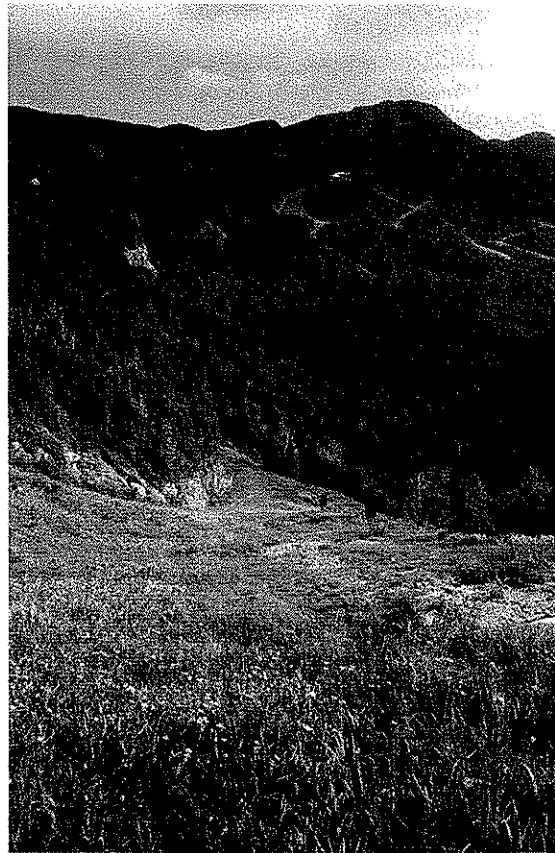


# **THE TERRITORIAL RESPONSES OF SIX SONGBIRDS TO SKI TRAILS AT SMUGGLERS NOTCH RESORT AND STOWE MOUNTAIN RESORT, VERMONT**

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Committee of Evaluators:

Allan Strong, School of Natural Resources, University of Vermont  
Rick Paradis, Environmental Program, University of Vermont  
Ian Worley, Environmental Program, University of Vermont

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Amanda Holmgren

## Abstract

One of the primary effects of ski area development on wildlife is through habitat fragmentation. When forests are cleared to make ski trails, the territorial behavior of some bird species may be affected. Some birds may select their territories with boundaries defined by the ski trails. In my study, I tested the territorial responses of six songbird species to conspecific playbacks of simulated intruders across ski trails of various widths. I conducted my research on the ski trails of Smugglers' Notch Resort and Stowe Mountain Resort. I also tested their responses within unfragmented forest to serve as a control. It was determined that ski trails have a varying effect on different species. The responses of the Blackpoll Warbler and Yellow-rumped Warbler to the playbacks were particularly affected by increasing trail widths. The Dark-eyed Junco showed very little change ( $P > 0.05$ ) in response to increasing widths. Trail width had no effect ( $P > 0.05$ ) on the time it took the birds to respond to the playbacks. It may be concluded that gaps created by ski trails serve as territory boundaries for several species of songbirds.

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## Introduction

Mountains in Vermont provide habitat for numerous avian species, many of which have somewhat specialized habitat requirements. Species composition changes with increasing elevation. Mountainous coniferous forest, dominated by red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*), begins at an elevation of about 3000 feet (915 meters) and extends to about 4000 feet (1219 m). Below 3000 feet, it begins to blend with mixed hardwood forest (Johnson 1998). There are many species that nest exclusively within mountainous coniferous forests, which is why fragmentation in such areas is particularly important to assess.

Many of the mountains in Vermont also contain ski areas, which can lead to drastic alterations in the landscape. The creation of ski trails is the epitome of fragmentation with gaps running down the mountains, slicing the remaining forest into fragments. While much of the original habitat still remains, the composition of the habitat changes because of the fragmentation of once intact forest. The species that are most threatened by forest fragmentation are those that have such specialized habitat requirements that they are unwilling to cross gaps in otherwise intact forest (Strong *et al.* 2002).

Many different aspects of ski areas can negatively impact certain species of wildlife. These aspects range from chemical deposits on the ski slopes to soil erosion from tree and vegetation removal (Tsuyazaki 1994) to the construction of ski lifts to water drainage for snowmaking purposes (Molles and Gosz 1980), affecting wildlife in different ways. The fragmentation and alteration of habitat through deforestation is one of the most common and significant impacts of ski area development on terrestrial wildlife. Habitat fragmentation results from the construction of ski area buildings as well as the ski trails and lifts.

It is thought that Neotropical migratory songbirds are particularly vulnerable to habitat fragmentation of all kinds (Robbins 1989). Forest fragmentation has largely been attributed to the decline of many populations of songbirds (Robinson *et al.* 1995). Many studies have found that the nesting, breeding, and other behaviors of birds are affected by fragmentation. Ovenbirds (*Seiurus aurocapillus*) were found to select nests that were more than 250 meters from the forest edge, which makes smaller forest fragments completely unsuitable as breeding habitat (Burke and Nol 1998).

An increase in fragmentation and edge leads to a reduction in the reproduction rate of some forest bird species, primarily through elevated nest predation and parasitism (Robinson *et al.* 1995). Parasitism exhibited by species such as the Brown-headed Cowbird (*Molothrus ater*) that actually benefit from fragmented areas exacerbates the decline of species that are already negatively affected by fragmentation. The species composition of the area is drastically altered with the reduction of habitat specialists and the increase in habitat generalists such as the Brown-headed Cowbird. There are also mammalian predators such as red squirrels (*Tamiasciurus hudsonicus*) in high elevations that pose a threat to nesting songbirds (Rosenberg *et al.* 1990). Additionally, the low food availability, lack of potential nesting sites, and microclimate in the areas closer to the edge decrease the quality of forest fragments (Burke and Nol 1998).

## Methods

### Study Area

My study was conducted on the ski trails and toll road of Stowe Mountain Resort in Stowe, Vermont (Appendix A), on the ski trails of Smugglers' Notch Resort in Jeffersonville, Vermont (Appendix B), and on the portions of the Long Trail indicated in Appendix C. Stowe Mountain Resort is located on Mt. Mansfield and Smugglers' Notch Resort is comprised of three peaks: Sterling Mountain, Madonna Mountain, and Morse Mountain. However, Morse Mountain, with a maximum elevation of 2250 feet (686 m) lies primarily below the spruce-fir line and was thus unsuitable as a study site. I focused on the parts of the ski trails that are within coniferous forests, dominated by red spruce and balsam fir. These areas begin to blend with northern hardwood forests at an elevation below approximately 3000 feet (915 m). The coniferous forests reach about 4000 feet (1220 m) in elevation on the higher mountains of Vermont, such as Mt. Mansfield, with a summit elevation of 4395 feet (1340 m) (Johnson 1998). The six birds that I studied nest in these forests, either exclusively or in addition to other habitat types. The ski trails of Stowe Mountain Resort and Smugglers' Notch Resort on which I conducted my study range from widths of 4.1 m to 38.2 m.

As a control, I used portions of the Long Trail, a hiking trail running the length of Vermont, where the gaps in forest cover were less than 1.5 m in width and had virtually no break in canopy cover. I focused on the parts of the Long Trail within one mile of the summits of Sterling Mountain and Madonna Mountain and of the forehead of Mount Mansfield (Appendix C). The forest cover on this part of the Long Trail is similar in terms of vegetation type (dominated by red spruce and balsam fir) to that of the intact forest within the ski areas.

### Study Species

I studied the following six passerine species: White-throated Sparrow (*Zonotrichia albicollis*), Dark-eyed Junco (*Junco hyemalis*), Swainson's Thrush (*Catharus ustulatus*), Magnolia Warbler (*Dendroica magnolia*), Blackpoll Warbler (*Dendroica striata*), and Yellow-rumped Warbler (*Dendroica coronata*). These six birds are all common nesting species in high elevation coniferous forests. I chose these species because they are all vocal, territorial, and abundant in the study areas. For example, Blackpoll Warblers are one of the most common warbler species, sometimes reaching a density of up to four pairs per hectare in breeding sites (Hunt and Eliason 1999). Swainson's Thrushes are most densely populated in the northeastern United States between the elevations of about 800 m to 1200 m (Noon 1981). I wanted to study birds that would provide enough data to make the study scientifically valid. Large sample sizes, offered by species with these characteristics, are an important means of testing for statistical significance.

