Observing Snowshoe Hares in Adirondack Forest Openings and Management Implications

Rainer H. Brocke

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ABSTRACT: In the Adirondack region, snowshoe hares are not commonly seen during most of the year because of their secretive nature and affinity for dense forest cover. However, in spring they can be observed in grassy forest openings. The mean duration of individual hare observations for mornings and evenings was 13 minutes. Ninety percent of the time was spent by hares sitting and feeding. Hares in openings stayed on the average of 2 m away from the forest edge. Snowshoe hares apparently venture into sunlit openings to feed on the dense spring growth of annual plants. Stem densities of grasses and annual plants in openings were 3.2 to 17.2 times as great as stem densities in adjacent forest during May. The high level of hare activity in openings in mid-May coincides with mean parturition and conception dates for the first and second litters respectively.

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1 This study was supported by the State University of New York, College of Environmental Science and Forestry and by Pittman-Robertson Project W-105-R, New York, the U.S. Fish and Wildlife Service and New York State Department of Environmental Conservation cooperating.
activity in openings declines abruptly in late May. On the basis of pellet
counts, hare use of 30 experimental openings and 30 forested plots adjacent
to conifer cover was significantly higher than that respectively of 30
openings and forest plots distant (200 m) from conifer cover. Hares
showed no significant preference for other variously treated experimental
openings. When approached by an observer walking along a forest trail,
snowshoe hares in small openings tend to escape before they are seen.
Hares can be observed more readily by persons in autos or on bicycles. On
the basis of Model 1, the efficiency of a given opening declines with
increasing numbers of hares using the opening in terms of time when hares
are visible and number of hares that can be seen simultaneously. On the
basis of Model 2, the probability of seeing hares in openings increases
with increasing number of hares using an opening and increasing time that
the opening is observed. The number of hares using openings is directly
related to the length of conifer forest edge, namely about 33 m per hare
in this study. The size of a forest opening required to meet a given
observation probability level can be estimated on the basis of Model 2. In
appropriate areas, snowshoe hare observation in residential lawns can be
enhanced by arranging and modifying cover in the vicinity of the lawn.
Management for hare viewing along observation routes through forest country
should be integrated with management for observation of other wildlife
species.

Recreational observation of wild animals has been recognized as an
important and valuable use of the wildlife resource (Hendee 1969, Allen et
literature contains little information about specific management methods
to enhance the viewing of wildlife, especially the viewing of wild mammals.
Recreational observation of wild mammals has quite naturally seen its
greatest development for large species in open savannas and grasslands
conditions, the only important management measure needed may be a road to
serve the viewing public. In forested areas, viewing of wild mammals has
received less attention, possibly because human vision is impaired

The ecological role of forest openings and edges has been studied
for a variety of ungulates (Severinghaus and Cheatum 1956:137, Lamprey
1963, Halls and Alcaniz 1968, McCaffery et al. 1974, Hirst 1975:56,
Drolet 1978, Papegeorgiou 1978, Evans 1979). Observability of white-
tailed deer (*Odocoileus virginianus*) along forest roadsides in the central
Adirondacks was increased 300 to 400 percent by clearing road shoulders
and seeding cleared areas with grasses and legumes (Sage and Tierson 1975).
In addition to the effects of habitat structure on viewability,
meteorological factors such as weather, light and seasonal cycles influence
observability of large and small mammals. (Newman 1959, Lord 1961, Kline
1965, Eltringham and Flux 1971, Zagata and Haugen 1974, Carbaugh et al.
1975, Fafarman 1979). Observability is also affected by the interaction of
observer and animal (Altmann 1958, Behrend and Lubeck 1968, Kucera 1976,
Schultz and Bailey 1978).

The snowshoe hare (*Lepus americanus*) is an unlikely subject for
recreational observation. It is infrequently seen by man wherever it
occurs because of its nocturnal habits, secretive nature, and affinity for
dense forest cover (Grange 1949, 1965, Keith and Surrendi 1971, Brooke 1975, Dolbeer and Clark 1975, Conroy 1979, Tomkins and Woehr 1979). But for a brief period in spring, snowshoe hares are visible in some forest openings and roadside locations in the Adirondack mountain region of New York State and elsewhere. The objectives of this study were to (1) observe the behaviour of snowshoe hares in forest openings and identify possible causes for this behaviour, (2) determine the effects of opening size and experimental opening treatments on hare use of openings and hare observability, (3) study snowshoe hare-observer interaction and the potential effects of such interaction on hare observability, and (4) outline management procedures to enhance recreational observation of snowshoe hares.

We thank J.P. Zarnetske, J. Chapman, S.C. Simkins, D. Wheeler and R.J. Cameron for their assistance in data collection. Helpful suggestions in statistical analysis were provided by W. Stiteler of this institution. We thank D. Behrend of this institution for reviewing the manuscript. We are grateful to J. Vadiveloo and A. Roth of the Mathematics Department, Syracuse University, Syracuse, N.Y. for developing the probability formulas.

STUDY AREA AND METHODS

The study area is located in the center of New York State's Adirondack mountain region. The biota of this region are north temperate, produced by short growing seasons and long, snowy winters. Elevations range approximately from 550 m to 1500 m. Deciduous tree species, including yellow birch (Betula alleghaniensis), sugar maple (Acer saccharum), and American beech (Fagus grandifolia), are dominant on the lower slopes. Conifers, including spruces (Picea spp.) and balsam fir (Abies balsamea) become more
dominant with increasing elevation; eastern hemlock (*Tsuga canadensis*) and eastern white pine (*Pinus strobus*) are locally common at lower elevations. Paper birch (*Betula papyrifera*) is characteristic on disturbed areas and burns at all elevations. At lower elevations, grassy areas used by snowshoe hares are usually man-made and man-maintained as openings created by logging or natural disturbance are soon overgrown.

Observations of snowshoe hares, pellet counts and vegetation tallies were variously made (1) in two large openings, Opening A located adjacent to a macadam highway and Opening B, a lawn surrounding a family dwelling; (2) in 60 small experimental openings and 60 forested control plots, and (3) along grassy shoulders bordering a macadam highway. Opening B was located in Huntington Forest, a 6000 ha forest research station. Opening A and road shoulders observed for hares were located within 15 km of the station. The behaviour of snowshoe hares was intensively observed in Openings A and B. All observations for Opening A, located next to a highway, were made from a vehicle parked across the highway from the opening. Observations in Opening B, a residential lawn, were made from the house in the middle of the lawn. As snowshoe hares are largely nocturnal, they were first observed in openings in the evening when their activity cycle begins and again in the morning when their activity ends. In the evening, observation began well before the first hare was seen and ended with failing light when hares were no longer clearly visible. In the morning, observation began before hares could be seen clearly, and ended well after the last hare was observed. The beginning and end of each hare's activity span was recorded to the nearest minute. Once every minute, the specific activity (sitting, feeding, moving etc.) and perpendicular distance from the forest were recorded for each hare. "Hare observations" are individual time spans.
when hares appeared in the openings and behaviour was recorded every minute for each hare. Experimental openings along the 2.98 km observation route were observed for snowshoe hares by a slowly walking person. Morning and evening trips were alternated between 2 observers and the 19 trips were evenly divided among them (9 and 10 trips respectively). Hare observation trips to determine relative viewing success while walking and bicycling were conducted by 1 person.

The experimental openings and forested control plots were distributed along a 2.98 km stretch of graveled forest road in Huntington Forest. Thirty of the 60 experimental roadside openings were located adjacent to conifer cover, while 30 openings were 200 m or more distant from conifer cover. The purpose of this experimental design was to test a previous finding (Brocke 1975) that Adirondack snowshoe hares require avenues of conifer cover to reach feeding areas such as openings. Six treatments (including distance from conifer cover) were applied to the 60 openings, 10 openings per treatment. Details are given in Table 6. Each of the 60 experimental openings was paired with an adjacent untreated, forested control plot of the same size, for a total of 60 control plots. Preparation of experimental openings was completed one growing season before they were observed for hare use. Large and small trees, branches, brush, debris and leaves were removed prior to raking by hand or by tractor-drawn springtooth harrow. Twenty of the experimental openings were left bare for natural seeding by grasses, sedges and other vegetation. Openings were mowed as needed. Experimental openings and adjacent control plots were identified with painted stakes and numbered signs. All openings were measured and mapped, and areas determined by planimetry. Use of experimental openings by hares was quantitatively assessed by counting fecal
pellets in 1 m\(^2\) quadrats located 5 m apart along the opening periphery, 2 m from the edge. Quadrats were randomly located in control plots. The density of annual plant stems was surveyed on 6 dates from April 27 through June 1. Plant stems at least 2 cm high were counted in 1 m\(^2\) quadrats in Openings A and B, experimental openings and in forest adjacent to respective openings. Quadrats in openings were located 2 m from the forest edge and 5 m within adjacent forest and all quadrats in openings and forest were placed 2 m apart.

