ASSESSING THE RELATIONSHIP OF CONIFER THERMAL COVER TO WINTER DISTRIBUTION, MOVEMENTS, AND SURVIVAL OF FEMALE WHITE-TAILED DEER IN NORTH CENTRAL MINNESOTA

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SUMMARY OF FINDINGS

The goal of this long-term investigation is to assess the value of conifer stands as winter thermal cover/snow shelter for white-tailed deer (*Odocoileus virginianus*) at the population level. Over the course of the 15-year study period, we radiocollared and monitored a total of 452 female deer, including 43 female newborn fawns. During the past 12 years, data generated from this study provided the basis for scientific and popular articles addressing supplemental feeding effects on winter food habits of white-tailed deer; age-specific survival and reproduction; cause-specific mortality; seasonal migration; safe capture, chemical immobilization and handling; wolf predation; bait selection and capture success; and disease of deer; as well as progress in applied geographic information system (GIS) technology. These papers allowed us to explore new, more scientifically rigorous analytical approaches to viewing the diverse data sets we were accumulating. During the past year, we've been concentrating our efforts on:
(1) examining annual variation in seasonal migration of deer and influential factors, as well as determining the most relevant and informative time origins and scales in survival analyses relative to the goals and objectives of our study; (2) using global positioning system (GPS) collars in field trials to determine the effects of habitat composition, body posture of deer and associated collar position on location acquisition performance; and (3) determining the effects of vegetative succession during the study period on classification of habitat types on the 4 study sites as the study progressed. These last 2 tasks are important to accurate determinations of habitat use by radiocollared deer throughout the study. All are described in more detail below.

INTRODUCTION

The goal of this long-term investigation is to assess the value of conifer stands as winter thermal cover/snow shelter for white-tailed deer at the population level. Historically, conifer stands have declined markedly relative to the increasing numbers of deer in Minnesota and elsewhere in the Great Lakes region. The level of logging of all tree species collectively, conifer stands specifically, has recently reached the estimated allowable harvest. Most land management agencies and commercial landowners typically restrict harvests of conifers compared to hardwoods, because of evidence at least at the *individual* animal level, indicating the seasonal value of this vegetation type to white-tailed deer and other wildlife species. However, agencies have anticipated increased pressure to allow more liberal harvests of conifers in the future. Additional information is needed to assure that future management responses and decisions are ecologically sound. Both white-tailed deer and the forests of the Great Lakes region have significant positive impacts on local and state economies, and they are highly regarded for their recreational value.

OBJECTIVES

The null hypotheses in this study are that conifer stands have no effect on the survival, movement, or distribution of female white-tailed deer during winters of varying severities. Relative to varying winter severities, the specific objectives of the comprehensive, quasi-experimental approach of this study have been to:

- monitor deer movements between seasonal ranges by aerial radio-telemetry, and more importantly, within winter ranges, for determination of home range size;
- determine habitat composition of winter home ranges and deer use of specific vegetation types;

- monitor winter food habits;
- monitor winter nutritional restriction and condition via serial examination of deer body mass and composition, blood and bladder-urine profiles, and urine specimens suspended in snow (snow-urine);
- monitor age-specific survival and cause-specific mortality of all study deer; and
- collect detailed weather data in conifer, hardwood, and open habitat types to determine the functional relationship between the severity of winter conditions, deer behavior (e.g., use of habitat) and their survival.

STUDY DESIGN AND PROGRESS

This study employed a replicated manipulative approach, which is a modification of the Before-After-Control-Impact design (BACI; Stewart-Oaten et al. 1986; see DelGiudice and Riggs 1996). The study involves 2 control (Willow and Dirty Nose Lakes) and 2 treatment sites (Inguadona and Shingle Mill Lakes), a 5-year pre-treatment (pre-impact) phase, a 4-year treatment phase (conifer harvest serves as the experimental treatment), and a 6-year post-treatment phase. The 4 study sites located in the Grand Rapids-Remer-Longville area of north-central Minnesota are 13.0-23.6 km^2 (5.0-9.1 mi^2) in area. The study began with the Willow and Inguadona Lakes sites during winter 1990-1991. The Shingle Mill and Dirty Nose Lakes sites were included beginning in winter 1992-1993. The objective of the experimental treatment (impact) was to reduce moderate (40-69% canopy closure) and optimum (≥70% canopy closure) conifer thermal cover/snow shelter to what is considered a poor cover class (< 40% canopy closure).

