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Winter habitat selection by white-tailed deer on Anticosti Island 2: relationship between deer density from an aerial survey and the proportion of balsam fir forest on vegetation maps

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Abstract: Determining at what scale to operate and how much cover is needed are important questions for winter habitat management of white-tailed deer, *Odocoileus virginianus* (Zimmermann, 1780), through logging. We used binary cover maps (reclassified forest vegetation maps) and windows of different sizes (0.2 km × 0.2 km, 0.5 km × 0.5 km, 1 km × 1 km, 2 km × 2 km, and 3 km × 3 km) to describe the relationship between deer density from an aerial survey and the proportion of balsam fir, *Abies balsamea* (L.) P. Mill., forest (BF) cover in a 270-km^2 block on Anticosti Island, Quebec. Maximum white-tailed deer densities reached were quite similar (31–34 deer/km^2) irrespective of window size, except for the 3 km × 3 km window for which maximum density remained half lower. Density increased with the amount of BF cover and then reached a plateau above 60% or 70% (two smaller windows) or decreased above 50% or 60% (1 km × 1 km and 2 km × 2 km windows). Results confirm goals previously used for habitat management of deeryards. This new method allows greater flexibility in research applications for describing density–cover relationships because both scale and proportion of cover can be analysed simultaneously.

Résumé : Pour aménager l'habitat hivernal du cerf de Virginie, *Odocoileus virginianus* (Zimmermann, 1780), par la coupe forestière, deux questions primordiales qui se posent sont l'échelle à laquelle opérer et la proportion d'abri à maintenir. Nous avons utilisé des cartes binaires d'abri (cartes forestières reclassifiées) et des fenêtres de différentes tailles (0,2 km × 0,2 km, 0,5 km × 0,5 km, 1 km × 1 km, 2 km × 2 km et 3 km × 3 km) pour décrire la relation entre la densité des cerfs, mesurée par inventaire aérien, et la proportion d'abri (peuplements de sapin baumier, *Abies balsamea* (L.) P. Mill., (BF) dans un bloc de 270 km^2 sur l'île d'Anticosti, Québec. Les densités maximales de cerfs atteintes étaient très similaires, quelle que soit la taille des fenêtres, sauf pour celle de 3 km × 3 km pour laquelle la densité maximale est restée deux fois plus basse. La densité a augmenté en fonction de la proportion de BF, pour ensuite atteindre un plateau au-dessus de 60 % ou 70 % (deux plus petites fenêtres) ou diminuer au-dessus de 50 % ou 60 % (fenêtres de 1 km × 1 km et de 2 km × 2 km). Les résultats confirment les objectifs utilisés jusqu'à maintenant pour aménager l'habitat des ravages de cerfs. Cette nouvelle méthode offre une plus grande flexibilité pour décrire la relation densité–abri dans un cadre de recherche, car elle permet d'examiner simultanément l'influence de l'échelle et celle de la proportion d'abri.

Introduction

At northern latitudes, white-tailed deer, *Odocoileus virginianus* (Zimmermann, 1780), congregate during the snow season in wintering areas characterized by good cover and the presence of abundant browse (Dumont et al. 1998). Forest logging is an important component of white-tailed deer habitat management programs in many provinces and states (Huot et al. 1984; Mattfeld 1984; Zwarts 1998). An immediate benefit of logging is that browse production increases rapidly in recent cutovers. On the negative side, cover might be impaired, as it takes some 30 years for a clear-cut area to develop into a suitable cover patch for wintering white-tailed deer. Therefore, the cutting schedule is a delicate planning operation because logging has long-term effects on white-tailed deer habitat as it shapes the landscape for de-

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cades to come. Important questions in this process are what forest types provide good-quality cover, what size and configuration are optimal for cover patches, how much cover is needed, and at what scale should we operate?