The distribution of daily hare activity was experimentally determined for 4 hares held individually in a 10 m x 20 m pen. The pen was partitioned into 8 interconnected compartments and monitored by 48 reed switches located in passageways. Natural cover was spread throughout the pen and food was located in each compartment. Each hare moved about freely in all compartments and its activity was recorded by a 20 pen Esterline-Angus strip chart recorder. Switch closures per hour were recorded for various periods of days for each hare. Hare activity was not determined for May because of weather-induced switch failures.

Models were constructed on the basis of field observations. Assumptions formulas and derivations for models are given in the text and appendix. We have used statistical procedures and methods described in Sokal and Rohlf (1969).
Rainer H. Brocke

RESULTS AND DISCUSSION

Daily Activity and Behaviour in Openings

Dimensions and areas of Openings A and B and 60 experimental openings are given in Table 1. Openings A and B are respectively 20 and 7 times larger than the mean size of experimental openings. Observation dates and times for Openings A and B are summarized in Table 2. These openings were watched from May 11 through June 29 for a total of 81 hours during 34 mornings and evenings (Table 2). Data on viewability of hares related to observation time spans are given in Table 3. The basis for this table is the Potential Viewing Period (PVP), defined as follows: For mornings, the PVP is that span of time between the earliest mean time when hares were clearly visible in the opening, and the latest time in the morning when a hare was seen in the opening. For evenings, the PVP is that span of time between the earliest time when a hare was seen in the opening and the latest mean time when hares were clearly visible. The PVP value of 100 minutes for evenings (Table 3) is approximately one half that for mornings. The shorter PVP for evenings may reflect a lag in the onset of hare activity in the evenings. Conversely, the longer morning PVP may reflect a corresponding lag in the cessation of hare activity. Mean viewability values for mornings are similar to evening values. For mornings and evenings combined, mean hare viewability (i.e. percent of the PVP when at least 1 hare is visible) is 27.1 percent, the mean number of hare observations per PVP is 2.4, while the maximum number of hares observed simultaneously per PVP is 1.5 (Table 3). An example of a sequence of snowshoe hare observations for 1 evening is given in Figure 1. One or more hares were under observation for a total of 83 minutes, and 4 hares used the opening simultaneously at 8:31 p.m. The first hare appeared in the opening at
Table 1. Dimensions and areas of Openings A and B and 60 experimental openings.

<table>
<thead>
<tr>
<th>Openings</th>
<th>Frontage a (m)</th>
<th>Depth b (m)</th>
<th>Forest Edge c (m)</th>
<th>Area d (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjacent to highway</td>
<td>98</td>
<td>46</td>
<td>150</td>
<td>3213</td>
</tr>
<tr>
<td>Opening B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential lawn</td>
<td>42</td>
<td>30</td>
<td>90</td>
<td>1208</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SE (N=60)</td>
<td>10.4 ± 0.6</td>
<td>17.5 ± 1.0</td>
<td>38.0 ± 2.2</td>
<td>163.7 ± 12.4</td>
</tr>
</tbody>
</table>

a Length of opening fronting on road or trail, usually greater than the width of the opening.

b The perpendicular distance from the road or trail to the farthest point on the back edge of the opening.

c Forest or shrub edge bordering the openings away from the road.

d Areas determined by planimetry of opening maps.
Table 2. Observation dates and times for Openings A and B

<table>
<thead>
<tr>
<th>Opening Time of Day</th>
<th>Inclusive dates of observation</th>
<th>Mean time period and time span (below, min)(^{b}) of opening observation X ± SE (N)</th>
<th>Mean time period and time span (below, min)(^{c}) of hare observation X ± SE (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPENING A Morning</td>
<td>May 11 - July 8</td>
<td>4:52 - 8:02</td>
<td>5:22 - 7:14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>190 ± 10 (10)</td>
<td>112 ± 69 (2)</td>
</tr>
<tr>
<td></td>
<td>Evening</td>
<td>6:30 - 9:01</td>
<td>7:33 - 8:26</td>
</tr>
<tr>
<td></td>
<td>May 13 - June 29</td>
<td>150 ± 14 (9)</td>
<td>53 ± 32 (3)</td>
</tr>
<tr>
<td>OPENING B Morning</td>
<td>May 14 - June 8</td>
<td>6:35 - 8:07</td>
<td>7:33 - 8:03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>92 ± 13 (6)</td>
<td>30 ± 6 (3)</td>
</tr>
<tr>
<td></td>
<td>Evening</td>
<td>6:47 - 8:44</td>
<td>8:04 - 8:26</td>
</tr>
<tr>
<td></td>
<td>May 12 - June 11</td>
<td>117 ± 5 (9)</td>
<td>22 ± 6 (7)</td>
</tr>
</tbody>
</table>

\(^{a}\) Opening A is located adjacent to a macadam highway; Opening B is a residential lawn.

\(^{b}\) Mean of time spans in minutes when opening was under observation. The number of mornings and evenings of opening observation is given by N.

\(^{c}\) Mean of time spans in minutes between the first and last times when 1 or more hares were observed in the opening. The number of mornings and evenings when 1 or more hares were observed is given by N.
Table 6. Viewability of hares in Openings A and B for 15 mornings or evenings when hares were seen. Data are excluded for 19 days when openings were observed but no hares were seen.

<table>
<thead>
<tr>
<th>Range of Dates, Time of Day</th>
<th>Mornings or Evenings N</th>
<th>Potential Viewing Period</th>
<th>Hare viewability time as % of Potential Viewing Period</th>
<th>Hare observations per Potential Viewing Period</th>
<th>Maximum number hares observed simultaneously per Potential Viewing Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 11 - 27 Mornings</td>
<td>5</td>
<td>5:14 - 8:31 a.m. 197 min.</td>
<td>27.0 ± 3.1 (8-40)</td>
<td>2.8 ± 0.4 (1-5)</td>
<td>1.6 ± 0.2 (1-3)</td>
</tr>
<tr>
<td>May 12 - June 11 Evenings</td>
<td>10</td>
<td>7:05 - 8:45 p.m. 100 min.</td>
<td>27.2 ± 5.9 (3-83)</td>
<td>2.2 ± 0.6 (1-9)</td>
<td>1.5 ± 0.3 (1-4)</td>
</tr>
<tr>
<td>May 11 - June 11 Mornings and Evenings</td>
<td>15</td>
<td>27.1 ± 3.0 (3-83)</td>
<td>2.4 ± 0.6 (1-9)</td>
<td>1.5 ± 0.2 (1-4)</td>
<td></td>
</tr>
</tbody>
</table>

a The Potential Viewing Period, defined in the text, is a function of the period of daily hare activity and the limitations of available light for viewing. For morning, the potential viewing period is given for Opening A only; for evening, the potential viewing period is given for Openings A and B. The PVP value for mornings was calculated on the basis of observations for Opening A only because earliest observation times for Opening B coincided with waking of house residents making the observations.

b Hare viewability is given as % of time of the Potential Viewing Period when at least 1 hare was under observation. Range of percentages is given in parentheses.

c Discrete appearances of hares in opening.

d Maximum number of individual hares observed in the opening simultaneously.
7:05 p.m. and observations ceased with failing light at 8:50 p.m. It should be noted that more than 4 individual hares may have used the opening as individuals were not distinguishable.

The temporal distribution of observed snowshoe hare activity in Openings A and B is graphically shown in Figures 2 and 3 for mornings and evenings respectively. In Figure 2, observation data for time classes prior to 7:00 a.m. are omitted (see explanation in footnote a, Table 3). The activity distribution for 4 penned snowshoe hares for periods from March 17 through July 3 is shown in Figure 4. It appears that the bulk of snowshoe hare activity occurs at night, with peaks of activity after sunset and before sunrise. Taken together, Figures 2, 3, and 4 suggest that only a small fraction of snowshoe hare activity in openings is observable during daylight hours.