These species also vary in their degree of habitat specialization, allowing for additional interspecific comparisons in their willingness to cross gaps. Many species cannot be classified simply as habitat generalists or specialists, but actually fall somewhere in between the spectrum. The selected species with the most generalized habitat requirements are the Dark-eyed Junco and White-throated Sparrow. These species are not as restricted to certain areas as forest specialists are. They are found at

higher and lower elevations and in both wooded and more open areas. The Yellow-rumped Warbler is more ecologically generalized than most other warblers, but it is still primarily confined to coniferous forest during the breeding season (Hunt and Flaspohler 1998). The Swainson's Thrush, Blackpoll Warbler, and Magnolia Warbler have more specialized habitat requirements than the White-throated Sparrow and Dark-eyed Junco. They are found more exclusively in coniferous forests during the breeding season (Evans Mack 2000, Hunt and Eliason 1999). Forest specialists are more confined to intact forested areas and are generally absent from edges and small forest patches (Brand and George 2001).

Wood-warblers, which include the Yellow-rumped warbler, Blackpoll Warbler, and Magnolia Warbler, are generally very territorial (Garrett and Dunning 2001), having territories that are well-defined spatially and not merely around the nesting sites. New world sparrows, which include the White-throated Sparrow and Dark-eyed Junco, are also territorial during the breeding season (Dunning 2001). Singing is an important part of the territory defense of songbirds, often becoming provoked when hearing an unfamiliar song (Gill 1995). Territorial singing serves as a signal to intruders that the territory is occupied by a male willing to defend that space and possibly its mate within that territory (Gill 1995). Birds are able to recognize the vocalizations of birds in neighboring territories. As long as the neighbors remain in their own territories, there will not be any conflict. However, if a singing neighbor is trespassing in another's territory, the male occupying that territory will act aggressively or attack the neighbor (Gill 1995). Thrushes are highly territorial during the breeding season as well, singing persistently as a means of driving away rival birds and for attracting females. Their songs convey one thing to rivals and another to potential mates. Thrushes are often aggressive in their attempts to force other birds away from their territories (Kricher 2001).

### Playback Experiments

Songbirds tend to be more active in the morning, which is the reason most research on these birds, including my research on Stowe Mountain Resort and Smugglers' Notch Resort, is conducted at that time of day. The use of bird songs to test territorial responses is effective because they often declare their territories by persistent singing (Gill 1995).

Playbacks of recorded bird vocalizations are often used to study a population's response to a particular scenario. For example, they can be used to lure birds into certain areas by simulating intruders, trying to evoke a response from the resident bird (Harris and Reed 2001). By simulating intruders, it can be determined whether or not the "intruder" is positioned within the other bird's territory because that bird will generally respond by approaching the intruder. My methods were modified from a study conducted by Rail *et al.* (1997) on testing territorial responses to forest fragmentation. My study took place between 4 June and 7 July 2002 between the hours of 05:00 and 10:00, when birds tend to be most responsive (Melemis and Falls 1982). I avoided mornings that were rainy, foggy, and windy. In these conditions, birds are less active and less likely to be singing. Also, the wind and poor visibility would lead to difficulty in discerning any singing or placement of a bird.

I spent five days on the ski trails and toll road of Stowe Mountain Resort and five days on the ski trails of Smugglers' Notch Resort. To get to my study sites, I drove up

the toll road of Stowe Mountain Resort to the Octagon Web Café (Appendix A), the maximum elevation of ski trails on Mt. Mansfield, or hiked up the Long Trail to the summit of Sterling Mountain and to Madonna Mountain (Appendix B-C). After arriving at these sites, I walked along the ski trails or toll road and listened for the songs of the White-throated Sparrow, Dark-eyed Junco, Swainson's Thrush, Magnolia Warbler, Blackpoll Warbler, and Yellow-rumped Warbler. When I heard one of these songs within about 20 m of the forest edge, I walked to the opposite side of the trail or road and played a recording of the song on a tape player at a volume similar to that of live birds for five minutes or until the bird crossed the trail. Each playback session was termed a "trial." I used six different loop tapes, enabling me to use a separate tape for each species without having to rewind after each trial. I recorded the time I started playing the recording and the time the bird crossed the trail. I considered a trail-crossing to be a response. If the bird did not respond after five minutes, the trial was discontinued and a "no response" was recorded. I then measured the width of the ski trail or road using a 50-m long tape measure. My research was completed when I had covered all of the ski trails above the spruce-fir line of the mountains.

I spent two days on a portion of the Long Trail on Mt. Mansfield, near Stowe Mountain Resort, and two days on a portion of the Long Trail around Smugglers' Notch Resort as my controls (Appendix C). As with the ski trails, I arrived at my control sites by driving up the toll road of Stowe Mountain Resort to the Octagon and by hiking up the Long Trail to the summit of Sterling Mountain and Madonna Mountain. I then walked along the Long Trail and listened for the songs of the same six species that were within an approximate 50-meter radius. I estimated the distance of the bird from where I stood to the nearest 5 m. I played the recording of that species' song for five minutes in the same way that I did along the ski trails or toll road. If the bird came to within 5 m of me, I considered that a response. I recorded the time I started playing the recording and the time it responded. Again, the playback was discontinued and a "no response" was recorded if the bird did not respond after five minutes.

#### Data Analysis

I used a linear regression analysis separately for each species and for all species combined in relating the times the birds took to cross the trails (response times) to the widths of the trails. I used the response time as the dependent variable and the trail width as the independent variable, only using the birds that actually responded and thus eliminating much of the data. By obtaining the  $r^2$  values, I could also determine the proportion of the variability that could be explained by the response times.

I used logistic regression as a predictor of how the width of the trail affects whether or not individual birds will respond by crossing the trail. Using response (dichotomous of yes or no) as a dependent variable and the width as an independent variable, I was able to measure whether the trail width affected each species' tendency to cross the trails. I performed this analysis on each of the species and for all of the species combined.

Using chi-square tests for each species, I evaluated whether the probability of response to a conspecific playback was random with respect to trail width, again testing each species individually and all species combined. I could determine if there was a difference in the probability that the birds crossed the trail from the expected or



randomized data. As opposed to the logistic regression analysis, trail widths were grouped into three categories: smallest to 10.0 m, 10.1 m to 20.0 m, 20.1 m to the largest. Expected values were calculated as  $n/6$ . The chi-square analysis in conjunction with the logistic regression analysis allowed for more definitive results that could be used to support one another.

For my control data set, I used a linear regression analysis to determine how the distance the bird was from me affected the response time. The response time was the dependent variable and the bird's distance from me was the independent variable. I separated the birds by species when doing the analysis and also did the same analysis when grouping all of the species together. Although I could not directly compare the actual distances of the birds from me to that of the trail width, I used the linear regression analysis, along with the logistic regression and chi-square analyses, to compare responses to playbacks at similar distances.

I also used logistic regression for my control data to see if the bird's distance from me was an effective determinant of the response (whether or not the bird approached to within 5 m of me). I used the response (yes or no) as a dependent variable and the bird's distance from me as an independent variable. The response variable was discrete, rather than continuous.

I used chi-square tests for each species and for all species combined in the control experiments as well. Similarly, I determined whether the response probability was random with respect to the bird's distance from me. Whereas the logistic analysis allows a visual assessment of the differences in response probability with increasing distances, the chi-square test allows a statistical comparison of response probabilities at varying distance categories. For all of the analyses, alpha was set at 0.05.

## Results

I conducted 220 experimental trials and 80 control trials, for a total of 300 trials. Out of the 220 experimental trials, 109 were conducted at Stowe Mountain Resort and 111 were conducted at Smugglers' Notch Resort (44 at Sterling Mountain and 67 at Madonna Mountain). Out of the 80 control trials, 39 were conducted on portions of the Long Trail within one mile of the forehead of Mt. Mansfield and 41 were conducted on portions of the Long Trail within one mile of the summits of Sterling Mountain or Madonna Mountain. When the birds heard the simulated song of a conspecific within the forest, they tended to respond by jumping from branch to branch above me while singing. The simulated song acted as a rival within their territory, about which they were agitated. The species that did respond generally acted very agitated upon their arrival, but some species more than others. Dark-eyed Juncos and White-throated Sparrows were particularly aggressive in their behaviors, usually calling and flying with quick motions from branch to branch around me in response to hearing the tape.

