Bull. N.J. Acad. Sci., 56(2), pp. 5–8.

Impact of Snow Cover on Movements and Habitat Choice by Suburban White-Tailed Deer (*Odocoileus virginianus*)

Eugene Potapov[1], Allen Bedford[1], Fredrik Bryntesson[1], Sherri Cooper[1], Bracken Brown[1,2] and David Robertson[3]

(1) Biology Department, Bryn Athyn College, Bryn Athyn, PA 19009
(2) 147 Mountain Road, Kempton, PA 19529
(3) Pennypack Ecological Restoration Trust, Huntingdon Valley, PA 19006

Abstract. *Twelve white-tailed deer* (Odocoileus virginianus) *fitted with GPS/GSM radio-collars that transmit spatial and temporal data at high-frequency intervals were monitored during snowfalls and periods of varying snow depths in a natural area preserve in the Philadelphia suburbs. Deer movements were compared using minimum convex polygons, minimum distance travelled, and aspect and slope of the areas traveled. Shallow snow did not affect deer movements, but deer traveled less in snow deeper than 12.5 cm, and stayed within smaller and highly individual areas, showing a preference for woodlands. During snowmelt, the deer preferred southerly facing slopes that melted first.*

Key Words: White-tailed deer, spatial analysis, GPS/GSM radio-tracking, snow

INTRODUCTION

Snow depth affects the ecology and reproduction of all northern ungulates both directly and indirectly through effects on available forage plants (Post and Stenseth, 1999). It appears that the northern border of the white-tailed deer (*Odocoileus virginianus*) distribution is determined by the depth of winter snow cover. In the northern parts of the range, snow depth tends to trigger deer to migrate to "deer yards" or "deer wintering areas," traditional areas of tolerable snow conditions (Morrison et al., 2003; Pekins and Tarr, 2008). It is believed that a snow depth of 40 cm acts as a trigger for this migration in New Brunswick (Sabine et al., 2003). When snow depth reached 50 cm, deer movements were reduced dramatically in New Brunswick, no longer determined by the presence of edible vegetation (Morrison et al., 2003). Similarly, for roe deer (*Capreolus capreolus*), a European species ecologically comparable to white-tailed deer, a snow depth of 50 cm is reported as a limiting factor that controls population growth of the deer in the northern part of their range (Danilkin, 1996; Mysterud and Østbye, 2006). In snowy areas, the availability of habitat that provides shallow snow refugia is integral to deer survival (Tefler, 1978).

Although deer yards have been studied in detail in the northern part of the white-tailed deer range (Morrison et al., 2003; Pekins and Tarr, 2008 and references therein), there is little information on the formation of deer yards in Pennsylvania. In this study, the impact of snow on movements of white-tailed deer in suburban Pennsylvania is analyzed within a broader tracking project run by Bryn Athyn College and the Pennypack Ecological Restoration Trust (PERT). This study is unique in that it uses a high resolution tracking dataset which allows extraction of daily movement patterns that can be related to snow depth and topography. In this case, topography is broken into two components—slope and aspect.

MATERIALS AND METHODS

A total of 31 deer were tracked using GPS collars in the Pennypack Preserve and surrounding suburban area. The Pennypack Preserve is managed by PERT, a private, non-profit conservancy located about 25 km (15 miles) northeast of central Philadelphia. PERT manages 3.27 km^2 (809 acres) of mature forests, regenerating woodlands, riparian forests, and fields of cool- and warm-season grasses in the Pennypack Creek valley. The preserve is open to the public from dawn to dusk and PERT allows controlled deer hunting during the state-sanctioned hunting season by the Bryn Athyn Marksmen's Association (BAMA), a private hunting club. Out of 31 tracked deer, 12 deer (four females and eight males) were monitored during winter (1 December to 1 April). Deer were fitted with Tellus GPS/GSM radio-collars (Followit, Sweden), and GPS location fixes were subsequently collected every five minutes between December 1, 2008 and March 31, 2011, yielding a total of 147,157 GPS fixes.

