Regional patterns of habitat use by a threatened forest bird, the Bicknell’s Thrush, in Quebec.

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Abstract:
Conservation of threatened species is often based on habitat models to inform management of habitat and populations. The suite of covariates included in the models is generally related to the vegetation structure and composition, topography and some landscape features. We examined habitat use by Bicknell’s thrush (Catharus bicknelli Ridgway), in two Appalachian regions of southern Quebec. We assessed the role of, vegetation and topography at two spatial scales, as well as relationships with Swainson’s thrush (Catharus ustulatus Nuttall). Bicknell’s thrush preferred sites at high elevations that underwent little or no thinning and where Swainson’s thrushes were abundant. This preference occurred in the two study regions and is consistent with findings from studies further south in its breeding range.

Key words: Bicknell’s thrush, Catharus bicknelli, breeding habitat use, abundance, habitat model, pre-commercial thinning, Swainson’s thrush, Catharus ustulatus.

Résumé:
Les modèles de prédiction de l’habitat sont souvent utilisés pour orienter la gestion de l’habitat et des populations dans un contexte de conservation d’une espèce menacée. Les covariables des modèles sont généralement reliées à la structure et à
la composition de la végétation, à la topographie et à certains aspects du paysage.

Nous avons investigué l'utilisation de l'habitat par la Grive de Bicknell (Catharus bicknelli Ridgway) dans deux régions des Appalaches du Québec méridional. Nous avons examiné la contribution de paramètres de la végétation et de la topographie à deux échelles spatiales ainsi que de la relation de l'espèce avec la Grive à dos olive (Catharus ustulatus Nuttall). La Grive de Bicknell démontre une préférence pour les sites localisés à hautes altitudes qui n'ont pas fait l'objet d'éclaircies, sinon très peu, des peuplements et où la Grive à dos olive était abondante. Cette préférence a été observée dans les deux régions étudiées et est semblable avec ce qui a été noté par d'autres travaux de recherche plus au sud dans son aire de nidification.

Mots-clés ; Grive de Bicknell, Catharus bicknelli, utilisation de l'habitat de reproduction, abondance, modélisation de l'habitat, éclaircie pré-commerciale, Grive à dos olive, Catharus ustulatus.
Introduction

Land-based efforts to conserve threatened species and their critical habitat rely heavily on habitat use models to inform management of habitat and populations (Camaclang et al. 2014). The predictive performance of habitat use models depends primarily on the goals and on the data selected to develop the model (Guisan and Zimmermann 2000). In many cases, models are derived from data collected in a limited portion of the target species’ range, and then broadly applied without first assessing potential spatial variation in the species’ habitat use (Fielding and Haworth 1995, Laughlin et al. 2013). Further, many published habitat use models have only considered covariates pertaining to vegetation structure and composition although several abiotic factors (e.g., topography, climate, site bio-chemistry, historical use) are increasingly documented as being important to the definition of avian habitat (Fielding and Haworth 1995, Tilgar et al. 1999, Tilgar et al. 2002, Norris et al. 2003, Seoane et al. 2004, Nocera and Forbes 2010, McFarland et al. 2013). Conspecific and heterospecific densities have also recently been shown to be important habitat attributes (Greene and Stamps 2001, Forsman et al. 2008, Nocera and Forbes 2010) through both conspecific and interspecific competition (Petit and Petit 1996, Confer et al. 2003) or attraction (Slagsvold 1980, Reed and Dobson 1993, Mönkkönen and Forsman 2002, Bourque and Desrochers 2006). Failure to consider key factors in habitat use models can lead to inadequate identification of critical habitat and erroneous conclusions about a species’ ecological needs and, thus, misguided conservation investments and land-use planning decisions (Camaclang et al. 2014).
In the Northeast of North America, five species of thrushes (*Catharus* spp.) tend to segregate their distributions according to an elevational gradient (Able and Noon 1976, Sabo and Whittaker 1979, Noon 1981). Amongst those is the threatened Bicknell’s thrush (*C. bicknelli* Ridgway, typically referred to as *C. minimus bicknelli* Ridgway before 1995; AOU 1995), the most habitat-specific thrush north of Mexico (Dilger 1956). Published studies portray Bicknell’s thrush mostly as a specialist of patchy, high elevation coniferous dominated forests, occurring at lower elevation only in the Canadian northern part of its distribution (Ouellet 1993, Gauthier and Aubry 1995, Rimmer et al. 2001, Lambert et al. 2005). This Northeastern endemic has been designated as threatened under Canadian law (Government of Canada, 2012) and as the highest conservation priority in Northeastern United States by *Partners in Flight* (Pashley et al. 2000).