Data collected on all 4 study sites included the following: (1) descriptive quantification of deer habitat by color infrared air photointerpretation, digitizing, and application of a geographic information system (GIS); (2) monitoring of ambient temperature, wind velocity, snow depth, and snow penetration (index of density) in various habitat types (e.g., openings versus dense conifer cover) by automated weather data-collecting systems, minimum/maximum thermometers, and conventional hand-held measurements; (3) deer capture, chemical immobilization, and handling data; (4) age determination by last incisor extraction and cementum annuli analysis; (5) physiological samples collected during captures and recaptures of radiocollared female deer and data generated by laboratory analyses, including complete blood cell counts (i.e., CBCs), serum profiles of about 20 characteristics, (e.g., reproductive and metabolic hormones, chemistries), urine chemistry profiles, and partial and complete body composition determination by isotope-dilution and visual ultrasound; (6) morphological measurements; (7) physiological assessment of winter nutritional restriction by chemical analysis of urine in snow; (8) seasonal migrations and other movements via very high frequency (VHF) and global positioning system (GPS) radiocollars; (9) habitat use; (10) annual and seasonal cause-specific mortality; (11) age-specific survival rates; (12) winter food habits; and (13) movements, territory size, survival, and cause-specific mortality of radiocollared wolves.

The 15th and final winter of data collection was 2004-2005. Over the course of the study period, we radiocollared and monitored a total of 452 female deer, including 43 female newborn fawns. During 1991 to 2006, in annual issues of the Minnesota Department of Natural Resources' (MNDNR) "Summaries of Wildlife Research Findings" we've presented summary data describing the winter weather conditions (e.g., weekly snow depths, monthly mean daily minimum and maximum ambient temperatures, winter severity index); live-capture success; and age distribution, pregnancy and fecundity (i.e., number of fetuses:doe) rates of the female cohort recruited for this study. Additionally, in those summaries we've addressed winter and annual mortality rates (and their relations to the varying severities of winter weather conditions), specific causes of mortality, and how the underlying age-specific hazard function (i.e., instantaneous probability of death) drove age-specific, seasonal, and annual survival rates of these females from birth to old age (up to 17.5 years old). To varying degrees we've presented preliminary descriptions of seasonal migration patterns of the collared deer; margins of safe capture, chemical immobilization, and handling; food habits; assessments of winter nutritional restriction and condition; as well as the territory sizes, survival, and specific fates of wolves ranging over the study sites.

Additionally, during the past 12 years, we've published a number of scientific and popular articles that have delved into supplemental feeding effects on *natural* winter food habits of white-tailed deer; age-specific survival and reproduction; cause-specific mortality; seasonal migration; safe capture, chemical immobilization and handling; wolf predation; bait selection and capture success; and disease of deer; as well as progress in applied GIS technology, in much greater detail than appropriate for the annual research summaries (Doenier et al. 1997; DelGiudice 1998; DelGiudice et al. 2001, 2002, 2005, 2006, 2007a; Carstensen et al. 2003, 2008; Carstensen Powell and DelGiudice 2005; Carstensen Powell et al. 2005; Raizman et al. 2005; Sampson and DelGiudice 2006; Barrett et al. 2008; Fieberg et al. 2008). Importantly, often as a result of collaborations with our Research Unit's biometricians (M. Riggs, J. Fieberg), these scientific articles and their associated in-depth analyses have allowed us to explore new, more scientifically rigorous and illuminating analytical approaches to viewing the diverse data sets we were accumulating during this long-term study (DelGiudice and Riggs 1996; DelGiudice et al. 2002, 2006; Fieberg and DelGiudice 2008a,b). These large data sets, analyses, and articles facilitated not only an increased understanding of numerous aspects of white-tailed deer ecology that we've been able to share with the scientific and management communities, but ultimately served as preparation for our most important upcoming data analyses relative to the long-term study's BACI design, primary goals, and objectives (described above). The many popular articles and presentations also allowed us to share current, interesting information synthesized from the data with numerous, diverse special interest groups, academic (K-12 and college-level) audiences, and the general public over the years.

