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Regional significance of peatlands for avifaunal diversity in southern Québec

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Abstract

Altough peatlands in southern Québec are facing increasing pressure, neither specific nor substantial protection measures have been implemented, partly due to a lack of information on this ecosystem. We determined the contribution of peatlands to bird regional diversity by measuring the difference between peatland and associated regional avifaunas. We sampled 112 peatlands located along the Saint Lawrence River during one breeding season. We used data on regional nesting bird assemblages from the Québec breeding bird atlas. Peatland bird species contrasted increasingly with regional avifauna from north to south or from undisturbed to managed landscapes. Of the 17 bird species found significantly more often in peatlands than in surroundings, some preferred peatlands in the whole study area and others preferred peatlands only in particular regions. Peatland avifaunas within regions were more similar to each other than to their regional avifauna, and differences between regions probably reflected changes in peatland physiognomy. We conclude that peatlands contribute to enrich local and regional avian diversity, particularly in the lowlands of the Saint Lawrence River, where industrial pressure on peatlands is highest. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Conservation; Peatland; Bird distribution; Atlas; *Dendroica palmarum*; *Melospiza lincolnii*

1. Introduction

The Brisbane Conference (Ramsar Convention, 1996) recognized that peatlands were under-represented wetlands in the global network of wetlands of international importance. Peatlands occur throughout southeastern Canada among a wide variety of ecosystems, ranging from hardwood to boreal spruce forests, and within landscapes often heavily transformed by human activity. Semi-forested bogs of southeastern Canada differ in many ways from large peatland systems found in the subarctic zone (Payette, 2001). The extent of southeastern semiforested bogs has been reduced by more than 25,000 km^2 by urban sprawl and agriculture (Keys, 1992; Poulin and Pellerin, 2001). Furthermore, forestry and peat mining have changed the structure and dynamics of another 400 km^2 of those peatlands. With an increasing demand for peat moss (Bergeron, 1995) and cranberry-derived products, threats to peatlands will continue as long as substantial protection measures are not taken. Despite some voluntary efforts by the peat industry, no integrated strategy exists yet for peatland conservation in much of southeastern Canada, where industrial use of peatlands is concentrated. One of the explanations for the uncoordinated efforts toward peatland conservation in the latter region and in most of North America is the lack of knowledge about peatland diversity patterns and their contribution to regional diversity.

Peatlands support a wide variety of plants specialized for the extreme acidic conditions of this ecosystem. Many animal species also breed or forage in peatlands, among which birds are the most diverse vertebrate group (Desrochers, 2001). However, unlike northern Europe, where surveys of peatland avifaunas date back from the 1950s (e.g. Sammalisto, 1957; Hakala, 1971;

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Väisänen and Järvinen, 1977; Virkkala and Rajasärkka, 2001), the significance of this ecosystem for the regional avifauna is not well documented in North America, and needs to be addressed. Yet, basic to the conservation argument is the assumption that avifaunas in this ecosystem is distinctive enough to warrant special protection. Thus, we need to evaluate peatland avifaunas relative to that of other ecosystems found regionally, including other wetlands. However, there is great ecological variation among regions of southeastern Canada, and it is unlikely that a single assessment of the regional of peatlands to regional bird diversity would be useful. Thus, to help highlight regions with highest priority for peatland conservation, we need to highlight regions in which peatland contribution to regional avifauna is highest. Finally, the importance of single peatlands to a region depends on idiosyncracies of each peatland, and should be highlighted by intra-regional comparisons of peatland birds.

In this paper, we developed a procedure to assess the importance of this widespread habitat to birds. We analyzed the composition of peatland bird assemblages along an extensive set of surveys over a 1050-km geographical gradient, and used multivariate similarity indices to compare these assemblages to those documented in the Québec Breeding Bird Atlas (Gauthier and Aubry, 1996) and provide a first region-specific, quantitative assessment of peatlands contribution to avifaunas. We also investigated regional differences in peatland vegetation in order to better understand patterns of avifaunal variation.