Bicknell’s thrush potential habitat has been modeled for the Northeastern United States based on elevation, latitude, and forest type (Lambert et al. 2005). That model was reported to perform well in that part of the species’ range, where the species is mostly restricted to sub-alpine and high elevation environments. However, as suggested by Lambert et al. (2005), the model yielded questionable results when applied in Maine and southeastern Canada, where forestry practices, and biotic as well as abiotic habitat characteristics differ (Lambert et al. 2005; K. McFarland and Y.A. unpublished data).

Besides its limited geographical scope, the habitat model developed by Lambert et al. (2005) did not consider potentially important factors such as forestry practices and possible interactions with the closely-related Swainson’s thrush (*C. ustulatus* Nuttall). Forestry practices are important to consider since most of Bicknell’s thrush range in
Canada is allocated for forest harvesting (COSEWIC 2009). Inappropriate logging
prescriptions derived from poorly performing habitat use models could unnecessarily
negatively impact local or regional economies, and erode the credibility of
conservation scientists in land use decision making. With respect to interspecific
interactions, some authors have reported the co-occurrence of Bicknell's and
Swainson's thrushes (Wallace 1939, Nixon et al. 2001), but others have
hypothesized that heterospecific competition results in spatial segregation (Able and
Noon 1976, Sabo 1980, Noon 1981, Mack and Yong 2000, Rimmer et al. 2001);
conversely, Bicknell's thrush could be using the presence of Swainson's thrush as an
indicator of high habitat quality (Forsman et al. 2008).

Here, we report on an analysis of geographic variation in habitat use by Bicknell’s
thrush, based on multi-year surveys in two regions of its Canadian range. We
assessed the relative roles of some habitat components, vegetation and topography
at two spatial scales, as well as relationships with Swainson’s thrush. This will
contribute to better understand this threatened species’ habitat, inform future habitat
use modelling and potentially support efforts to designate it critical habitat.

Methods

Study areas

Our study was conducted in two areas approximately 150 km apart, both in the
Appalachian Mountains range. First, Mont Gosford, Quebec (elevation: 790–1193 m;
45.3° N, 70.87° W), adjacent to the Quebec-Maine border at the edge of the White
Mountains, ME, is characterized by slopes sometimes greater than 30°. The study
area (± 70 km²) was dominated by balsam fir (*Abies balsamea* Mill.) with small and patchy occurrences of white spruce (*Picea glauca* Moench), red spruce (*P. rubens* Sarg.) and white birch (*Betula papyrifera* Marshall). The area was almost entirely clear cut in the early 1970s, with only a few residual forest pockets left intact. In some part of this study area, thinning operations were conducted in the mid-1980s and mid-1990s (see Aubry et al. 2011 for more details). No other significant forestry activities occurred in Mont Gosford study area since then.

Second, Massif du Sud (elevation: 680–917 m; 46.6° N, 70.48° W), located 65 km east of Quebec City, is a 120 km² plateau composed of 20 summits standing out in a rolling hill, agro-forestry environment. The study area covered 45 km² and was dominated by balsam fir. Since the early 1980s and up to 2007, forestry activities targeting old coniferous stands created a mosaic of forest stands differing primarily in tree density, structure and age rather than species composition (Paulette 2010). This territory also supports wind energy infrastructure (75 turbines for 150 MW, in operation since 2012), downhill, glade and cross-country skiing, as well as other all seasons low intensity recreational activities (Paulette 2010, MRC de Bellechasse and MRC des Etchemins 2013).

