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Master's Project: An Ecological Assessment of Backcountry Ski Trails at Bolton Backcountry in Bolton, VT

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An Ecological Assessment of Gladed Ski Trails at Bolton Backcountry in Bolton, Vermont

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Executive Summary

The Bolton Valley Nordic and Backcountry Ski Parcel is a recent acquisitions of the Vermont Department of Forests, Parks, and Recreation (FPR). It is the most trail dense parcel managed by FPR. The acquisition of this parcel aligns with FPR's current focus on creating effective management strategies for backcountry skiing, a fast growing recreational sport in Vermont. There is little ecological data on the effects of backcountry skiing on wildlife habitat and forest health. The Bolton Backcountry offers an opportunity to study the ecological effects of cutting backcountry ski trails.

Four focal species were used to compare wildlife habitat suitability of the glades and adjacent forest areas. A focal species is one whose requirements for survival are linked to factors important for maintaining healthy ecosystems. The focal species used for the study were black bear (*Ursus americanus*), Canada warbler (*Wilsonia canadensis*), black-throated blue warbler (*Dendroica caerulescens*), and scarlet tanager (*Piranga olivacea*).

Wildlife suitability for black bear was assessed using the United States Fish and Wildlife Service's Habitat Suitability Index. Habitat Suitability Indices are based on aquatic and vegetation factors. Collecting data for the habitat suitability indices therefore led to the accumulation of vegetation data that can be used to make inferences about the forest. The study was set up with control (forested) plots and treatment (gladed) plots. Results showed that black bear habitat suitability was significantly ($p<.05$) different between control and treatment plots. Habitat suitability was lower in treatment areas due to the lower diversity of berry-bearing herbaceous plants. This finding aligns with the herbaceous percent cover data that suggests a lower diversity of herbaceous plants in treatment versus control plots. A lack of diversity in the forest vegetation can affect the kind of animals that live there.

The black-throated blue warbler nest site suitability suggested there were more saplings in the control plots. This finding builds on the lack of diversity noted in the herbaceous layer of the treatment plots because vertical structure (small trees, saplings, shrubs, and herbaceous plants) provide more places for creatures to nest, seek cover, and find food. In this way, vertical structure adds diversity to the forested landscape.

There was not a noticeable difference between control and treatment sites for the nest site suitability for Canada warbler and scarlet tanager. The main components of their habitat suitability were downed woody debris and canopy cover respectively. These two factors were consistent throughout the property. The consistently closed canopy across the treatment area compounds the lack of herbaceous diversity and vertical structure because not enough light gets through the canopy to stimulate early successional species. The presence of New York fern noted on treatment plots makes using any selective group cutting inadvisable because the New York fern will thrive in a canopy opening and shade out other species.

It is important to not develop in the Special Treatment Area delineated by the Vermont Land Trust, which includes the montane spruce-fir forest. Cutting glades through spruce-fir has been shown anecdotally to have a negative impact at Mad River Glen and is discouraged in research on wildlife at traditional alpine resorts (Strong et al. 2002).

Finally, building on the partnerships and the community associated with it, the Bolton Valley Nordic and Backcountry Ski Parcel offers the perfect opportunity to be the hands-on backcountry ski education hub for northern Vermont. The Friends of Bolton Valley already tend to the backcountry trail maintenance every fall. Establishing a more formal Trail Maintenance workshop for the public would begin to spread trail standards as well as help the state maintain the extensive network of trails on the parcel. Another set of workshops could be focused on trail design, planning, layout, and cutting. These would further help standardize and spread the desired terrain management practices currently being established by FPR, partners, and the Vermont Backcountry Alliance.

The Bolton Backcountry provides FPR with a great land management opportunity. It offers a place to further study the ecological impacts of glading as well as to test out the current best management practices for glade cutting and improve upon them. Finally, it offers a place to engage the public as recreationists and, more importantly, as land stewards.

Introduction to the Ecological Assessment

The newly acquired Vermont Department of Forests, Parks, and Recreation 1,140 acre Bolton Valley Nordic and Backcountry Trails Parcel (Bolton Backcountry) is a result of community action. In 2012, the land was slated to be sold to a private interest that would limit public access to the trails. The long-time users of the trails rallied together to form the Friends of Bolton Valley, which raised awareness about the pending sail and initiated a call to action. The group's success caught the attention of Vermont Land Trust, which helped to secure $1.85 million dollars in about a year for the purchase of the land. The money was a combination of personal donations and grants. The Vermont Department of Forests, Parks, and Recreation (FPR) currently manage Bolton Backcountry in partnership with Vermont Land Trust, the Green Mountain Club, the Catamount Trail Association, the Friends of Bolton Valley, and others. Bolton Valley Resort, LLC has a five-year lease with FPR for continued use of the Nordic and backcountry ski trails.

The Bolton Backcountry is an exciting acquisition for various reasons. The parcel adds to a large, contiguous block of forested landscape that is integral for wildlife habitat and forest health. The headwaters of the Joiner Brook, a Winooski River tributary, are on the land and FPR management will ensure the health of that resource. The parcel is also dominated by a recreation trail system. The presence of both wildlife and intense recreation on the property creates an opportunity for state land managers.

> Michael Snyder, Commissioner of Vermont Forests, Parks, and Recreation, noted in 2013 "[Bolton Valley Nordic and Backcountry Trails Parcel is] the largest concentration of this kind of ski terrain on state lands. Our role will be to model and demonstrate good land stewardship, but people are going to have to continue to care for it to make this work."

In the past ten years, a boom in backcountry skiing has pushed FPR toward developing a new management strategy. Backcountry skiing entails accessing skiable terrain by hiking to the area you want to ski. Backcountry skiing is also characterized by skiing in maintained forested areas, colloquially known as tree skiing or glade skiing. Glade skiing is defined for this document as a ski run, maintained in the woods where a skier can make multiple linked turns between trees. Glades are maintained to keep them fun and useable. Maintenance of glades includes removal of the forest understory to prevent skier injury.

The acquisition of the Bolton Backcountry offers the state an opportunity to study the ecological effects of backcountry skiing. Recreation traditionally affects five major components of an ecological system: biodiversity, water, soil, vegetation, and wildlife. This study addresses the effects of glades on three of these: biodiversity, forest vegetation, and wildlife habitat suitability. Four focal species were chosen for wildlife habitat suitability analysis: black bear (*Ursus americanus*), black-throated blue warbler (*Wilsonia canadensis*), Canada warbler (*Dendroica caerulescens*), and scarlet tanager (*Piranga olivacea*). The results of the study will be incorporated into a long-term management plan for Bolton Backcountry.

Bolton Valley Nordic and Backcountry Trails Parcel Context

Land Use History

The 1,140-acre Bolton Valley Nordic and Backcountry Trails Parcel (Bolton Backcountry) is a result of the land purchases made by Edward Bryant in the 1920s. Bryant was a transplant from Massachusetts who graduated from the Harvard School of Forestry in 1907. He ran his own Forestry Consulting business and later worked for the United States Forest Service (USFS). In 1922, he purchased 4,400 acres from a Connecticut-based timber company, American Brass Company. The land had been clear-cut of all valuable timber in the late 1800s. Bryant facilitated reforestation of his land with a focus on red spruce stands.

Bryant was also a ski enthusiast and leader of the Bolton Mountain Club. In the late 1920s, Bryant began cutting Nordic trails on Bolton Mountain, including Heavenly Highway, with the help of Otto Schnieb - an early proponent of American downhill skiing. Bryant envisioned Bolton Mountain as a lift-serve downhill ski area.

Bryant's individual passion aligned with the concurrent vision of state forester, Perry Merrill, who asserted that the development of skiing in Vermont could finance a system of state parks and forests. In the 1930s, Merrill utilized the Civilian Conservation Corps (CCC) to facilitate his dream. CCC crews cut ski trails on Mt. Mansfield, Killington, Okemo, and other mountains in Vermont. These initial trails and their success at drawing visitors to Vermont established downhill skiing as a source of recreation and revenue for the state.

Vermont's economy today still depends on the ski industry established in the 1940s.
In the late 1940s, Bryant tried to get the financing for a rope tow and base lodge, but he fell ill and passed away in 1951. His land was sold to Plant and Griffith Lumber Company for timber production. The land was again sold in 1968 to the Bolton Valley Corporation.

In the 1970s, a local ski enthusiast, Gardiner Lane, began re-cutting Bryant's old trails as well as new ones. Lane's trails make up the bulk of the current day Bolton Backcountry parcel trail system, including some of the glades. Gardiner was also a founding member of the Old Goats, a hardy group of men and women who continue to maintain the trails on the property today. The Old Goats group started the Friends of Bolton Valley group that was responsible for spearheading the campaign to conserve the Bolton Valley Nordic and Backcountry Trails parcel.

Bolton Backcountry has a few larger trails that cut through the property. The Catamount Trail crosses the parcel, including Section 22, the Bolton to Trapps trail. The Woodward Trail is another point-to-point excursion that goes from the top of the Vista Quad to Little River State Park in Waterbury. The Long Trail, a long-distance hiking trail, also historically crossed the parcel. The Bolton Camp structure is a Green Mountain Club structure built in the 1930s.

Over the past 100-years, this parcel has been heavily impacted through human use (Figure 1). State ownership presents the opportunity for a long-range management plan that includes humans, but does not discount ecology.

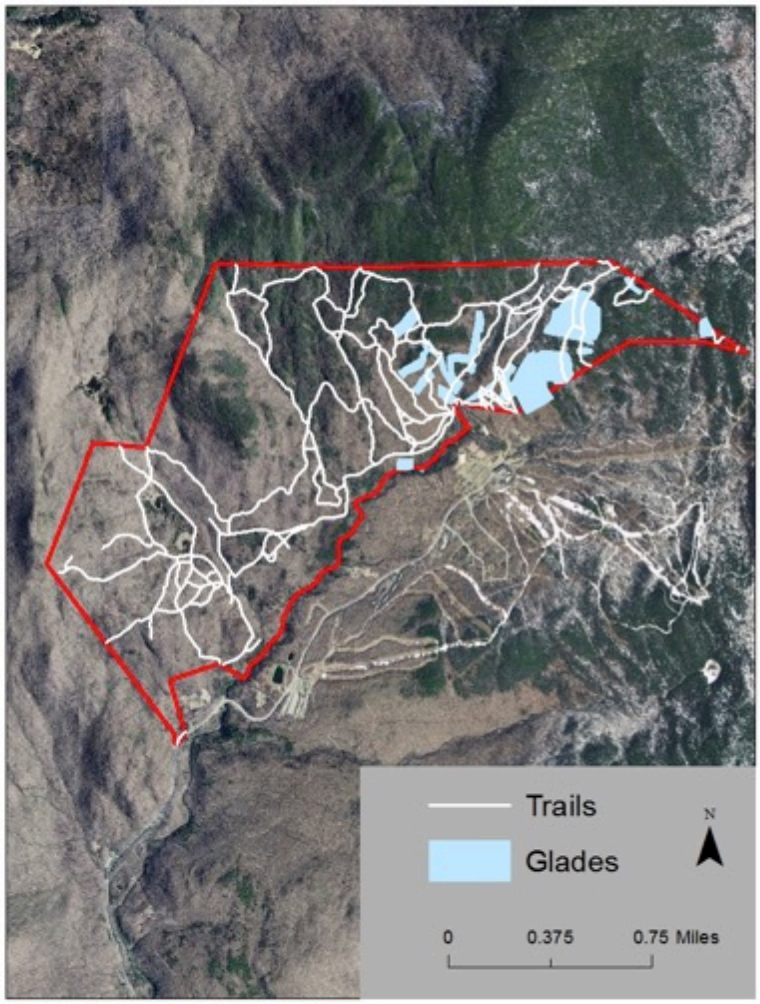


Figure 1. Map of Bolton Backcountry land with trails and glades marked. Trails do exist outside of the boundary line, but were not included for simplicity.