Data on behavioural characteristics of snowshoe hares are summarized in Table 4. The time spans for 36 hare observations in Openings A and B for mornings and evenings combined averaged 13 minutes (Table 4). Ninety percent of observed hare activity is equally divided between sitting and feeding categories. The feeding category refers to hares standing on four legs or walking and feeding on vegetation. The sitting category refers to hares sitting upright on their haunches. The distinction between these 2 categories is not absolute as sitting hares were often chewing stems or blades of grass. Hares were in motion 10 percent of the time (Table 4), usually changing location but occasionally chasing each other or jumping in high arcs. The concurrent presence of hares in openings appeared to be largely due to chance. Fifty eight percent of all observations on 78 percent of all mornings and evenings when hares were seen, were of
Table 4. Behavioural characteristics of snowshoe hares observed in Openings A and B.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Observations N</th>
<th>Time span (Min.) of individual hare observations X ± SE (Range)</th>
<th>Time span (Min.) of hare activity (X ± SE)</th>
<th>Perpendicular distance (m) from opening edge X ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X ± SE (Range)</td>
<td>Sitting</td>
<td>Feeding</td>
</tr>
<tr>
<td>Morning</td>
<td>14</td>
<td>10.1±3.3 (1 - 43)</td>
<td>6.1±1.8</td>
<td>3.5±1.7</td>
</tr>
<tr>
<td>Evening</td>
<td>22</td>
<td>14.9±2.6 (1 - 46)</td>
<td>5.8±1.4</td>
<td>7.4±1.8</td>
</tr>
<tr>
<td>Morning and Evening</td>
<td>36</td>
<td>13.0±2.1 (1 - 46)</td>
<td>5.9±1.1</td>
<td>5.9±1.3</td>
</tr>
</tbody>
</table>
solitary animals. Locations of snowshoe hares in openings, regardless of their behavioural activities, were consistently close to the forest edge, namely 2.0 ± 0.2 m (X ± SE, Table 4). We casually inspected openings to determine what factors might be responsible for this consistent behaviour. We observed that the growth of grasses and herbs was commonly suppressed within a strip approximately 1 m wide adjacent to the forest edge, apparently as a result of a light shadow and accumulated leaf litter (often conifer needles). In sum, it appears that the mean distance of 2 m from the forest edge selected by snowshoe hares approximates the closest point to escape cover which also provided access to food.

The edge-related behaviour of snowshoe hares observed in openings is probably a response to potential predation and appears to be part of a more comprehensive behavioural relationship to escape cover. In a series of automobile trips to observe hares along an abandoned macadam highway, we had the opportunity to observe hares escaping at short range (hares can be observed more successfully from an automobile than on foot, a point discussed farther in the text). On 4 occasions, hares were sitting characteristically close to cover when they were approached by a slowly moving vehicle. They fled into adjacent cover, disappearing almost instantly. On 2 occasions when hares escaped towards conifer cover over distances exceeding 10 m, they briefly stopped just outside the edge of cover before entering it. Apparently the closeness of cover provided security for these hares so that they stopped for a last look. On 2 separate occasions, the observer left the automobile to inspect the location where a hare had fled into cover 30 minutes previously. Each animal was flushed from a form, established 1 to 2 m within the edge of conifer cover where it had entered. In the Adirondacks, snowshoe hares
have an affinity for dense conifer or mixed cover throughout the year (Brooke 1975) and commonly spend the daylight hours in forms under overhanging conifer branches adjacent to forest openings. In such locations, hares can readily see approaching predators, while remaining relatively invisible. In the chapparal and coastal sage communities of California, Bartholomew (1970) found a bare zone adjacent to shrub stands created largely by the grazing of 2 rabbit species. He observed that these species did not venture far from shrubs, apparently to help them escape from predators. The close association of several large herbivore species with forest edge has been observed in east Africa (Lamprey 1963). Lamprey’s explanation for this behaviour is that forest dwelling species feeding in the open grassland escaped from predators into adjacent forest.

Seasonal Use of Openings

The viewability of snowshoe hares in Openings A and B from May 11 through July 10 is illustrated in Figure 5. Hare viewability is defined as the percent of the Potential Viewing Period (PVP), mornings or evenings, when at least 1 hare was visible. Hare viewability percentage means for 5 day intervals from May 11 through May 31 ranged from 7.5 percent to 43 percent (Figure 5). Viewability percentages for individual mornings and evenings during this period ranged from 0 percent to 83 percent. Hare viewability in openings declined greatly by the beginning of June (Figure 5).

In general, there appeared to be no discernable effect of weather on the use of openings by snowshoe hares, with one marked exception discussed farther in the text. Hares were observed in openings on all
but 2 of 15 mornings and evenings of observation from May 12 through May 27. During this period, precipitation was variable and most days were cool. Temperatures for morning and evening observation periods ranged from 2° to 14° C. Cloud conditions ranged from clear to complete overcast, while some days were foggy and hazy. From June 1 through July 8, hares were seen on only 4 of 19 mornings and evenings. It was not raining on any of those days, but there was no precipitation on 11 other mornings and evenings when hares were not seen. The exceptional case in which weather clearly did affect hare behaviour in openings occurred on May 20, 1976. An unusual snowstorm deposited approximately 34 cm of snow in the study area. By the evening of May 20, snow remained in Openings A and B to a depth of 16 cm. The temperature was 4° C and a light rain was falling. No hares were seen in Opening B. One hare was observed feeding on grass in a small snow-free patch in Opening A for a total of 3 percent of the PVP. By contrast, the mean hare viewability for the month of May for 13 mornings and evenings when hares were seen was 30.3 percent. The low mean viewability percentage for the May 16 to May 20 interval, namely 7.5 percent (Figure 5), reflects the depressing effect of the May 20 snowstorm on hare viewability. In sum, it appears that hares were relatively active in openings in May, regardless of most weather conditions. It should be noted that the observations above provide little insight into the effects of weather on snowshoe hare biology. Important weather effects on snowshoe hare reproduction and survival have been documented by Meslow and Keith (1971). We believe that weather influences the reproduction and survival of Adirondack snowshoe hares in ways outlined by the latter authors.
The May period of intensive opening use by snowshoe hares (Figure 5) coincides with a high level of reproductive activity. In the Adirondacks, the mean parturition date of the first litter of young and the mean conception date for the second litter are May 17 and 15 respectively (Brocke 1977). These dates fall within the period of greatest hare activity in openings. As females generally produce at least 2 litters in the Adirondacks (Brocke 1977), practically all females are pregnant during the first half of May and pregnant as well as lactating during the second half. Thus, it appears that the spring growth of annuals in openings provides essential nutrients to hares when their nutrient needs are high. However, in early summer when reproductive demands are equally high, hares apparently feed to a much larger extent within the forest, judging from the relatively lower level of hare activity in openings during June and July (Figure 5).

The intensive feeding of snowshoe hares in forest openings in May is to a large extent explainable by the faster spring growth of annuals in openings compared to forest. The stem densities of annual plants for late April, May and early June in Openings A and B and adjacent forest are given in Table 5 and Figure 6. Stem density means for Openings A and B are from 4.8 to 11.2 times as great as corresponding values for adjacent forest (June 1 and May 4 surveys respectively, Table 5). For the smaller experimental openings, the mean stem densities are 3.2 to 17.2 times as great as corresponding values for adjacent forest (May 25 and May 11 survey dates, Table 5). For any given survey day, stem density means for larger openings (Openings A and B) are consistently higher than those for the smaller experimental openings (Table 5, Figure 6). A corresponding relationship holds for forest adjacent to larger and
Table 5. The density of annual plant stems at least 2 cm high for surveys in April, May and June in Openings A and B and adjacent forest, and in experimental openings and adjacent forest.