The linear and logistic regression and chi-square results are presented in Figures 1-3. The linear regression analysis (Fig. 2) for each of the six species and for all species combined demonstrated that trail width was not a significant determinant for response time (all  $P > 0.05$ ). The  $r^2$  values ranged from 0.00 to 0.063, indicating little predictive power in trail width as a variable. As was the case with the experimental data, none of the linear regression analyses for the six species within the control data were statistically

Species	Coefficient	Coefficient	t-stat	t-stat	$\chi^2$ (df)	$\chi^2$ (df)	$r^2$	$r^2$	p-value	p-value
	exp.	control	exp.	control	exp.	control	exp.	control	exp.	control
BLPW	-0.225	-0.393	-2.347	-1.688	9.825 (1)	9.020 (1)	0.170	0.544	0.019	0.091
YRWA	-0.157	-0.126	-2.572	-1.246	9.179 (1)	1.935 (1)	0.154	0.119	0.010	0.213
WTSP	-0.110	-0.432	-2.163	-1.847	5.100 (1)	7.290 (1)	0.123	0.486	0.031	0.065
SWTH	-0.029	-0.056	-0.632	-0.783	0.415 (1)	0.697 (1)	0.011	0.070	0.528	0.434
MAWA	-0.087	-0.030	-1.069	-0.212	1.221 (1)	0.045 (1)	0.043	0.007	0.285	0.832
DEJU	-0.109	NA	-1.127	NA	1.283 (1)	NA	0.062	NA	0.260	NA
all combined	-0.070	-0.091	-3.464	-2.735	13.045 (1)	8.916 (1)	0.044	0.132	0.001	0.006

Figure 1. Results of logistic regression analysis

Species	Coefficient	Coefficient	t-stat	t-stat	$r^2$	$r^2$	p-value	p-value
	exp.	control	exp.	control	exp.	control	exp.	control
BLPW	0.005	0.033	0.044	1.408	0.000	0.124	0.966	0.181
YRWA	-0.059	0.100	-1.123	1.388	0.059	0.129	0.275	0.188
WTSP	0.037	0.045	1.234	0.989	0.044	0.089	0.226	0.346
SWTH	-0.024	0.018	-0.817	0.392	0.063	0.025	0.433	0.709
MAWA	0.018	0.096	0.278	1.796	0.008	0.316	0.787	0.115
DEJU	-0.002	0.027	-0.059	1.770	0.000	0.343	0.953	0.127
all combined	-0.015	0.033	-0.868	2.150	0.006	0.065	0.387	0.035

Figure 2. Results of linear regression analysis

Species	$\chi^2$ (df)	$\chi^2$ (df)	p-value	p-value
	exp.	control	exp.	control
BLPW	8.125 (2)	12.419 (2)	0.017	0.002
YRWA	8.534 (2)	4.500 (2)	0.014	0.105
WTSP	2.147 (2)	0.577 (1)	0.342	0.445
SWTH	3.697 (2)	1.071 (2)	0.157	0.585
MAWA	1.193 (2)	0.741 (2)	0.551	0.690
DEJU	1.337 (2)	NA	0.512	NA
all combined	13.266 (2)	8.242 (2)	0.001	0.016

Figure 3. Results of chi-square analysis

**Key**

- BLPW: Blackpoll Warbler
- YRWA: Yellow-rumped Warbler
- WTSP: White-throated Sparrow
- SWTH: Swainson's Thrush
- MAWA: Magnolia Warbler
- DEJU: Dark-eyed Junco

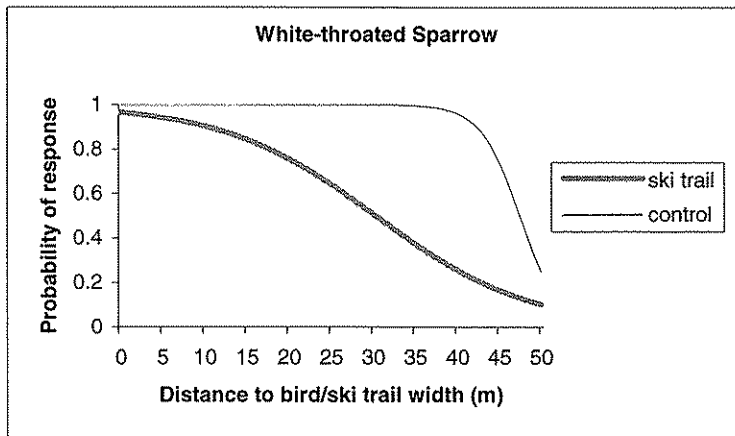
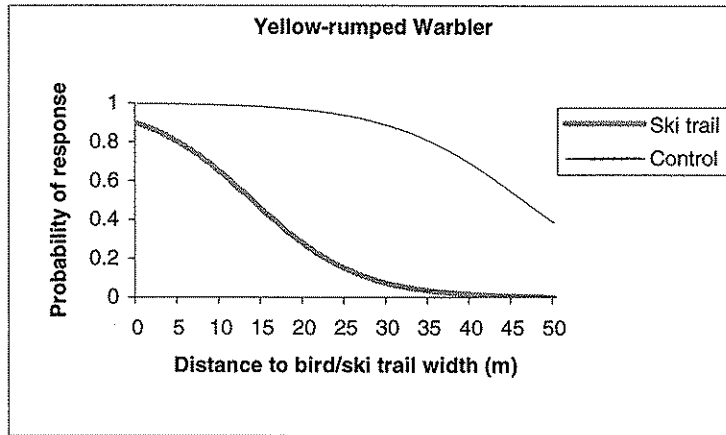
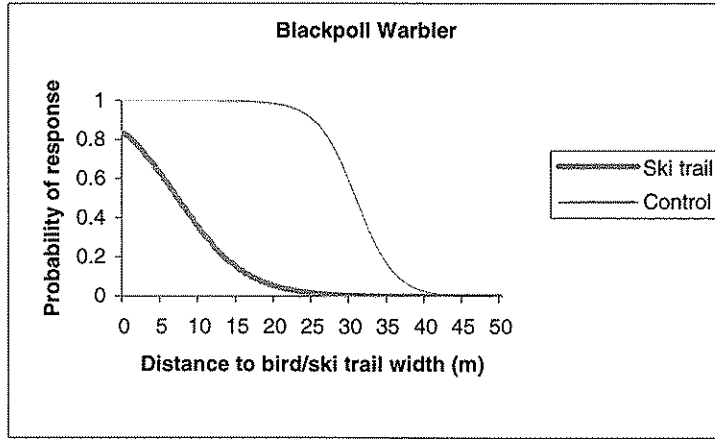


Figure 4a. Probability of birds' responses based on trail width/distance from me  
 For ski trails: BLPW ( $P=0.019$ ); YRWA ( $P=0.010$ ); WTSP ( $P=0.031$ )  
 For control: BLPW ( $P=0.091$ ); YRWA ( $P=0.213$ ); WTSP ( $P=0.065$ )