Landscape Context and Wildlife Connectivity

The Bolton Backcountry parcel is 1,140 acres covering an elevation gradient from 1000-2800 ft. It is located in Bolton, Vermont and is within 30 miles of Vermont's largest city, Burlington (Figure 2). The parcel is the newest addition to the Mt. Mansfield State Forest, the largest contiguous landholding of FPR. It is approximately 40,000 acres, covers three counties, and includes seven towns. Across the Winooski valley to the south lays the 25,000-acre Camels Hump Management Unit. These two large public land holdings are part of a major north-south wildlife travel corridor in north central Vermont.

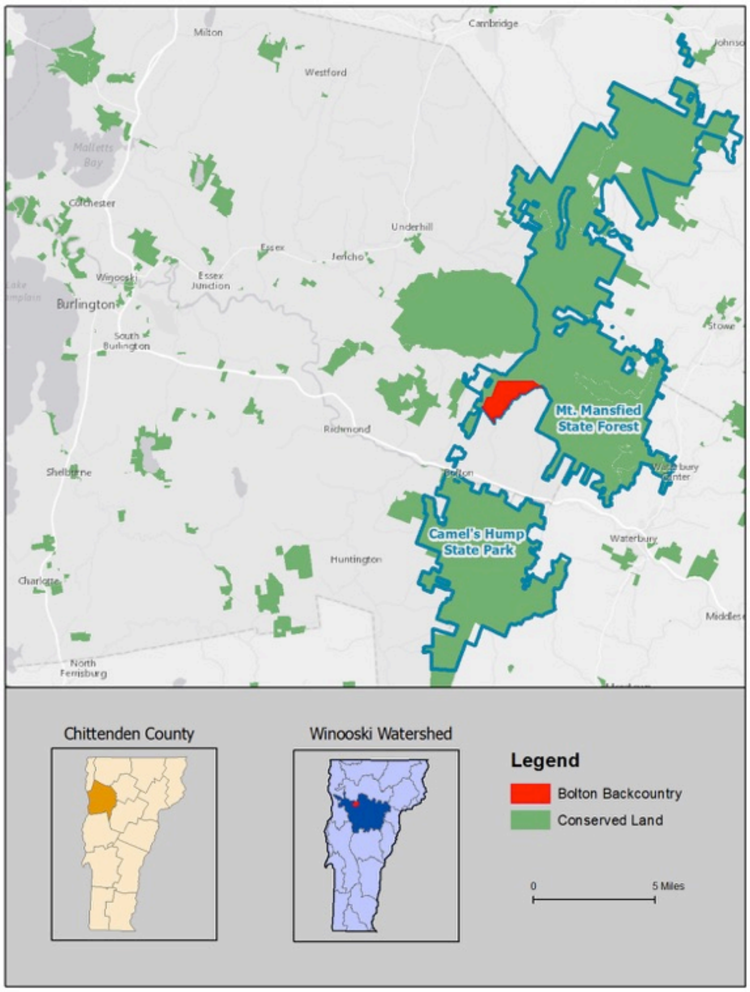


Figure 2. The Bolton Backcountry land in context.

The landscape between Camels Hump Management Unit and Mt. Mansfield State Forest runs through the Winooski Valley. In 2008, a coalition of local conservation advocates, Vermont Land Trust, and the state defined this area as core habitat for wildlife and named it the Chittenden County Uplands. It is considered at high risk for development due to its proximity to Burlington.

Linking core wildlife habitat into wildlife corridors that improve large-scale landscape connectivity is important in the face of a changing climate. The warming temperatures are changing vegetation, which forces migratory animals to move further north to find habitat and food. Bolton Backcountry adds to the landscape level connectivity and provides the needed conserved land base for this moving wildlife population as well as the current wildlife population.

Methods

Study Area

Bolton Backcountry in Bolton, Vermont in northwestern Vermont is 1,140 acres spanning 1,800 to 2,800 feet in elevation. The whole parcel is made up of a matrix of northern hardwood forest, montane yellow birch-spruce forest, spruce-fir forest, and a beaver meadow complex. The land is notably rugged with rock outcrops and talus slopes spread throughout the landscape. When these outcrops occur at around 2000 feet they provide suitable conditions for spruce-fir to grow. When viewed from above these outcrops form fingers and tiny islands of coniferous canopy betwixt the deciduous trees. This landscape also holds approximately 60 miles of ski trails and 70 acres of mapped glades. The dense trail network leaves little space untouched by recreationists in winter.

The seventy acres of glades are the focus of this study. There is pressure to expand the glade acreage on the property due to an increased pubic interest in backcountry skiing. The gladed area will be known as the treatment area throughout the document. The 70 acre control area was chosen because of similar forest cover type, soil type, and elevation.

Focal Species

Due to the size of the parcel and the time constraint of the project, four focal species were chosen: black bear, black-throated blue warbler, Canada warbler, and scarlet tanager. The United States Department of Fish and Wildlife (USFWS) has a habitat suitability index established for the black bear (1987). The three bird species habitat suitability needs were created using primary literature.

Black bear, scarlet tanager, black-throated blue warbler, and Canada warbler were chosen as focal species. All of these species are likely to live on the parcel due to size of the forested landscape as well as its cover type and elevation. Focal species is an umbrella term that encapsulates indicator, umbrella, flagship and keystone species (Miller et al. 1999). These species were chosen because of their sensitivity to forest fragmentation and their dependence on diverse forest structure.

Indicator species are sensitive to ecological changes and can be useful for monitoring habitat quality, and can provide an early warning system for the loss of integrity in an ecosystem (Miller et al. 1999). The three birds chosen are dependent on different aspects of forest structure, which makes them viable indicator species for changes created by glade cutting. If a forest lacks the specific requirements that make up their habitat suitability index, the birds are less likely to be there.

Black bear was chosen as a flagship species because they are charismatic and recognizable to the public (Miller et al. 1999). Black bear cover large areas in their seasonal movements, using different parts of a forested system for spring, summer, and fall food as well as winter denning. Black bear are also highly sensitive to habitat fragmentation and alteration because of their dependence on a variety of habitat types throughout the year.

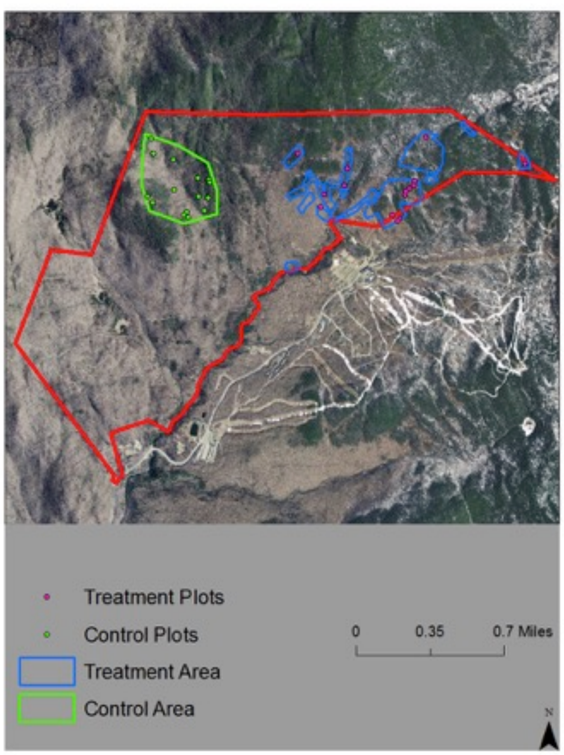
Habitat Suitability Index - Black Bear

The Habitat Suitability Index (HSI) created by the United States Department of Fish and Wildlife (USFWS) was used to analyze bear habitat data (Appendix B). HSIs use a 0-1 scale to express habitat suitability. The higher the HSI (i.e. 0.8), the more likely an animal is to live there. Every HSI is specific to one animal species. For instance, the black bear habitat suitability index has an equation for spring, summer, and fall food that are combined to make a total HSI for black bear. For the discussion in this paper, an HSI of 0.8-1 is high value habitat, 0.4-0.7 is medium value habitat, and 0-0.3 low value habitat.

Nest Site Habitat Suitability - Birds

The three birds selected do not have USFWS HSIs. The focus of this study was on nest site suitability. To create nest site suitability indices (NSSI) for each bird, I used a combination of information about nest site selection from primary literature and the Vermont Audubon Silviculture with Birds in Mind Program (Appendix C). Like the bear HSI, the multiple variables were combined to form a total Nesting Site Habitat Suitability Index of high (0.8-1), medium (0.4-0.7), and low (0-0.3).

Figure 3. A map of the control and treatment areas with random plots.



Vegetation Data

Wildlife habitat suitability models use vegetation data. A modified approach to the United States Forest Service's Field Inventory and Analysis (FIA) approach was used to collect the forest vegetation data. The traditional FIA approach uses a cluster of four 0.25 acre sub-plots to make up one, one-acre plot. I used one FIA sub-plot as my main plot.

There were approximately 70 acres of mapped glades on the Bolton Backcountry. The gladed area is referred to as the 'treatment' area throughout this document. It is a treatment area because it is altered from the original forested state (control). A 70 acre control area was defined to match the soil type, elevation, aspect, and natural community type of the treatment area. Once both areas were defined, 15 random points were generated for each 70 acre area. These points were used as plot centers for the vegetation data collection using the FIA protocols (see Appendix A). I collected data on woody species, tree diameter at breast height (dbh), herbaceous species, and percent cover of herbaceous and woody species, downed debris, and canopy closure.

I started data collection in late June and finished in mid-August. I visited all the treatment plots first, followed by all of the control plots. I started with the treatment plots because I was still figuring out the control design and needed to begin data collection. I bushwhacked to each plot using a GPS loaded with the randomly generated points. Data collection took approximately two hours per plot. I visited two to three plots per day.

Vegetation Results

A suite of forest vegetation data was collected in order to assess wildlife habitat suitability. This section walks through the different sets of data collected and outlines the trends present. Further years of data collection in the treatment areas may reveal more about the long-term effects of glading on forest species composition and regeneration.