<table>
<thead>
<tr>
<th>Location</th>
<th>Quadrat counts per survey date</th>
<th>Survey dates and stem counts (Stems/m², X ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>April 27</td>
</tr>
<tr>
<td>OPENINGS A AND B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counts in openings</td>
<td>20</td>
<td>150 ± 18</td>
</tr>
<tr>
<td>Counts in forest</td>
<td>20</td>
<td>18 ± 3</td>
</tr>
<tr>
<td>Presence of snow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>small patches in openings</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>large patches in forest</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>EXPERIMENTAL OPENINGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counts in openings</td>
<td>10</td>
<td>20 ± 9</td>
</tr>
<tr>
<td>Counts in forest</td>
<td>10</td>
<td>3 ± 1</td>
</tr>
<tr>
<td>Presence of snow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>large patches in openings</td>
<td>none in</td>
<td>none in</td>
</tr>
<tr>
<td>small patches in forest</td>
<td>none in</td>
<td>none in</td>
</tr>
</tbody>
</table>

Kainer H. fcsrocke
smaller openings respectively.

The differences in plant growth considered above are largely explainable in terms of variations in air and soil microclimate (Geiger 1966). In general, daytime temperatures of openings during the warm months tend to be higher than those of adjacent forest. In an example cited by Geiger (1966, p. 345) the air temperature 10 cm above ground, in an opening, on a summer day (2 p.m.) was 3.8°C higher than in the forest, while soil temperature at a depth of 10 cm in the opening was 6.6°C higher than adjacent forest. For openings of various sizes (Geiger 1966, p. 352), the midday temperature excess of openings over forest ranged from 0.7°C for a small opening (similar in size to experimental openings) to 5.2°C for a larger openings (similar in size to Opening B). In this study, microclimatic effects are reflected in the presence and size of snow patches observed in openings and adjacent forest (Table 5). There was less or no snow in openings compared to adjacent forest for all survey dates when snow was recorded (Table 5). In large openings (Opening A and B) and adjacent forest, snow had melted completely by May 4. In small experimental openings, patches of snow were observed on May 4 and snow persisted in adjacent forest through May 11 (Table 5). The most pronounced difference in plant growth rates between Openings A and B and adjacent forest was recorded on May 25 (Table 5, Figure 6). This large difference in the density of plant stems coincides with the highest level of hare activity observed in Openings A and B (May 21 to 25 time interval, Figure 5).

In sum, the data presented above suggest the following ecological relationships between Adirondack snowshoe hares and forest openings:
1. In spring, the growth rate of annual plants in openings is much greater than in conifer or mixed forest. This accelerated growth of annuals is a result of more light and higher temperatures in openings compared to adjacent forest.

2. Heightened reproductive activity in May places unusually high nutritional demands on snowshoe hares. Consequently, hares are attracted to forest openings to feed, where a greater biomass of annual plants is available. In May, hares feed intensively in openings, regardless of most weather conditions.

3. The temporary use of forest openings by snowshoe hares may appear to be a deviation from their normal affinity for dense cover. However, hares in openings select consistently close escape distances to the forest edge, suggesting that their use of opening edges is a compromise between the availability of escape cover and a good food supply.

4. The density of annual plant stems within the forest increases steadily so that by the end of May, it reaches a level equal to that of openings in early May. While the reproductive demands on the nutritional regime of snowshoe hares continues unabated into June, their use of forest openings declines abruptly at the end of May to a much lower level for the summer. Apparently, the supply of annual plants within the forest at the end of May is adequate to meet the nutritional demands of hares.
Observability in Experimental Openings and Roadsides

The treatment scheme for 60 experimental openings is given in Table 6. Each experimental opening was paired with an adjacent forested control plot, for a total of 60 control plots. The relative use of these openings and plots by snowshoe hares as indicated by pellet count densities is given in Table 7. Mean pellet counts for openings and control plots adjacent to conifer cover are significantly higher than means for openings and forested plots distant (i.e. > 200 m) from coniferous or mixed deciduous-coniferous forest (Table 7, Comparison Nos. 1 and 2, p < 0.01 for t value, Mann-Whitney U statistic). Indeed, pellet counts of 0 were recorded for 29 of 30 openings and 21 of 30 forested plots, all located distant from conifer or mixed forest. Differences between mean counts for all other comparisons are not statistically significant (Table 7, p > 0.05, Comparison Nos. 3 to 6). There is an indication that fertilized openings may have been preferred over unfertilized ones (Table 7, Comparison Nos. 4 and 5). In Scotland, Miller (1969) recorded selective feeding by mountain hares (Lepus timidus) and rabbits (Oryctolagus cuniculus) on plots of fertilized heather. In sum, the data in Table 7 suggest that the most important habitat factor contributing towards the seasonal presence of hares in openings is the presence of conifer or mixed forest cover nearby.

Observation data for the experimental openings and control plots are given in Table 8. Nineteen observation trips were made at an average speed of 1.90 km/hr. (Table 8). No hares were seen in a total observation route of 56.6 km (19 X 2.98 km). This finding was quite
Table 6. Treatments for 60 experimental openings along a forest road. Each experimental opening was paired with an adjacent forested control plot, for a total of 120 openings and plots.

<table>
<thead>
<tr>
<th>Proximity to Conifers</th>
<th>Natural seeding only ( N )</th>
<th>Natural seeding with lime and fertilizer ( N )</th>
<th>Clover seeding with lime and fertilizer ( N )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conifers near ( a )</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Conifers distant ( b )</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

\( a \) Opening adjacent to conifer cover.

\( b \) Opening located at a distance of 200 m or more from conifer cover.

\( c \) Seeding and natural growth in cleared areas.

\( d \) Openings limed with dolomitic limestone \((\text{CaCO}_3 \cdot \text{MgCO}_3\)) at 2.5 metric tons/ha and fertilized with 10-10-10 fertilizer at 1120 kg/ha.

\( e \) Medium red clover and ladino clover applied at the rate of 10 kg/ha and 4.5 kg/ha respectively,
Table 7. Comparisons of hare pellet count means for combinations of 60 variously treated experimental openings and 60 forested control plots. Hare pellets were counted in a total of 4 quadrats (1 m²) per opening or forested plot.

<table>
<thead>
<tr>
<th>Comparison Number</th>
<th>Treatment Comparison</th>
<th>Openings or Forested plots (Quadrats)</th>
<th>Pellets/m X ± SE</th>
<th>tS value1 for U statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Openings - conifers near</td>
<td>30 (120)</td>
<td>6.13 ± 2.21</td>
<td>4.61 **</td>
</tr>
<tr>
<td></td>
<td>Openings - conifers distant</td>
<td>30 (120)</td>
<td>0.60 ± 0.60</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Forested Plots - conifers near</td>
<td>30 (120)</td>
<td>1.08 ± 0.27</td>
<td>3.59 **</td>
</tr>
<tr>
<td></td>
<td>Forested Plots - conifers distant</td>
<td>30 (120)</td>
<td>0.13 ± 0.05</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Openings - conifers near</td>
<td>30 (120)</td>
<td>6.13 ± 2.21</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Forested Plots - conifers near</td>
<td>30 (120)</td>
<td>1.08 ± 0.27</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Natural Seeding - conifers near</td>
<td>10 (40)</td>
<td>3.59 ± 2.84</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>Natural Seeding + Fertilizer - conifers near</td>
<td>10 (40)</td>
<td>8.47 ± 3.72</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Natural Seeding - conifers near</td>
<td>10 (40)</td>
<td>3.59 ± 2.84</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Clover + Fertilizer - conifers near</td>
<td>10 (40)</td>
<td>6.33 ± 4.90</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Natural Seeding + Fertilizer - conifers near</td>
<td>10 (40)</td>
<td>8.47 ± 3.72</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Clover + Fertilizer - conifers near</td>
<td>10 (40)</td>
<td>6.33 ± 4.90</td>
<td></td>
</tr>
</tbody>
</table>

1 "tS" value calculated for the Mann-Whitney U-test statistic (Sokal and Rohlf, 1969).

** Highly significant (p<0.01)
unexpected. One reason for this lack of success may have been a negative reaction of hares to the quietly walking observer. Every effort was made to see hares in openings. However, the periphery of each opening came into view only gradually as the observer approached. When the entire opening was finally visible, the observer was very close (approximately 17 m, Table 1) to all points in the opening. Hares probably escaped undetected as they heard or saw the observer approaching. This explanation is supported by the casual observation of work crews riding past experimental openings in vehicles. On 5 occasions in May and June, work crews saw 1 or 2 hares in 4 openings.

