IMPACT OF MOOSE BARK STRIPPING ON MOUNTAIN ASH IN VERMONT

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ABSTRACT: Moose (*Alces alces*) have always been present in Vermont, but their population began to increase from approximately 25 in 1960 to the present when their population is estimated to be approximately 2,500. The increase in moose numbers began in the northeastern part of the state and has gradually spread south. State wildlife biologists have noticed the loss of American mountain ash (*Sorbus americana*) in some stands due to bark stripping by moose. Mountain ash fruit is a valuable fall soft mast resource for other wildlife, notably black bears (*Ursus americanus*). We assessed bark stripping throughout Vermont, examining 1,535 mountain ash stems at 42 sites. Trees wounded by moose accounted for 27% of the total. There was no bark stripping in the southern part of the state where the moose population is still low, but 1/3 of all trees in northern regions were wounded. A conservative estimate of mortality associated with bark stripping was 7% of all stems $\geq$5 cm within a total mortality of 23%. More trees will die in time as the result of pathogen introduction and/or continued girdling. Once girdling reached 3/4 of total tree circumference, the incidence of mortality was higher than expected. Bark stripping on a local scale could be severe; at some sites 3/4 of the total circumference of all stems was girdled. Mortality was significantly correlated with amount of girdling ($y = 49.759x + 12.555$, $r^2 = 0.51$, $P < 0.0001$). Girdling was significantly correlated with moose activity as measured by pellet group counts ($y = 0.0195x + 0.1756$, $r^2 = 0.37$, $P < 0.0001$). Amount of girdling or mortality was not correlated with aspect, altitude, tree size, or tree density. Trees on gentler slopes sustained more damage than those on steeper slopes ($\chi^2 = 9.509$, $P < 0.049$). There was significantly more moose activity ($Z = -2.797$, $P < 0.0052$) near logging operations as well as more girdling ($Z = -2.018$, $P < 0.044$). Mountain ash are protected from moose on steep rocky slopes, and near ski areas ($n = 5$ sites). However, regeneration may not be able to keep pace with loss due to bark stripping, and an overall decline of the species is expected as the moose population in Vermont continues to increase. Some local stands of mountain ash have already been eradicated.

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Moose (*Alces alces*) were essentially extirpated in Vermont in historic times through a combination of unregulated hunting and habitat loss. In 1960, there were thought to be only about 25 individuals in the northeastern corner of the state (Willey 1984). Since then moose have increased to approximately 2,500 animals and have spread throughout the state (Alexander 1993, Alexander *et al.* 1998). The Vermont Department of Fish and Wildlife has monitored moose numbers, age structure, physical condition, and reproduction through non-hunting mortality (mostly moose-car collisions), necropsies, and sighting reports. In 1993 a limited hunt was initiated, which has provided further information about the herd (Alexander *et al.* 1998). This study was the first to assess any kind of widespread habitat usage by moose in Vermont.

Mountain ash (*Sorbus* spp.) is a preferred browse species for moose (Peek

1974, Miquelle 1983, Cumming 1987, Kuznetsov 1987). Moose also eat *Sorbus* spp. bark. Mountain ash abundance has declined on Isle Royale, Lake Superior, Michigan, due to a combination of moose bark stripping and browsing pressure on regenerating plants (Murie 1934, Hanson *et al.* 1973, Krefting 1974, Snyder and Janke 1976). Biologists in Vermont have observed that some stands of mature American mountain ash (*S. americana*) are being badly damaged by moose bark stripping (C. E. Alexander, Vermont Department of Fish and Wildl., *pers. comm.*). They are interested in the possible decline of mountain ash because it is an important soft-mast species for many species of birds and some mammals, notably black bears (*Ursus americanus*) (Van Dersal 1938, Rogers 1977). Mountain ash is particularly valuable in the northeastern part of the state where other types of soft-mast are limited. Studies have shown that fall food resources are a limiting factor in black bear survival and recruitment (Hugie 1982, Elowe 1987). Since the Vermont Department of Fish and Wildlife desires to protect and enhance wildlife habitat quality in general (Anonymous 1997), and particularly black bear habitat (Darling *et al.* 1997), the possible decline of mountain ash due to moose bark stripping is a concern.