Trees - Seedlings to Saw Logs

The hypothesis for tree data was that there would be more seedlings and saplings in the control plots than in the treatment area. Seedlings and saplings fall into the 0-6 ft range of the forest understory, which is the **area** of the forest removed during yearly glade maintenance. It was hypothesized that there would be more pole logs on the control plots since seedlings and saplings are regularly cut out of treatment plots. Finally, it was hypothesized that there would be more saw logs on the treatment plots, since glades are maintained with the intention of keeping large dbh trees. The <1" dbh saplings are lumped into seedlings in this figure because the tree data was broken out into four age classes - seedling, sapling, pole, and saw log - defined by the University of New Hampshire Extension (2010).

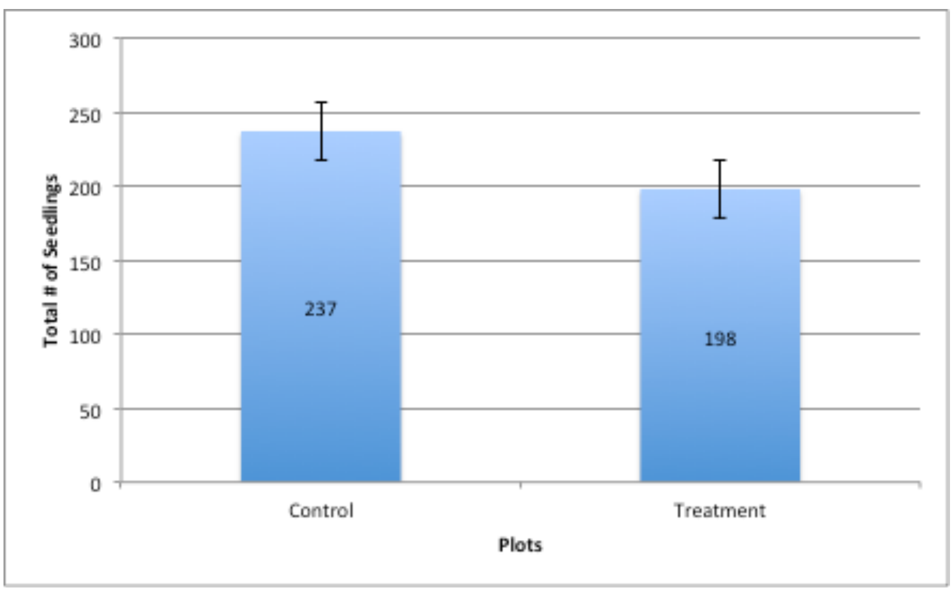


Figure 4. Total Number of Seedlings in Control and Treatment Plots. Seedlings include trees <1" diameter breast height. There are slightly more seedlings in the control area than in the treatment area. This aligns with the hypothesis for this age class.

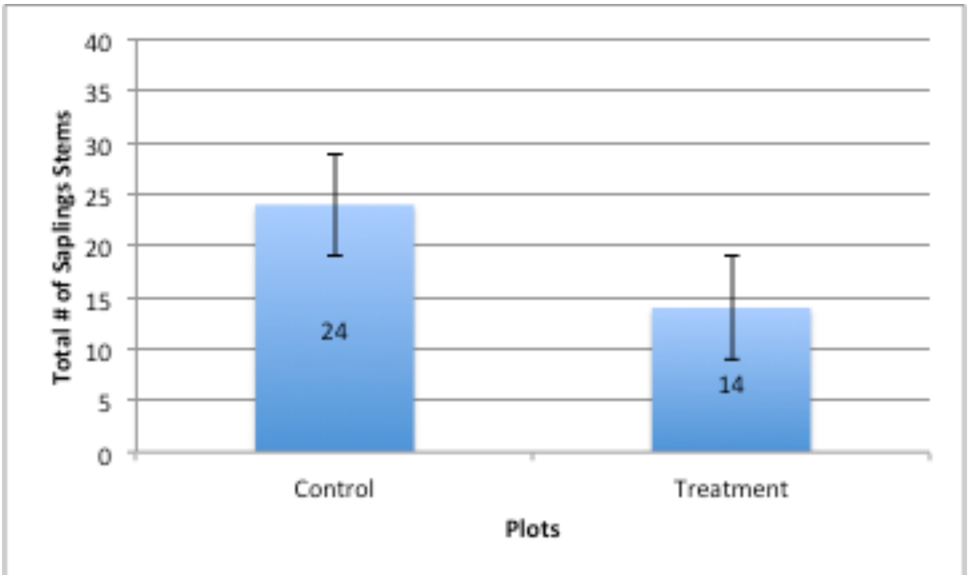


Figure 5. Total Number of Sapling Stems in Control and Treatment Plots. Saplings include trees >1"-4.5" diameter breast height. There are twice as many sapling stems in the control plots compared to the treatment plots. This aligns with the hypothesis for this age class. As mentioned before this age class is cut out by backcountry skiers because these trees interfere with the descent. They are whippy and can hit you in the face and catch your skis, poles, and other equipment.

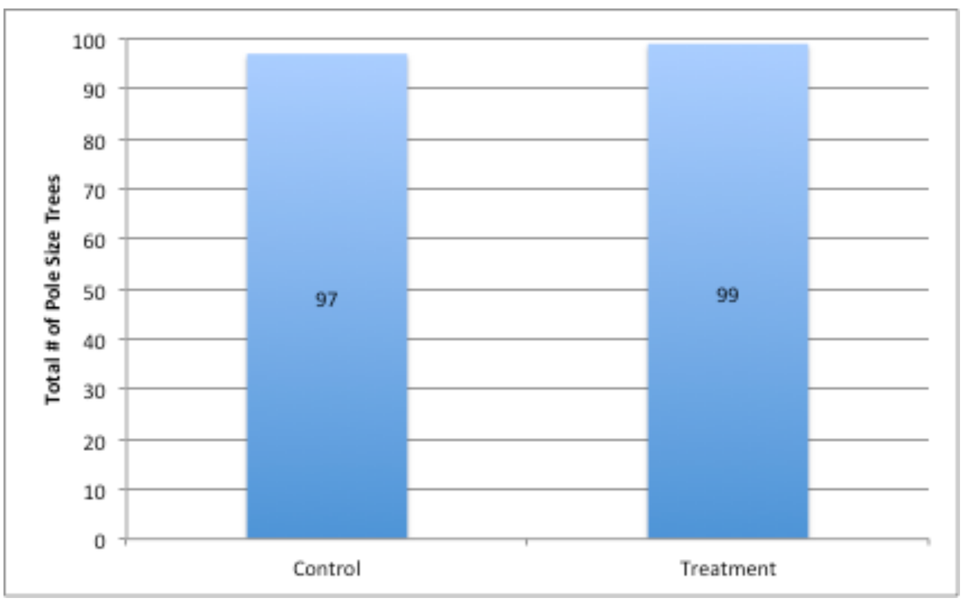


Figure 6. Total Number of Pole Size Trees in Control and Treatment Plots. Pole size trees include trees >4.5"-12" diameter breast height. These results were surprising because it was hypothesized that there would be more pole size in the treatment plots since younger age classes are cut out. There are roughly the same number of pole size trees in control and treatment plots. This finding does support the fact that the forests being compared have a similar composition, which means differences in the younger age classes are likely because of human activity versus natural differences between the forests.

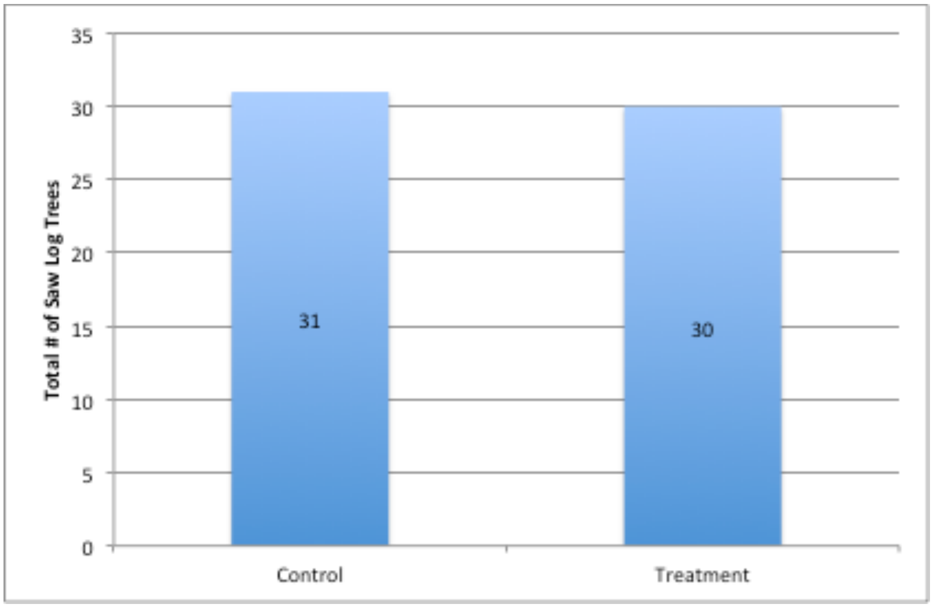


Figure 7. Total Number of Saw Log Trees in Control and Treatment Plots. Saw Log trees include trees >12" diameter breast height. These results align with what was expected. There are roughly the same number of saw log trees in control and treatment plots. This finding supports the fact that the forests being compared have a similar composition, which means differences in the younger age classes are likely because of human activity versus natural differences between the forests.

The trends shown in Figures 5-8 support the idea that there is a difference between the understory (seedling/sapling age class) in control and treatment plots.

Canopy Cover

Canopy cover observed across the study area was very closed. This was confirmed by the data (Figure 9).

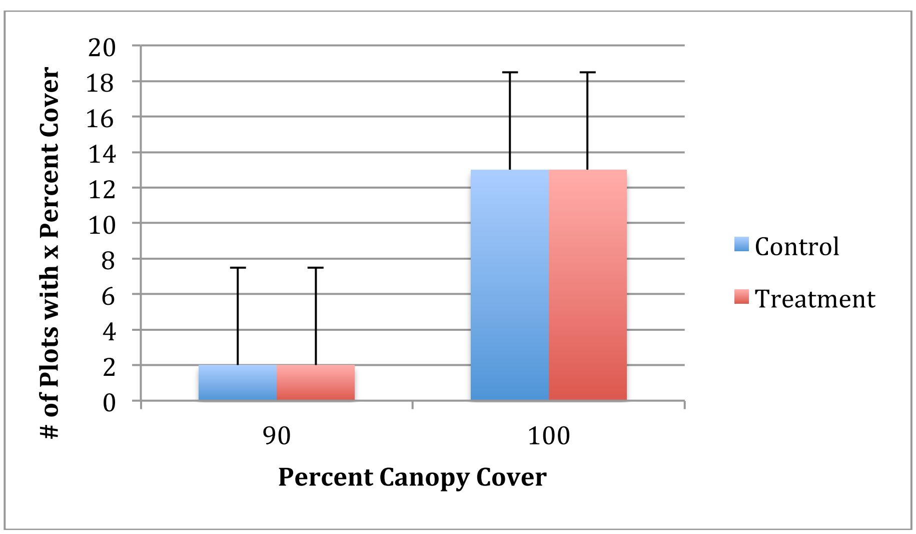


Figure 8. Number of Plots in Control and Treatment Plots with x Percent Canopy Cover. This shows that all of the plots have >90% canopy cover. This supports that the two areas are similar.