Habitat selection analysis is adept at identifying the cover types that animals prefer or avoid (Manly et al. 1993). Telemetry data and geographic information system (GIS) analysis can provide information on optimal patch size and configuration (Bissonette 1997). Questions related to the amount of cover required on the long term and to the scale at which to operate are difficult to answer but may have great economic impact. Goals for the proportion of cover to maintain are derived from general observations in actual deeryards (Gill 1957; Smith and Verkruysse 1983; Crawford 1984; Vermont Fish and Wildlife Department 1986; Germain et al. 1991; Zwarts 1998). Scale refers to the size and delineation of units used to plan habitat management, which are often arbitrary administrative units such as forest compartments or tenure ownership limits. We suggest that describing the relationship between the white-tailed deer density distribution and the proportion of suitable cover at different scales should provide a more rational basis to answer the questions related to the scale at which to operate and the amount of cover required. With the empirical approach based on actual deeryards, an important limitation is that the proportion of cover among deeryards has a narrow range. Furthermore, many deeryards are needed but are not often available. The relationship between the white-tailed deer density and the proportion of cover can also be computed using data from individual plots in aerial surveys (e.g., Potvin and Gingras 2002). The sample size in such surveys is large, but the shape and size of the plots may be far from the scale at which white-tailed deer select habitat. The size of the home range of a white-tailed deer in winter was about 1 km^2 (Tierson et al. 1985), while the plots were only 0.21 km^2 and were very narrow (60 m × 3.5 km) in the study by Potvin and Gingras (2002).

This paper presents a new method to describe the relationship between white-tailed deer density and the proportion of cover, using aerial survey data and forest vegetation maps. Through GIS analysis, we use binary cover maps and windows of different sizes to describe this relationship over many scales and a wide range of cover proportions. Our study took place on Anticosti, a large forested island in the Gulf of St. Lawrence that supports a high density of white-tailed deer. Since 1995, different forest logging techniques were tested to restore balsam fir (*Abies balsamea* (L.) P. Mill.) stands, the best cover type for white-tailed deer in winter on the island. These stands are being jeopardized by overbrowsing (Potvin et al. 2003*a*). Intensive aerial surveys have been conducted to study habitat selection (Potvin and Gingras 2002; Potvin et al. 2003*b*). We use a data set from those surveys to examine the relationship between white-tailed deer density and the proportion of cover (balsam fir forest) in windows of different sizes. We hypothesize that a window size closer to the winter home range of the white-tailed deer will result in higher densities than smaller or larger windows. We also hypothesize that the white-tailed deer density will initially increase with the amount of cover and then reach a plateau, which is indicative of an "optimal" condition.

Materials and methods

The study area and aerial survey method are described in Potvin et al. (2003*b*). In January 1999, 260 white-tailed deer groups (374 animals) were located in a double-count aerial survey in 173 plots (60 m × 3.5 km) systematically distributed over a 270-km^2 forest block (Fig. 1). The density was 12.5 ± 2.1 deer/km^2 (mean ± 90% confidence interval (CI)).

A forest map, generated by photo-interpreting aerial photographs at a 1 : 10 000 scale, was used to define cover types. The minimal mapping unit was 8 ha but could be decreased to 4 ha if a sharp contrast existed with neighbouring patches. For habitat selection analysis in a previous study, the forest map was aggregated into 10 cover types (Potvin et al. 2003*b*). White-tailed deer preferred three cover types: WHITE SPRUCE STANDS WITH HIGH REGENERATION IN BALSAM FIR, REGENERATION, and BALSAM FIR. WHITE SPRUCE STANDS WITH HIGH REGENERATION IN BALSAM FIR are stands >7 m high having >50% basal area in white spruce, *Picea glauca* (Moench) Voss, and >5% density of high regeneration in balsam fir in the understory (1.5–7 m). REGENERATION includes all stands <7 m. Stands >7 m high with >50% basal area in balsam fir are classified as BALSAM FIR type. For the present study, we pooled WHITE SPRUCE STANDS WITH HIGH REGENERATION IN BALSAM FIR and BALSAM FIR cover types into a single type called BF. REGENERATION was not considered in the analysis because this habitat type provides food but no cover.