During the past year, we've been concentrating our efforts on several tasks, including: (1) examining annual variation in seasonal migration of deer and influential factors, as well as determining the most relevant and informative time origins and scales in survival analyses relative to the goals and objectives of our study (see abstracts elsewhere in this issue of "Summaries of Wildlife Research Findings"); (2) using GPS collars in field trials to determine the effects of habitat composition, behavior and body posture of deer and associated collar position on location acquisition performance; and (3) determining the effects of vegetative succession on classification of habitat types on the 4 study sites as the study progressed. This final task is important to accurate determinations of habitat use by radiocollared deer throughout the study. Below we describe how we are assessing vegetative succession and the types of changes we've observed on our study sites. We also discuss how we have begun to examine GPS collar performance on study deer and the potential effects of "missed locations" (i.e., masking) on determinations of habitat importance.

Habitat Analyses and Updates

Detailed baseline habitat analyses using mirror stereoscope interpretation of color infrared air photos (1:15,840) and GIS (Arc/Info, ArcView) were completed early in the study. Forest stand types were classified according to their dominant 2-3 tree species, height and winter canopy closure. Open habitat types, water sources, and roads were also delineated. Our classification system was developed with the specific intent that it would facilitate an examination of potential relations between use of habitat types by white-tailed deer and their winter biological requirements.

During the 15-year study period there was potential for natural and human-induced changes of the vegetation/habitat to occur. Because we are examining habitat use by study deer (via radio-telemetry) during each year, it was important to update the classification of the habitat layers of the 4 study sites to account for vegetative succession, as well as habitat destruction (e.g., by flooding). This was particularly important for types that were openings when the study began, as well as for conifer types with canopies that may have succeeded from a less dense closure class (A [< 40%] or a B [40-69%]) to a more dense class (B or a C [≥70%]).

We had current air photo coverage taken and rectified by the MNDNR's Resource Assessment Laboratory during fall 2006, again at a scale of 1:15,840. We then were able to compare specific habitat types from the initial interpretation with the current coverage and determine whether significant change, particularly in conifer canopy closure and height classes or dominant species had occurred. Overall, on the Willow Lake control site, conifers increased 22.6% due to succession, with increases specifically in canopy closure classes A, B, and C of 29.7, 26.9, and 16.5%, respectively (DelGiudice et al. 2007b, Table 1). Conversely, on the Dirty Nose Lake control site, conifers declined 22.7%, with specific changes of 20.5, 30.8, and 23.7% in canopy closure classes A, B, and C, respectively. At the Inguadona Lake treatment site, conifers were reduced by 18.2% (primarily associated with the mid-study treatment harvests); A and C classes had decreased by 19.0 and 65.5%, respectively. Overall, there was a net increase of 39.7% in the B canopy closure class. Finally, at the Shingle Mill Lake site, decreases in all classes (A, 8.2%; B, 27.5%; and C, 7.5%) accounted for an overall decrease in area of conifers of 12.9%. Net changes in conifer canopy closure classes were attributable primarily to a combination of natural and human-induced sources: (1) destruction of stands by natural seasonal flooding; (2) planned, mid-study, treatment conifer harvests; (3) non-study, planned timber harvests committed to by cooperators (primarily U. S. Forest Service) prior to initiation of the study; and (4) gradual natural succession during the 13–15 years each site was part of the long-term study. Based on comparisons of the initial and final habitat analyses by color infrared photo-interpretations, we have recently completed extensive field measurements of stand heights for pre-selected habitat types, which had changed or were considered most likely to have changed, over the course of the study period. Based on linear regression analyses, these measurements and study-long changes in canopy closure classes, will permit us to estimate when (i.e., specific year) during the 15-year study period a given habitat type changed (e.g., based on stand height) from one type to another (T. Burke, Department of Forest Products, University of Minnesota, personal communication). This determination will facilitate more accurate assessments of deer use of habitat types throughout the study period.