Data on the relative observability of snowshoe hares while walking and bicycling along macadam roads are given in Table 9. The mean number of hares seen per trip while bicycling and walking are 1.2 and 0.2 respectively. These means are significantly different ($t = 2.17$, $p < 0.05$). Although the mean duration of walking trips is practically equal to the mean duration of bicycling trips (Table 9), the comparability of these trips may be questioned as the bicycle route is about 7 times as long as the walking route. However, we judge that the probability for encountering hares per unit time while walking was at least as great as that while bicycling because the entire walking route was bordered by prime hare habitat. Taken together, the results from Tables 8 and 9 suggest that snowshoe hares react more negatively to a person on foot than to a person riding in or on a vehicle. Negative reactions of large mammals to silently walking humans have been observed by others. In Yellowstone National Park, Altmann (1958) observed that moose ($Aloes alces$) fled at long distances as she approached silently under cover, while groups of noisy tourists "with car doors slamming" could approach the same animals.
Table 8. Observation data for 60 experimental openings and 60 control plots distributed along 2.98 km of forest road. Observers were walking.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Mean Time of trip</th>
<th>Trips N</th>
<th>Time per trip $\bar{x} \pm SE$ (hrs.)</th>
<th>Speed of travel $\bar{x} \pm SE$ (km/hr)</th>
<th>Hares Seen N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>5:38 - 7:10</td>
<td>10</td>
<td>1.52 ± 0.13</td>
<td>2.09 ± 0.18</td>
<td>0</td>
</tr>
<tr>
<td>Evening</td>
<td>6:05 - 7:55</td>
<td>9</td>
<td>1.95 ± 0.21</td>
<td>1.69 ± 0.20</td>
<td>0</td>
</tr>
<tr>
<td>Morning and Evening</td>
<td>19</td>
<td>1.72 ± 0.13</td>
<td>1.90 ± 0.20</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Table 9. Observability of snowshoe hares while walking and bicycling along macadam roads. Hares were seen in various openings and along shoulders adjacent to roads.

<table>
<thead>
<tr>
<th>Trips</th>
<th>Duration of Trip (hrs.)</th>
<th>Length of Route (km)</th>
<th>Occasions hares seen per trip</th>
<th>Hares seen per trip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$X \pm SE$</td>
<td>$X \pm SE$</td>
<td>$X \pm SE$</td>
<td>$X \pm SE$</td>
</tr>
<tr>
<td>Walking - mornings and evenings</td>
<td>8</td>
<td>2.4 ± 0.1</td>
<td>2.0 ± 0.0</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td>Bicycling - mornings</td>
<td>8</td>
<td>1.9 ± 0.3</td>
<td>13.8 ± 1.6</td>
<td>1.1 ± 0.1</td>
</tr>
</tbody>
</table>
closely. White-tailed deer (*Odocoileus virginianus*) in Manitoba (Kucera 1976) allowed a vehicle or rider on horseback to approach closely more often than a walking person. In an Adirondack study of flight behaviour in white-tailed deer, Behrend and Lubeck (1978) noted that the response of deer to vehicles was less pronounced than to people afoot. White-tailed deer in Wisconsin (Eckstein et al. 1979) remained close to noisy heavy equipment and men working with power saws, but moved away when approached silently.

**Models**

Certain observations in this study suggested to us that chance might play a substantial role in determining the success of snowshoe hare observation. Firstly, while the lack of success in seeing hares during observation trips is explainable in terms of hare behaviour, chance may have affected success. Secondly, the feeding time of hares is short, namely 13 minutes per FVP (Table 4), and mean number of hare observations per FVP is not large, namely 2.4 (Table 3). These data indicated that under some circumstances, the probability of seeing a hare might be small, assuming that hare observability is a function of the overlap between the hares short feeding period and the length of time that the opening is being watched. Thirdly, the mean maximum number of hares observed simultaneously per FVP, namely 1.5 (Table 3) is approximately one half as high as the highest value recorded for all mornings and evenings of observation, namely 3 to 4 (Table 3). The discrepancy between these values seemed explainable as a probability function, assuming that hares were resident near each opening and fed there regularly. Finally, we observed a direct relationship between the size of openings and the number of hares using openings. While our data on this relationship are few,
they suggested that the probability of seeing a hare in an opening is a function of the number of hares using the opening, which in turn is a function of opening size.

Two hypotheses addressing the question of the role of chance in snowshoe hare observation are:

H1: The probability of observing 1 or more snowshoe hare in an opening during a given PVP is directly related to the number of hares using the opening.

H2: The probability of observing 1 or more snowshoe hares in an opening during a given PVP is directly related to the length of time that the opening is being watched.

The phrase "1 or more hares" in these hypotheses is based on the premise that equal satisfaction is derived from seeing 1 hare as from seeing several hares. Thus, an implied measure of satisfaction is simply the percentage of time in the PVP when at least 1 hare is viewable.

We tested these hypotheses using 2 models, as follows:

Model 1

This is an empirical model, indirectly testing H1 by relating the percent of time that one or more hares are visible to the hypothetical number of hares using an opening. Assumptions for this model are as follows:

1. Hare observation takes place in the evening and the Potential Viewing Period (PVP, as defined previously) extends from 7:05 p.m. to 8:45 p.m. for a period of 100 minutes, based on Table 3.

2. Each hare uses the opening once during the evening PVP for a
feeding period of 15 minutes, based on the mean time of 14.9 minutes for individual hare observations given in Table 4.

3. The starting time for each hare's presence in the PVP is randomly located within the 100 minute PVP. The earliest time for the commencement of all individual feeding periods is obviously 7:05 p.m. However, feeding periods extending beyond the terminal time of 8:45 p.m. are truncated and the feeding time beyond 8:45 p.m. is not recorded.

4. The number of hares using the opening simultaneously ranges from 1 to 10. There are 50 iterations for each number, for a total of 500 iterations.

The hypothetical "feeding periods" of hares were drawn on graph paper, and randomly located within the 100 minute feeding period using a table of random numbers. An example of 1 iteration for 10 hares is given in Figure 7. The percent of the PVP when 1 or more hares was "observed" was determined graphically for each iteration (Figure 7) and a mean was calculated for each group of 50 iterations. These mean values were used to generate the following equation:

\[
\log_{10} Y = 0.0148X - 0.117 \quad (r=0.988)
\]

Where Y is the number of hares using the opening and X is the percent of time when 1 or more hares are visible in the opening.

Empirical values and values computed from the equation are given in Table 10. It is apparent that although the percent of time when 1 or more hares are visible increases with each increment of 1 hare (Line 1, Table 10), this increase is progressively smaller (Line 2, Table 10) decreasing from 21.3 percent over the first hare to 3.2 percent over the
Table 10. Snowshoe hare observability determined from Model 1, an empirical model (see text).

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>% of time 1 or more hares are visible (X)</td>
<td>7.9</td>
<td>29.2</td>
<td>40.1</td>
<td>48.6</td>
<td>55.1</td>
<td>60.5</td>
<td>65.0</td>
<td>68.9</td>
<td>72.3</td>
<td>75.5</td>
</tr>
<tr>
<td>2</td>
<td>Increase (difference) over previous % value above</td>
<td>-</td>
<td>21.3</td>
<td>10.9</td>
<td>8.5</td>
<td>6.5</td>
<td>5.4</td>
<td>4.5</td>
<td>3.9</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>X Maximum number of hares viewed simultaneously per iteration (N=50)</td>
<td>1.00</td>
<td>1.34</td>
<td>1.74</td>
<td>2.10</td>
<td>2.40</td>
<td>2.64</td>
<td>3.06</td>
<td>3.36</td>
<td>3.60</td>
<td>3.82</td>
</tr>
<tr>
<td>4</td>
<td>Highest maximum number of hares viewed simultaneously in 50 iterations (Freq.)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(50)</td>
<td>(17)</td>
<td>(1)</td>
<td>(10)</td>
<td>(4)</td>
<td>(5)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(2)</td>
</tr>
<tr>
<td>5</td>
<td>Ratio: X Max./Hares in opening</td>
<td>1.00</td>
<td>0.67</td>
<td>0.58</td>
<td>0.52</td>
<td>0.48</td>
<td>0.44</td>
<td>0.44</td>
<td>0.42</td>
<td>0.40</td>
<td>0.38</td>
</tr>
<tr>
<td>6</td>
<td>Ratio: Highest Max./Hares in openings</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.80</td>
<td>0.66</td>
<td>0.71</td>
<td>0.62</td>
<td>0.55</td>
<td>0.60</td>
</tr>
</tbody>
</table>

---

**a** Values calculated from the equation \( \log_{10} Y = 0.0148X - 0.117 \) (r=0.988), where Y is the number of hares using the opening and X is the % of time when one or more hares are visible (see text for assumptions).