Downed Woody Debris

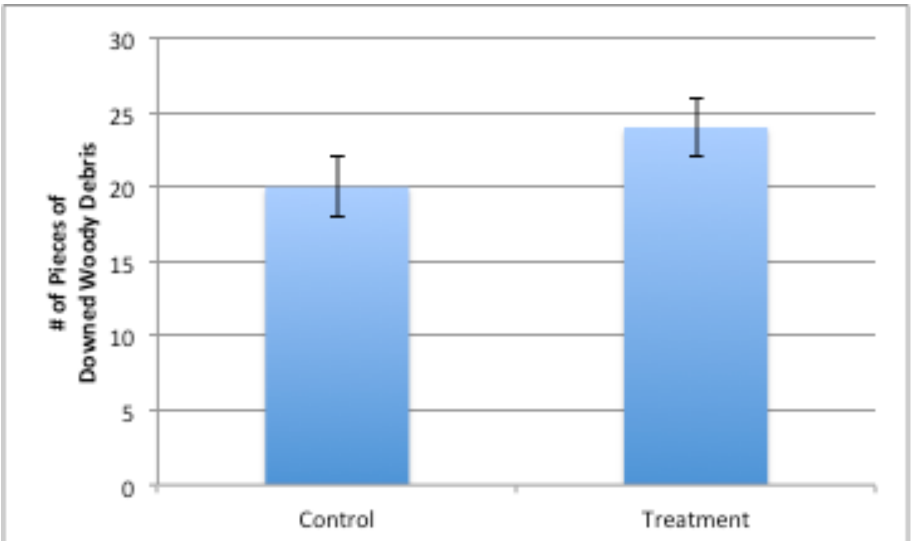


Figure 9. Total Number of Pieces of Downed Woody Debris on control and treatment plots. Downed woody debris is an important part of forest structure. It creates micro climates near the forest floor and as it decomposes releases nutrients back into the soil. Wildlife, invertebrates, and fungi thrive in these pieces of dead wood. There were slightly more recorded on the treatment plots than the control plots. The treatment plot downed woody debris was all much further along in decomposition than the control plots. Some trees had recently fallen while others were barely recognizable. This may be related to the fact that newer downed trees are often cleared from glades to the nearest forest island.

Soil pH

One of the criteria for choosing the control area is that it had the same soil types present as are found in the treatment plots. While in the field soil pH was recorded at each plot.

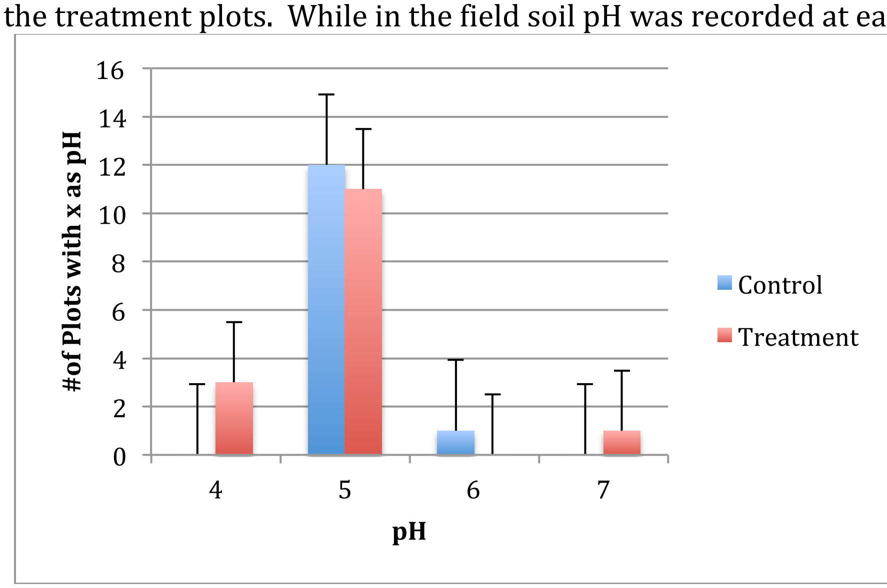


Figure 10. Number of plots in the study area with x soil pH. Most of the plots had a soil pH around 5. Soil pH can influence what types of vegetation grow in an area, the consistent pH supports that the control and treatment area were similar.

New York Fern Percent Cover

Species and percent cover data was collected at three quadrats on each plot. Species were then recorded at the plot level as well. This data, particularly in relation to herbaceous vegetation, is the most likely to be affected by the seasonal difference in data collection. Data was collected at all treatment plots in early to mid-July, while control plot data was collected from late-July to mid-August. Ferns were observationally larger in August on the whole property. The hypothesis related to ferns is that there would be a higher percent coverage of ferns on the treatment plots. This figure looks particularly at New York Fern because of its ability to shade out other plants and create a carpet of ferns.

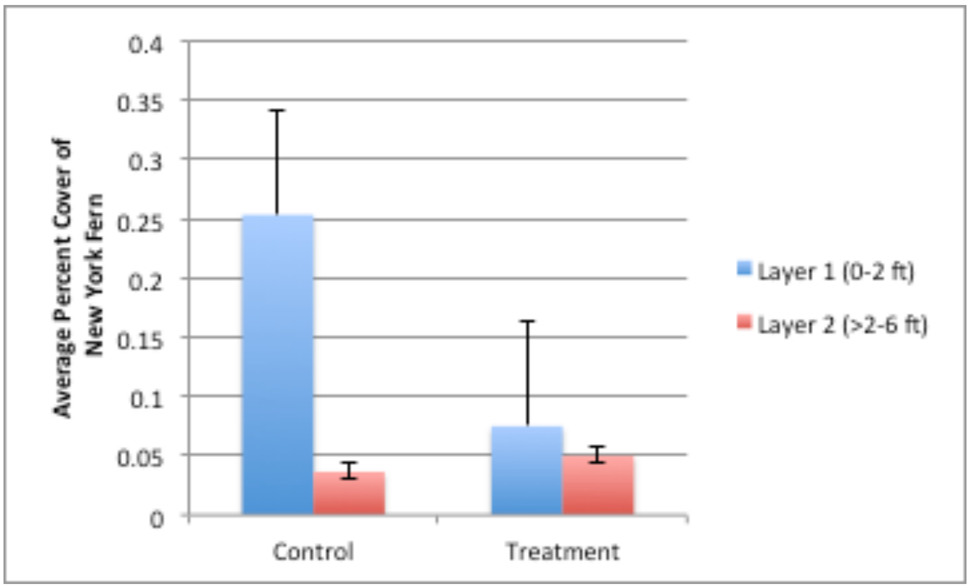


Figure 11. The average percent cover of New York Fern in the first two layers of the forest on control and treatment plots. The trend in data shows that there is a higher percent cover of New York Fern on control plots. As mentioned above, this is likely due to the time of season percent data was collected. Although this does not support the hypothesis, it does show that New York Fern is present on the property.

Vegetation Biodiversity

At every plot all vegetative species present were recorded. There were more species in control plots than treatment plots. Both woody and herbaceous species were counted. Since the woody species were almost the same, the main difference in species is in the herbaceous layer.

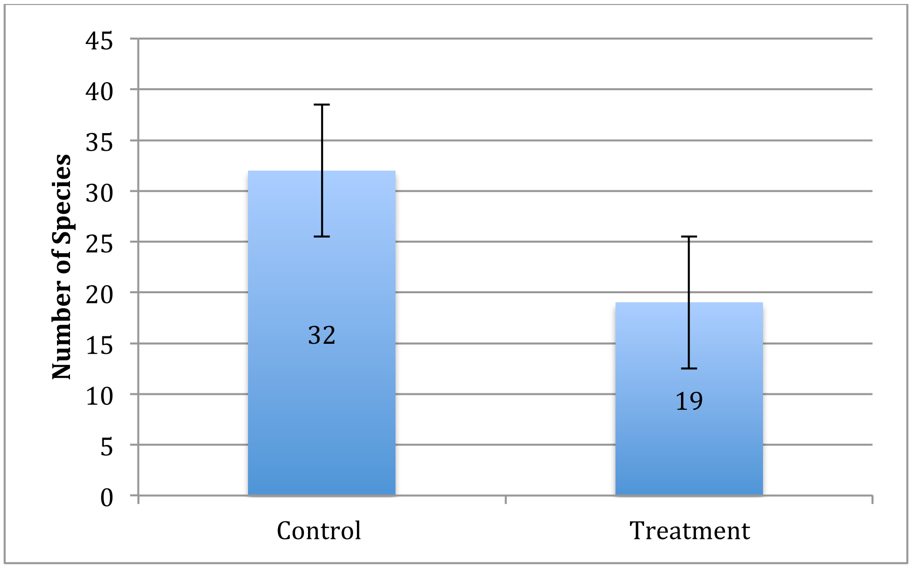


Figure 12. The total number of vegetative species on control and treatment plots. There were more species recorded on control than treatment plots. This difference could be important when thinking about the future of the treatment area and what it might look like if it stops being used as a ski run.

Discussion

It is currently unclear what the future forest in the treatment area may look like, due to the lowered herbaceous diversity, the small size of the sapling age class, and the presence of New York fern in the herbaceous layer. A disturbance in this forest will not follow the traditional disturbance successional pattern due to the presence of New York fern in the plots and hay-scented fern on the property. Both of these fern species will take over a newly created opening and suppress the growth of other vegetation (discussed further in management suggestions). Their presence can preclude certain species, thus affecting the species composition of the forest.

Wildlife Habitat Suitability Results

American Black Bear (*Ursus americanus*)

The American black bear is an elusive, large mammal that lives throughout Vermont. Since black bears eat meat, they are considered a top-level consumer and thus their presence on a landscape affects the biological structure and composition of ecosystems (Long et al. 2011). Bears are dependent on large swaths of intact forest that contain a matrix of forest types including wetlands, American beech stands, and forest openings. Black bears have 5-8 months to fulfill a year's worth of nutritional needs and each forest type fills a different food need. The bulk of their weight gain occurs with the emergence of berries and nuts in the summer and fall, respectively. Food availability is the main determining factor of their home range size. A localized failure of a food source, particularly fall nut production, results in longer distance foraging. A food stressed bear is more likely to push beyond the forest and begin to cross the human interface, raiding bird feeders and garbage cans as well as cash crops.

Results and Discussion

The treatment area had a lower HSI for black bear than the control area (Table 1). This was due to the lower diversity of berry-bearing species on the treatment plots. The treatment plots had only one berry-bearing species, hobblebush, while the control plots had three species. This difference was important because of the way the HSI is calculated (see Appendix B). A seemingly small difference in diversity had a large effect on the suitability index for summer food, which influenced the overall HSI.