The aerial survey data and cover map were managed with ArcView version 3.2 and Spatial Analyst extension (ESRI Inc., Redlands, California). The map was in grid format (10 m × 10 m cells) and extended 2 km outside the aerial survey block to eliminate edge effects in the following steps. We selected only BF pixels in the cover map and transformed it to a binary format (BF = 1, else = 0). Five map sets of the relative abundance of BF were then computed by counting for each pixel the number of BF pixels inside windows of different sizes (0.2 km × 0.2 km, 0.5 km × 0.5 km, 1 km × 1 km, 2 km × 2 km, and 3 km × 3 km), centred on the focal pixel. Pixel values from each map set were reclassified according to the following proportions (%) of BF in the window: <10, 10–20, 20–30, 30–40, 40–50, 50–60, 60–70, 70–80, and ≥80. Aerial survey sample plots were recorded as linear features and white-tailed deer groups located by observers as point features in the database. To calculate the white-tailed deer density in the entire block corresponding to each BF class i, we measured the total length of the plot fragments (L_i; km) and the number of white-tailed deer observed (D_i) by overlaying the sample plot line layer and the white-tailed deer group point layer over the pixels of the corresponding reclassified BF cover map. The area sampled (A_i; km^2) was obtained by taking into account the 60-m width of a plot

$$A_i = L_i \times 60/1000$$

and the density (deer/km^2) in class i was calculated as D_i/A_i. No density was computed if the area sampled in a class occupied <0.6 km^2, which corresponded to fewer than three aerial survey plots.

Fig. 1. Distribution of balsam fir (BF) cover type in the study area on Anticosti Island. Lines are aerial survey plots (60 m × 3.5 km) and points are the occurrences of white-tailed deer (*Odocoileus virginianus*) groups observed.

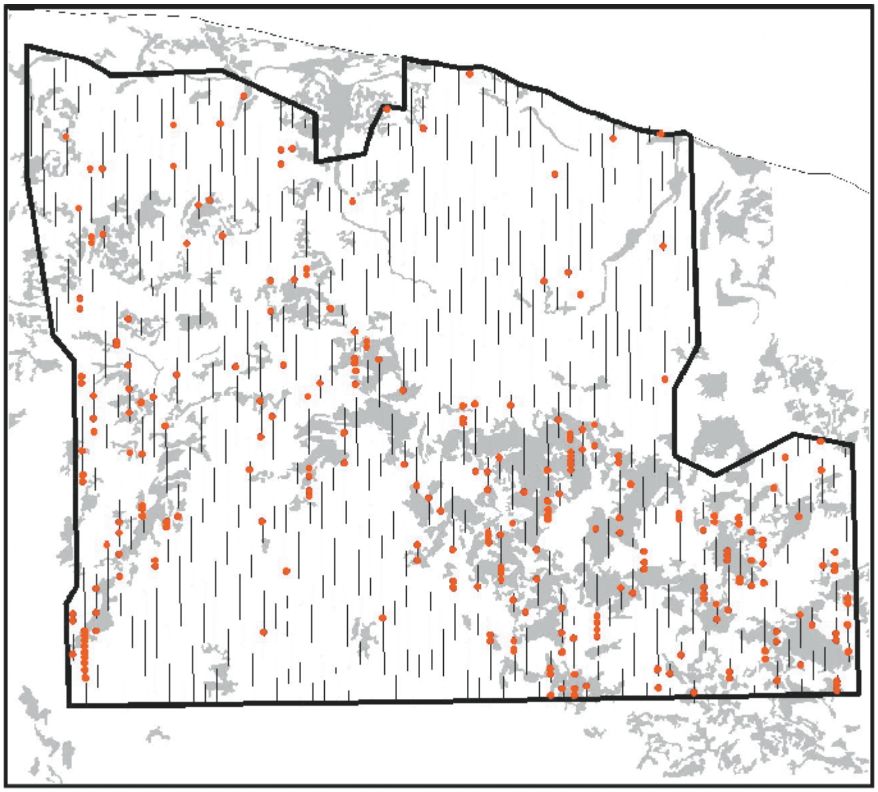
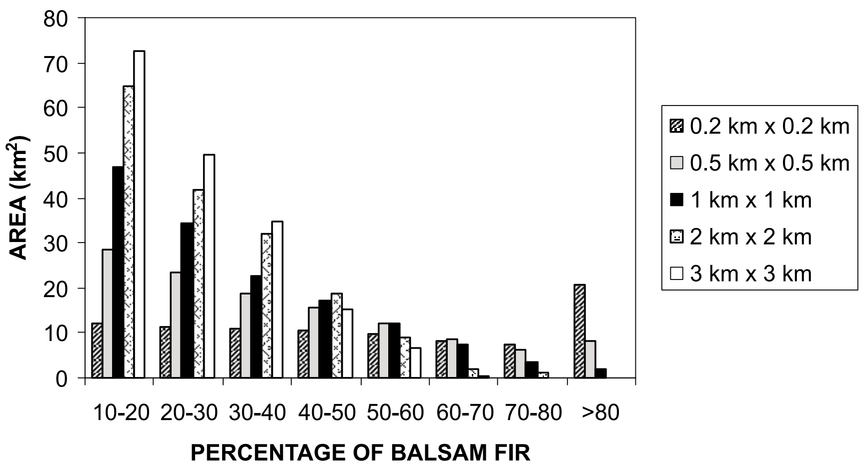