**Point counts**

At Mont Gosford, we monitored Bicknell’s and Swainson’s thrushes in 2001, 2002, 2003, 2004 and 2007. The two species were surveyed at 99 point count stations in 2001, to which we later added 30 stations. All stations were visited once each year. Point count stations were located along forestry roads (*n* = 11), foot trails (*n* = 78) and off trails (*n* = 40). All stations were ≥250 m apart and located ≥50 m from stands
with a different tree composition and/or structure. At Massif du Sud, we conducted 158 point counts in 2007, along forestry roads (n = 80) and foot trails (n = 129) at 209 159 stations. All point counts were conducted between 2–28 June, during thrushes’ 160 dawn and dusk choruses (03:10–07:45, 18:00–21:30) (Ball 2000). At each station, 161 thrushes within 100 m of the observer were counted, first during a 15 min passive 162 listening period, followed by 1 min of broadcasting of Bicknell’s thrush calls and 163 songs, followed by another 5 min of listening during which we counted all previously 164 reported birds, and any individuals deemed new based on their location. During 165 surveys, the position of each thrush was indicated on a 1:1000 map to reduce the 166 risk of double counting. Other than Bicknell’s and Swainson’s, other thrush species 167 were rarely observed (<5% of all point counts conducted) and were ignored from 168 further analyses.

Our survey protocol was selected based on estimates of Bicknell’s thrush detection 170 probabilities derived from an occupancy model with constant probability of 171 occupancy across all sites where Bicknell’s thrushes were reported at least once 172 (Y.A. and M. Mazerolle, in preparation). Detection probability for a given 5–min 173 period depended on the survey technique (passive listening vs post-playback). 174 Detection probabilities reached 88 - 96% at the end of the sampling period we used 175 (i.e., 20 min with playback), while a sampling period of 5 or 10 min without playback 176 yielded detection probabilities <53% and <78% respectively. Given uncertainty 177 about the closure of site occupancy (sensu Mackenzie et al. 2006) by Bicknell’s 178 thrushes during those surveys, we interpret our estimates of detection probabilities 179 as minima. Dettmers et al. (1999) also reported better performance of habitat
models for low detectability species, like Bicknell’s thrush, as count duration increases (from 3 to 20 min).

**Vegetation and topography**

The habitat was characterized using vegetation and topography variables, within 100 and 250 m of each point count station (Table 1). Vegetation variables were tree composition, ground cover, and the structure of the forest stands. We classified forest stands from eco-forestry GIS layers (Government of Quebec 2009, ESRI 2010) and field observations as: Balsam Fir dominated; Balsam Fir with White Birch as sub-dominant; and Non-Balsam Fir. We classified stand structure according to silvicultural activities since the early 1980s as: Unthinned, characterized by high stem density; Thinned in 1986, with medium to low stem densities and high abundance of fruit trees; and Thinned in 1996, with low stem densities at the time of point counts (see Aubry et al. 2011). For the Massif du Sud study area, we added Recent Clear Cut (<10 years) to the previous categories. We estimated ground cover in the field, from 1 m above ground and classified it as open if ground was dominated by moss, organic litter or mineral/rocks and closed if it was dominated by ferns and herbaceous plants. Topography variables were elevation at point counts and its variation within 100 and 250 m (Canadian Digital Elevation Data 2000) as an index of the ruggedness (or steepness) of the habitat.