2. Study area

Peatlands of southern Québec (south of 52°N) are concentrated in the lowlands of the gulf and estuary of the St Lawrence River, the lowlands of Lac Saint-Jean, and, in the western part of the province, in the Abitibi plain (former Ojibway glacial lake). We included in our sample all these regions except Abitibi. Eight natural regions based on geomorphology, climate and vegetation were included in our study area (Government of Québec, 1984; Fig. 1). These natural regions also differ in their land use. Southernmost regions are more populated and exhibit heavily transformed landscapes, whereas northern regions have few inhabitants and mostly undisturbed landscapes.

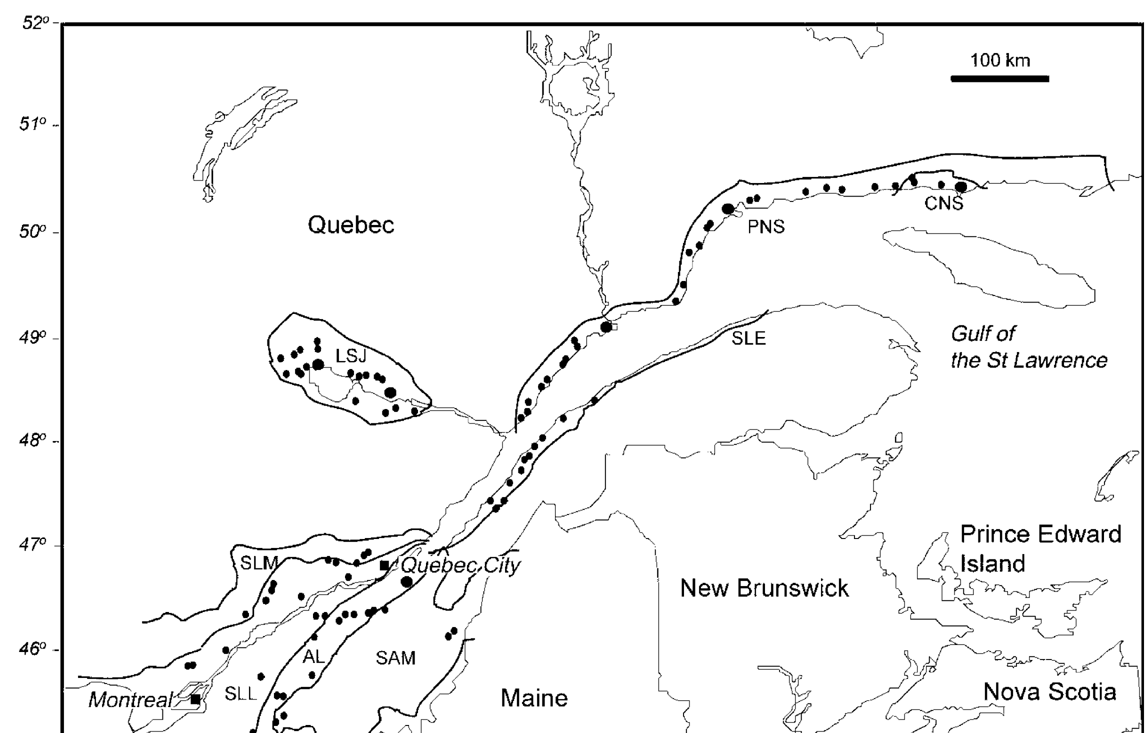

Fig. 1. Location of the 112 peatlands studied. Each dot represents one (small dots) or three to five (large dots) studied peatlands. Natural regions are indicated according to the following codes: LSJ, Lac Saint-Jean Lowlands; SLE, Southern Littoral of the Estuary; SLM, Southern Laurentian Mountains; AL, Appalachian Lowlands; SLL, St Lawrence Lowlands; PNS, Coastal Plain of the North Shore; CNS, Cuestas of the North Shore; SAM, Secondary Range of Appalachian Mountains. Limits of natural regions are approximate.

One hundred and twelve bogs (ombrotrophic peatlands) were selected from the Atlas of peatlands of southern Québec (Buteau, 1989), so that their number in each natural region was proportional to their abundance (Fig. 1). We measured peatland area on 1:15 000 aerial photographs, using a digital planimeter. Sampled peatlands ranged in size from 0.09 to 48.40 km^2 (median = 0.68 km^2).