Seasonal Food	**Suitability Index**	
	Control	Treatment
Spring	Medium	Medium
Summer	High	Low
Fall	Low	Low
Final HSI	**Medium**	**Low**

Table 1. The black bear HSI showed a significant different ($p<.05$) between the control and treatment plots. The difference was largely influenced by the lack of diversity in berry-bearing plants on the treatment plots. This lack of diversity in the treatment plots is reflected in the larger vegetation data set.

The data suggest a difference in total vegetation diversity between the control and treatment areas (Figure 13, p. 18). Control and treatment plots were visited only once and at different times of the growing season, but is unlikely that this temporal difference in data collection would influence this difference in species diversity.

The disparity in species diversity implied that glading affected forest biodiversity. The loss of biodiversity in a forest is linked to loss of resiliency or the ability of the forest to rebound after a disturbance. This makes the forest more vulnerable to unexpected changes, which is a concern because of more frequent extreme weather that can cause disturbance. The loss of forest diversity in turn affects the diversity of the creatures living in it, from insects to carnivores.

The rocky outcrops and talus slopes found across the study area might provide good denning sites for a black bear. It is possible for black bears to be woken up from their sleep in the winter by humans engaging in non-motorized recreation. Understanding what the distribution of black bears in the area is and if there are known denning sites on Bolton Backcountry is important. When black bears are awoken, they often do not return to hibernation and their fitness will suffer. Mother bears will not only abandon their denning sites, but their cubs as well (Goodrich & Berger 1994). A loss of individual fitness and young could have negative effects on the larger black bear population dynamics.

Birds

Canada warbler, black-throated blue warbler, and scarlet tanager are all sensitive to forest fragmentation. They also all live in deciduous or mixed forests. The Bolton Backcountry's landscape context offers enough unbroken forest to allow the prediction that these birds would live on the parcel. All of the birds were recorded as present on the parcel by the Vermont Audubon Rapid Bird Survey in the spring of 2014.

Vermont developed a Wildlife Action Plan in 2003 to create a targeted wildlife conservation strategy for the state. The Vermont Wildlife Action Plan developed criteria for Species of Greatest Conservation Need through the expertise of six Action Plan Teams. Some of the criteria used to define these species include: degree of species rarity, habitat fragmentation, and habitat conversion or succession changes. The species were also given a conservation rank of high, medium, or low. Those that ranked high or medium were considered Species of Greatest Conservation Need (SGCN), while the low-ranking species were expected to benefit from conservation efforts of the SGCN. In this way, the plan would protect threatened species as well as keep common species common.

Habitat-Related	Non-Habitat-Related
Climate Change	Competition
Habitat Alteration/Degradation	Disease
Habitat Conversion	Genetics
Habitat Fragmentation	Harvest/Collection
Hydrologic Alteration	Incompatible Recreation
Impacts of Roads and Trails	Loss of Prey Base
Inadequate Distribution of Successional Stages	Loss of Relationship with other species
Inadequate Disturbance Regime	Parasitism
Invasion by Exotic Species	Pollution
Sedimentation	Predation or Herbivory
	Reproductive Traits
	Trampling & Direct Impacts

Table 2. This table from the Vermont Wildlife Action Plan outlines the two problem categories for birds and other wildlife in Vermont. The main problems for Vermont's birds and other wildlife relate to change in habitat such as conversion of habitat and distribution of successional stages.

Canada warbler (*Wilsonia canadensis*)

Canada warblers are found throughout Vermont with populations concentrated on the mid-slopes of the Green Mountains. The top habitat threats for Canada warbler in Vermont are conversion of habitat, habitat alteration, habitat fragmentation, and habitat succession. The VT Wildlife Action Plan placed a high priority on monitoring Canada warbler's response to both natural and human-caused habitat changes. The Canada warbler is considered a high priority SGCN.

Forest structure plays a crucial role in Canada warbler nest site suitability. Scientists suspect that the Canada warbler's 30-year population decline in the Northeast is likely a result of a change in forest structure from an early- and mid-successional forested landscape to a mature forest lacking a dense understory. Processes that decrease forest understory such as heavy deer browse have made Canada warblers scarce in the affected forests, such as oak forests in Pennsylvania.

Canada warblers nest on or near the ground in recessed pockets of moss hummocks, root balls, and deep leaf litter. Their nest sites tend to be in thickets or areas with dense ferns. Dense cover for the nest site is a key nest site requirement.

The control and treatment plots both offer medium nest site suitability for the Canada warbler (Table 3). Although in the field it appeared that there was more downed woody debris in the control plots the data do not bear that out (see page 10 of this document). Much of the downed woody debris recorded on both treatment and control plots was at a USFS decomposition level of 5 or more meaning that it was decomposing and would crumble to the touch. There was no way to account for this lack of decomposition diversity in the NSSI.

Downed woody debris is an important component of the forest. It influences the biodiversity of wildlife. Downed woody debris provides habitat for nesting from birds to bears: ruffed grouse use logs during courtship rituals, weasel family members tunnel under logs during winter, and there are whole communities of fungi, insects, and micro-organisms that live on them (Hagan 1999). The downed decomposing trees also provide germination sites for yellow birch as well as return nutrients to the forest.

Nest Site Habitat Suitability		
	Control	*Treatment*
Downed woody debris	High	High
Fern percent cover	Low	Low
Understory percent cover	Medium	Medium
Final NSHSI	**Medium**	**Medium**

Table 3. Nest site suitability for Canada warblers calculated using NSSI (Appendix C). Per plot NSSIs were calculated, these were averaged to get a final NSSI. There is not a difference between control and treatment plots. Downed woody debris is an important component of forest structure.

Black-throated blue warbler *(Dendroica caerulescens)*

The black-throated blue warbler is another Neotropical migrant that breeds in Vermont. Black-throated blue warblers nest in the dense understory of the forest, in deciduous shrubs as well as coniferous and hardwood saplings**.** In a central New Hampshire study, nests were found in hobblebush (51%), American beech (21%), and sugar maple (9%) with the rest of the nests found in softwoods (red spruce, balsam fir) or lesser maples (mountain maple, striped maple)**.** The nests are built about two feet off the ground in the fork of these low shrubs or saplings, often with a dead stick or branch to support the nest.

In Vermont, the black-throated blue warbler was considered a medium priority species of greatest concern. The black-throated blue warbler's specific habitat threats in Vermont were conversion of habitat, habitat alteration, and habitat fragmentation.

The nest site habitat suitability for black-throated blue warbler was medium in the control plots and low in the treatment plots (Table 4), suggesting that there is a difference between nest site habitat suitability in the treatment and control plots.

Nest Site Habitat Suitability		
	Control	*Treatment*
Saplings <4.5-1" dbh	Low	Low
Saplings <1" dbh	Medium	Low
Understory percent cover	Medium	Medium
Final NSHSI	**Medium**	**Low**

Table 4. Nest site suitability for black-throated blue warbler was calculated using NSSI (Appendix C). Per plot NSSIs were calculated, these were averaged to get a final NSSI. The results suggest a difference between control and treatment plots. The black-throated blue warbler NSSI was based mainly on saplings present and understory percent cover (0-6 feet). The low NSSI in the treatment plots may reflect the regular maintenance, which requires the removal of saplings and other brush that creates an obstacle for skiers.

Scarlet tanager (*Piranga olivacea*)

Noted for its vivid coloration, the Scarlet Tanager is another Neotropical migrant that lives in Vermont's woods. The scarlet tanager is not a species of greatest concern in Vermont, however, that does not make it less important to include in this study. The Cornell Lab of Ornithology did extensive research on scarlet tanager in relation to forested ecosystems because of its commonness.

Scarlet tanagers prefer closed canopies, large deciduous trees, and an uninterrupted view to the forest floor for nest site habitat. Prescott (1965) found in a study in New Jersey that all nests recorded were in trees with a dbh of >8.8 inches. According to Peck and James (1987), nests in Ontario were located in maple (31.5%), American beech (21%), eastern hemlock (15.7%), elm (10.5%), hawthorn (10.5%), and spruce (10.5%). Nests in Vermont tended to be at around 32 feet from the ground (Laughlin and Kibbe, 1985). The nests themselves are built away from the trunk at a juncture of two or more smaller branches. Nests are placed in a cluster of leaves that provide cover from above with an unobstructed view of the ground below.

The overall nest site suitability for the scarlet tanager was medium for both control and treatment plots (Table 5). This was not surprising, given the high percent canopy closure and large dbh trees. The difference in the understory percent cover index between control and treatment differs from the Canada warbler and black-throated blue warbler because understory cover is not a desired habitat attribute. Scarlet tanagers prefer low percent cover of understory, so the low index in the treatment plot actually reflects a high understory percent cover.

Nest Site Habitat Suitability		
	Control	Treatment
Canopy Closure	High	High
Trees >8.8"	Medium	High
Understory Percent Cover	Medium	Low
Final NSHSI	**Medium**	**Medium**

Table 5. Nest site suitability for scarlet tanager was calculated using NSSI (Appendix C). Per plot NSSIs were calculated; these were averaged to get a final NSSI. The NSSI was medium for both plots, which is not surprising due to the high percent canopy cover and the number of large dbh trees. The percent cover of understory is included because scarlet tanagers like a low percent understory cover so they have a clear line of sight below their nests.

Bird Discussion

The bird NSSIs gave some insight into the similarities and differences between the treatment and control plots.

The Canada warbler and scarlet tanager medium NSSIs reinforce the similarities between the treatment and control areas that are laid out in the methods section. Canada warbler is closely associated with downed woody debris and scarlet tanager with a closed canopy. Both of these were present throughout the study area.

The consistently closed canopy across the treatment area compounds the lack of herbaceous diversity and vertical structure because not enough light gets through the canopy to stimulate early successional species. The presence of New York fern noted on treatment plots makes using any selective group cutting inadvisable because the New York fern will thrive in a canopy opening and crowd out other species.

The black-throated blue warbler nest site suitability suggested there were more saplings and a higher percent understory cover in the control plots. Vertical structure of the forest is important because small trees, saplings, shrubs, and herbaceous plants provide places for creatures to nest, seek cover, and find food. In this way, vertical structure adds physical diversity to the forested landscape. This finding builds on the lack of biodiversity in the herbaceous layer of the treatment plots noted in the black bear HSI. The combination of this lack of physical diversity and biodiversity may precede a simplified forest structure.

These findings were specific to the Bolton property. The land-use history, including historical logging on the Bolton Backcountry has left a fairly even-aged forest everywhere on the parcel. This means that there are many large trees creating a full canopy with little understory. Further study should be done on the long-term effects of glading on forest structure, diversity, and regeneration. "Use of sampling design in which the proportion of random plots in each forest type represented the proportion of that forest type on the property would help elucidate the effects of glading in different forest cover types, which would help with the next iteration of management plans. It would be helpful to compare effects between forest cover types so that management can be better targeted.

Recommendations

Forest Management

The focus of this study was on the effects of backcountry skiing on the site-specific wildlife habitat suitability for bear, black-throated blue warbler, scarlet tanager, and Canada warbler. The management strategies were developed with the focal species needs in mind.