**Statistical analysis**

We used generalized linear models (GLMs) with a negative binomial error structure (Proc Genmod; SAS 2009), with point count stations as repeated-measure subjects
for the Mont Gosford multi-year data set. Because Bicknell’s thrush is non-territorial when breeding (Goetz et al. 2003, Aubry et al. 2011) and both males and females vocalize (Ball 2000, Rimmer et al. 2001), we used the number of individual counted as response variable. We grouped regressors into three sets: vegetation (type and structure within 100 and 250 m of point count station, and ground cover), topography (elevation at point count station and its variation within 100 and 250 m), and interspecific interactions (Swainson’s thrush counts). We designed eight models (Tables 2 and 3) and selected amongst them using the Quasilikelihood Information Criterion (QAIC<sub>c</sub>) (Pan, 2001) for the Mont Gosford multi-year data set, and the Akaike information criterion (AIC<sub>c</sub>) for the Massif du Sud single-year data set. As detection is not perfect, our modeling approach offers limited inference regarding occupancy. However, since detection probability approached one (discussed above) we consider that raw counts were sufficient for the aims of this study. Furthermore, closure of occupancy status, as required by occupancy models, is difficult to define in the case of Bicknell’s thrush given the large home range of males (e.g., Aubry et al. 2011) and the complex mating system of the species (Goetz et al. 2003).

We also ran GLMs with Bicknell’s thrush reporting rates data as response variable and a binomial distribution (Y.A. unpublished data). The best models were essentially the same in the two sets of analyses with the only change being the loss of point count station elevation as a parameter at Mont Gosford. For simplicity, we therefore present only GLMs based on abundances data.

Finally, we used principal components analysis (PCA, Proc factor procedure) (SAS 2009) to visually explore the relationships between the eleven environmental variables recorded and the occurrence of both thrush species (Table 5).
Results

Bicknell’s thrush reporting rates and counts were substantially lower than those of Swainson’s thrush at both sites (Table 4, Fig. 1 and 2). At Mont Gosford, we observed important annual variation in Bicknell’s thrush reporting rates (35–67% of stations; Table 4) and counts (0.69 ± 0.11 to 1.58 ± 0.15 individuals per station; Table 4). When reported, Bicknell’s thrush numbers varied from 1.64 ± 0.13 to 2.34 ± 0.17 individuals per occupied station (Table 4). At Massif du Sud, Bicknell’s thrush was reported at 24% of stations, where 1.78 ± 0.16 individuals were present on average when reported (Table 4).

At both study areas, habitat use GLMs accounting for vegetation, topography and Swainson’s thrush abundance performed best (Table 2). At Mont Gosford, the proportion of stand thinned in the 1980s, elevation of point count station, elevation variation within 250 m of station, and Swainson’s thrush abundance were significantly associated with Bicknell’s thrush abundance, the first one negatively and the other three positively (Table 3). At Massif du Sud, only two of these variables, elevation of point count station and Swainson’s thrush counts, were significantly associated with Bicknell’s thrush counts (Table 3).

With a principal component analysis (Table 5), we reduced the variation from all habitat covariates to two factors accounting for 58% of the total variance (factor 1: 33% and factor 2: 25%). The first two components were strongly associated to stand structure. The unthinned area was negatively correlated with factors 1 and 2, while the area thinned in the 1980s was positively correlated with both factors. Factor 2
was also strongly negatively correlated with the area thinned in the 1990s, and
positively with elevation and its variation. According to this analysis, Bicknell’s thrush
stations broadly overlapped with those with Swainson’s thrushes (Fig. 3). However,
stations with Bicknell’s thrushes only were mostly clustered in unthinned stands
represented in the left quadrants of the ordination (Fig. 3).

Discussion

Habitat use models

Three results from our study suggest large-scale consistency in Bicknell’s thrush
breeding habitat relationships. First, the best Bicknell’s thrush habitat use model we
developed included topographic, vegetation and interspecific interactions. The
species tended to preferentially use sites at high elevations that underwent little or no
thinning and where Swainson’s thrushes were abundant. These results are
consistent with the findings of studies conducted in the southern part of the species’
range (Atwood et al. 1996, Lambert et al. 2005). Second, Bicknell’s thrush at our
study sites in managed forests used dense regenerating stands and were notably
less abundant in recently thinned stands. The same pattern was noted in studies
conducted in managed forests in other parts of the species range (Nixon et al. 2001,
Connolly et al. 2002, Chisholm and Leonard 2008, Aubry et al. 2011). Third, the
minimum elevations at which we found Bicknell’s thrush at Mont Gosford (790 m)
and Massif du Sud (680 m) closely matched predictions under Lambert et al. (2005)
model (i.e. 781 m and 679 m, respectively).
In contrast, our analyses indicated a lack of consistency in Bicknell’s thrush relationship with habitat ruggedness. The variation of elevation within a 250 m radius from the point count was significantly positively associated with the presence of Bicknell’s thrush at Mont Gosford, but not at Massif du Sud. An association with steep terrain has been noted in most of the species’ U.S. range (Frey 2008). Those differences may simply reflect habitat availability at the various sites. For instance, our two study areas exhibit different overall topographies, with 70% of all point counts having an elevation variation >80 m within 250 m at Mont Gosford, compared to 30% at Massif du Sud.