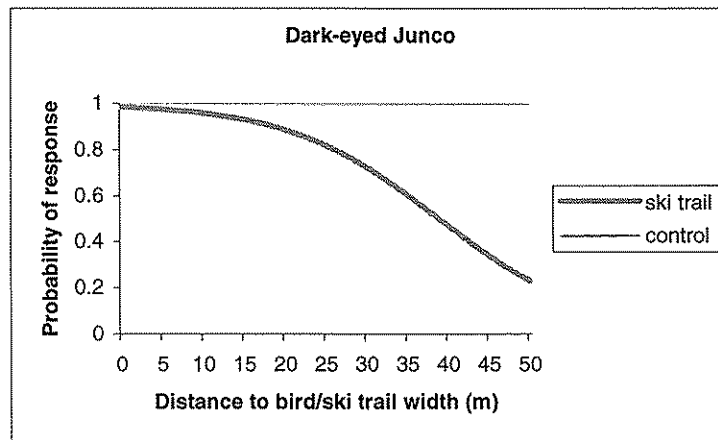
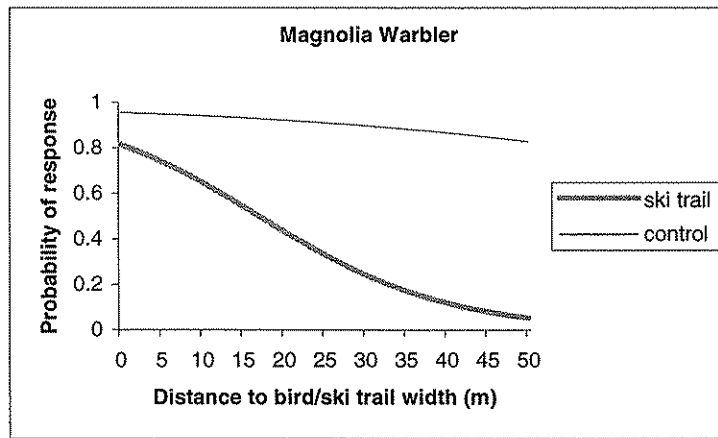
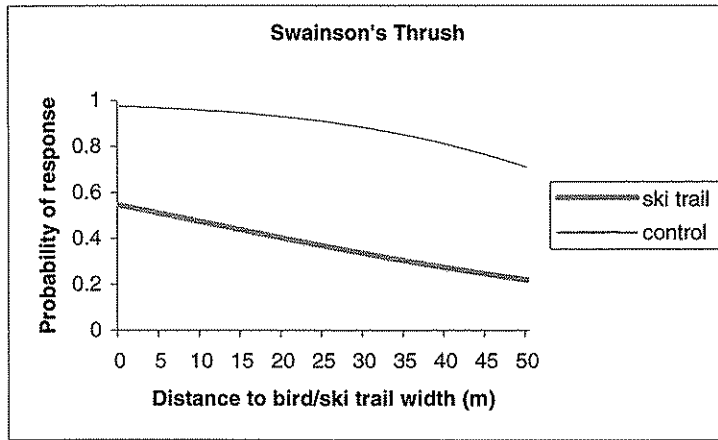


Figure 4b. Probability of birds' responses based on trail width/distance from me  
 For ski trails: SWTH ( $P=0.528$ ); MAWA ( $P=0.285$ ); DEJU ( $P=0.260$ )  
 For control: SWTH ( $P=0.434$ ); MAWA ( $P=0.832$ ); DEJU ( $P=NA$ )

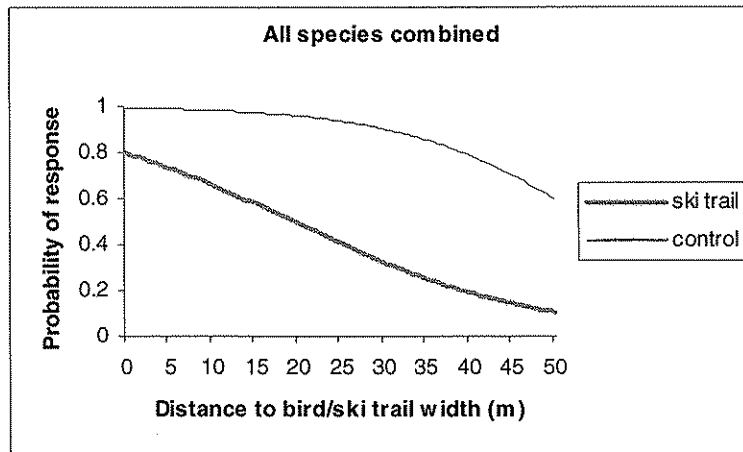


Figure 5. Probability of birds' responses based on trail width/distance from me for all species combined. For ski trails: ( $P=0.001$ ) For control: ( $P=0.006$ )

significant (all  $P>0.05$ ). The bird's distance from me could not be used as a measure of the time to respond. However, the analysis for all of the species combined was significant ( $P=0.035$ ).

The logistic regression results shown in Figures 1 and 4 indicate that for the Blackpoll Warbler, White-throated Sparrow, and Yellow-rumped Warbler, trail width had a significant negative effect on the probability of response to a conspecific playback ( $P<0.05$ ). The likelihood of these species responding to the playbacks decreased with increasing trail widths. Trail width was not a significant predictor of response probability ( $P>0.05$ ) for the Swainson's Thrush, Magnolia Warbler, and Dark-eyed Junco. The chi-square analysis produced similar results as the logistic regression analysis (Fig. 3). For all the species combined, the response probability was dependent on the width of the trail ( $P<0.05$ ). In terms of individual species, the Blackpoll Warbler and Yellow-rumped Warbler's responses could be attributed to the trail widths. The probability of Yellow-rumped Warblers crossing the trails declined from 75.0% within the category containing the shortest trail widths to 47.4% within the middle range of widths to 12.5% on the widest trails. The probability of Blackpoll Warblers crossing the trails declined from 50.0% in the shortest widths to 19.0% in the middle range to 0% on the widest trails. Despite the nonsignificant results for the four other species, the analyses still showed a gradual decline in the probability of positive responses (birds that did cross the trail) with increasing trail width for the Dark-eyed Junco, Magnolia Warbler, and White-throated Sparrow. However, in most cases, the decreases were so slight that the width could not be considered an effective determinant of response probabilities. For the Swainson's Thrush, the probability of the birds crossing the trails declined from 80.0% on the narrowest trails to 31.3% in the middle range. However, the probability increased to 42.9% on the widest trails, so trail width could not be used to determine the bird's response for this species. Because of small sample sizes for the Magnolia Warbler and Swainson's Thrush on wider trails, it is difficult to determine whether or not the

responses are based on trail width. There was a greater number of ski trails that were less than 20.0 m in width and a greater number of birds singing in these trails, so small sample sizes in wider trails were difficult to avoid. As with the logistic regression analysis, the results of the chi-square analysis for the control experiments were also significant ( $P=0.016$ )

In the control experiments, the overall proportion of trials to which the birds responded was very high (Fig. 6). Dark-eyed Juncos responded in 100% of the trials and the response rates in the other species varied from 90% for the Magnolia Warbler to 80% for both the Swainson's Thrush and White-throated Sparrow.

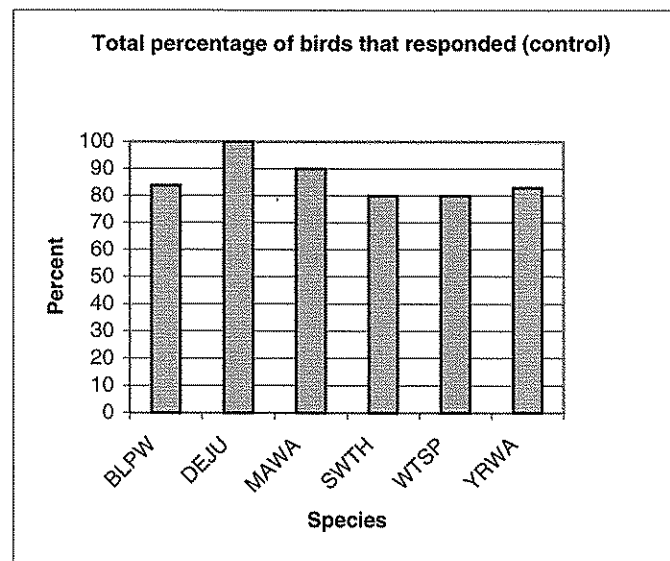


Figure 6. Total percentage of each species that responded to playbacks within unfragmented forest.

Since the proportion of birds that responded was so high in the control experiments, it is difficult to conclude whether or not the bird's distance from me was an effective determinant of whether or not the bird responded. Dark-eyed Juncos had a particularly high response rate, responding in 100% of the trials in the control experiments. Because of this, no statistics could be calculated for the logistic regression analysis.