Management Concern 1:

Glade development and maintenance simplifies forest structure:
(1) Loss of vertical forest structure
(2) Presence of ferns in the understory
(3) Loss of diversity in the herbaceous layer

Glading likely produces these results because of yearly maintenance over an extended time scale.

Management Recommendation:

The results of this ecological assessment indiate that Bolton Backcountry should not expand backcountry ski trails or glades; trail density on the parcel is already high. The current trail system needs a lot of maintenance, so spending time and money on that will be better than creating new glades for the long-term ecological health of the parcel. Bolton Backcountry is designated a Backcountry Skiing Management zone, which seems like a good precedent to set. Since the full effects of backcountry skiing are not yet well understood, designating specific areas as management zones will help the users self-regulate and the state focus limited resources where they can do the most good.

Management Concern 2:

Disturbance of black bear during hibernation by backcountry skiers.

Management Recommendation:

Bolton Backcountry is full of talus slopes, craggy cliffs, and downed woody debris. These are all ideal places for black bear to den. They are also usually close to ski trails. Black bears that are disturbed during winter by humans or dogs are likely to abandon their dens and not return to hibernation. If female bears are disturbed, they will abandon their dens and the cubs in them (Goodrich and Berger 1994). This disturbance can also adversely affect an individual's physical condition.

I recommend that the area be surveyed to determine if bears are denning on the Bolton Backcountry property. If it is found that they are, an off-limits management area should be established and a program of skier education and outreach be undertaken, similar to the Peregrine Falcon approach in the Smugglers Notch portion of Mt Mansfield State Forest.

Monitoring

Data collection and photo-point monitoring of existing glades

Bolton Backcountry offers an exciting opportunity to begin long-term monitoring of glades. It should be started by 2016, so as not to lose the PVC piping that marks the center points of the plots. Long-term monitoring may help shed light on some of the regeneration questions arising as well as wildlife use pattern changes. Monitoring should occur at a 5-year interval. Photos and data should be collected at each treatment site. Current treatment plots on the Bolton Valley Parcel can be stratified into northern hardwood, mixed, and spruce-fir plots in the Northern Green Mountain Biophysical region. By stratifying the data, you can then find a plot match with the Mt. Mansfield State Forest plot reference data set. Data collected on these plots can then be compared to state plots with long-term data sets. Accessing the state-level data will make the data comparison more robust.

Photo-point monitoring will give insight into glade forest structure and regeneration over time. The Adirondack Hiking Club (2009) uses photo-point monitoring in the Adirondack High Peaks. The results have been used to show the effectiveness and value of their mountain stewards program. The results of the Bolton Backcountry photo-point monitoring can be used to inform foresters and other land managers about long-term changes, which will influence future management plan actions.

In 2014, photos were taken at Bolton Backcountry from each plot center facing N, S, E, and W. A PVC pipe marks the center of each plot. Using GPS coordinates and the PVC center-point, consistent photos can be taken every year.

At each plot:
Navigate to plot center using given GPS coordinates and plot center PVC pipe
Set up a tripod set at 5' 6"
Take pictures facing N, S, E, and W from plot center

To allow for best matches to the original photos a series of photos should be taken at each cardinal direction. These can then be visually matched to the original photos using foreground and background features such as distinct trees and rocks. as reference points.

Forest

The methods to collect vegetation data used for this project are straightforward and described in Appendix A. Having two interns work on the data collection would greatly speed up the process. They would likely be able to do a plot in an hour or less. Data entry should mirror other data collected by the state, so talking to the Forest Health Specialist at the State of Vermont will be important.

Wildlife

Habitat suitability indices can be recalculated with this new vegetation data to see if the indices change over time. Setting up wildlife cameras on at least one plot during data re-collection would be helpful for seeing what is actually passing through the glades.

Education and Outreach:

The Bolton Valley Parcel offers a great opportunity to engage the backcountry skier community in land stewardship and offer a place to offer standardized trail maintenance and cutting techniques.

For years the Bolton Backcountry trails have been maintained by the Old Goats and now, the Friends of Bolton Valley. Expanding this trail maintenance community would be advantageous to the state by mitigating impacts of the trails. It would also establish a baseline for trail layout, cutting, and maintenance for the backcountry skiing community.

Bolton Valley Nordic and Backcountry Ski Trails Education Incubator

Phase 1: Fall 2015

Trail Maintenance 101 *(1-day)*
Partners: Friends of Bolton Valley, Catamount Trail Association, Green Mountain Club

The Bolton Backcountry has 100 km of trails, 15 of which are groomed. Since ski trails tend to follow the fall line, the trails need a lot of water drainage maintenance all over the property, which likely contributes to soil erosion.

The volunteer maintenance of these trails can be standardized by the professional guidance from the Green Mountain Club and Catamount Trail Association. The focus should be on drainage and proper clipping.

I suggest having the GMC or CTA work with the Friends of Bolton Valley to host a Trail Maintenance 101 workshop during their fall sessions of trail maintenance.
Long-term I suggest the state establish a small tool cache for the parcel itself.

Audience:
Friends of Bolton Valley

Vermont Backcountry Alliance
General Public

Incentivization:
Currently the Friends of Bolton Valley do trail maintenance in the fall and they have a hand shake agreement with Bolton Valley LLC that links days spent doing maintenance with free day passes. This agreement could be solidified to continue the flow of volunteer help used to maintain an extensive trail network on state land.

Phase 2: Fall 2016

***Glade Planning and Layout 101**- (2-day weekend workshop)*
Partners: Catamount Trail Association, Vermont Backcountry Alliance, United States Forest Service - Rochester, Mad River Glen

Audience - Backcountry skiers who ski on Bolton Backcountry and throughout Vermont.

Day 1 - Glade Planning and Layout

- Discuss the ecological effects of glading
  - Walk through large, old glades such as A1A and note simplification of forest
  - Walk to plot point 1 - new glade - discuss the problems with the cut
    - i.e. too steep, no vegetative cover

- Talk about appropriate ways to choose terrain and layout glades
  - 3 principles of good trail layout (Appendix E)
  - Look at maps or a proposed project to facilitate a discussion
  - Walk a pre-scouted new line on the property with the group talking about the key components of a backcountry trail

Day 2 - How to Properly Cut a Glade

Focus on the importance of hand cutting, no chainsaws, and that you should cut small, ski for a season, then go back, and make adjustments.

Conclusion

Bolton Backcountry offers an opportunity to understand the ecological effects of backcountry skiing. There are trails present on the property that have been glades for forty years and some that were just cut five years ago. The older glades are wide and exemplify the resultant simplified forest structure more acutely than the newer, narrower glades. The trend of glades to grow from narrowly trimmed trails to wide expanses of cleared understory is important to think about as more trails are cut across the state. What will all those newly cut trails look like in forty years?

Another interesting aspect of backcountry skiing is how many popular areas are associated with the alpine ski resort. All the major ski resorts such as Killington, Stowe Mountain, and Jay Peak have backcountry ski trails off the backsides of the mountains. This means that the highest peaks in Vermont are heavily impacted by human use. On one side, there is the traditional alpine ski resort development, while on the other there are trails cutting through the forest. This is of great concern to wildlife populations because it means that a larger portion of their habitat is fragmented. For instance, moose might have been displaced from the spruce/fir habitat on the ski resort side and now reside on the backside of the mountain. The presence of trails on the backside of the mountain means that the moose are under stress from the unpredictable presence of backcountry skiers. Where can the moose move to now? And how does the stress of dislocation and disturbance interact with other potential stressors, such as high winter tick loads?

Bolton Backcountry can be an anchor for education and outreach about these wildlife and forest effects for the backcountry skier community. The state should continue to assimilate information on the effects of backcountry skiing on wildlife and wildlife habitat suitability. Further inventorying, research, and monitoring will facilitate a suite of best management practices that ensure the continued use and future health of the northern forest.

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Appendix A

FIA Methods

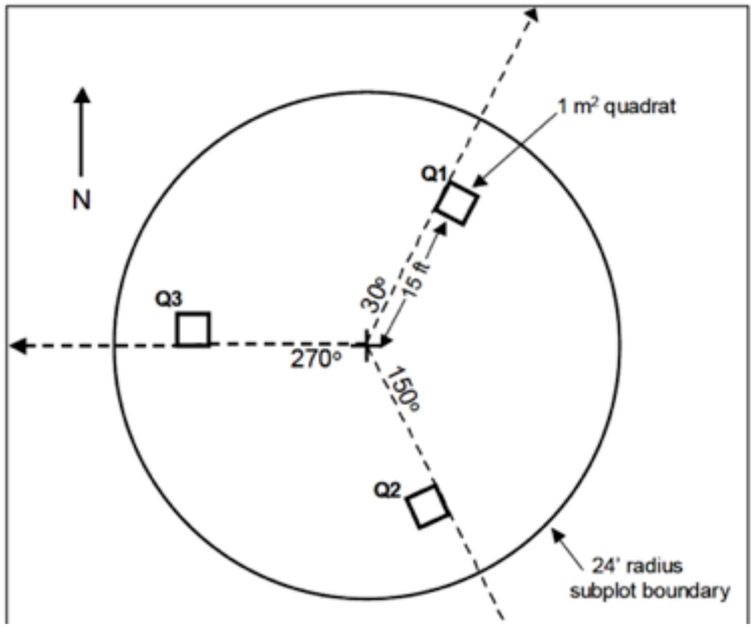


Figure 1. Plot used for data collection. Tree data and percent cover data were collected at plot level, sapling/seedling data at micro plot, vegetation data and percent cover at quadrats, and woody debris and soil along the transects.

Plot:
At each site I collected data in the same order - plot, micro plot, transect, quadrat. At the plot level I used a 24 ft piece of p-cord starting at the N azimuth and walking. I recorded species, dbh, and height of all standing trees >4.5 in. I used a hand held densiometer to estimate canopy cover. Canopy measurements and a picture were taken from plot center facing North, East, South, and West. I used ocular observation to determine percent cover at the plot level (Daubenmire 1959). Four height classes of cover were used: 0-2 ft, >2-6 ft, >6-16 ft., and >16 ft. Percent cover fell into seven categories: 0, 2-5, 6-25, 26-50, 51-75, 76-95, 96-100. For data analysis, these categories were simplified to 0%, 5%, 10%, 38%, 63%, 86%, and 97% (Daubenmire 1959).

Micro plot:
I collected the regeneration data in a 6.8 ft radius micro plot located 90 degrees and 12 ft from the plot center. I identified and measured the dbh of standing trees <4.5-1". Standing trees <1" and seedlings were identified and counted. Seedlings were only counted up to 20.

Transects:
I collected downed woody debris (DWD), fine woody debris (FWD), soil duff and litter layer depths on transects. The transects were set up at 30, 150, and 270 degrees and ran from

plot center to plot edge. A 24 ft piece of p-cord was used to demarcate transects. I walked from plot center out to record DWD crossing the transect. If DWD crossed the transect, I recorded tree species, dbh, and decay class. I walked along the transect again to count FWD that crossed the transect recording it is as small, medium, or large. Soil pH was taken at the end of the 270 degree transect. I collected soil pH measurements at the end of the 270-degree transect.