Detailed spatial and temporal analyses of annual deer use of habitat types on the study sites relative to specific winter weather conditions and overall winter severity will begin during the current year. A preliminary analysis has shown that during phases of the study associated with mild to average winter conditions, deer distribution over the study sites was more dispersed and use of vegetative cover was more variable, whereas when influenced by severe winter conditions, deer locations were more concentrated in dense conifer cover. Location data sets from 32 GPS-radiocollared deer (programmed to collect data at 1–4-hour intervals over 24-hour daily periods) during 2001–2006, will be used to augment analyses of data collected by aerial location (from fixed-wing aircraft) of VHF-radiocollared deer and to enhance our understanding of deer use of winter cover types relative to varying weather conditions.

Evaluating GPS Collar Performance and Accounting for "Masking"

A second important prerequisite to accurately assessing winter use of habitat by deer is to evaluate and understand performance in the field of the GPS collar technology being used and to account for "masking," which is the effect that *failed* attempts, relative to pre-programmed location-sampling and specific habitat types, can have on determinations of their use and importance to deer. We have been applying ourselves to this effort using a 3-prong approach, which included examining indicators of technical performance (e.g., percent success, 2- versus 3-dimensional [D] locations, position dilution of precision [PDOP] values) for: (1) GPS collars fitted to our free-ranging female deer; (2) GPS collars placed (e.g., upright or on a side) within various pre-selected habitat types during controlled performance trials; and (3) a GPS collar fitted to an intact deer carcass, which allowed us to test the potential effects of body posture and head/neck position on collar performance within different habitat types (Sampson and DelGiudice 2008).

Data collection is complete and analyses are ongoing. However, we already have learned much about the performance of our GPS collars relative to habitat type and deer behavior and body posture. Herein, we provide several highlights. Overall mean fix success rate for our collared deer on their winter range was 72.4% (SE = 3.5, range = 25.0-99.0%, *n* = 32) versus 95.5% for the test collars (SE = 1.7, range = 46.0-100.0%, *n* = 34, Table 1). Because the GPS trials included collars placed in the same variety of habitat or vegetation types (e.g., open, dense conifer stands, aspen (*Populus* spp.) regeneration) used by deer during winter, without any significant variation in fix success rate ($\geq$90% for 31 of 34 collars, $\geq$95% for 25 of these), these combined data sets indicate that vegetative characteristics associated with structure (e.g., canopy closure, stem density) were not primary factors affecting fix success rate. Additionally, simply placing the GPS collar on its side had no apparent effect on the fix success rate. In the trials we did note a significant linear relation between percent of 3-D locations and percent success ($r^2 = 0.73$, $P < 0.0001$) and between percent locations with PDOP values of 0-5 and percent success ($r^2 = 0.30$, $P = 0.0008$).

These findings prompted us to consider whether position of the GPS collar on the deer, particularly relative to behavior of the animal and associated body posture (e.g., bedding), affected the fix success rate. We observed that the frequency of "missed locations" was greatest during the middle of the day (Figure 1) when white-tailed deer tend to be least active (Kammermeyer and Marchinton 1977, Marchinton and Hirth 1984). To explore this possibility, we fitted a recently road-killed deer with a GPS collar and placed it in a curled up, bedded position within vegetation types similar to those used by our GPS-collared free-ranging deer on their winter ranges (e.g., aspen regeneration, conifer stands with moderate to dense canopy closures). The collar was programmed to sample 1 location per hour over 1 to 5 days with the receiver position being either "in" (i.e., facing the deer's body) or "out" (i.e., facing away from the deer's body by varying degrees). What we noted was that when the GPS collar receiver was turned in, the mean fix success rate was only 16.8% (SE = 11.0, range = 0-60%, number of trials = 6), whereas, when it was even *slightly* exposed, the mean fix success rate was 95.8% (SE = 2.3, range = 89-100%, number of trials = 5). We will be performing additional analyses and further details will be presented elsewhere (Sampson and DelGiudice 2008), but thus far, evidence indicates that body posture and the associated position of the GPS collar receiver may be the primary factor influencing the fix success rate of the collar. These results will assist us in subsequent rigorous analyses of habitat use by our collared deer during winter, including how to account for missed locations in the data sets of each deer.