These data were analyzed using ArcGIS (ESRI, Redlands, California) software. Hawth's Tools (Beyer, 2004) and ArgosTools extensions (Potapov and Dubinin, 2003; Potapov and Khronusov 2005) were used to compute animal movement parameters. The movement tracks were distinguished from outliers (cold-start errors) using a variant of the ArgosFilter program for R (Freitas et al., 2008; see http://cran.r-project.org) adapted for GPS locations and implemented in Excel. Minimum Convex Polygons (MCPs) (*sensu* Hooge and Eichenlaub, 1997) were used to calculate the daily home range of each deer, along with daily Minimum Distance Traveled (MDTs). The daily MCPs and MDTs were regressed against depth of snow cover. The snow depth data were derived from the Snow Data National Dataset (http://lwf.ncdc.noaa.gov/snow-and-ice/dly-data.php) for Green Lane, Palm 3, and Valley Forge stations in Montgomery County, PA and Neshaminy Falls, Sellersville and Springtown stations in Bucks County, PA. All data were averaged for each day (local time) of the observation period. Periods of deep snow (>25 cm) and periods of snowmelt (continuous reduction of snow at a rate not less than 3 cm per day over at least three days) were differentiated in order to quantify the habitat choice of the deer in terms of slope and aspect of the slope during these periods. Snowmelt dates were recorded as well as periods with ice crust by direct observations in the field. The slope (measured in degrees of inclination) and aspect (landscape orientation in relation to true north) were calculated for every recorded winter season location coordinate. Slope and aspect for the region covered by the instrumented animals were determined from the DVRPC 2005 Topographic Contours of Montgomery County (Delaware Valley Regional Planning Commission, 2006).

The data analyzed for this study were limited to periods of snow cover. In winter 2008–09, snow depth exceeded 13 cm (5 inches) for a total of 25 days. In 2009–10 and 2010–11, the duration of continuous snow cover exceeded three weeks in each year, and snow depth exceeded 25 cm for 8 days in 2009–10 and 5 days in 2010–11. Several significant snowstorms measured >5 (major) on the NESIS severity scale during 2009–10 and 2010–11 (Kocin and Uccellini, 2004).