**b** Mean values computed directly from empirical data in model. Means are for 50 iterations for each graphed setup of 1 to 10 hares.

**c** Highest value recorded for maximum number of hares viewed simultaneously in 50 iterations. Frequency of observation in parentheses.
ninth hare. The mean maximum number of hares viewable per iteration (50 iterations per hare complement ranging from 1 to 10) ranges upward to 3.82 (Line 3, Table 10), a value far short of the 10 hares using the opening. There is a close correspondence between certain modelled values in Table 10 and observed values in Table 3. For morning and evening PVPs (Table 3), the maximum number of hares observed simultaneously per PVP ranges from 1.5 to 1.6, while the highest maximum number observed for all PVPs ranges from 3 to 4 (see range of maximum values, Table 3). The former values are approximately one half as large as the latter values. In Table 10, the mean maximum number of hares viewed simultaneously ranged from 1.74 (Line 3, Table 10) for the 3 hare complement to 2.64 for the 6 hare complement. The corresponding highest number of hares viewed simultaneously for all iterations ranged from 3 to 4 (Line 4, Table 10). The former values are slightly larger than one half of the latter values, similar to the previous comparison. Of course, we do not know how many hares actually used Openings A and B. However, the data in Table 10 suggest that for a 3 to 4 hare complement using a given opening. The highest maximum number observed in a modest sample is approximately equal to the number using the opening.

In Model 1, the highest maximum number of hares recorded within each group of 50 iterations (Line 4, Table 10) ranges from numbers equal to hares using the hypothetical opening, to a maximum of 6 hares observed simultaneously for the 10 hare complement. The ratios of values given in lines 3 and 4 (Table 10) to corresponding numbers of hares using the opening, are respectively given in lines 5 and 6, Table 10. These ratios provide some measure of the efficiency of various hare complements in providing observer satisfaction, assuming that the number of hares seen
Rainer H. Brocke

simultaneously is 1 criterion of satisfaction. This efficiency level tends to drop as the hare complement gets larger (Lines 5 and 6 Table 10). Thus, although more hares may be seen more times in a "9 hare opening", the latter complement may have little advantage over a "5 hare opening" in terms of numbers of hares seen simultaneously (Lines 3, 4, 5 and 6, Table 10).

In sum, the results of Model 1 indirectly support hypothesis H1 that the probability of observing 1 or more snowshoe hares in an opening is directly related to the number of hares using the opening.

Model 2

This model tests both hypotheses H1 and 2. The model estimates the probability of seeing 1 or more snowshoe hares for variable observation periods and complements (numbers) of hares using an opening when the PVP and feeding period of hares are given. The equation for the Model is:

\[
P = 1 \left( \frac{0.5 (V - F)^2 + 0.5 (V - 0)^2}{V^2} \right)^N
\]

where the symbols are:

P = P (seeing one or more snowshoe hares in an opening)

V = Potential Viewing Period. For this model, the value is 100 minutes (see Assumption 1 for Model 1).

F = Feeding period of snowshoe hares when hares are in the opening. For this model, the value is 15 minutes (see Assumption 2 for Model 1).

0 = Observation period when the opening is being watched (variable).

N = Number of hares using the opening (variable).

The derivation of this equation is given in Appendix A.
Probability values computed from the equation for selected observation periods and various numbers of snowshoe hares using the opening are given in Table 11. These probability values increase (1) with increasing numbers of hares using the opening and (2) with increasing length of the observation period, supporting both hypotheses H1 and H2. However, the succeeding probability value increases diminish steadily with each increment, (Table 11) a characteristic probability effect also reflected in the empirical data of Model 1 (Lines 1 and 2, Table 10). If a probability of 0.80 is arbitrarily selected as an acceptable value, then the following combinations from Table 11 (underlined values) are approximately equivalent, namely watching: a "10 hare opening" for 1 minute, a "6 hare opening" for 10 minutes, a "4 hare opening" for 20 minutes, a "3 hare opening" for 40 minutes, and a "2 hare opening" for 1 hour. From a management standpoint, these equivalent combinations indicate the following: (1) Openings which are briefly passed along an observation route must be used by a larger number of hares if the observer is to have a reasonable chance of seeing a hare. (2) The probability of seeing a hare in any given opening can be increased by lengthening the observation period. Additional increments of observation time are particularly effective for periods of shorter duration, (Table 11). (3) Openings which are used by a small complex of hares must be observed for longer periods of time to assure an acceptable probability of seeing a hare. Hence, such openings are not ideal along observation routes where the observation time for each opening is liable to be short. However, openings used by a small number of hares may provide acceptable viewing benefits if they surround a dwelling whose occupants observe the opening casually during the course of routine activities.
Table 11. The probability of observing 1 or more snowshoe hares in an opening when various complements (numbers) of hares use the opening and observation periods are varied. Values are computed from the equation for Model 2 (see text and Appendix A).

<table>
<thead>
<tr>
<th>Hares Using Opening N</th>
<th>1 min.</th>
<th>10 min.</th>
<th>20 min.</th>
<th>40 min.</th>
<th>60 min.</th>
<th>80 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.15</td>
<td>0.23</td>
<td>0.32</td>
<td>0.46</td>
<td>0.56</td>
<td>0.62</td>
</tr>
<tr>
<td>2</td>
<td>0.28</td>
<td>0.41</td>
<td>0.54</td>
<td>0.71</td>
<td>0.81</td>
<td>0.86</td>
</tr>
<tr>
<td>3</td>
<td>0.39</td>
<td>0.54</td>
<td>0.69</td>
<td>0.84</td>
<td>0.92</td>
<td>0.95</td>
</tr>
<tr>
<td>4</td>
<td>0.48</td>
<td>0.65</td>
<td>0.79</td>
<td>0.92</td>
<td>0.96</td>
<td>0.98</td>
</tr>
<tr>
<td>5</td>
<td>0.56</td>
<td>0.73</td>
<td>0.86</td>
<td>0.96</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>6</td>
<td>0.62</td>
<td>0.79</td>
<td>0.90</td>
<td>0.98</td>
<td>0.99</td>
<td>1.00</td>
</tr>
<tr>
<td>7</td>
<td>0.68</td>
<td>0.84</td>
<td>0.93</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>0.73</td>
<td>0.88</td>
<td>0.96</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>0.77</td>
<td>0.91</td>
<td>0.97</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>10</td>
<td>0.80</td>
<td>0.93</td>
<td>0.98</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Probability values of 1.00 are rounded off from values slightly less than 1.00
On the basis of modelled values and data presented above, it is possible to estimate the probability of observing hares in experimental openings in the absence of any negative reaction of hares to the walking observer. Using the formula for Model 2, the probability of observing a hare in each of the experimental openings is 0.14 (see Appendix B for calculations). A minimum probability estimate of seeing 1 hare in at least 1 of the 60 openings can be computed, assuming that hares were using only those openings adjacent to conifer cover (30 openings, Tables 6 and 7). This computed probability value is 0.99 per observation trip (see Appendix C for calculations), supporting our inferences that snowshoe hares were escaping into cover before they were seen by the walking observer (Table 8).

Management

It is useful to know the relationship of opening size to the number of hares using a given opening so that the size of openings can be determined for selected hare observation probabilities. Some data on this relationship are given in Table 12. We do not know how many hares actually used Openings A and B. However, the maximum number observed simultaneously for all mornings and evenings (namely 3 to 4, Table 12) may be an acceptable estimate judging from the near equivalency of modelled values for the highest maximum number of hares "observed" in Model 1 and the number of hares "using the opening" (Table 10). The values for Opening C, a small experimental opening, may be low because the opening was not regularly watched. However, in casual observations from vehicles subsequent to the study, we did not observe more than 2 hares in any of the experimental openings. Although the data in Table 12
Table 12. The maximum number of snowshoe hares observed simultaneously in openings related to opening dimensions.