Bicknell’s thrush shows strong site fidelity (Rimmer et al. 2001, Y.A. personal observation) and may remain in disturbed forest stands because of the presence of a female or conspecifics. By focusing on habitat structure, elevation and terrain, we may have overlooked behavioral characteristics that may influence habitat use. To refine Bicknell’s thrush habitat use models, other parameters should be considered, including habitat fragmentation, patch size and isolation, and the presence and number of conspecifics (Laughlin et al. 2013, Cunningham and Johnson 2012, Mönkkönen and Forsman 2002, Frey 2008, Mönkkönen et al. 1999).

Abundance

Overall occurrence and numbers of Bicknell’s thrushes were lower at Massif du Sud than at Mont Gosford, though their abundance at occupied sites was similar. This may reflect reduced availability of suitable habitat in the more recently logged and thinned forests at Massif du Sud.
Connoly (2000) similarly hypothesized that a difference in abundance of Bicknell’s thrushes at two study sites in southern Quebec was linked to contrasting forest management histories. She recorded higher densities at Mont Mégantic, where the last forestry activities had occurred in the late 1950s, than at Mont Gosford where large clear cuts occurred in the 1970s and thinning as recently as 1996.

Interestingly, Nixon et al. (2001) reported Bicknell’s thrush densities in harvested forest landscapes dominated by young regenerating clear-cuts in New-Brunswick (16 individuals * 100 ha⁻¹) that were similar to those we noted at Massif du Sud (13.7 individuals * 100 ha⁻¹). In contrast, we obtained estimates of 22 to 50.3 individuals * 100 ha⁻¹ at Mont Gosford where the forest was less recently impacted by forestry operations. It should be noted though that drawing similarities and differences between Nixon et al. (2001) and our results is compounded by the fact that we used different survey protocols (6 min of passive listening vs 20 min with playback, respectively) associated with different detection probabilities ($P = 0.40$ versus 88 to 96%).

Overall, these results suggest that Bicknell’s thrush numbers at the landscape level are negatively impacted by the extent and recency of forestry operations. Similarly, Chisholm and Leonard (2008) linked the presence of Bicknell’s thrush in thinned or heavily managed area in New-Brunswick to the amount of residual unthinned patches.

**Relationships between Bicknell’s and Swainson’s thrushes**

We observed Bicknell’s and Swainson’s thrushes at all sampled elevations at both our study areas, actually co-occurring at a majority of point count stations.
Conversely, several studies reported an elevational segregation between Bicknell’s and Swainson’s thrushes (Able and Noon 1976, Morse 1979, Noon 1981, Dellinger et al. 2007) which Holmes and Sawyer (1975) related to differential adaptation to a temperature gradient. Wallace (1939) reported that the two species were “not found together” on the northeast side of Mt. Mansfield, Vermont, in the mid-1930s while they “distinctly overlapped, and nests of both in close proximity were found at less than 2900 feet [884 m] and at more than 3000 feet [914 m]” on the southwest side. However, K. McFarland (personal communication, 2015) reports that Swainson’s thrush is now present up to the tree-line (±1250m) at the same sites, indicating an upward elevational shift since the 1930s. On a broader scale, Swainson’s thrushes were recently observed at a majority of stations at all sampled elevations in the northeastern United States (Fig. 4) (2007 Mountain Birdwatch Monitoring Program, 705 point counts, elevational range 630–1472 m) and in the Canadian Maritime region (Fig. 5) (2007 High Elevation Landbird Monitoring Program, 232 point counts, elevational range 87–781 m). All these results suggest that, if the two species were formerly segregated, this may not be the case anymore. Further surveys are needed close to the treeline throughout the species breeding range to confirm this.