Fig. 2. Area occupied by pixels whose neighbourhood has between 10%–20% and >80% BF cover type in the study area on Anticosti Island. Neighbourhoods correspond to windows of 0.2 km × 0.2 km, 0.5 km × 0.5 km, 1 km × 1 km, 2 km × 2 km, and 3 km × 3 km, centred on the 10 m × 10 m focal pixel.



Results

BF cover type occupied 49.7 km^2 or 18.4% of the aerial survey block (Fig. 1). Mean patch size was 34 ha (SD = 124, range = 0.2–1472 ha, n = 147). Some patches (n = 9) located at the edge of the study block were smaller than the 4-ha minimal mapping unit because their area extended outside the block. The largest patches and greatest concentrations were found in the southeastern quarter of the block, while more fragmented patches were present in the western half.

Locations corresponding to focal pixels having ≥80% BF in a 0.2 km × 0.2 km window occupied 21 km^2 compared with 8 km^2 for a 0.5 km × 0.5 km window and 2 km^2 for a 1 km × 1 km window (Fig. 2). No pixels had ≥80% BF in a 2 km × 2 km window or ≥70% BF in a 3 km × 3 km window. Pixels with >10% BF in the largest window occupied almost the entire block (179 km^2), while those with the same proportion in the smallest window cumulated only 91 km^2 (Fig. 3). Conversely, the 0.2 km × 0.2 km window resulted in larger numbers of pixels than the other windows for all

Fig. 3. Distribution of pixels whose neighbourhood has over 10%, 30%, 50%, and 70% of BF cover type in the study area on Anticosti Island. Neighbourhoods correspond to windows of 0.2 km × 0.2 km, 1 km × 1 km, and 3 km × 3 km, centred on the 10 m × 10 m focal pixel.

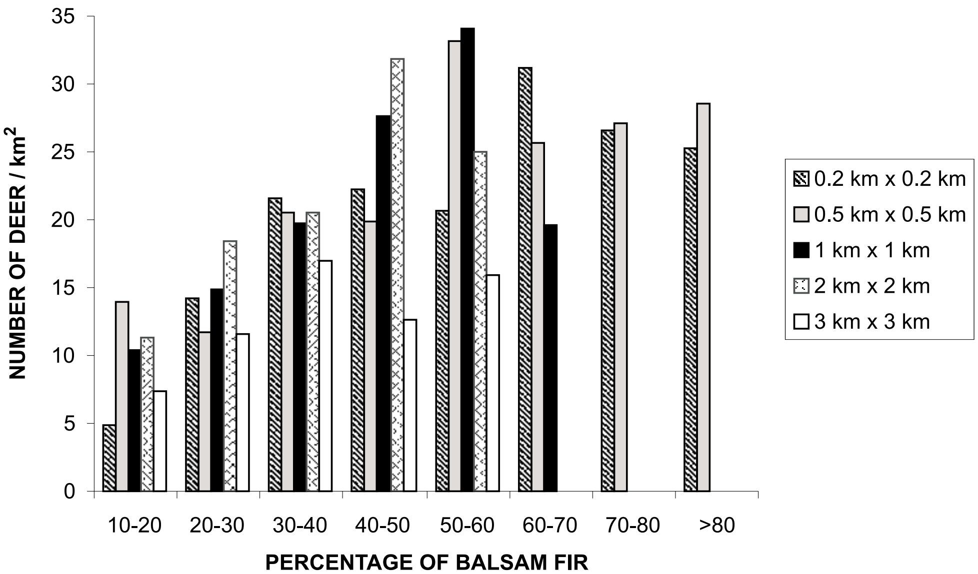
proportions of BF >70%. The spatial pattern changed with window size. As both window size and proportion of BF increased, the locations became more concentrated in the southeastern quarter where BF was most abundant and BF patches had larger sizes.