The objectives of this study were: (1) to assess the pattern and extent of moose bark stripping of mountain ash on local and regional scales; and (2) to assess the effect of bark stripping on the abundance of this important soft-mast resource. In the process, we obtained a snapshot of moose habitat usage throughout the state of Vermont.

STUDY AREA

Any area containing mountain ash within the state of Vermont was considered a potential site for sampling. However, mountain ash grows mostly at higher altitudes as an associate of boreal and transitional forests (Forbes and Daviault 1964), and large portions of the state were unsuitable as study sites. We located sites by using a map of terrain above 740 m (2,500 ft), where the ecotone between northern hardwood and boreal forests generally occurs. A map of relative moose-density zones developed by the Vermont Department of Fish and Wildlife was used to stratify sites into 1 of 4 regions. Moose density in the regions was determined through game warden reports and a population model (Alexander *et al.* 1998:34-35). The regions were: (1) high density, or 0.4 moose/km^2 of deer range; (2) moderate-to-high density, or 0.2 moose/km^2; (3) moderate density, or 0.1 moose/km^2; and (4) moderate-to-low or low density, or 0.05 moose/km^2 or less. Within each of the 4 regions 10 sites were selected, except for Region 3 (moderate density), where 12 sites were chosen because of its larger area. Mountain ash were sampled, therefore, at a total of 42 sites throughout the state (Fig. 1).

METHODS

General Sampling

Sampling was conducted from May 12 to September 29, 1998. Only mountain ash stems with a dbh $\geq$ 5 cm were assessed. At each site we sampled trees on plots measuring 25 m x 20 m until $\geq$ 30 stems had been counted. The plots were located immediately adjacent to each other along a transect. Starting points and direction of transects were randomly selected except where there was only a small clump of trees. Number of plots/site varied from 0.5 to 15, due to variation in tree density. Starting points could be 10 - 100 m (in 10 m increments) from the point at which mountain ash were first encountered. At a few sites, transects were not used because the trees were either too spread out, or because their distribution was clumped (e.g., only growing on

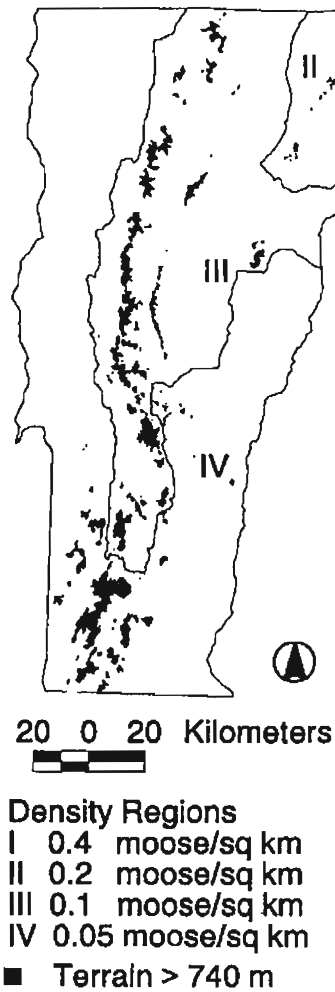

Fig. 1. Relative moose density regions in Vermont in 1998, and terrain above 740 m (2,500 ft). Terrain above 740 m represents potential mountain ash distribution.

tops of boulders). At these sites, tree density could not be measured. An effort was made to stay within 30-40 stems per site so as not to bias results. A total of 1,535 mountain ash stems were sampled.

Each mountain ash was assessed for total amount of girdling, current year's girdling, and viability. Since girdling was highly irregular in shape and difficult to measure exactly, an estimate of the fraction of circumference girdled was made. Estimates of amount of bark stripping were placed in 7 categories. Class 0 denoted no bark stripping and sound bark. Class 1 denoted up to 1/4 of the circumference of the stem girdled by bark stripping. Girdling increased by quarters in classes 2-4. Completely girdled stems were put in Class 5. An additional category, Class 6, denoted tree damage that could not be positively attributed to moose (Table 1). Some Class 6 trees were dead and had almost no bark left on them. Current girdling (from the previous winter) was classed in the same categories if it could be positively identified as new by the light color of the wounds. However, some current girdling was probably undetected, because it had already faded.

