregnant and non-pregnant does as Wood et al. (1986) reported for mule and white-tailed deer. Therefore, the test was not as diagnostic as we had hoped and we could not make the conclusions about the pregnancy status of the does that received VIT that failed in 2000 and 2001, and the adult does that received VIT in 2000 and that were recaptured in 2001. Future researchers who are working with mammals that do not have a high rate of pregnancy in adults should use either a portable ultrasound to identify pregnancy (Smith and Lindzey 1982) or to capture animals late enough in gestation when palpation for a fetus may be possible.

The design of the VIT was modified in 2001 from 2000 to continuously transmit a signal and the pulse rate would alter once it was motionless for 2 hours. This modification minimized the time we spent searching for does to make sure we were within range to hear a signal from an expelled VIT. We received a weak batch of batteries in our 2001 field season, and many of those VIT from our winter capture efforts failed by the time of fawning. This can easily be circumvented by using adequate batteries and was not the result of miscalculating the transmitting life of the modified 2001 VIT. Perhaps the greatest improvement to the future design of the VIT would be to have as strong of signal as possible so that it could be detected from greater distances.

Garrott and Bartmann (1984) indicated that a 2 hour motion delay of the implant was too short because of the sedentary nature of pre-parturient does. The VIT would give "false alarms" that the VIT was expelled, but in fact it was still implanted in a motionless doe. We experienced 7 "false alarms" over the course of 2 field seasons. We suggest that 2 hours is a sufficient time delay and that the false alarm of having a VIT incorrectly indicate that it had been expelled was acceptable compared to the risk of giving the fawn more time to move farther away from the birth site. Livezey (1990) reported newborn fawns moving between 0.5 to 2.0 km within the first 48 hours of life, thus making the area too large to search adequately.

The motion delay was also important because we did not want to interrupt bonding between the doe and the fawn, while at the same time, we did not want to allow too much time to pass to allow the fawn to move further from the birth site. Livezey (1990) summarized the concerns of marking induced abandonment and mentions the importance of allowing uninterrupted parental bonding. Our VIT signal delay was set for 2 hours. If we detected the signal the moment it turned on, it still took a minimum of 1 hour to triangulate on the VIT, organize and gather technicians for a fawn search, and hike towards the VIT. We rarely pushed a doe off of the birth site and the majority of the time we never saw the doe and the fawn was lying motionless near the birth site. We could not attribute any of our fawn mortalities to abandonment.

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CONCLUSION

In this research, we studied the ecology of newborn Columbian black-tailed deer fawns. We examined the birth site selection by adult does (Chapter 1) and observed that does select parturition sites based on the habitat characteristics at a scale even larger than their home-range. We compared birth sites to random sites within the study area boundary at 4 different areas (sub-stand, stand, home-range, and landscape) around each site as well as variables that described the site itself. Across all scales examined, does, in general, consistently selected sites that were flatter, had more forest edge, and were near early seral stage forest. These characteristics more favor the does need for forage brought on by the new energy requirement of lactation than the does need for avoiding predators by seeking thick cover and concealment. When all models were compared, the models at the landscape level best explained the variation between the birth and random sites.

We were able to fit newborn fawns with radiocollars and monitor their habitat use and survival (Chapter 2). Fawns were more closely associated with open and early seral stage forest when compared to the available habitat categories in the study area. Fawn survival to 76 days was 44% (95% confidence interval=23-66%) and predation was the main cause of death. We modeled survival using fawn morphometrics, movement, and landscape-level habitat characteristics of the capture site. The road density within a 1,000 m radius of the capture site best explained survival of fawns. Fawns living in a high road density area have a higher probability of surviving than fawns living in more remote regions. We cannot distinguish the mechanism for this observation and suggest more investigation is needed. However, we feel that roads reduce predator density due to human disturbance (both vehicle noise and hunting), and thus potentially allowing more fawns in those habitats to survive longer.

We were able to do both of the studies described above using vaginal-implant transmitters (VIT) inserted into adult does. These transmitters are turned on when they are motionless after being expelled, thus identifying the birth site and assisting the researchers ability to find the newborn fawns in dense, mountainnous terrain. In Chapter 3, we evaluated the performance of the VIT and felt that the VIT was extremely useful and the insertion procedure did not harm does or fawns. By monitoring the VIT at least 3 times per day and by modifying the VIT so that it continuously transmitted so that we knew the status of the VIT in the second field season, increased our ability to locate fawns at the birth site.

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