For all of the species combined within the control experiments, the results were significant ( $P=0.006$ ), but less significant than those of the combined species of the experimental data ( $P=0.001$ ). The responses of the birds were affected by the distance of the bird from me, but they were not as affected as they were by trail widths. While there was a greater probability of birds responding when the bird was closer to me, there was a more gradual change in response probability as the distance increased (Fig. 5). For example, across ski trail widths of 10 m, 30 m, and 50 m, the probabilities of response were 0.66, 0.32, and 0.11, respectively, versus 0.98, 0.90, and 0.60 in the control group.

Distance in and of itself had little effect on the response probabilities of the Yellow-rumped Warbler and White-throated Sparrow (Fig. 4) as opposed to gaps, or ski trails, of comparable distances, which had a significant effect on these species' probabilities of response. Distance alone also did not have a significant effect on the response probabilities of the Magnolia Warbler, Swainson's Thrush, and Dark-eyed Junco ( $P>0.05$ ). The response probability of the Blackpoll Warbler was affected by distance ( $P<0.05$ ).

### Discussion

The six species varied in their responses. Dark-eyed Juncos crossed the ski trails the most frequently whereas Blackpoll Warblers were least likely to cross the ski trails. For all of the species combined, ski trails affected the response probability more than the distance alone within unfragmented forest affected response probability. Trail width had little effect on the response times for all the species combined, whereas the distance the bird was from me had a significant effect on the response time. However, none of the distances for each individual species affected the response times.

Because the logistic regression analysis only produced statistically significant results for the Blackpoll Warbler, Yellow-rumped Warbler, and White-throated Sparrow, it cannot be determined from this study whether or not the other species are affected. The chi-square analysis only produced significant results for the Blackpoll Warbler and Yellow-rumped Warbler. The chi-square analysis was done with the width categories, rather than the actual widths, as was the case for the logistic regression analysis. Therefore, it is difficult to say with confidence whether or not the White-throated Sparrow's response behavior was affected by the width of the trail. However, in noting its generalized nature, it would seem unlikely that wide trails would significantly affect them because they have been found to be more prevalent in forests with numerous openings (Falls and Kopachena 1994). They also have been known to nest along edges cleared for logging roads and camps (Clark *et al.* 1983).

There were definite trends within the responses of the other species as well, but not enough to be conclusive. Forest specialists are well known to be negatively affected by fragmentation (Rail *et al.* 1997). Crossing a ski trail would be more of a risk for forest specialists than for generalist species such as the Dark-eyed Junco, whose territory and nesting habitat may include open areas such as these. Generalists can tolerate a broader range of environmental conditions, whereas forest specialists such as the Blackpoll Warbler have very little room for variation within their habitat requirements and have great difficulty colonizing different habitat types (Bolen and Robinson 1999). Since Blackpoll Warblers are found almost exclusively in subalpine forests and spruce-fir forests during the breeding season throughout eastern North America (Morse 1979), the decreasing probability of trail crossing with increasing trail width could be expected.

The Yellow-rumped Warbler's crossing probability was also dependent on the width of the trail. While it may be considered more of a generalist species, most of its variation in habitat use occurs during the nonbreeding season, in which they are found across a range of habitat types from agricultural and residential areas to relatively open forest types such as mangroves and pine forests (Lynch 1989, Wunderle and Waide 1993). Its breeding habitat is composed primarily of mature coniferous and mixed

coniferous habitat (Sabo 1980, Franzreb 1978, Douglas *et al.* 1992) and is much less common in early successional forests (Parker *et al.* 1994).

From this study, it cannot be determined with statistical significance whether or not trail width affected the response of the Swainson's Thrush. As with the Blackpoll Warbler and Yellow-rumped Warbler, the Swainson's Thrush is most often found in coniferous forests during its breeding season, but it is also relatively abundant in some early successional habitats (Noon 1981). Therefore, ski trails might not have as much of an effect on their movement or behavior as they would have if they only nested within the forest interior.

It also cannot be determined whether or not trail width is a determinant for crossing probability for the Magnolia Warbler. It prefers to nest in dense, young conifers in either pure stands or mixed with hardwoods (Hall 1994), but has been found to be tolerant of both undisturbed forest and small-scale clearcuts in certain areas (Titterington *et al.* 1979). The general trend was a decrease in the response with increasing trail width, but it is difficult to determine whether or not the responses to the cleared trails within Smugglers' Notch Resort and Stowe Mountain Resort can be related to the response to the clearcuts in Titterington's study. Different bird species are not only affected by the clearing of the land, but also by the degree of development after the clearcutting has occurred (Titterington *et al.* 1979). It was often the case that wider ski trails in my study had little tree regeneration, where many of the narrower trails had visible regeneration throughout the trail. The presence or lack of vegetation within the ski trails might have affected the response probabilities of the birds. Future research might combine this study with that by Titterington *et al.* (1997), conducting playback experiments to determine responses to increasing trail width but also taking into account vegetation type.

The logistic regression analysis containing all species combined was a significant test for the control data. Distance played a role in the response of the bird. However, in the three species that individually tested, distance had no significant effect on their responses. The species did not vary greatly within the control data, the response rates ranging from 100% to 80%. The Blackpoll Warbler, the species least likely to cross large gaps, still had a response rate of 84% within the control experiments. Although the actual distances of the ski trails and within the control experiments cannot be considered equivalent, the trends can still be compared (Fig. 4). The reason for this is that the trail width was not necessarily the distance the bird was from me since I used all birds that were singing within 20 m of the forest edge. Within the fragmented ski areas, there is a significant decline in response probability as the trail width increases. While there is also an overall decline in response probability with increasing distance within the unfragmented forest, it is not as great as it is along the ski trails.

Within the control experiments on the Long Trail, the birds probably occupied continuous territories with adjacent boundaries, as the portions of the Long Trail on which I conducted my research contained gaps of less than 1.5 m. Since there were no discontinuities in the habitat structure, I was able to compare the birds' territorial responses in continuous forest to their responses to ski trails.

On the other hand, gaps in the forest were potential gaps in the territories or served as boundaries to the territories. If the ski trail did not act as a territory boundary, the birds that heard the playback would typically respond, as they generally did within the control experiments. From the results of this study, the ski trails were not territory



boundaries for the Dark-eyed Junco in particular. However, if ski trails served as territory boundaries, the birds would not cross the trails, even if provoked by a simulated conspecific intruder. Since in some cases, such as with the Blackpoll Warbler, wider trails affected the probability of their responses, these trails were a more significant boundary than the narrower trails.

The response times could not be determined by the trail width or the bird's distance from me. As with the logistic regression analysis, the actual distances between the control experiments and on the ski trails are not equivalent, but the trends in varying response times can still be compared with increasing distances. For all species combined, trail width was not a determinant of response time, but in the control experiments, distance could be used to determine response time. When there was no trail, as in the control experiments, the response time should only be related to the distance the bird was from me. The trail might add a psychological barrier, causing the birds to hesitate by checking for predators or figuring out whether or not they should cross after having arrived at the edge. The time the birds took to do these things was inconsistent, leading to a lack of relationship between trail width and response time.

Since birds tended to sing more frequently along the edges of narrower trails and there was a greater number of trails less than 20.0 m in width, sample sizes for all of the species were smaller for wider trails. Because of this, variations from any general trend on wider trails could have affected the results more than if experienced on the narrower trails. Because some species were not as prevalent or did not sing as much as others even in the narrower trails, the smaller sample sizes on wider trails for these species resulted in each response having a more significant impact. Further research might be conducted on the dependence of species density near edge on trail or gap width.

Several steps might be taken to eliminate much of the impact ski trails have on birds. Fewer wide trails near the top of the ski areas (above the spruce-fir line) might benefit such birds as the Blackpoll Warbler, having greater apparent territorial success in narrower trails or in unfragmented forest. Encouraging the regeneration of trees along the edges of trails in the higher sections of the ski trails might lessen the impact of the trails on the territorial responses of birds.