Maximum densities reached were quite similar irrespective of window size, except for the 3 km × 3 km window for which maximum density remained half lower (Fig. 4). The maximum densities occurred at 60%–70% BF for the 0.2 km × 0.2 km window (31 deer/km^2), at 50%–60% BF for the 0.5 km × 0.5 km window (33 deer/km^2) and the 1 km × 1 km window (34 deer/km^2), and at 40%–50% BF for the 2 km × 2 km window (32 deer/km^2). White-tailed deer densities increased with the proportion of BF in the windows and then reached a plateau or decreased.

Discussion

The average size of the winter home range of a white-tailed deer on Anticosti Island has been recently estimated at

Fig. 4. Relationship between white-tailed deer density and the proportion of BF cover type in five neighbourhoods in the study area on Anticosti Island. The proportion of BF cover type is computed inside windows of 0.2 km × 0.2 km, 0.5 km × 0.5 km, 1 km × 1 km, 2 km × 2 km, and 3 km × 3 km, centred on the 10 m × 10 m focal pixel. No relationship was computed >60% BF for the 2 km × 2 km and 3 km × 3 km windows and >70% for the 1 km × 1 km window because these classes were not present or the area sampled was a too small.



65 ha by GPS telemetry (F. Potvin and C. Dussault, unpublished data). Our first hypothesis was that a window size closer to the size of the home range would result in higher densities than smaller or larger windows. Except for the largest window (3 km × 3 km), this was not the case because densities were quite similar irrespective of window size. At 50%–60% BF, the 0.2 km × 0.2 km and 2 km × 2 km windows had substantially lower densities than the 0.5 km × 0.5 km and 1 km × 1 km windows, but the opposite situation prevailed at 60%–70% BF for the smaller one and at 40%–50% BF for the larger one. This lack of difference suggested that among the range of window sizes tested, only the largest one was higher than the scale at which white-tailed deer select winter habitat. Testing windows smaller than 0.2 km × 0.2 km would not be appropriate, since this size corresponded to the minimal mapping unit of the vegetation map (4 ha).

White-tailed deer density increased with the amount of BF cover, confirming our second hypothesis. This was no great surprise because BF was already known as a preferred cover type on Anticosti Island (Potvin and Gingras 2002; Potvin et al. 2003*b*). More interesting was the fact that a plateau was reached above 60% or 70% BF for the two smaller windows or that density decreased above 50% or 60% for the 1 km × 1 km and 2 km × 2 km windows, which was indicative of an "optimal" condition. White-tailed deer is considered an edge species that benefits from the interspersion of food and cover (Harlow 1984). A landscape dominated by pure BF cover therefore might not be an ideal mosaic, as opposed to a landscape where other habitats, such as regenerating stands, are well dispersed. This probably explains why a plateau is reached or density decreases after 50%–70% BF. A similar conclusion on the advantages of interspersion between food and cover has been born out by Dumont et al. (1998) at a finer scale (within forest stands).

For management purposes, our results suggest that the optimal proportion of cover would be 40%–60% BF inside 0.5 km × 0.5 km to 2 km × 2 km units. The proportion suggested for deeryards in Quebec for the Lower St. Lawrence and Gaspé Peninsula regions, areas sharing winter conditions similar to Anticosti, is 32%–50% (Zwarts 1998). This value, obtained from empirical data across deeryards, is of the same order as our results on Anticosti. For research applications, our method allows great flexibility for describing density–cover relationships because both scale and proportion of cover can be analysed simultaneously.

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