3. Methods

3.1. Peatland birds and vegetation

In each peatland, we located a sampling station in a section representative of its physiognomy. In large peatlands (> 1000 ha), we placed two sampling stations separated by at least 1 km. Each sampling station was at least 200 m from the peatland edge (% trees > 5 m exceeding 50%), except in smaller peatlands, where we placed a sampling station approximately in the centre. We made a single bird survey at each sampling station during the breeding season of 1994 (from 27 May to 2 July 1994), progressing towards the North as was done for the Québec Breeding Bird Atlas (Gauthier and Aubry, 1996), to take into account differences in breeding time caused by arrival time and climatic conditions. We surveyed birds only under conditions with no rain or strong winds, using playbacks of bird songs to increase sampling efficiency and focus on territorial individuals (Johnson et al., 1981; Lynch, 1989). Song playbacks were broadcast at maximum volume using a tape recorder (Realistic model CTR-76) connected to a 2 watt loudspeaker (Realistic 40-1259B). The recording consisted of songs of 35 bird species previously observed in the bogs under study, and known to breed in wetlands (Godfrey, 1986). Species were sorted on the recording by increasing frequency of observation during a pilot study conducted the previous year, except for short-eared owl *Asio flammeus*, which was added at the end of the tape. Each song was repeated three times with intervening periods of 5 s of silence. A final silent period was added at the end of each species' set of songs, for a total of 60 s per species. Responses to playbacks were noted when a bird sang, called, or came to the speaker within three minutes after its conspecific vocalization started. Throughout the duration of the recording (35 min), we recorded all other birds estimated to be seen or heard inside the peatland. Birds in flight were recorded only if they were less than 10 m above ground.

We described vegetation according to the following strata: mosses, lichens, herbs, ericaceous or non-ericaceous shrubs, and trees (< 2 m, 2–5 m, > 5 m). The latter group was identified to the species level. We visually estimated the percent cover of each of the strata and of open water (pools) in a 100-m radius from the centre of the sampling station, allowing total percent cover to exceed 100%.

3.2. Regional species assemblages

The Atlas of breeding birds of southern Québec (Gauthier and Aubry, 1996) was used to determine which bird species nested around peatlands. Atlas data were collected during six consecutive breeding seasons from 1984 to 1989. Only records of probable or confirmed nesters were used, because of the larger sampling effort than in peatlands (> 8 h of survey per atlas square selected for analysis in this paper), which led to a large number of casual species in the Atlas database. We assumed that species breeding ranges did not change between the atlassing period and 1994. The atlas territory was divided according to a 10×10-km grid that followed the Universal Transverse Mercator (UTM) system. The 112 sampled peatlands were contained in 85 of these 10×10-km squares, which we termed "reference squares". For peatlands surveyed in more than one square, the reference square was the one that contained their largest number of sampling stations. For very large peatlands, reference squares were centred on sampling stations. We selected all squares adjoining those comprising at least one sampled peatland, and termed them "reference areas". Thus, for a given reference square, eight squares served for comparisons of birds present in peatlands (our data) with those present in surrounding landscapes. Due to the presence of water, however, fewer than eight squares were available for certain reference squares in the regions LSJ, SLE, PNS and CNS. Also, adjoining squares with less than 20% of land surface because of water or UTM zone limits were pooled with their closest neighbour. Poorly covered squares, i.e. with a count of species at least 20% less than its neighbours, were also discarded. After applying these constraints, 102 of the 112 peatlands sampled were amenable to comparisons with the surrounding region.