Our primary analytical approach during the coming year will include examination of survival and cause-specific mortality, migration, habitat use, physiological condition/status, and food habits data relative to the multi-year pre-treatment, treatment, and post-treatment phases of the study for deer inhabiting the control and treatment sites.

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Table 1. Mean (+ SE) location-sampling success and indicators of performance for global positioning system (GPS) collars fitted to free-ranging female white-tailed deer and during controlled trials in the same habitat as the collared deer, near Grand Rapids, MN, winters 2000-2001 to 2006-2007.[a]

Deer/Trial	*n*[b]	% success 1 location/hr	% success 1 location/4 hr	Overall % success	% 3-D locations[c]	% PDOP values[d]		
						0-5	6-10	>10
Deer	32	72.0 (4.0)	70.7 (4.2)	71.0 (3.9)	64.4 (1.8)	78.6 (1.2)	14.8 (0.6)	7.0 (0.7)
Trials	34	95.6 (1.6)	94.5 (2.5)	95.6 (1.6)	89.0 (2.2)	86.1 (1.1)	11.3 (0.8)	2.6 (0.4)

[a]Trials involved setting GPS collars upright or on their side in various winter habitat types for several days, programmed to sample a location at 1 location per hour or 1 location per 4 hours.
[b]Sample size varied from 25 to 32 and 31 to 34 for the above performance indicators of collars fitted on deer or used in trials, respectively, depending on whether the sampling schedule included 1 location per hour or per 4 hours, or both. Additionally, on rare occasion, collar malfunction did not allow recording of data for an indicator.
[c]Three-D locations are 3-dimensional, which requires 4 satellites to simultaneously fix the location.
[d]PDOP is the position dilution of precision; lower values have been associated with more accurate location determination.

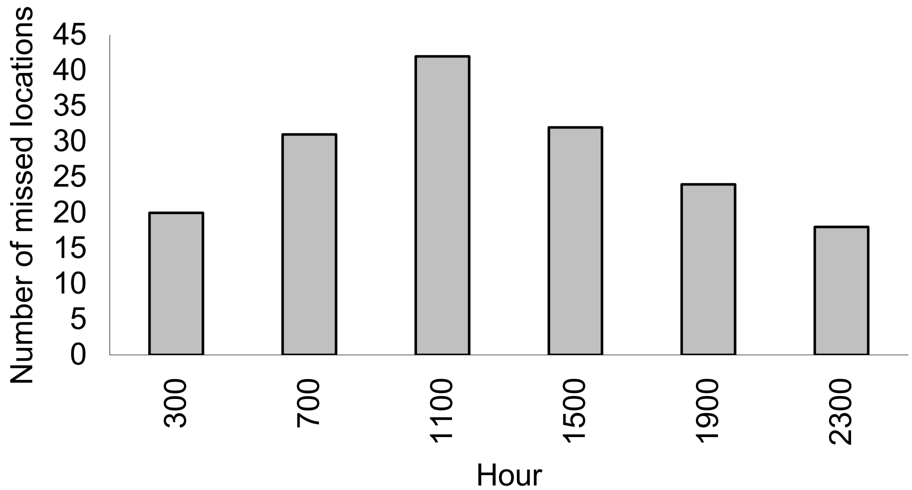

Figure 1. Typical temporal distribution of missed locations for adult, female white-tailed deer (no. 709) fitted with global positioning system collars programmed to sample 1 location per hour or 1location per 4- hour interval, near Grand Rapids, Minnesota, winter 2001-2002. Percent success for this deer was 60% (243 of 404 possible locations) at 1 location per 4-hour interval.