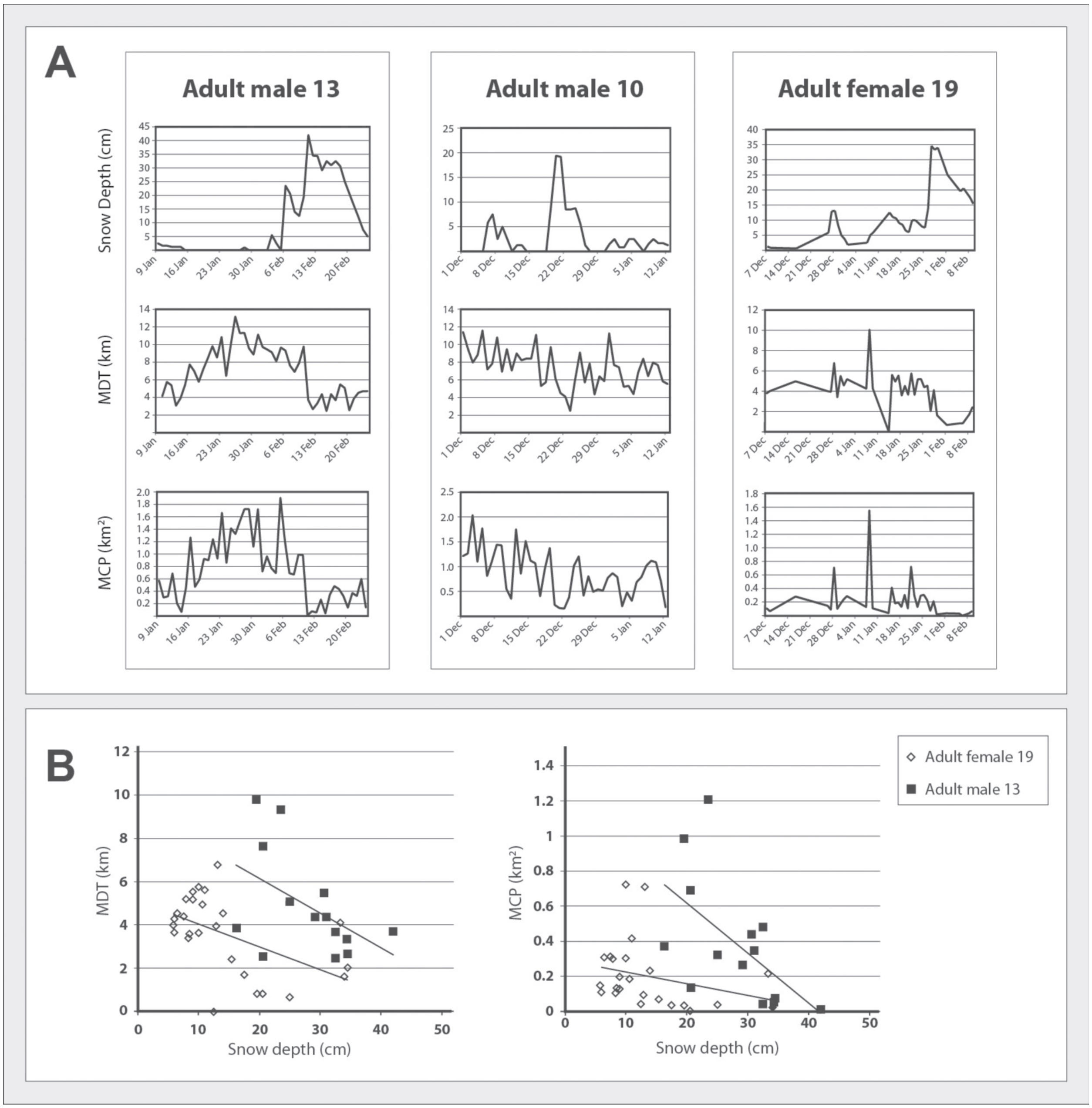

Figure 1. The results indicate a reduction in Minimum Distance Traveled (MDT) for all animals tracked as snow depth increased above 12.5 cm, and the daily range (as measured by Minimum Convex Polygon (MCP)) decreases for male but not female deer in response to snow. **A.** Comparison of snow depth (cm, top row), daily MDT (km, middle row), and daily MCP sizes (km^2, bottom row) for three study animals: adult male No. 13, adult male No. 10 and adult female No. 19. **B**. *Left:* relationship between snow depth and MDT is significant for both females and males. Adult female No. 19: $y = -0.11x + 5.08$; $R^2 = 0.26$. Adult male No. 13: $y = -0.16x + 9.41$; $R^2 = 0.24$. *Right:* relationship between snow depth and MCP sizes was significant in males but not in females. Adult female No. 19: $y = -0.0067x + 0.29$; $R^2 = 0.097$. Adult male No. 13: $y = -0.028x + 1.18$; $R^2 = 0.33$. This effect is apparent for snow depths exceeding 12.5 cm in both females and males.

RESULTS AND DISCUSSION

In 2009–10 and 2010–11, snow depth appeared to affect deer movement. The sizes of MCPs were lowest when snow was deepest (Fig. 1A). The effect of snow depth on the daily MCPs was not statistically significant for females, but was statistically significant for males (Fig. 1B), perhaps because males have larger MCPs. Snow depth had a significant effect on MDTs when snow depth exceeded a threshold value of 12.5 cm (Fig. 1B). MDTs showed a noticeable decline with an increase in snow cover (Figs. 1A-B). Two individuals did not move at all during the peak snow cover recorded on Jan. 27–30, 2011. In