3.2.1. Similarities of bird assemblages between peatlands and surrounding landscapes

Owing to the large size and the relatively high sampling effort associated with reference areas, peatland avifaunas represented subsets of regional avifaunas, thus preventing the use of simple presence–absence of species for the analysis of avifaunal similarity. Thus, to obtain nontrivial measures of avifaunal similarity, we obtained semi-quantitative estimates of relative abundance of species in peatlands and associated reference areas. For each natural region, we calculated each species' relative frequency (number of occurrences divided by number of peatlands sampled in region) to create a dichotomic occurrence index. Species were classified as either common (occurrence ⩾50%) or uncommon (occurrence <50%). For birds in reference areas, we calculated species' relative frequencies for each set of eight (or fewer) atlas squares adjoining each sampled peatland, and not for entire natural regions. We assume that species' relative frequencies for peatlands and associated reference areas were comparable because each relative frequency was obtained *within* a given dataset, thus controlling for differences in sampling effort and area sampled.

We evaluated whether species frequencies of occurrence in peatlands and their surrounding landscape were similar with the Kolmogorov-Smirnov statistic for two samples ($n=102$ sites for each of the two samples). Similarities of bird species assemblages between peatlands and surrounding atlas squares were calculated with the Jaccard similarity index. We chose the Jaccard similarity index because it is not sensitive to sample size, and weights equally all species without regard for abundance, which was not reliable with the census method we used. We used the Tukey–Kramer method to assess the significance of all possible comparisons of bird assemblages, particularly to determine whether similarities in bird assemblages between peatlands and surrounding landscapes varied among regions. The Tukey–Kramer procedure is conservative, but well suited for samples of unequal sizes (Sokal and Rohlf, 1995).

3.2.2. *Similarities of peatland bird assemblages within natural regions*

We evaluated the similarity of bird assemblages between sample peatlands within six of the eight natural regions encompassed in the study area. The two remaining regions had too few sample peatlands to make comparisons meaningful. As with comparisons involving birds of peatlands and surrounding habitats, we ran multiple comparisons for all possible pairs of inter-region similarities using the Tukey–Kramer method.

Similarities do not allow identifying species that contribute to regional variation, so we also performed a correspondence analysis (CA). In this analysis, bird occurrences (presence/absence), reference squares (those with sample peatlands) and associated natural regions were projected in the same factorial space, allowing visualizing regional bird species associations.

3.2.3. *Changes in peatland vegetation structure along the geographic gradient*

We performed a principal coordinate analysis (PCoA) to evaluate whether peatland vegetation structure varied along a geographic gradient. PCoA allows the use of similarity coefficients other than Euclidean distance (van Tongeren, 1995), and performs well even for similarity matrices with many double zeros (Legendre and Legendre, 1998). Environmental variables were latitude, longitude, peatland size, and the set of vegetation data (ground cover of each stratum, including open water). To perform the analysis, data were standardized and distributed among eight classes for each variable. We calculated similarities between peatlands with the Gower index, because different types of descriptors can be used with this general index (Gower, 1971). We plotted similarities in the original multidimensional space vs. similarities in reduced space (Shepard, 1962), to evaluate whether the projection in reduced space accounted for a high fraction of the variance and whether original distances were correctly represented by the first dimensions (Legendre and Legendre, 1998).

4. Results

4.1. *Similarity of bird assemblages between peatlands and surrounding landscapes*

Regional species richness did not vary according to latitude in the study area ($r=0.4$, $n=6$, $P=0.38$). Nevertheless, in the southernmost region (SLL) bird assemblages in peatlands were more different from bird assemblages in surrounding landscapes than in most other regions (Fig. 2). Peatland avifaunas contrasted increasingly with regional ones from north to south or from undisturbed to managed landscapes ($r_s=0.94$, $n=6$, $P<0.01$). Similarities of bird assemblages between peatlands and surrounding landscapes were low, varying between 0.09 and 0.15. These low values resulted in part from the discrepancy between the number of bird species recorded in peatlands and their surroundings, the latter covering many habitat types, which increased species richness. However, peatland