For viability, trees were classed as either alive or dead. Trees showing the slightest sign of life were classed as alive. Mortality figures are therefore conservative. Some dead trees had been so for several years. If we could identify the snag as a mountain ash we included it, no matter how decomposed it was. Therefore, the term "mortality" refers to numbers of dead stems rather than a death rate.

Moose activity at each site was estimated by pellet-group counts. Pellet groups were counted in an area totaling 1,000 m^2. They were first counted along the 25-m tree transects, but only in a 4-m-wide swath. If there were < 10 transects, we walked a 4-m-wide belt transect until 1,000 m^2 had been sampled. Only pellet groups with dry pellets from winter feeding were counted. Because the sites were sampled from spring through fall of 1998 in a variety of ground cover conditions, pellet-group counts varied in accuracy. The counts were conservative in areas of heavy ground cover, but more accurate in places where ground cover was sparse.

Landscape Parameters

At each site, we recorded altitude, aspect, and slope. Degree of slope was an

Table 1. Number of mountain ash stems sampled in Vermont's relative moose density regions, May - Sept 1998. Classes 1 - 5 represent girdling caused by moose bark stripping.

		Moose Density (moose/km^2)			
Class	Circumference Girdled	0.4	0.2	0.10	0.05
0	None	215	243	174	214
1	<1/4	23	18	21	0
2	1/4-1/2	39	33	21	0
3	1/2-3/4	43	14	23	0
4	>3/4	38	33	45	0
5	100%	16	17	33	0
6	Indeterminate	55	71	80	65
	Total	429	429	397	280

ordinal variable with 4 levels. We noted if the site was on a ridge or mountainside. Human influence was assessed by noting proximity to logging operations, hiking trails, or ski areas. If the latter were < 200 m away from the plots, they were considered proximate. "Logging operations" were defined as those logged sites that were estimated to be ≤ 10 years old.

We noted the general size of mountain ash trees at each site using the categories: sapling, sapling/pole, pole, pole/mature, and mature. Since mountain ash are generally small trees, these categories denoted slightly smaller diameters than is generally accepted by standard forestry practices. Other woody species at the sites were identified as well.

Girdling Index

In order to create a site-specific girdling index variable, we took each tree in each class at a site and multiplied it by the midpoint value of that class. For instance, Class 1 (1-25% girdling) trees were multiplied by 0.13, and Class 4 (76-99%) by 0.88. Class 5 trees were multiplied by 1.00. These were summed and divided by the total number of trees per site to create the overall index for that site. Class 6 trees, those that had bark wounds that could not be positively identified as moose bites, were excluded from the index. Some of the latter were dead and may have been barked by moose, but the evidence had already decayed. Therefore, the index is conservative. The site-girdling index, then, is an estimate of the ratio of circumference girdled by moose:total circumference.

SAS software was used for all statistical analyses (Schlotzhauer and Littell 1987). Nonparametric tests were employed because none of the variables had normal distributions. These included Spearman's rank correlations for interval-interval or interval-ordinal variable comparisons such as the girdling index to pellet group counts, and the girdling index to aspect (an ordinal variable with 8 levels). Wilcoxon rank sum tests were used for interval-ordinal and interval-nominal variable comparisons such as the girdling index to slope, and girdling index to human influences. Chi-square contingency tables were used for ordinal-nominal variable comparisons, such as classes of girdling to region.

RESULTS

Regional Patterns

In the entire state, 27.2% of all stems were positively identified as having been stripped by moose. None of the stems in the low moose density region were stripped. In the other 3 regions, 35.3% of all stems had been stripped. Since some stems classed as having indeterminate damage must have been stripped by moose, we added a proportionate number of those to make estimates of potential damage; e.g., 27.2% of the indeterminate stems were added to the statewide total of 27.2% for a total of 32% potentially stripped stems (Table 2). With such an estimate, approximately 1/2 of the stems in areas with moose activity have been wounded as of 1998 (Table 2).

There was no significant difference in the amount of bark stripping in the high, moderate-high, and moderate moose density regions (Fig. 2). As noted above, there was no bark stripping at all in the low density region, therefore this region was significantly different from the other 3 regions (all $Z > 9.1$, all $P < 0.0001$). Because of the lack of moose bark stripping in the south, all those sites were excluded from further site-specific analyses. Site girdling indices varied from 0 to 0.77 (i.e., about 75% of the total stem circumference girdled). These data had a non-normal distribution with especially heavy tails; i.e., there tended to be little damage, or a great deal of damage.