### Conclusion

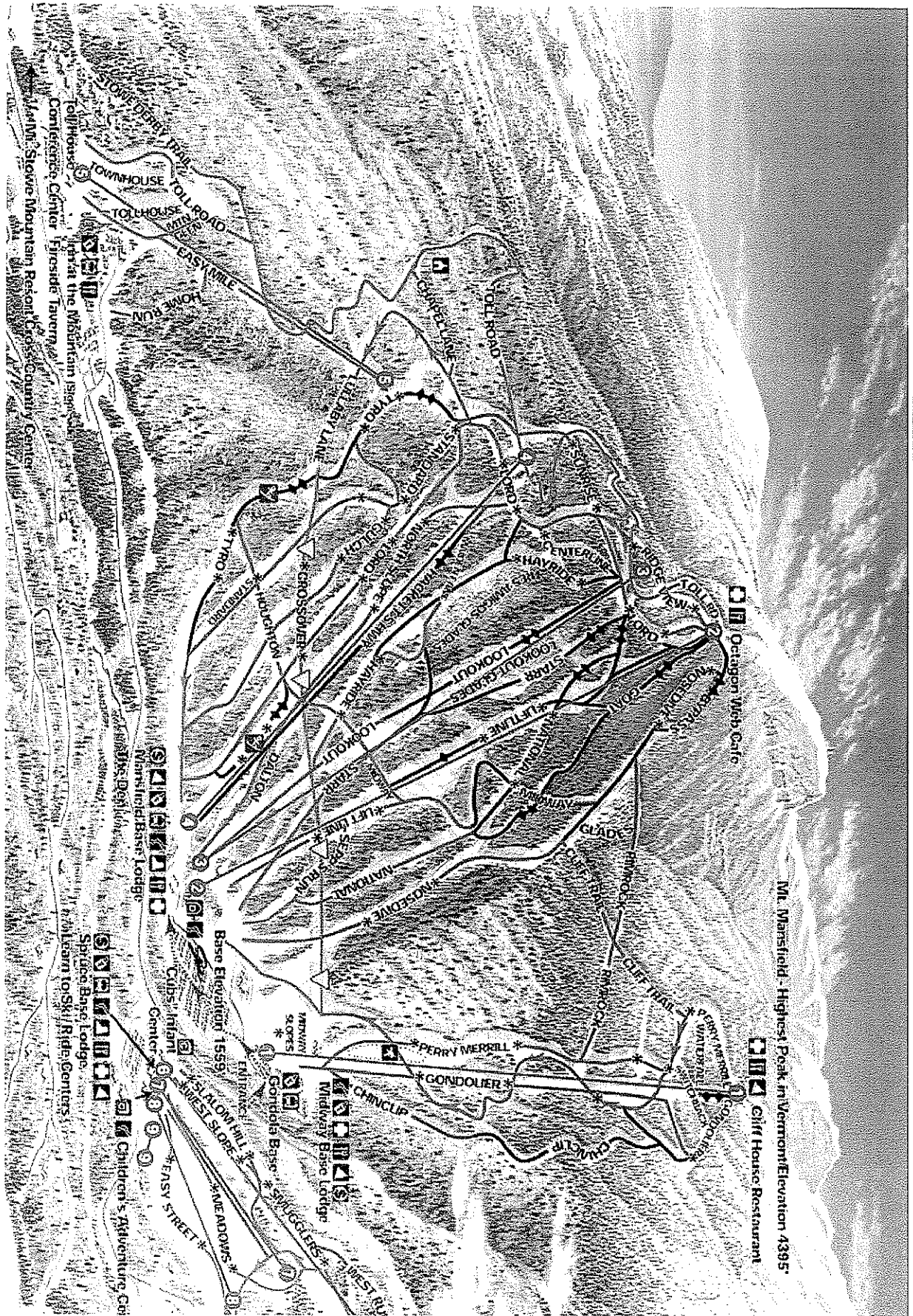
The presence of ski trails has a varying effect on different species. The responses of the Blackpoll Warbler and Yellow-rumped Warbler to simulated territorial intruders were particularly affected by increasing trail widths. On the other hand, the Dark-eyed Junco showed very little change in response with increasing widths. The responses of the Magnolia Warbler, Swainson's Thrush, and White-throated Sparrow were not as definitive, lying within the range of the other species. While there are similar trends for these species, it can only be said with certainty that the ski trails act as territory boundaries for the Blackpoll Warbler and Yellow-rumped Warbler.

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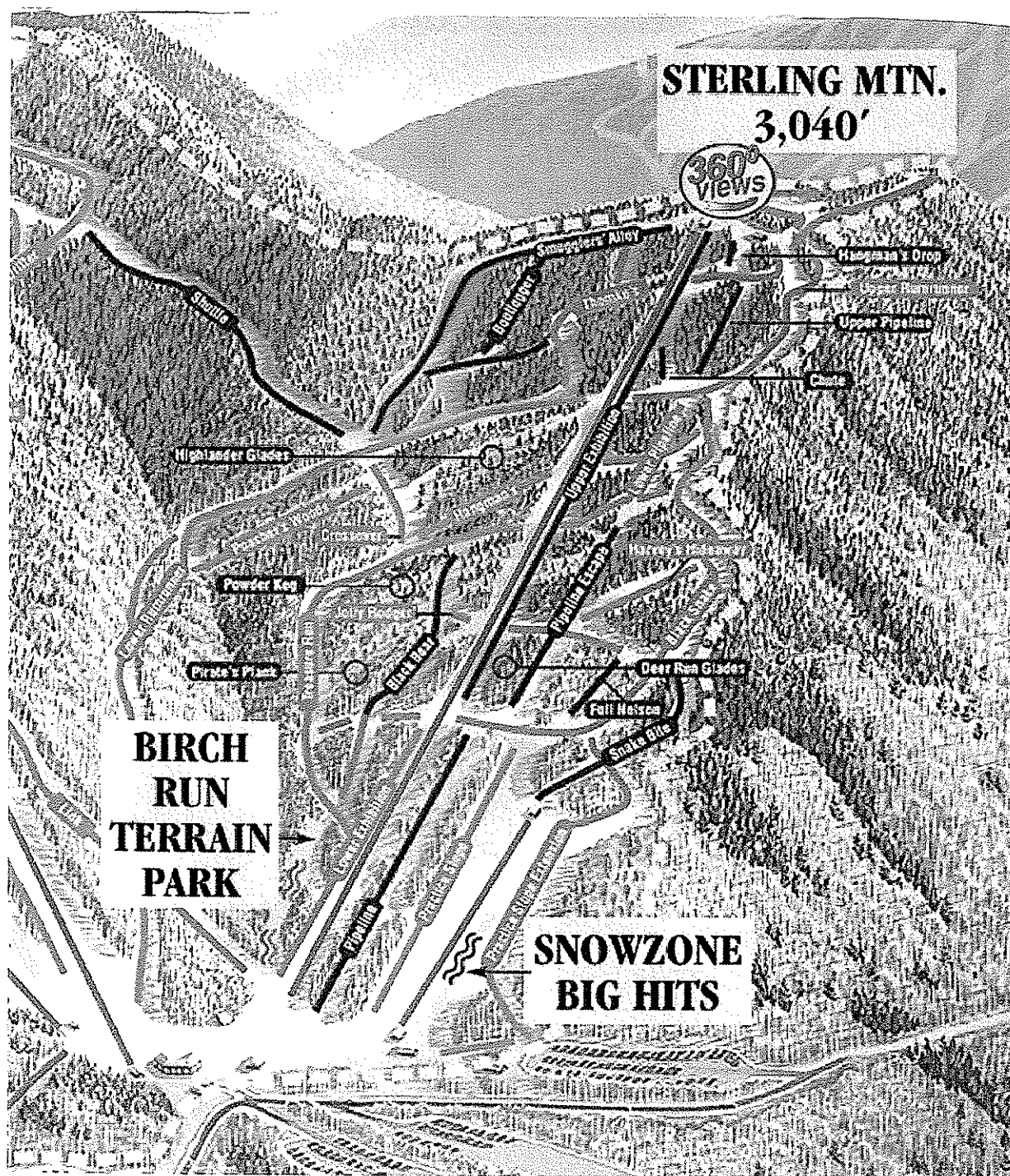
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# Appendix A: Trail map of Stowe Mountain Resort



The — represents the areas on the ski trails on which I conducted my research  
 Taken from:  
 Stowe Mountain Resort. 2002. Stowe, VT. Available: <http://www.stowe.com>.  
 [2002, Nov. 2].

Appendix B: Trail map of Smugglers' Notch Resort (Sterling Mtn.)