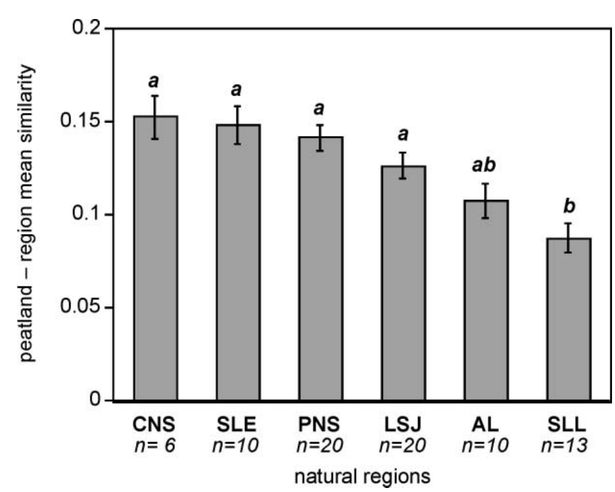

Fig. 2. Similarity of bird species between peatlands and surrounding landscapes within regions. Vertical lines represent standard errors. The same letter above bars indicates that regions did not differ at $P=0.05$ (Tukey–Kramer's test). See caption of Fig. 1 for natural region codes. Note that, from left to right, regions are ordered from north to south.

and surrounding bird assemblages were also very different not only because the former was a small subset of the latter, but also because of different species rankings by occurrence (KS = 0.647, $P = 0.0001$).

A total of 17 bird species were found significantly more often in peatlands than in surrounding landscapes in at least one 100-km^2 reference square (Table 1). However, only four bird species were found significantly more often in peatlands than in surrounding landscapes in more than 10% of the 85 reference squares: white-winged crossbill (8 times), Nashville warbler (12 times), Lincoln's sparrow (20 times) and palm warbler (28 times). White-winged crossbills were more common in peatlands than regionally in more than half the reference squares of the North Shore; Nashville warblers in one-third of the references squares of the North Shore and Southern Littoral of the Estuary. Lincoln's sparrows were far more common in peatlands than regionally in the St Lawrence Lowlands region (85% of the reference squares), in half of the reference squares of the Appalachian Lowlands, and one-quarter of the reference squares of the Secondary Range of Appalachian Mountains. Finally, palm warblers were typically found in peatlands in the Lowlands of Lac-Saint-Jean, the Secondary Range of Appalachian Mountains (common in peatlands vs. uncommon regionally in 100% of the reference squares in both regions), and also in 80% of the reference squares of the Appalachian Lowlands.

4.2. Similarities of peatland bird assemblages within natural regions

Similarities between peatland bird assemblages varied between 0.223 for the Cuestas of the North Shore and 0.385 for the Lowlands of the Lac Saint Jean (Fig. 3). These values were about twice as high as those calculated to compare bird assemblages in peatlands and surrounding habitats. Therefore, peatland avifaunas within regions were more similar to each other than to their regional avifauna. However, peatlands of the Cuestas of the North Shore were significantly less similar to one another than peatlands in other regions, because they supported many uncommon shorebirds or aquatic species with patchy distributions, such as common terns, common and red-throated loons, ospreys, or greater yellowlegs.

4.3. Changes in peatland vegetation structure along the geographic gradient

The PcoA highlighted a striking contrast between northeastern and southwestern peatlands, as shown by the correlation values between geographic variables and the first and third dimensions of the reduced space (Table 2). Northeastern peatlands were characterized by numerous, and often very large, pools. By contrast, peatlands in other parts of the study area lacked such large pools. Peatlands on the North Shore and the Cuestas also had fewer and, typically, smaller (<2 m high) trees. Otherwise, tree species remained identical over all the study area. Northern peatlands also were more subject to lichen colonization, had greater herb cover and less shrub cover. southeastern peatlands were covered by more trees, ericaceous shrubs, lichens and mosses, but less non ericaceous shrubs. The second dimension represented a gradient from wet to dry peatlands, which was evidenced by positive correlation with shrubs and lichens, and negative correlation with herbs, mosses and pools. The first three eigenvalues of the PCoA explained 15% of the model's variance. According to the scatter diagram, the projection in reduced space accounted for a high fraction of the variance and the relative positions of objects in the first three dimensions were similar to those in the multidimensional original space.