Even though new damage was underestimated, it was still positively correlated with overall damage ($r^2 = 0.632, P < 0.0001$) and with moose activity ($r^2 = 0.425$, $P < 0.0001$). New damage was not closely correlated with mortality. At least 8% of trees statewide had new bark stripping damage. This represents 29.4% of all bark-stripped trees.

Moose Activity and Stem Mortality

Moose activity was positively significantly correlated with overall damage ($y = 0.0195x + 0.1756, r^2 = 0.37, P < 0.0001$) and new damage ($r^2 = 0.425$, $P < 0.0001$), but not with mortality. Pellet groups were present in 100% of the high-density sites, 80% of the moderate-high density sites, 58% of the moderate sites, and 0% of the low-density sites. The high-density region also had the most pellet groups overall (96), but the moderate region had more pellet groups overall than the moderate-high density region (56 and 36, respectively). However, if one outlier is removed from the moderate density region, then the 2 latter regions are comparable (35 and 36, respectively).

Statewide, total mortality of mountain ash stems was 23.4%. Stems that showed even the slightest trace of life were counted as living, so our mortality counts were conservative. Only 7.3% of the dead stems

Table 2. Percent mountain ash stems wounded by moose, percent related mortality, and percent total mortality. The low density region had no moose bark stripping damage and was excluded from the second row. The third row represents only those sites with sign of moose activity (pellet groups). A percentage of stems having an undetermined cause of damage (Class 6) was included in the second set of columns.

	Moose girdled stems		Including Class 6 Estimate		
Area	Wounded	Dead	Wounded	Dead	All Mortality
Statewide	27.2	7.3	32.0	8.5	23.4
3 Regions	35.3	8.8	38.6	10.3	24.3
Sites with moose	43.8	11.5	49.3	13.1	30.1

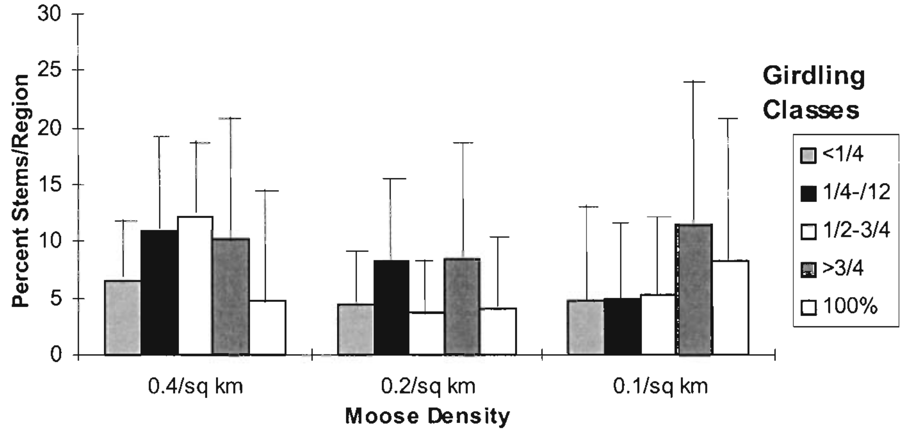

Fig. 2. Percentages of moose-girdled mountain ash stems (≥ 5 cm dbh) in 3 relative density regions in Vermont, May - September 1998. Stems having an undetermined cause of damage are not included. There were no significant differences between the 3 regions with moose bark stripping, but all were significantly different from the low-density region, which had no bark stripping at all ($P < 0.0001$ for all comparisons).

showed evidence of moose bark stripping (Table 2). However, since some of the stems classed as having indeterminate damage may have originally been wounded by moose, this is also a conservative estimate. Three quarters of the dead, barked stems were ≥ 3/4 girdled. Mountain ash mortality was significantly correlated with amount of bark stripping (r^2 = 0.41, $P < 0.0004$). Mortality was positively correlated with the girdling index ($y = 49.759x + 12.555$, r^2 = 0.51, $P < 0.0004$). Mortality increased as amount of girdling increased ($\chi^2 = 263.9$, $P < 0.001$). Once girdling reached 3/4 or more of stem circumference, frequency of mortality was greater than expected mortality under the null hypothesis that girdling has no effect on viability of stems (Fig. 3).