The — represents the areas on the ski trails on which I conducted my research

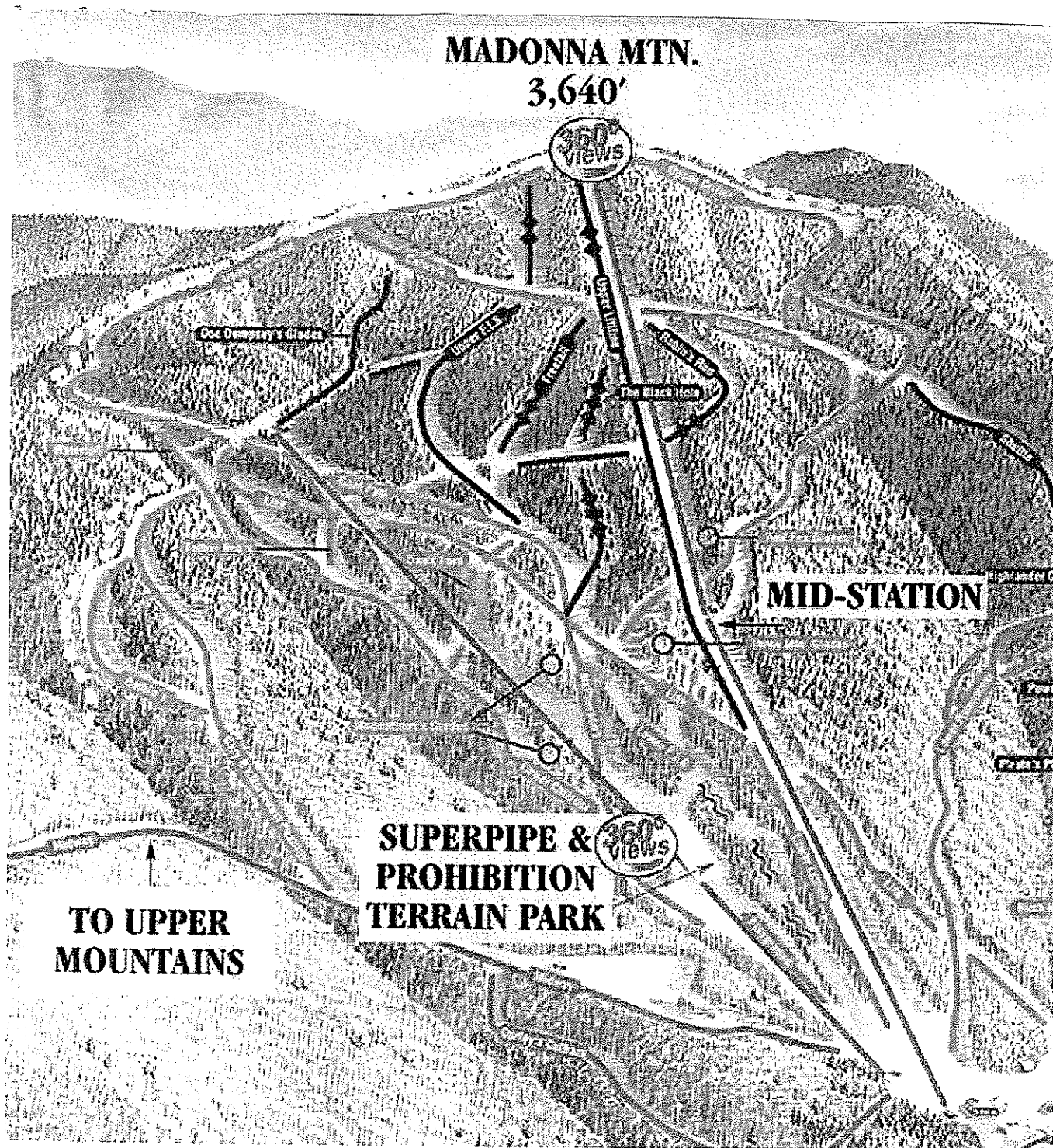
Taken from:

Smugglers' Notch Resort. 2002. Jeffersonville, VT. Available: <http://www.smuggs.com>.

[2002, Nov. 2].

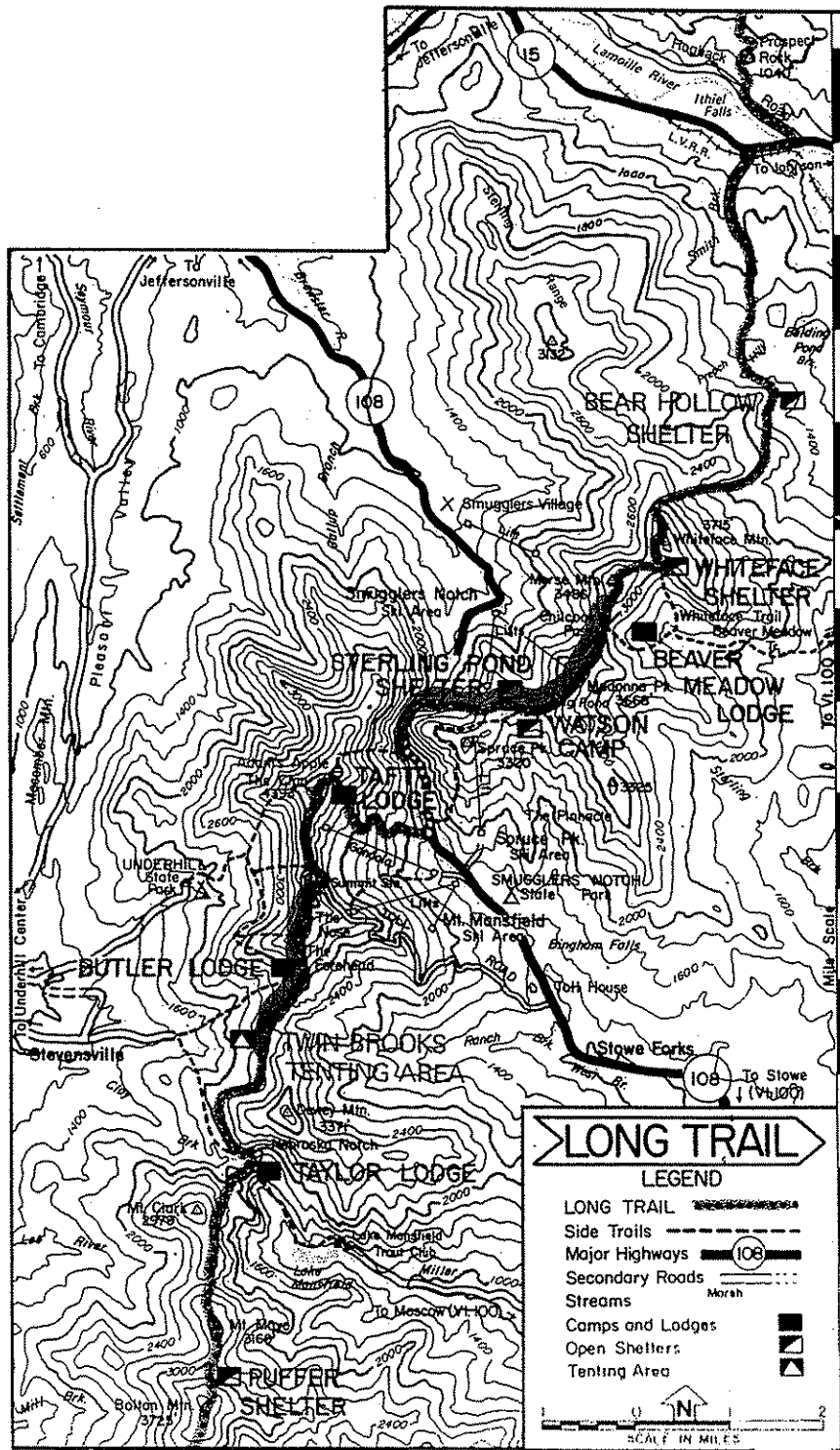



Trail map of Smugglers' Notch Resort (Madonna Mtn.)



The — represents the areas on the ski trails on which I conducted my research  
Taken from:  
Smugglers' Notch Resort. 2002. Jeffersonville, VT. Available: <http://www.smuggs.com>.  
[2002, Nov. 2].