Quadrat:
I used a one meter squared quadrat made of PVC to collect herbaceous and shrub layer data on each transect, 15 feet from plot center. It was placed on the right side of the transect with the bottom left corner touching the p-cord. I made a species list of all vegetation in the quadrat. I then repeated the ocular observation technique used at the plot level to collect percent canopy cover data for each species per quadrat.

Appendix B

Habitat Suitability Index for American Black Bear

This study looked at the habitat suitability of bear based on food availability. I used the United States Fish and Wildlife Service Black Bear Habitat Suitability Index (HSI) model created in 1987, by wildlife biologists and other experts.

The model is structured around three major components: (1) variables estimating abundance and quality of seasonal foods within specific cover types; (2) variables that are used to estimate the cover type composition within an evaluation area; and (3) a human disturbance component.

I did not include the third component, human disturbance, in my project. The human use component that the HSI uses focuses on large-scale human disturbance such as roads and agriculture. The Bolton Backcountry is located in a 70,000-acre habitat block without roads and is not in close proximity to agriculture, which did not align with the HSI definition of human disturbance.

I focused on the habitat suitability based on food availability. The model description notes that habitat quality is chiefly a function of the quantity, quality, and distribution of food. There are three equations for bear, one for each season (spring, summer, and fall). Each equation comprises one or more variables.

Spring Food:
Spring food (SISP) availability is assessed by the percent of area in wetland cover types (Figure 1).

$$SISP=SIV1$$

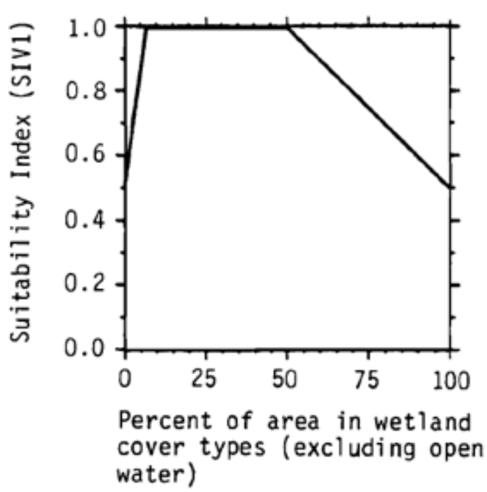


Figure 1. Spring food suitability index - USFW 1987

Summer food:
Summer food was analyzed using a combination of percent canopy cover of soft mast producing species (SIV2) and the number of soft mast producing species present at $\geq$1% canopy cover (SIV3). I chose soft mass species from the list in the HSI. The only overlapping species from the list and my data were raspberry, hobblebush, wild sarsaparilla, and bunchberry.

SIV2 and SIV3 are combined in the following equation to get the suitability index for summer food (SISU; Figure 3):

$$SISU=(SIV2 \times SIV3)^{1/2}$$

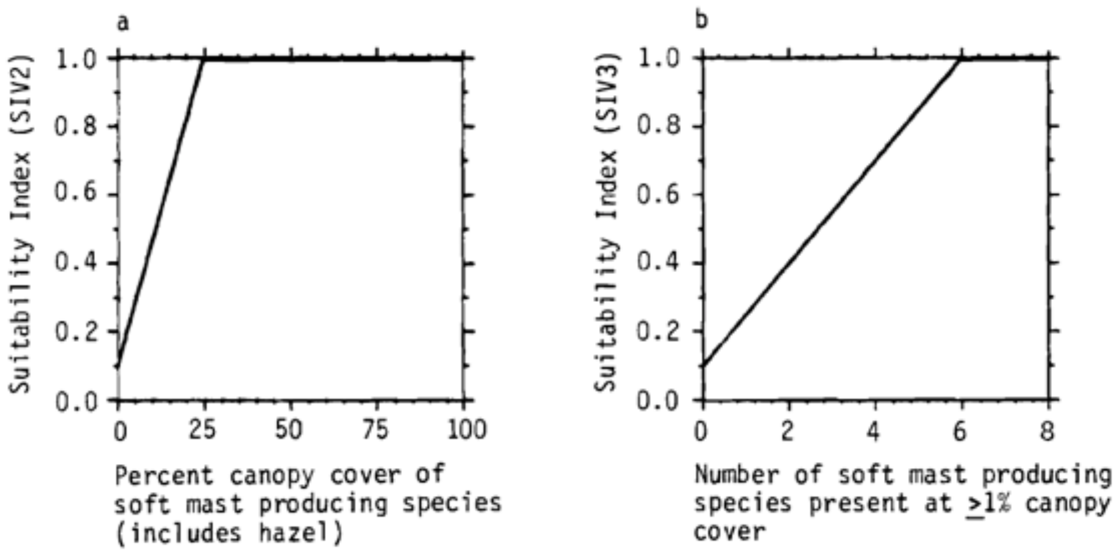


Figure 2. The two parts of the summer suitability index. They address both the percent cover of soft mast as well as the diversity of soft mast species.

The fall food component is also made up of two variables that look at the abundance and diversity of hard mast. Again, I used the list of hard mast in the HSI. The only hard mast present on site was American beech. The first variable, SIV4, examines the basal area of hard mast producing species $\geq$40 years in age. In the HSI they use the basal area of hard mast producing species $\geq$40 years in age. Since I did not age the trees, I chose to use trees that were $\geq$4 in. dbh. According to the USFS Silvics Manual, an American beech of 6 cm (~4 in.) dbh can be estimated to be 40 years old (2004). The second component, SIV5, looks at the number of hard mast producing species present with at least one mature tree per 0.4 ha (Figure 6) Again the 4 in dbh cut off was used for this variable.

SIFA=(SIV4 x SIV5)$^{1/2}$

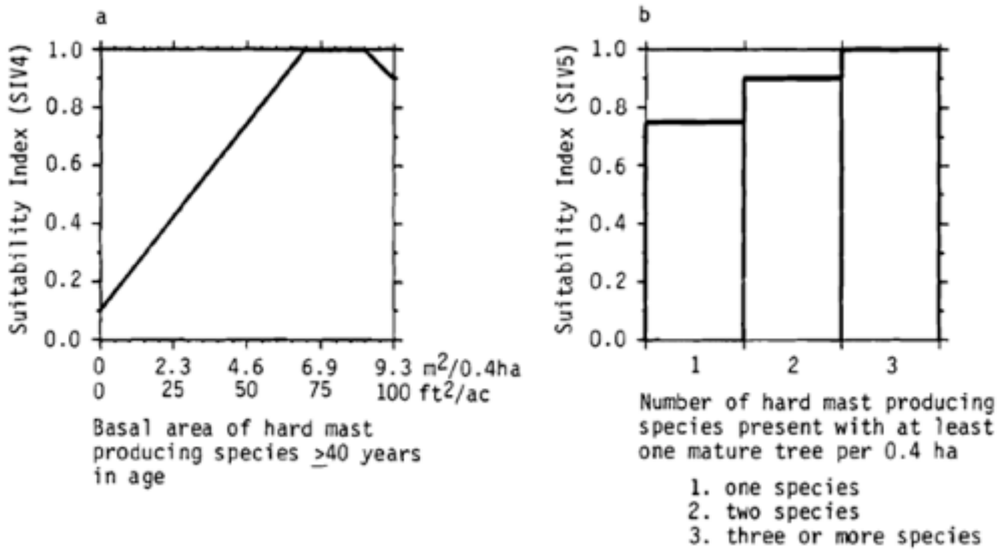


Figure 3. Fall food suitability. Looking at the basal area and diversity of hard mast producing species.

There were no wetlands in the study area, I entered 0 percent for all plots. The summer vegetation data came from the quadrats species ID and percent cover. The hard mast information came from the plot level tree data.

Appendix C.

Habitat Suitability - Birds

When calculating birds HSIs parameters for high, medium, and low were set at 0.8-1, 0.4-0.7, and 0-0.3 respectively. When using these categories to establish variable indices the mean of each range of numbers was used. Therefore in variable equations high equals 0.9, medium equals 0.55, and low equals 0.15.

For the final HSI tables the words high, medium, and low represent the originally established ranges.

All of the birds nesting site habitat suitability indices are based on nest site preferences established in primary literature.

These are all based on the assumption that due to the landscape context of the parcel and the general habitat requirements of the birds that these bird species would live in the area. A Vermont Audubon Rapid Bird Survey done in the spring on 2014 detected all three species.

Canada Warbler

Nesting site habitat suitability for Canada warbler was established through nest site preferences established in the primary literature. The three variables for nest site selection were downed woody debris (DWDI), percent fern cover (FCI), and percent understory cover (0-6 ft) (UCI). This model is based on the assumption that these are the top indicators of nest site preference. Canada warblers are also interested in dense leaf litter, which was uniform throughout the data collection sites. The actual terrain of the forest floor, which is challenging to quantify and is assumed uniform for this model, also influences them.

For this model it was assumed that the more coarse woody debris the better. Canada warblers have been none to nest in rather close quarters for instance 5 nests were found along 150 feet of stream in Vermont (Conway 2010). The high, medium, and low rankings were based on descriptions of DWD established by the Silviculture with Birds in Mind Program (SBM; Table 1). SBM defines DWD as downed logs and branches >4 inches in diameter. Due to the size of the research plots low:0-1 pieces, medium:2-3, and high:4+. The decomposition level of the tree was not taken into consideration. The number of pieces of DWD (V1) were tallied and multiplied by the weight (high, medium, low; V2) to get the DWDI (1).

$$DWDI = V1*V2$$

Habitat Quality	High	Medium	Low
What it looks like	Many downed trees, logs, and big branches in the area Quite a few tree tops and/or brush piles in the area Difficult or impossible to walk through in places	Scattered logs and big branches or groups where a few trees have fallen over together Some tree tops and/or brush piles in the area Occassionally need to step over or walk around logs or fallen trees	No - or very few - DWD in the area DWD that is present is small diameter and scattered Easy to walk through - like a park
Recommendation	Don't disturb downed logs, trees, and stumps High-density patches of DWD are sufficient; does not need to cover whole area	Don't disturb DWD Add to woody material when harvesting by leaving as much on site as possible	Add to woody material when harvesting Avoid whole-tree harvesting

Table 1. Habitat quality ranking associated with the presence of coarse woody debris according to the Silviculture with Birds in Mind program created by the Vermont Department of Forests, Parks, and Recreation in conjunction with Vermont Audubon.