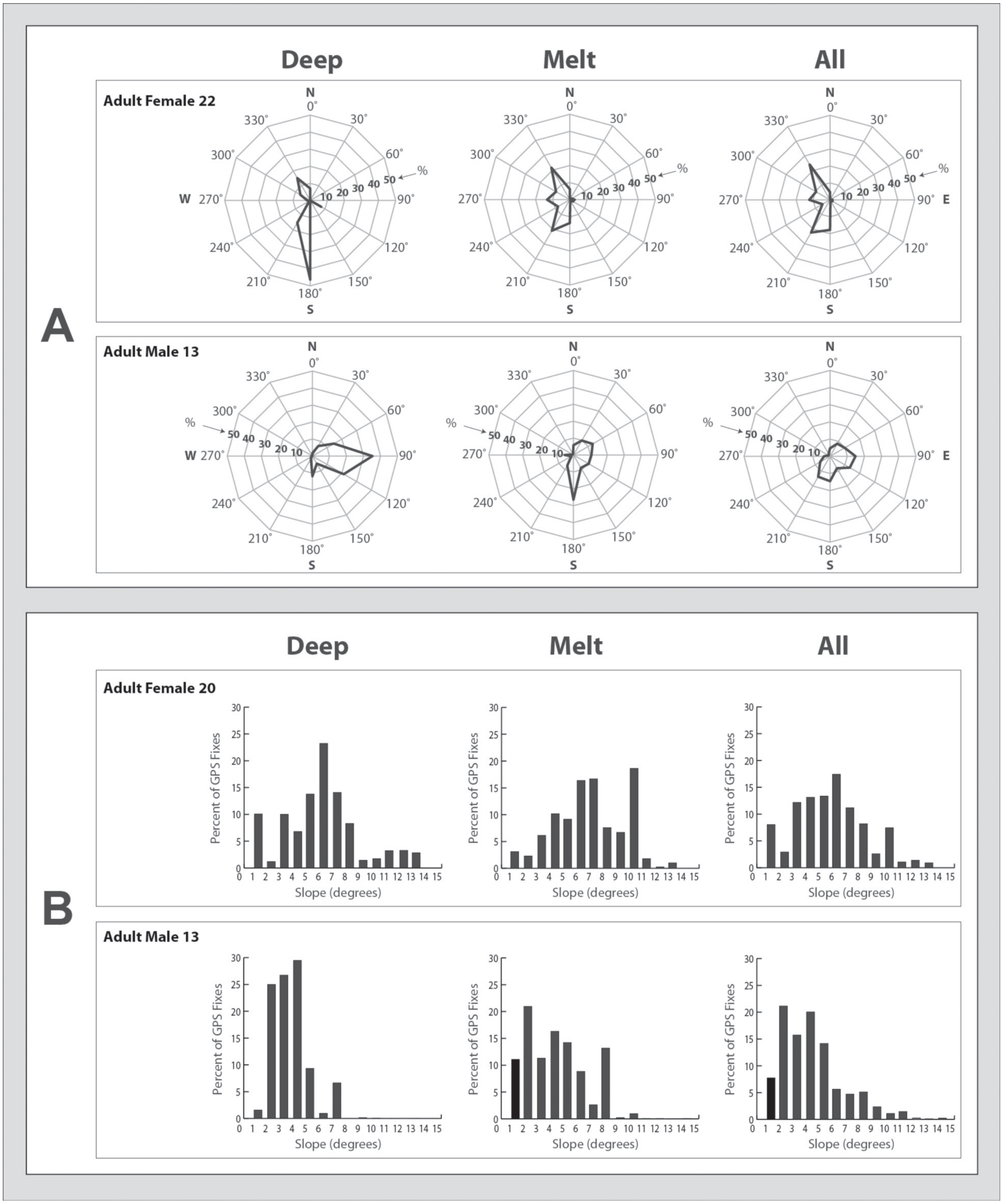

Figure 2. The results indicate that deer preference for landscape aspect (A) and for slope inclination (B) narrows in the presence of deep snow (depth above 25 cm). **A.** Percent of fixes plotted against slope aspects (direction, in degrees with true north as 0°). *Above:* adult female No. 22. *Below:* adult male No. 13. **B.** Percent of fixes plotted against slope steepness (in degrees). *Above:* adult female No. 20. *Below:* adult male No. 13. For both A and B: deep snow (left column), snowmelt (middle column), and all points (right column).

general, there were no statistical correlations among daily MCPs, MDTs and snow depths during the winters of 2007–08 and 2008–09 when snow cover was minimal.

The deer had a noticeable selection for slope aspect during deep snow periods. Individual animals preferred sites with particular and very narrow aspects when the snow was deep. For example, 48% of fixes for female deer No. 22 in deep snow were constrained to an aspect range of 22.5˚; in melting snow, the frequency of fixes for this deer at this particular aspect range fell to 32% (Fig. 2A). When snow was melting, the animals stayed on gentle slopes oriented toward the south or on steeper slopes that had cleared of snow. There was no apparent winter deer yard that was utilized by the deer tracked in this study.

During deep snow, the data indicate that all deer narrowed their individual spatial range (Fig. 1A-B), preferred wooded habitat by both day and night, travelled little, and avoided open fields (data not shown). These results are consistent with the results of a study carried out in British Columbia (D'Eon, 2001), which demonstrated that on snowy days, deer tend to stay on slopes with lower than average snow depth. Aspect and slope were good predictors of stands of trees, and all three factors affected snow depth (D'Eon, 2004), thus linking refuge sites with particular vegetation cover. The overall preference of the observed deer in this study for gentle slopes (see Fig. 2B) is consistent with observations made in New Brunswick that, at snow depths of 20–50 cm, deer stayed on slopes <4.5º (Morrison et al., 2003).

During snowmelt periods, the deer preferred gentle south-facing slopes and fringes of fields, but maintained a relatively narrow spatial range. These positions may provide the driest locations, and may also be an adaptation to minimize encounters with potential predators. Coyote (*Canis latrans*) have killed deer in the preserve during winter months. Deep snow can handicap a deer if it needs to escape from a predator. It has been shown (Nelson and Mech, 1986) that gray wolf (*Canis lupus*) predation on white-tailed deer is highest when snow is very deep. One movement pattern captured in the data set is the response of one of the does to a possible coyote attack. This movement, which occurred when the snow depth was 30 cm, involved a ~500 m track along a snow-free paved road that was not used before or after this encounter.