<table>
<thead>
<tr>
<th>Opening</th>
<th>Mornings or evenings hares seen (N)</th>
<th>Area 1 (m²)</th>
<th>Forest edge bordering opening (m)</th>
<th>Maximum number hares observed simultaneously</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mornings or evening</td>
</tr>
<tr>
<td>Opening A</td>
<td>5</td>
<td>3213</td>
<td>150</td>
<td>1.8 ± 0.6</td>
</tr>
<tr>
<td>Opening B</td>
<td>10</td>
<td>1208</td>
<td>90</td>
<td>1.4 ± 0.4</td>
</tr>
<tr>
<td>Opening C^a</td>
<td>2</td>
<td>97</td>
<td>32</td>
<td>1.0 ± 0.0</td>
</tr>
</tbody>
</table>

^a Opening C is one of the experimental openings where hares were incidentally observed by work crews passing in trucks.
are not extensive, they do suggest that the length of forest edge bordering openings bears a consistent relationship to the maximum number of hares observed, i.e. about 33 m of edge per hare (Table 12). This is to be expected if hares are primarily a product of the forest habitat and if hares use only that portion of the openings bordering the forest edge (Table 6).

For management purposes, a first approximation relating road frontage or opening depth to the length of edge bordering the opening and hence the estimated number of hares using the opening, is derived as follows: Assume that openings have the shape of one half circle such that opening depth \( D \) equals the radius, the road frontage \( F \) equals the diameter and the forest edge \( E \) equals one half of the circumference.

Then if:

\[
\text{Radius} = \frac{3}{2} \frac{\text{Circumference}}{m}
\]

in equivalent terms:

\[
D = \frac{E}{3.14}
\]

In terms of hares \((H)\) and edge per hare \((m/1H)\)

\[
E = \frac{m/1H \cdot H}{H}
\]

then

\[
D = \frac{m/1H \cdot H}{3.14}
\]

or

\[
D = H \cdot \frac{m/1H}{3.14}
\]

or

\[
F = 2H \cdot \frac{m/1H}{3.14}
\]

Using the mean value of 33 m edge/hare (Table 12), the term

\[
\frac{m/1H}{3.14} = 10 \text{ m approximately}
\]

and

\[
F = H(20 \text{ m}) \text{ approximately}
\]
The assumptions for this relationship are that the habitat bordering the entire forest edge of the opening is suitable for hares and that the opening has a circular forest border. The value of forest edge per hare (m/1H) will vary locally depending on the mean hare population density for several years in the local habitat. In our study area, the population levels were relatively stable over a period of 5 years prior to this study (Brooke 1977). Using this relationship, it is possible to estimate the approximate size of a specific forest opening which is necessary to meet a predetermined level of observation probability for a given length of observation time. For example, for our data, at a selected observation probability level of 0.8 (Table 11) and an observation period of 10 minutes, a "6 hare opening" would be required. If \( F = H (2C!m) \) the road frontage of such an opening would be 120 m.

Man and equipment hours expended to prepare the 60 experimental openings are given in Table 13. All work could have been done with hand tools, chain saws and pickups. However, the use of heavy equipment saved many man hours, particularly in removing large trees. Approximately 6.5 man hours were expended per opening, which is equivalent to 396 man hours/ha (160 man hours/acre). These values will differ depending on local conditions and the extent to which the process of clearing has already been accomplished.

From a practical standpoint, snowshoe hare habitat management for hare observation in the Adirondack region falls into two categories, namely (1) snowshoe hare observation in residential lawns in sparsely or moderately settled forest land and (2) snowshoe hare observation along roadsides and in forest openings. A synopsis of management implications and recommendations is given below under 2 corresponding topic headings.
Table 13. Man and heavy equipment hours expended to prepare 60 experimental openings.

<table>
<thead>
<tr>
<th>Treatment and activity</th>
<th>Man hours</th>
<th>Man hours per opening</th>
<th>Heavy Equipment hours&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Equipment hours per opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting and clearing (chain saw), skidding</td>
<td>170</td>
<td>2.8</td>
<td>32 skidder</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 dump truck</td>
<td>0.1</td>
</tr>
<tr>
<td>Hoeing and raking</td>
<td>100</td>
<td>1.7</td>
<td>15 tractor and spring tooth harrow</td>
<td>0.2</td>
</tr>
<tr>
<td>Fertilization, seeding and misc. labor</td>
<td>31</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Construction and placement of signs</td>
<td>76</td>
<td>1.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mapping</td>
<td>16</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>393</strong></td>
<td><strong>6.5</strong></td>
<td><strong>52</strong></td>
<td><strong>0.9</strong></td>
</tr>
</tbody>
</table>

<sup>a</sup> Pickups were regularly used and pickup hours are not itemized.
Rainer H. Brocke

Management - Residential Lawns

Snowshoe hares are best observed in May when they feed on the spring growth of grasses and annuals. As most home yards and lawns are mowed throughout the summer, hare observation can continue beyond May, although hares feed much less in openings during summer. In most cases, the home viewer will elect to watch hares from the dwelling at some time during the evening feeding period of hares, namely about 7:00 p.m. to 8:45 p.m. Hare observation stretches the benefits of wildlife viewing in the evening beyond the time when many songbirds and mammals are active. Snowshoe hares feeding on home lawns are relatively oblivious to residents as long as they remain inside the dwelling. While hares are generally not compatible with pet cats kept outdoors, we observed that they become habituated to the presence of dogs.

The size of the average residential lawn is adequate from the standpoint of observation probability because the aggregate time that the lawn is casually observed is relatively long, tending to maximize observation probabilities (see modelled values, Table 11). Hares will enter the lawn where dense conifer cover comes closest to it. As hares feed close to the forest edge, the contour of the forest edge should ideally approach the dwelling within the viewing area, so that hares are within easy viewing distance from the living room. Bird feeders and other wildlife attractants can also be located in this area.

The presence of conifer or mixed cover near or adjacent to the lawn is essential. Of equal importance is that the conifer or mixed cover adjacent to the lawn is continuous with habitat occupied by a snowshoe hare population. Snowshoe hares travel along lanes of conifer and mixed cover...
to reach feeding areas (Brocke 1976). While young stands of mixed coniferous-deciduous forest can be good hare cover, older stands of mixed cover can be improved by selectively cutting the deciduous component. Young dense stands of conifer cover between 3 m to 5 m in height harbor the densest populations of snowshoe hares in the central Adirondacks (Brocke 1976).

In sum, management for hare observation in a given residential lawn consists primarily of arranging and modifying cover in the vicinity of the lawn so that hares can be readily observed from the dwelling. The local occurrence of snowshoe hares is obviously essential. Such management is particularly appropriate for vacation homes and cabins. Management techniques and observation procedures can be transmitted to the public through appropriate extension services.

Management - Observation Routes

Openings and roadsides in forest country can be integrated into a wildlife observation route. To maximize the probability of seeing hares, such a route in the Adirondack region should be traveled in the morning from approximately 5:30 a.m. to 8:30 a.m. and in the evenings from 7:00 p.m. to 8:30 p.m. May is the best month for seeing hares. By early June, grass and vegetation in roadsides and openings has grown too tall to see hares clearly. As this time coincides with the decreased use of openings by hares, it is doubtful whether openings and roadsides should be mowed more than once a year, which is the minimum necessary to suppress the growth of woody plants.

Snowshoe hares react negatively towards walking humans and tend to escape before they are seen. Riders of bikes, automobiles and possibly
horses have a better chance of seeing hares and at least that portion of
the observation route passing through hare habitat might be completed
while riding.

Roadsides and openings can be managed for hare observation wherever
forest trails or roads intersect conifer or mixed forest stands which are
inhabited by hares. As hares feed approximately 2 m from the forest edge,
road shoulders can be narrow, namely just wide open enough to permit the
growth of grass and other annuals. Where road shoulders are uneven they
can be graded and seeded (see Sage and Tierson, 1975). Elsewhere, cutting
and mowing may be all that is required to encourage the growth of annuals.
We do not recommend the management of heavily traveled roads or highways
for snowshoe hare observation. Hare mortality in summer due to heavy
vehicular traffic can be great along such roads (Brooke, unpublished data).