Canada warblers also choose nesting sites density of cover provided by fern and understory brush. Fern percent cover weight (V4) was assessed as high (over 30%), medium (6-30%), and low (1-5%; Stewart et al. 2012). The species of fern is not important for preference. Therefore, the percent cover of all ferns from 0-6 ft was calculated (V3).

$$FCI = V3*V4$$

The final index is the understory cover index. This was calculated using the total percent cover from 0-6 feet (V5). The high, medium, and low criteria were based on descriptions of understory habitat quality established by SBM (V6; Table 2).

$$UCI = V5*V6$$

Habitat Quality	**High**	**Medium**	**Low**
What it looks like	Very dense cover throughout No invasive plants	Moderate cover throughout area Or scattered patches of dense cover No invasive plants or scattered ind	Little or no understory Or wide-spread invasive plants
Recommendations	Monitor for invasive plants regularly	Look for opportunities to release seedlings/saplings Remove invasive plants	Look for opportunities to stimulate understory Look for excessive deer browse sign Remove invasive plants

Table 2. Habitat Quality Index for the understory of a forest. Courtesy of Silviculture with Birds in Mind Program

Since each index already included a weighting metric, the final nesting site habitat suitability index is a simple mean finding equation.

$$NSSI = (DWDI+FCI+UCI)/3$$

Black-throated blue warbler

The three variables used to establish nest site habitat suitability were number of saplings <4.5-1" dbh, number of saplings <1" dbh, and percent understory cover from 0-6 ft. Zero to six feet was chosen because most nests are found at around 2 feet. Saplings were only counted if they were preferred nesting site species (Table 3). The assumptions of this model are that black-throated blue warbler will choose sites with preference species over sites without preference species present. Another assumption is that there are enough sites for every black-throated blue warbler and that black-throated blue warbler are not using poorer nest sites due to population density pressure. In addition, the data that was collected on micro plots is taken to be representative of the plot itself.

Preference	Species
High	Hobblebush
Medium	American beech
	Sugar maple
Low	Red spruce
	Balsam fir
	Mountain maple
	Striped maple

Table 3. These are the preferred nesting site species for black-throated blue warbler (Holmes 2005).

The index for saplings <4.5-1" dbh (SI) was calculated by counting the number of saplings per preferred species (V1) in micro plots and multiplying it by the weight of the species (V2).

$$SI = V1*V2$$

The index for small saplings <1" dbh (SSI) was calculated by counting the number of small saplings per preferred species (V3) per micro plot and multiplying it by the weight of the preferred species (V2).

$$SSI = V3*V2$$

The final index is the understory cover index. This was calculated using the total percent cover from 0-6 feet (V4). The high, medium, and low criteria were based on descriptions of understory habitat quality established by SBM (V5; Table 2).

$$UCI = V4*V5$$

Since each index already included a weighting metric, the final nesting site habitat suitability index is a simple mean finding equation.

$$NSSI = (SI+SSI+UCI)/3$$

Scarlet Tanager

The three variables used to establish scarlet tanager nest site suitability were percent canopy closure, trees larger than 8.8" dbh, and percent understory cover (0-6 ft). Scarlet tanagers prefer a closed canopy with trees larger than 8.8" dbh. A high percent understory cover is a negative effect on nest site habitat suitability because scarlet tanagers like to be able to have a clear view to the ground.

The canopy closure variable (CVI) was calculated using canopy cover data from the field (V1). This was multiplied by a weight factor defined by SBM (Table 4). Since a high percent canopy cover is favored the high metric is associated with closed ≥ 80 percent (V2).

$$CVI = V1*V2$$

Condition	**Closed ≥80%**	**Intermediate 30-80%**	**Open ≤30%**
What it looks like	No sky is visible through the trees	Canopy openings may be patchy or evenly dispersed	Canopy is generally lacking with only a few scattered trees >30 ft
Associated birds	Scarlet Tanager Blue-headed vireo	Black-throated blue warbler Veery	American Woodcock White-throated sparrow

Table 4. Canopy closure conditions as defined by FBP. Scarlet tanagers are associated with a closed canopy, which will demark closed as high quality, intermediate as medium, and open as low quality nest site habitat.

When there is enough canopy closure, scarlet tanager seek out preferred trees of 8.8" dbh or greater to establish a nest (Table 5). The number of preferred species trees larger than 8.8" dbh were counted (V3) and multiplied by their appropriate weigh metric (V4).

$$PTI = V3*V4$$

Preference	**Species**
High	Maple sp. American Beech
Low	Red Spruce

Table 5. These are the preferred nesting site tree species for the scarlet tanager.

Since scarlet tanagers prefer uninterrupted site to ground the percent understory cover can negatively influence site suitability. For scarlet tanager, the description of the understory is the same as in Table 2, but the value associated with is the inverse. Therefore, a high quality ranking in the table actually represents low quality for scarlet tanagers. The percent cover of understory from (0-6) ft was calculated (V5) and multiplied by the appropriate weighted metric (V6).

$$UCI = V5*V6$$

Since each index already included a weighting metric the final nesting site habitat suitability index is a simple mean finding equation.

$$NSSI = (CVI+PTI+UCI)/3$$

Appendix D. Woody and Herbaceous Species List

Woody and Herbaceous Species	
Latin name	**Common Name**
Abies balsamea L.	Balsam fir
Acer pensylvanicum L.	Moose maple
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Acer spicatum Lam.	Mountain maple
Aralia nudicaulis L.	Wild sarsaparilla
Arisaema triphyllum L.	Jack in the pulpit
Aster sp. L.	Aster
Athyrium filix-femina L.	Lady fern
Betula alleghaniensis Britt.	Yellow birch
Betula papyrifera Marsh.	Paper birch
Carex intumescens Rudge	Bladder sedge
Clintonia borealis Raf.	Blue-beaded lily
Coptis trifolia L.	Goldenthread
Cornus canadensis L.	Canadian bunchberry
Dennstaedtia punctilobula Michx	Hay-scented fern
Dryopteris campyloptera Clarkson	Mountain wood fern
Dryopteris intermedia Muhl. ex Willd.	Evergreen wood fern
Dryopteris marginalis L.	Marginal wood fern
Erythronium americanum L.	Trout lily
Fagus grandifolia Ehrh.	American beech
Gaultheria procumbens L.	American wintergreen
Helianthus sp. L.	Sunflower
Huperzia lucidula Michx.	Shining clubmoss
Maianthemum canadense Desf.	Canada mayflower
Medeola virginiana L.	Indian cucumber-root
Monotropa uniflora L.	Indian pipe
Oxalis montana Raf.	Mountain woodsorrel
Picea rubens Sarg.	Red spruce
Polygonatum pubescens Willd.	Hairy solomon's seal
Polypodium appalcahianum Haufler & Windham	Rock polypody
Prunus pensylvanica L.f.	Pin cherry
Rubus sp. L.	Bramble
Sorbus americana Marsh.	Mountain ash
Streptopus lanceolatus Reveal.	Rose-bellwort
Thelypteris noveboracensis L.	New York fern
Tiarella cordifolia L.	Foamflower
Trillium erectum L.	Stinking Benjamin
Uvularia sessilifolia L.	Sessile-leaf bellwort
Veratrum viride Ait.	False hellebore
Viburnum lantanoides Michx.	Hobblebush
Viola sp. L.	Violet

Appendix E. Effective Glade Planning Framework

Jon Appleton of Mad River Glen Ski Resort created a forestry management plan in the early 2000s as an attempt to formalize glade cutting with a focus on maintaining forest health and water quality. The United States Forest Service consulted Mad Rive Glen as well about their management techniques, drawing on vegetation islands (mentioned later) to create a plan for glade development in the Rochester Ranger District of Vermont.

Mad River Glen focuses on keeping people happy and on trail as well as strategies to best protect forest health.

The three key rules for laying out trail are:
1) The lines are fun, so people will not leave the trail
(2) Cutting down trees does not create better terrain and might lessen snow held by the total line
(3) Do not cut in spruce/fir forest (starting around 2,200 to 2,500 ft)

When creating new trails, it is important to think about the type of terrain current glade selection covers. Steep terrain is good for powder and challenge, whereas rolling terrain is fun for all abilities. Once the audience is established, trail planning can commence.

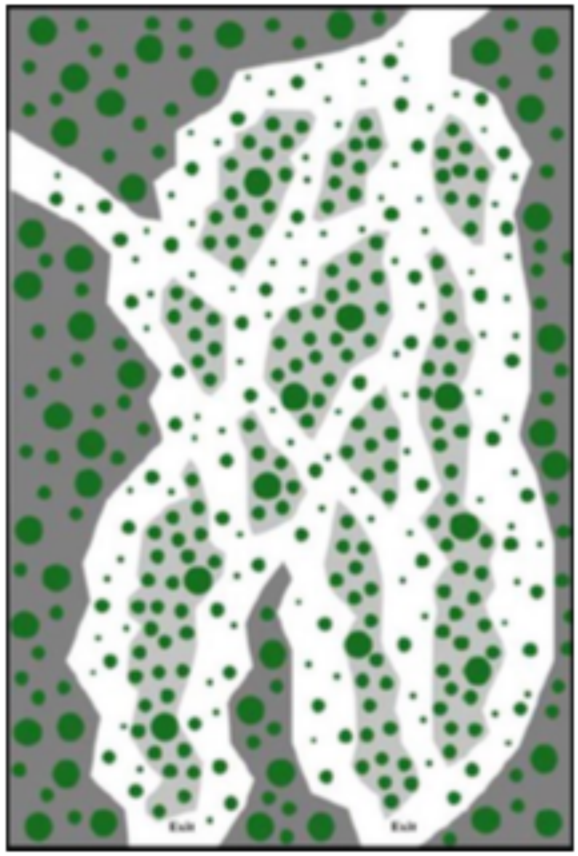
Planning should focus on:
Northerly exposures because they hold snow the longest; Rolling terrain because it is fun; Northern hardwood forests; Stable soil; Fall lines

Unlike hiking trails, ski trails run down the fall line. Potential routes should be scouted during the non-snow months, preferably during "stick season" when the topography of the land is more visible than during mid-summer. Flagging a desired route and visiting it during several seasons allows for revisioning and a full understanding of the issues that may arise from its location. Following the line in winter will give you an idea of what it would be like to ski it.

Glade management should include a focus on retaining structural diversity of the forest. One way to do this involves using vegetation islands. Basic triangular islands have been used at Mad River Glen for about ten years, with anecdotal success. The Green Mountain National Forest's current proposal builds on this idea and includes specific uneven-aged silvicultural practices to promote a structurally diverse forest condition.

Vegetation Islands:
Islands range in size; Include a diversity of species and ages; Include both vertical and horizontal woody structure

Continued contact with the Green Mountain National Forest to find out how the vegetation islands work over time will lend more information for future revision of glade management.



Example of tree-skiing zone layout utilizing a braided line design with retained vegetation islands, courtesy of Green Mountain National Forest.

Appendix F. Treatment Plot Center Coordinates (Degrees-Minutes-Seconds)

Plot	West	North
0	72-50-44.986	44-25-36.732
1	72-51-14.213	44-25-33.3
2	72-50-41.73	44-25-39.995
3	72-51-4.939	44-25-42.843
4	72-51-13.156	44-25-36.646
5	72-50-49.62	44-25-31.575
6	72-50-37.678	44-25-50.842
7	72-50-44.632	44-25-37.634
8	72-50-46.565	44-25-30.684
9	72-50-42.128	44-25-38.927
10	72-50-43.74	44-25-38.536
11	72-50-3.056	44-25-44.301
12	75-51-22.189	44-25-46.776
13	72-50-47.638	44-25-30.167
14	72-51-6.171	44-25-38.725