In conclusion, snow depths >12.5 cm significantly reduced the daily MDTs of both males and females, and daily MCPs of males in this study. The deer preferred wooded habitat, a narrow range of slope and slope aspect, and avoided open fields during deep snow periods. While deer in the study area responded to a threshold snow depth of 12.5 cm, they do not congregate in deer yards, even in deeper snow (>25 cm). White tailed deer response to a threshold depth of 12.5 cm is lower than previously reported. The high resolution data allow the study of deer response to the short periods of snow that are typical of southeastern Pennsylvania.

ACKNOWLEDGMENTS

We would like to acknowledge Brad Nyholm, Dallas Hendricks, Laird Klippenstein, Michael Rodgers, Eric A. Rohtla and David W. Cooper for fieldwork related to this study, along with other employees of PERT and hunters of BAMA for their help in the field. We also thank Eugene Meyer and an anonymous reviewer for their comments on a previous version, and the Mid-Atlantic chapter of the Ecological Society of America and the New Jersey Academy of Science for the opportunity to publish this paper. This research project is funded by Bryn Athyn College, the Grant Doering Research Trust Fund, and the Pennypack Ecological Restoration Trust.

LITERATURE CITED

BEYER, H. 2004. *Hawth's Analysis Tools for ArcGIS.* Available at http://www.spatialecology.com/htools.

DANILKIN, A. 1996. *Behavioural Ecology of Siberian and European Roe Deer*. Chapman & Hall, London. 296 pp.

Delaware Valley Regional Planning Commission. 2006. *DVRPC 2005 Topographic Contours of Montgomery County*. Available at Pennsylvania Spatial Data Access: http://www.pasda.psu.edu

D'EON, R. G. 2001. Using snow-track surveys to determine deer winter distribution and habitat. *Wildl. Soc. Bull*. 29: 879–887.

___. 2004. Snow depth as a function of canopy cover and other site attributes in a forested ungulate winter range in southeast British Columbia. *B.C. J. Ecosys. Manage*. 3:1–9.

FREITAS, C., C. LYDERSEN, M. A. FEDAK and K. M. KOVACS. 2008. A simple new algorithm to filter marine mammal Argos locations. *Mar. Mam. Sci*. 24: 315–325.

HOOGE, P., and B. EICHENLAUB. 1997. *Animal movement extension to Arcview*. ver. 2.0. Alaska Science Center - Biological Science Office, U.S. Geological Survey, Anchorage, AK.

KOCIN, P. J. and L. W. UCCELLINI. 2004. A Snowfall Impact Scale Derived From Northeast Storm Snowfall Distributions. *B. Am. Meteorol. Soc*. 85: 177–194.

NELSON, M. and L. MECH. 1986. Relationship between snow depth and gray wolf predation on white-tailed deer. *J. Wildl. Manage*. 50:471–474.

MORRISON, S., FORBES, G., YOUNG, S., LUSK, S. 2003. Within-yard habitat use by white-tailed deer at varying winter severity. *Forest Ecol. Manag*. 172: 173–182.

MYSTERUD, A., and E. ØSTBYE. 2006. The effect of climate and density on individual and population growth of roe deer *Capreolus capreolus* at northern latitudes – the Lier valley, Norway. *Wildl. Biol*. 12: 321–329.

PEKINS, P. J., and M. D. TARR. 2008. *A critical analysis of the winter ecology of white-tailed deer and management of spruce-fir deer wintering areas with reference to Northern Maine*. Cooperative Forestry Research Unit Research Report RR-08-02, University of Maine, Orono, ME. Available at: http://www.umaine.edu/cfru/All_coop/Publications/Pekins_RR_Complete.pdf

POST, E., and N. C. STENSETH. 1999. Climatic variability, plant phenology, and northern ungulates. *Ecology* 80:1322–1339.

POTAPOV, E., and M. DUBININ. 2003. *Argos-tools manual*. An Arcview-Gis extension. Available at: http://gis-lab.info/programs/argos/index.html.

___, and V. KHRONUSOV. 2005. *Argos-tools Manual*. An ArcGIS 9x extension to process Argos satellite telemetry data. Available at http://xbbster.googlepages.com/argos-tools.

SABINE, D. L., S. F. MORRISON, H. A. WHITLAW, W. B. BALLARD, G. J. FORBES, and J. BOWMAN. 2002. Migration behavior of white-tailed deer under varying winter climate regimes in New Brunswick. *J. Wildl. Manag*. 66: 718–28.

TEFLER, E. S. 1978. Cervid distribution, browse and snow cover in Alberta. *J. Wildl. Manag*. 42: 352–361.