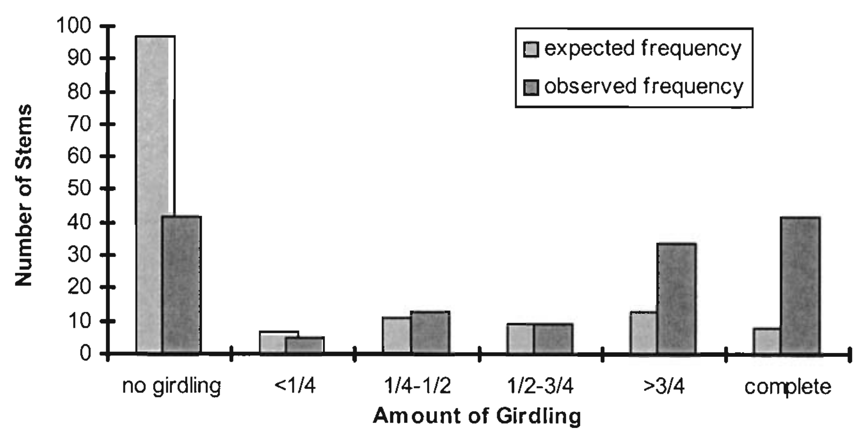

Fig. 3. Mountain ash mortality as a function of degree of girdling by moose in Vermont, May - September 1998. Stems with indeterminate damage are excluded ($n = 145$). Once girdling reached ≥3/4 of a stem's circumference, frequency of mortality was greater than expected mortality under the null hypothesis that girdling has no effect on viability of stems. Expected values were generated by a contingency table ($\chi^2 = 263.9$, $P < 0.001$).

Twelve percent of all mountain ash stems sampled were $\geq$ 3/4 girdled. On a local scale, total mortality per site ranged from 7% to 74%.

Landscape Factors

Correlation analysis showed no significant relationships between amount of bark stripping or mortality and aspect, altitude, position on a ridge, tree size, or tree density. There was no relationship between moose density region and tree density, which varied widely from 62 stems/ha to 1,800 stems/ha. Trees on gentler slopes sustained more damage than those on steeper slopes (χ^2 = 9.509, $P < 0.049$), which agreed with heightened moose activity on gentler slopes (χ^2 = 12.7, $P < 0.013$). There was significantly more damage near logging operations (Z = -2.018, $P < 0.05$), which was in agreement with heightened moose activity near logging (Z = -2.798, $P < 0.0052$). Although our sample size was small (n = 5 sites), moose appeared to avoid ski areas, at least in winter when most bark stripping is done. There were no pellet groups and no bark stripping damage at any of the ski area sites.

DISCUSSION

Site Ecology

Mountain ash were found most commonly in the transitional zone between northern hardwood and boreal forest types, and less commonly in the boreal zone. Balsam fir (*Abies balsamea*), heartleaf birch (*Betula papyrifera* var. *cordifolia*), and red spruce (*Picea rubens*) were its most common associates. Sometimes mountain ash stands were limited to rocky ridges. Mountain ash were rarely found in hardwood stands with sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*).

Where there was moose activity, the understory varied from slightly browsed to devastation of woody species. At some sites there were "fern parks" where only ferns (primarily *Dennstaedtia punctilobula*) and mature trees remained. Hobblebush (*Viburnum alnifolium*) and striped maple (*Acer pensylvanicum*) were often heavily browsed. Mountain maple (*Acer spicatum*) was another common species and was often browsed and broken by moose. At several sites mountain ash stems were also broken. Whether moose or bears were responsible for this was unclear. In a few areas there were bear claw marks on the trees, and on one site these occurred with moose bite marks. How much bear sign was obscured by moose later eating bark off the trees could not be determined.

Regional Pattern

The moose population in Vermont has expanded throughout the state in the last 40 years, beginning from the northeastern corner and spreading south and west (Alexander 1993). For that reason, and also because the northeast is relatively undeveloped, it contains the highest density of moose. Moose in the central part of the state are more concentrated in the Green Mountains than in the more developed valleys. Even though moose have expanded their range to the Massachusetts border (Alexander 1993, *pers. obs.*), their numbers are still low in the south compared to the northern part of the state.