The cost of constructing and maintaining forest openings is high
and cannot be justified for hare observation alone. From a practical
standpoint, such openings should be managed to view a complex of wildlife
species. In the Adirondacks, white-tailed deer commonly feed in forest
openings, especially in spring and early summer. On several occasions,
one of us (Sage) observed black bears (*Ursus americanus*) grazing in
roadsides and openings in May (Sage and Tierson 1975). Smaller mammals of
various species are occasionally visible in openings and in May, many bird
species are readily observed along forest edges. In the Adirondacks,
hare observation in openings can be combined with beaver viewing by
locating openings next to beaver floodings or on the far side of open
beaver ponds. This combination is a natural one, as many beaver-flooded
areas are open and conifer hare cover is often associated with lowland
beaver habitat.
The dimensions of forest openings are critical from the standpoints of (1) observer-hare interaction and (2) hare observation probability. Our results with small experimental openings indicate that snowshoe hares are disturbed when approached at short range and escape before they are seen. We infer that hares are progressively less prone to escape with increasing observation distance. Therefore, openings should be at least moderately deep to minimize potential disturbance by the observer. Openings shaped like a half circle (with the observation route equivalent to the circle diameter) may be a good compromise between opening depth and length of forest edge. According to our data and modelled values for the study area, a "4 hare opening" must be observed for about 20 minutes to realize an observation probability of 0.8, while a "6 hare opening" must be watched for about 10 minutes to realize the same observation probability. Using the rule of thumb developed above (i.e. for the study area, Road Frontage = No. Hares Using Opening X 20 m) the road frontage for the latter openings is approximately 80 m and 120 m respectively, assuming that openings are shaped like a half circle and are adjacent to good hare habitat. These values are only illustrative; observation probabilities and opening dimensions will vary with local conditions. Hare observation success can be increased by lengthening observation time for any given opening. Small openings should be observed for longer periods of time.

In sum, management for hare viewing along observation routes should be integrated with equivalent management for other wildlife species. Roadsides and openings can be developed for hare observation wherever forest trails or roads intersect conifer or mixed forest hare habitat. Hares are best watched while the observer is riding a bicycle, auto or
possibly a horse. Openings should be at least moderately large to yield an acceptable observation success level. Observation success can be increased by lengthening observation time for any given opening. The development of wildlife observation routes is especially appropriate for public lands where public use can be controlled in observation areas, and for private lands where observation rights can be sold or leased.
LITERATURE CITED


APPENDIX A: Derivation of the equation for Model 2.

Estimate the probability of seeing 1 or more snowshoe hares in a given opening.

Let $V$ = Potential Viewing Period, as defined in the text.

$F$ = Feeding period of snowshoe hares (see text).

$O$ = Observation period when opening is being watched.

$N$ = Number of hares using the opening.

Then $P$ (seeing one or more snowshoe hares in an opening) = 

$$1 - \left( \frac{0.5 (V - F)^2 + 0.5 (V - O)^2}{V^2} \right)^N$$

Proof:

Let $X$ = time person begins observing opening.

$Y$ = time hare enters opening and begins feeding.

Then $X$ is uniformly distributed over the interval $(0, V)$ and $Y$ is also uniformly distributed over the interval $(0, V)$.

Assuming that $N$ hares enter the opening independently of each other (at random), then

$P$ (seeing at least 1 hare) = 1 - $P$ (not seeing any of the $N$ hares) = 1 - $\prod_{n=1}^{N} P$ (not seeing a particular hare)

$P$ (not seeing a particular hare) = $P$ ($Y + F < X$ or $X + O < Y$)

This probability can be evaluated diagramatically as follows:
P (Not seeing a particular hare) = \( \frac{1}{\sqrt{2\pi}} \) \( (\text{area shaded portion}) \)

\[
P = \frac{0.5 (V - F)^2 + 0.5 (V - 0)^2}{V^2}
\]

Hence P (seeing one or more hares in a given opening)

\[
P = 1 - \left( \frac{0.5 (V - F)^2 + 0.5 (V - 0)^2}{V^2} \right)^N
\]

APPENDIX B: The probability of seeing 1 hare in 1 experimental opening.

The observation time is derived as follows:

Speed of travel is 1900 m/hr. or 32 m/min. The mean frontage of an opening is 10.4 m, so the length of time to pass the opening on the average is \( \frac{10.4}{32} = 0.32 \) min.

Assume that the meaning of symbols is given above and:

\[ V = 100 \text{ min.} \]
\[ F = 15 \text{ min.} \]
\[ 0 = 0.32 \text{ min.} \]
\[ N = 1 \text{ hare} \]

Using the equation for Model 2:

\[
P = 1 - \left( \frac{0.5 (V - F)^2 + 0.5 (V - 0)^2}{V^2} \right)^N
\]

\[
P = 0.14
\]

APPENDIX C: The probability of seeing a hare in at least 1 of the 30 experimental openings adjacent to conifer cover.

Let \( A \) = Event of seeing a hare in the \( i^{th} \) opening, \( i = 1,2, \ldots, 30 \).

\( \bar{A}_i \) = Event of not seeing a hare in the \( i^{th} \) opening.
If \( P(A_1) = 0.14 \) (Appendix B)

then \( P(\overline{A_1}) = 1 - 0.14 = 0.86 \)

then \( P \) (seeing a hare in at least 1 of the experimental openings)

\[
= P \left( \bigcup_{i=1}^{30} A_i \right) \\
= 1 - P \left( \bigcap_{i=1}^{30} \overline{A_i} \right) \\
= 1 - (0.86)^{30} \quad \text{assuming independence in not seeing a hare in the openings}, \\
= 1 - 0.01 \\
= 0.99
\]

\( P = 0.99 \)
CAPTIONS FOR FIGURES

Figure 1. An example of individual snowshoe hare observations (appearances of hares) in Opening A for the evening of May 13. A minimum of 4 individuals was present. Bars do not represent sequential appearances of the same hares.

Figure 2. Distribution of observed snowshoe hare activity for mornings, in Openings A and B. Bars represent the total number of partial or complete observation time spans of hare activity falling within 30 minute time classes for 5 mornings from May 11 through May 27. Data for time classes prior to 7:00 a.m. have been omitted because they were available for Opening A only.

Figure 3. Distribution of observed hare activity for evenings in Openings A and B. Bars represent the total number of partial or complete observation time spans of hare activity falling within 15 minute time classes for 8 evenings from May 12 through June 11.

Figure 4. Distribution of nightly activity for 4 penned snowshoe hares for periods ranging from March 17 through July 3. Bars represent the number of switch closures as % of total daily switch closures (daily activity) within 1 hour time classes. Wedges represent time of sunrise and sunset.

Figure 5. Seasonal use of Openings A and B by snowshoe hares. Bars represent means of morning and evening hare viewability values within 5 day intervals. Hare viewability is given as percent of the
Potential Viewing Period (PVP) (see text) when 1 or more hares were under observation. Numbers above bars or class intervals represent the total number of mornings and evenings when openings were observed. Arrows and wedges represent mean conception and parturition dates respectively (see text).

Figure 6. The increase in density of annual plant stems (stems/m²) at least 2 cm high from April 27 through June 1 in various openings and adjacent forest. Lower solid and hashed lines represent stem densities within forest adjacent to (1) Openings A and B, and (2) experimental openings respectively.

Figure 7. An example of 5 iterations from an empirical model (Model 1) in which 10 hares use an opening at random, each for a 15 minute period during an evening PVP of 100 minutes (see text).
MARCH 17 - APRIL 1
15 NIGHTS ♀
8083 SWITCH CLOS.

PERCENT OF DAILY ACTIVITY

12
10
8
6
4
2
0

TIME

12 6 10 2 4 6 8 10 12
P.M.  A.M.
APRIL 11 - 23
12 NIGHTS
1949 SWITCH CLOS.

PERCENT OF DAILY ACTIVITY

TIME

P.M.

A.M.

12 2 4 6 8 10 12
JUNE 13 - 21
8 NIGHTS
1466 SWITCH CLOS.

PERCENT OF DAILY ACTIVITY

TIME
Hare viewability, % of PVP

MAY 15 17

SNOW STORM

1 SE

JUNE 14 21

5 DAY CLASSES
OPENINGS A AND B

EXPERIMENTAL OPENINGS

STEM DENSITY, STEMS/M²

SURVEY DATES

0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200

APR.27 MAY 4 11 18 25 JUN.1