Where Bicknell’s and Swainson’s thrushes co-occur, agonistic interactions between the two species have been reported (Able and Noon 1976, Sabo and Whittaker 1979, Rimmer et al. 2001) and interpreted as evidence of competition (Noon 1981, Sabo 1980). The positive correlation in the abundance of the two species at both our study areas should not be interpreted as evidence for or against interspecific competition, because our study was not specifically designed to assess interspecific competition (Connell 1983). Nixon et al. (2001) did not find a correlation between the
densities of the two species in New-Brunswick, but this may be because Swainson’s thrush was ubiquitous and had saturated available habitat at their study areas.

Specifically designed studies would be required to assess the occurrence of interspecific competition and, if present, whether it is mitigated through micro-habitat or niche partitioning, or behavioral strategies (Dilger 1956, Noon 1981, Dellinger et al. 2007, Laughlin et al. 2013).

Our study contributes to a better understanding of the nesting habitat of Bicknell’s thrushes. In particular, we have confirm consistency in Bicknell’s thrush breeding habitat relationships over most of its breeding range. Our results are also consistent with the hypothesis that Bicknell’s thrush numbers at the landscape level are related to the amount of forest habitat unimpacted by recent forestry activities. However, factors not related to habitat may contribute to the low abundance of this threatened species, as compared to the co-occurring Swainson’s thrush. For instance, conspecific attraction may cluster individuals sufficiently to leave areas of suitable habitat unoccupied (Muller et al. 1997). Thus, even if our study provides support for the use of habitat models to understand Bicknell’s thrush populations over large geographical areas, we need to better understand individual and group behaviour and the species’ population dynamics to develop better, locally-relevant habitat use models. Better models will be especially valuable for areas of managed forests, where erroneous prescriptions based on weak models would be costly.

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URL :http://www.mrcbellechasse.qc.ca/meganet/media/docs/prms_pag_projet_pour_sad_des_mrc.pdf)


Table 1. Point count station variables and description at Mont Gosford and Massif du Sud, Quebec, Canada.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetation</strong></td>
<td></td>
</tr>
<tr>
<td>Tree species</td>
<td>Tree species dominating the stand within 100 m radius (3 categories: Balsam Fir dominant, Balsam Fir with White Birch sub-dominant, and other - no-Balsam Fir dominant)</td>
</tr>
<tr>
<td>% unthinned / 100 m</td>
<td>Proportion of unthinned stand within 100 m radius</td>
</tr>
<tr>
<td>% thinned in 1980s / 100 m</td>
<td>Proportion of stand thinned in the 1980s within 100 m radius</td>
</tr>
<tr>
<td>% thinned in 1990s / 100 m</td>
<td>Proportion of stand thinned in the 1990s within 100 m radius</td>
</tr>
<tr>
<td>% unthinned / 250 m</td>
<td>Proportion of unthinned stand within 250 m radius</td>
</tr>
<tr>
<td>% thinned in 1980s / 250 m</td>
<td>Proportion of stand thinned in the 1980’s within 250 m radius</td>
</tr>
<tr>
<td>% thinned in 1990s / 250 m</td>
<td>Proportion of stand thinned in the 1990s within 250 m radius</td>
</tr>
<tr>
<td>Ground cover</td>
<td>Dominant ground cover: open (moss, litter, mineral) or closed (ferns, herbaceous plants)</td>
</tr>
<tr>
<td><strong>Topography</strong></td>
<td></td>
</tr>
<tr>
<td>ΔAlt / 100</td>
<td>Elevation variation within 100 m radius</td>
</tr>
<tr>
<td>ΔAlt / 250</td>
<td>Elevation variation within 250 m radius</td>
</tr>
<tr>
<td>Elevation</td>
<td>Elevation above sea level at the center of the station</td>
</tr>
<tr>
<td><strong>Swainson’s thrush</strong></td>
<td>Abundance of Swainson’s thrush in the survey period</td>
</tr>
</tbody>
</table>
Table 2. Model selection at the point count level using abundance of Bicknell’s thrush as the response variable and 8 a priori models as explanatory variables for Mont Gosford, 2001-2007, and Massif du Sud, 2007, Quebec, Canada.