# Appendix C: Map of portion of Long Trail near Stowe Mountain Resort and Smugglers' Notch Resort



The  represents the portions of the Long Trail on which I conducted my research  
 Taken from:  
 The Green Mountain Club. 1996. Long Trail Guide. Northlight Studio Press, Barre, VT.

## Appendix D: Photographs of study species

### Magnolia Warbler



Taken from:  
The Nature of New England. 2002. (Credit: [www.arttoday.com](http://www.arttoday.com)). Available:  
<http://www.nenature.com/Images/MagnoliaWarblerLRR.jpg>. [2002, 29 Dec.].

### Yellow-rumped Warbler



Taken from:  
Morris, Arthur. The Virtual Birder, North American Birding and Birds. Available:  
<http://www.virtualbirder.com/vbirder/arthur/wg/mid/BIRD026.jpg>. [2002, 29 Dec.].

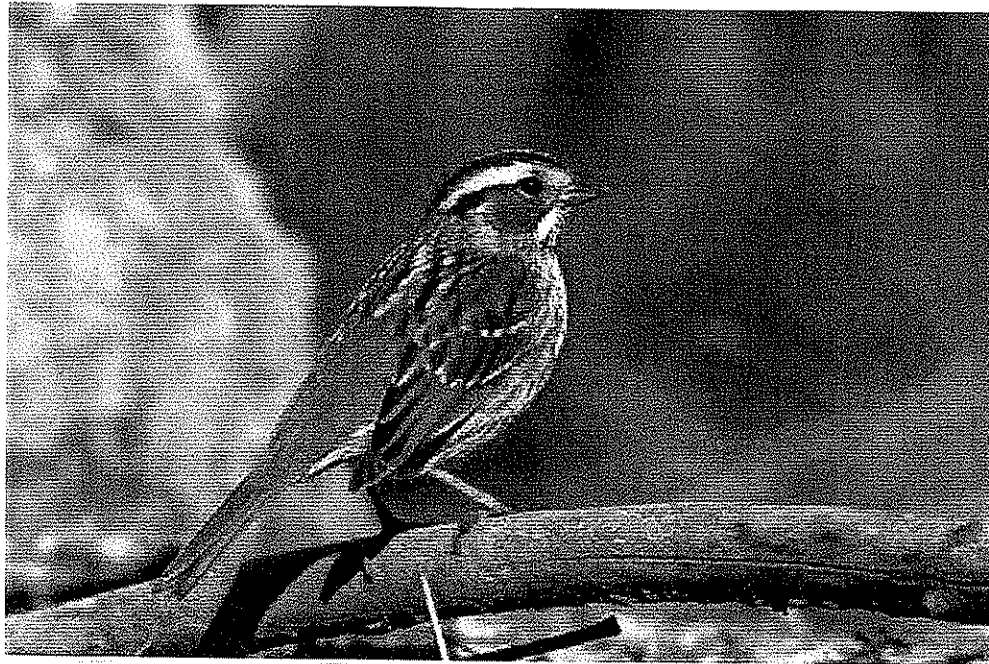


## Blackpoll Warbler



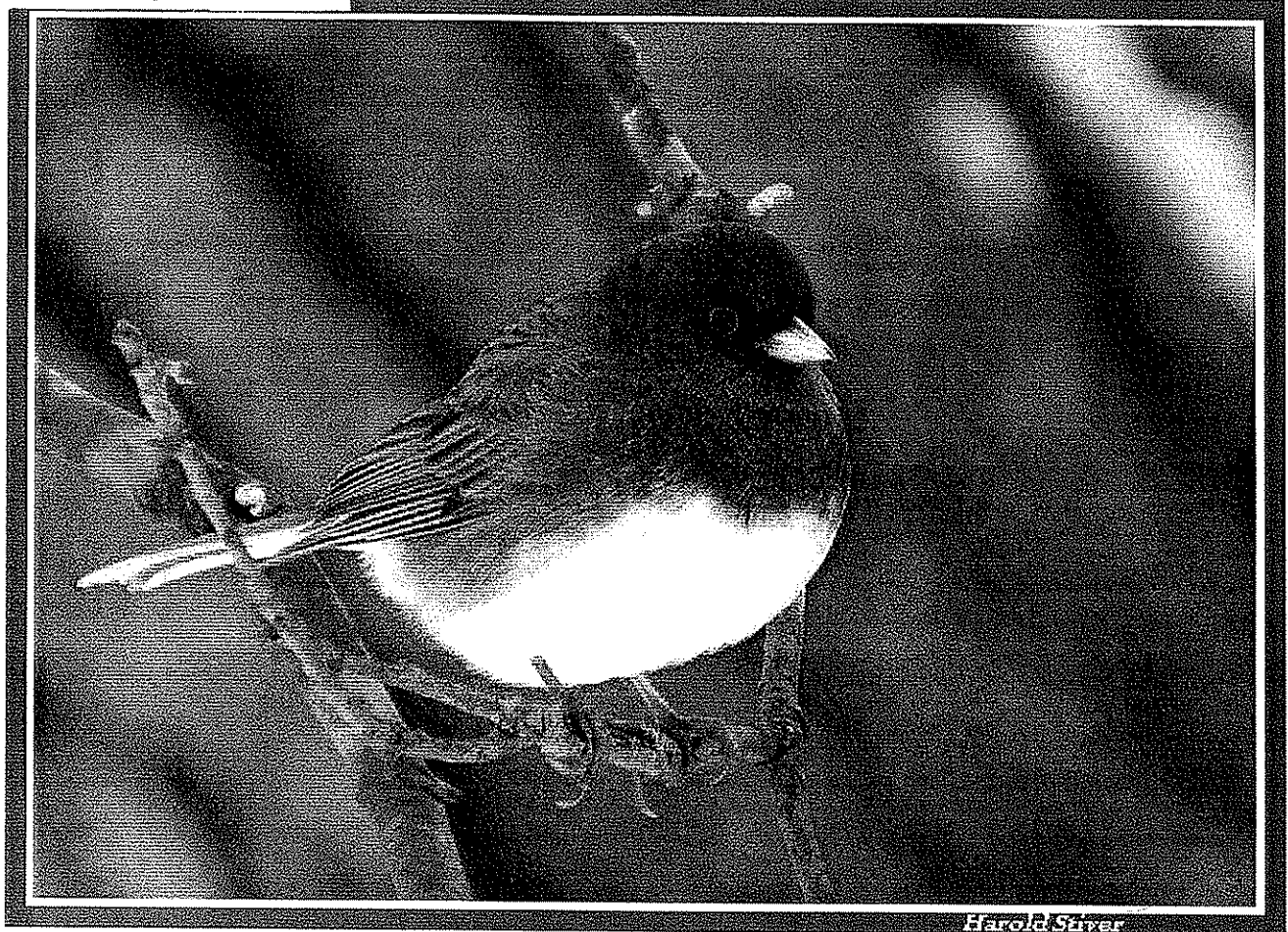
Taken from:  
The Nature of New England. 2002. (Credit: [www.arttoday.com](http://www.arttoday.com)). Available:  
<http://www.nenature.com/Images/BlackpollWarblerLMD.jpg>. [2002, 29 Dec.].

## White-throated Sparrow



Taken from:  
The Nature of New England. 2002. (Credit: [www.arttoday.com](http://www.arttoday.com)). Available:  
<http://www.nenature.com/Images/WhiteThroatedSparrowLRR.jpg>. [2002, 29 Dec.].

## Dark-eyed Junco



Taken from:

Stiver, Harold. 2002. Bird Images by Harold Stiver. Available:

[http://www.ontfin.com/Dark\\_Eyed\\_Junco2.jpg](http://www.ontfin.com/Dark_Eyed_Junco2.jpg). [2002, 29 Dec.].

## Swainson's Thrush



*Swainson's Thrush* Harold Stiver

Taken from:

Stiver, Harold. 2002. Bird Images by Harold Stiver. Available:

[http://www.ontfin.com/Swainsons\\_Thrush2.jpg](http://www.ontfin.com/Swainsons_Thrush2.jpg). [2002, 29 Dec.].