An unexpected result of this study was that the moderate density region (0.1 moose/km^2) had damage comparable to the higher density regions (0.4 moose/km^2, and 0.2 moose/km^2). The moderate density region encompassed much of the narrow spine of the Green Mountains, but also included large areas of less favorable moose habitat at lower altitudes. Even though the moderate density region had pellet groups in only 58% of the sites compared with 80% and 100% of the moderate-high and high density sites, the number of pellet groups were comparable between the moderate and moderate-high density regions (35, subtracting an outlier, and 36 respectively). In the moderate density region moose may be concentrated at higher altitudes where mountain ash occurs. Therefore, within the altitudinal range of the study, moose density in the moderate density region may not be appreciably different from that of the higher density regions. If we had studied a more ubiquitous species (such as striped maple) we may have gotten different results.

An alternative hypothesis is that when moose reach a threshold density, barking increases markedly at preferred feeding sites. Jezierski and Kuczawksi (1987) reported that when moose density in northeastern Poland reached 0.1 moose/km^2, barking increased exponentially at such sites. This is the same density calculated for the moderate region in Vermont.

The Polish researchers also noted that as moose density increased, moose continued to feed at these favored sites rather than moving to new sites, thus markedly increasing damage in a limited area. This could explain why the distribution of our data had heavy tails. Either moose fed casually as they moved through an area (little or no damage), or they fed heavily at one preferred spot (considerable damage).

Every site we visited that had pellet groups also had mountain ash bark damage, except for one where every tree was growing on top of boulders out of reach of moose. There was significantly more damage near logging operations that contained large amounts of browse than at sites that were not adjacent to logging. It appears that mountain ash bark is a preferred food, and is not eaten because there is a shortage of browse. The fact that there was no significant difference between levels of moose barking in the high density and moderate density regions also lends support to this hypothesis.

Bark Stripping and Stem Mortality

Mountain ash mortality was significantly correlated with bark stripping, but the percentage of dead, barked stems were only 1/3 that of total dead stems statewide. Stems that showed even the slightest trace of life were counted as living, and some of the dead stems with indeterminate damage must have originally been barked, so this is a conservative measure. It is not surprising that mortality was low, since trees do not die immediately when wounded. Trees having $\geq$ 3/4 girdling had greater mortality than expected. This result agrees with the findings of Miquelle and Van Ballenberghe (1989). When girdling is < 3/4 of total circumference, stems may live for years. However, as time passes, more partially girdled stems will die as moose continue to girdle them and pathogens invade. Many stems had more than one year's bite marks on them. There were some stems that had cankers or woolly aphids (*Eriosoma* sp.) ringing the wounds. Fire blight (*Erwinia amylovora*) was present in others. It is possible that fire blight can be transferred by moose teeth (D. Tobi, Univ. Vermont For. Dep., *pers. comm.*). Moreover, some of the wounded trees are not able to produce as much fruit as they would have had they been sound. Their usefulness as a food resource is therefore diminished, even though they are alive (D. Tobi, *pers. comm.*).

Protection from Moose

Mountain ash trees are protected occasionally because of their ability to grow on rocky hillsides, cliffs, and on top of boulders, which are inaccessible to moose. Whether bears and other animals can access them depends on how steep and rocky the area is. On the southeast ridge of Dorset Mountain, bears visited trees on a slope that is inaccessible to moose. However, some mountain ash thus protected are only accessible to birds.

This species may also find protection on ski slopes. Since the open slopes are sunny, there is often a great amount of early successional mountain ash growing along them. Moose appear to avoid ski areas, at least in winter. Mountain ash fruit is the only soft-mast species that persists into winter. Birds have been observed using this food source at ski areas (D. Tobi, *pers. comm.*). However, bears appear to avoid ski slopes after leaf fall because there is no longer enough cover (F. Hammond, Vermont Dep. Fish and Wildl., *pers. comm.*). Therefore, mountain ash fruit on ski slopes may not be available to bears after leaf fall.