<table>
<thead>
<tr>
<th>ID</th>
<th>Models</th>
<th>Mont Gosford</th>
<th>Maissif du Sud</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>K</td>
<td>QAIC&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>1</td>
<td>Null</td>
<td>1</td>
<td>1136.9</td>
</tr>
<tr>
<td>2</td>
<td>Vegetation</td>
<td>12</td>
<td>1039.6</td>
</tr>
<tr>
<td>3</td>
<td>Topography</td>
<td>4</td>
<td>1030.8</td>
</tr>
<tr>
<td>4</td>
<td>Swainson’s thrush</td>
<td>2</td>
<td>1131.4</td>
</tr>
<tr>
<td>5</td>
<td>Vegetation - Topography</td>
<td>15</td>
<td>989.9</td>
</tr>
<tr>
<td>6</td>
<td>Vegetation - Swainson’s thrush</td>
<td>13</td>
<td>1029.4</td>
</tr>
<tr>
<td>7</td>
<td>Topography - Swainson’s thrush</td>
<td>5</td>
<td>1022.8</td>
</tr>
<tr>
<td>8</td>
<td>Vegetation - Topography - Swainson’s thrush</td>
<td>16</td>
<td>975.8</td>
</tr>
</tbody>
</table>
Table 3. Parameter estimates for response of Bicknell thrush’s abundance to vegetation, topography and Swainson’s thrush counts at Mont Gosford and Massif du Sud, Québec.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mont Gosford</th>
<th>Massif du Sud</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
</tr>
<tr>
<td>Balsam Fir dominant</td>
<td>-0.164</td>
<td>0.292</td>
</tr>
<tr>
<td>Balsam Fir and White Birch</td>
<td>-0.023</td>
<td>0.245</td>
</tr>
<tr>
<td>Other - no Balsam Fir</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>% Unthinned / 100 m</td>
<td>-2.546</td>
<td>1.354</td>
</tr>
<tr>
<td>% Thinned in 1980s / 100 m</td>
<td>-2.918</td>
<td>1.317</td>
</tr>
<tr>
<td>% Thinned in 1990s / 100 m</td>
<td>-2.501</td>
<td>1.603</td>
</tr>
<tr>
<td>% Unthinned / 250 m</td>
<td>-0.416</td>
<td>2.614</td>
</tr>
<tr>
<td>% Thinned in 1980s / 250 m</td>
<td>0.411</td>
<td>2.639</td>
</tr>
<tr>
<td>% Thinned in 1990s / 250 m</td>
<td>-1.497</td>
<td>3.024</td>
</tr>
<tr>
<td>Closed (vs open) ground cover</td>
<td>-0.169</td>
<td>0.154</td>
</tr>
<tr>
<td>Δ Elevation / 100 m</td>
<td>-0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>Δ Elevation / 250 m</td>
<td>0.013</td>
<td>0.047</td>
</tr>
<tr>
<td>Elevation at point count</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Swainson’s thrush abundance</td>
<td>0.091</td>
<td>0.021</td>
</tr>
</tbody>
</table>
Table 4. Reporting rates (%) and abundance (Mean ± SE) of Bicknell’s and Swainson’s thrushes at Mont Gosford and Massif du Sud, Quebec, Canada.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mont Gosford</th>
<th>Massif du Sud</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>99</td>
<td>129</td>
</tr>
</tbody>
</table>

**Bicknell’s thrush**
- Reporting rate
  - 56% 64% 67% 43% 35% 24%
- Global abundance
  - 0.91 (0.11) 1.26 (0.13) 1.58 (0.15) 0.79 (0.10) 0.69 (0.11) 0.43 (0.07)
- Abundance when Bicknell’s reported
  - 1.64 (0.13) 1.95 (0.15) 2.34 (0.17) 1.82 (0.13) 1.98 (0.20) 1.78 (0.16)

**Swainson’s thrush**
- Reporting rate
  - 98% 87% 96% 95% 91% 91%
- Global abundance
  - 3.48 (0.17) 3.39 (0.26) 4.33 (0.26) 3.88 (0.20) 3.29 (0.18) 3.40 (0.16)
- Abundance when Bicknell’s reported
  - 3.38 (0.24) 3.49 (0.25) 4.52 (0.31) 4.23 (0.33) 3.31 (0.32) 3.98 (0.31)
- Abundance when Swainson’s reported
  - 3.56 (0.17) 3.90 (0.21) 4.5 (0.26) 4.07 (0.20) 3.62 (0.17) 3.76 (0.14)
Table 5. Correlations between individual variables and the first two Principal Components for the ordination of point count stations at Mont Gosford and Massif du Sud, 2001-2007.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Unthinned / 100 m</td>
<td>-0.929</td>
<td>-0.243</td>
</tr>
<tr>
<td>% Thinned in 1980s / 100 m</td>
<td>0.454</td>
<td>0.790</td>
</tr>
<tr>
<td>% Thinned in 1990s / 100 m</td>
<td>0.721</td>
<td>-0.507</td>
</tr>
<tr>
<td>% Unthinned / 250 m</td>
<td>-0.970</td>
<td>-0.103</td>
</tr>
<tr>
<td>% Thinned in 1980s / 250 m</td>
<td>0.468</td>
<td>0.775</td>
</tr>
<tr>
<td>% Thinned in 1990s / 250 m</td>
<td>0.730</td>
<td>-0.567</td>
</tr>
<tr>
<td>Closed (vs open) ground cover</td>
<td>0.350</td>
<td>0.291</td>
</tr>
<tr>
<td>Δ Elevation / 100 m</td>
<td>-0.131</td>
<td>0.524</td>
</tr>
<tr>
<td>Δ Elevation / 250 m</td>
<td>-0.245</td>
<td>0.513</td>
</tr>
<tr>
<td>Elevation at point count</td>
<td>-0.405</td>
<td>0.450</td>
</tr>
<tr>
<td>Swainson’s thrush</td>
<td>0.102</td>
<td>0.059</td>
</tr>
<tr>
<td>% of total variance explained</td>
<td>33</td>
<td>25</td>
</tr>
</tbody>
</table>
Figure 1. Proportion of stations where Bicknell’s (circles) and Swainson’s thrushes (triangles) were reported according to elevation (50 m interval) at Mont Gosford (2001-2007; solid line), and Massif du Sud (2007; dashed line), Quebec, Canada.

Figure 2. Mean number (± SE) of Bicknell’s (circle) and Swainson’s (triangle) thrushes according to elevation (50 m interval) at Mont Gosford (2001-2007; solid line), and Massif du Sud (2007; dashed line), Quebec, Canada.

Figure 3. Habitat ordination for Bicknell’s and Swainson’s thrushes at Mont Gosford and Massif du Sud, 2001-2007, Quebec, Canada.

Figure 4. Bicknell’s (black) and Swainson’s thrushes (grey) A) Proportion of occupied station, B) Mean number per point count according to elevation (50 m interval), Mountain Birdwatch program (n = 705 point counts; 10 min surveys), 2007, New-York, Vermont, New-Hampshire, and Maine, United States.

Figure 5. Bicknell’s (black) and Swainson’s thrushes (grey) A) Proportion of occupied station, B) Mean number per point count according to elevation (50 m interval), High Elevation Landbird Program (n = 232 point counts; 10 min surveys), 2007, New-Brunswick and Nova-Scotia, Canada.
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