Bear Habitat Quality

According to the black bear Habitat Suitability Index developed by Rogers and Allen (1987), optimum soft-mast abundance exists when the canopy contains $\geq$25% soft-mast species. Additionally, the index assigned greatest value for habitat containing 6 different species of soft mast as a hedge against bad fruiting years for 1 or more species. Mountain ash is one of the few soft-mast fruits in northern high-altitude areas. Moreover, moose barking targets the mature fruit-bearing trees. Although there are other soft-mast species within the home range of any particular bear, bear habitat quality must be reduced in areas where mountain ash abundance declines due to moose barking.

The abundance of fall food resources has been found to affect bear reproductive success (Jonkel and Cowan 1971; Rogers 1976, 1977; Beeman and Pelton 1980). Scarcity of mountain ash may not result in direct bear mortality, but recruitment may be lowered in places where mountain ash has been eradicated by moose bark stripping.

The Future of Mountain Ash in Vermont

Bark damage on mountain ash due to moose and subsequent mortality operate within the context of natural regeneration, disease, and other mechanical injury (such as injury by bears and ice). However, it is clear from this study that moose are killing mature mountain ash in Vermont. Barked trees are found mostly in maturing stands where there is competition with other species for direct sunlight needed by mountain ash. Moose browse heavily on root suckers, which sprout in response to wounding of the main stems. Saplings that could replace mature trees are often subject to heavy browsing and may be permanently stunted or killed. On Isle Royale, even though mountain ash has not been wiped out, young stems are maintained at the shrub level and do not grow into mature trees (McKinnes *et al.* 1992). Abundance of mature fruit-bearing trees in Vermont will probably decrease in the future, especially as the moose population continues to grow. As moose density increases in the southern part of Vermont, barking and browsing of mountain ash will begin to have an impact, as it has in northern and central parts of the state.

Even though the species is probably not threatened statewide, mountain ash can be and has been wiped out on a local scale. On one site, 75% of the trees were already dead, and every tree was barked. Some sites on which we could find no mountain ash had apparently supported this species in the recent past. It is suggested that some of the sites from this study be resampled in the future to further our understanding of moose bark stripping and its role in the abundance of mountain ash. Since mountain ash stands are not common, active management to protect them may be warranted.

MANAGEMENT IMPLICATIONS

Conservation of Mountain Ash

Logging is one means by which a forested environment is disturbed and succession set back. Mountain ash, as an early successional species, needs these disturbed areas in which to grow. Logging also provides large quantities of browse that attracts moose. Because logging was positively significantly correlated with moose activity ($Z = -2.797, P < 0.0052$) and moose barking of mature mountain ash adjacent to the logging ($Z = -2.018, P < 0.044$), managers may choose to curtail logging in areas where there is a desire to preserve mature mountain ash stands.

Since barking of mountain ash appears to be moose-density dependent, stabilizing or even reducing moose densities within specific limits is a means to minimize damage. With sustained population control, damaged stands may recover in time.

Habitat Assessment

Twig counts to quantify level of browsing is a common means to measure moose habitat usage (Peek 1974, Snyder and Janke 1976, Miquelle 1983, Cumming 1987). Quantifying bark stripping is much faster, can be used over larger areas, and avoids confusion with deer (*Odocoileus* spp.) sign except in rare instances of deer barking near wintering areas. However, it could not be used in areas where elk (*Cervus elaphus*) and moose coincide because elk also strip bark. The statistical correlation between bark stripping and moose activity was significant in this study ($r^2 = 0.377, P < 0.0001$), even though pellet groups were counted under less than ideal conditions, and the girdling index is an approximation. The degree of browsing appeared to be comparable to the degree of the barking at each site, even though we did not quantify browse. This method would also have an advantage over pellet-group counts, which are limited to a short season in spring between snowmelt and leaf flush.

Quantifying bark stripping could be an especially good method when researchers and managers wish to assess the degree of moose habitat usage quickly, as long as there are no other large ungulates barking trees in that area. Wounds are quite visible, even years after the original damage occurs. Current year's damage is harder to assess, but it was still shown to be significantly correlated with moose activity ($r^2 = 0.425, P < 0.0001$). Such assessment would not have to be limited to mountain ash. All barked trees could be counted, regardless of species. Another option would be to quantify barking of a tree species that is only moderately palatable. Using such a species would perhaps give a better index of moose activity in a given area, as opposed to a species like mountain ash that appears to be preferred. Research testing the strength of the correlation between levels of browsing and bark stripping of several species would be very helpful to further assess the usefulness of this method.

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