5. Discussion

5.1. Contribution of peatlands to local and regional avian diversity

Peatland bird assemblages were not mere subsets of those found in surrounding landscapes, but were comprised of several species uncommon outside peatlands. Here, we want to stress that the method we used was very conservative, as we compared bird data from a single season and small areas (sampled peatlands) to bird data from several years and much larger areas (200–800 km^2; atlas squares), which also included peatlands. Therefore, the power of detecting a species more common in peatlands than in the surrounding landscape was small compared to the converse (not finding a regionally found species in peatland). Nevertheless, 17 of the 102 bird species recorded in peatlands occurred more frequently in this habitat than they did among reference squares in the surrounding landscape.

The majority of species found mostly within peatlands are typically boreal, thus forming "islands" of boreal avifauna in regions otherwise dominated by more temperate species, especially in the Appalachian and Saint Lawrence lowlands (Gauthier and Aubry, 1996). This was the case for yellow-bellied flycatcher and purple finch (*Carpodacus purpureus*), which are characteristic of boreal coniferous forests (Erskine, 1977). For these species, the presence of peatlands could help maintain populations regionally, though this habitat might be suboptimal for them. Of the 17 peatland-associated species, three others are of special interest to regional conservation. Palm warblers are peatland specialists during the breeding season (Wilson, 1996), and most of the world population breeds in Canada's peatlands

Table 1
Avian species found significantly more often in peatlands than in surrounding landscapes (see text for details)[a]

English name	Scientific name	Code	Conservation score for:[b]					Frequency of occurrence (%)							
			Responsibility	Concern	Vulnerability	Trend	Trend uncertain	CNS (6)	SLE (10)	PNS (20)	LSJ (20)	AL (10)	SLL (13)	SAM (4)	SLM (2)
American bittern	*Botaurus lengitinosus*	AMBI	4	3	3	3	1	0	0	5	10	0	15	50	0
Red-tailed hawk	*Buteo jamaicensis*	RTHA	2	2	2	2	3	0	0	0	0	10	8	0	50
Ring-billed gull	*Larus delawarensis*	RBGU	–	–	–	–	–	50	0	0	0	0	8	0	0
Great black-backed gull	*Larus marinus*	BBGU	–	–	–	–	–	33	0	20	0	0	0	0	50
Common nighthawk	*Chordeiles minor*	CONI	1	2	1	3	3	0	0	0	5	10	0	0	50
Yellow-bellied flycatcher	*Empidonax flaviventris*	YBFL	5	3	3	3	3	17	40	10	10	0	8	75	0
Golden-crowned kinglet	*Regulus satrapa*	GCKI	4	3	2	3	3	0	10	10	0	0	0	0	50
Ruby-crowned kinglet	*Regulus calendula*	RCKI	4	3	2	3	3	17	80	35	60	40	23	75	0
Hermit thrush	*Catharus guttatus*	HETH	3	3	3	2	3	17	80	50	90	70	62	100	0
Nashville warbler	*Vermivora ruficapilla*	NAWA	3	3	3	3	1	33	90	80	100	90	92	100	0
Magnolia warbler	*Dendroica magnolia*	MAWA	5	3	3	3	3	33	80	65	55	60	15	75	0
Palm warbler	*Dendroica palmarum*	PAWA	5	3	3	3	3	17	20	25	70	70	46	50	0
Common yellowthroat	*Geothlypis trichas*	COYE	2	3	2	3	3	67	100	75	80	100	100	100	50
Northern cardinal	*Cardinalis cardinalis*	NOCA	1	3	3	3	1	0	0	0	0	10	0	0	50
Savannah sparrow	Passerculus sandwichensis	SASP	4	3	2	3	3	100	10	65	35	70	38	0	0
Lincoln's sparrow	*Melospiza lincolnii*	LISP	4	2	2	1	3	67	50	90	75	70	54	100	0
White-winged crossbill	*Loxia leucoptera*	WWCR	5	3	2	3	5	17	30	60	40	20	0	0	0

[a] Frequencies of occurrence (%) of bird species within peatlands in the different studied regions are based on the number of reference squares (within parentheses).
[b] 1 = lowest, 5 = highest. See details in Downes et al. (2000).

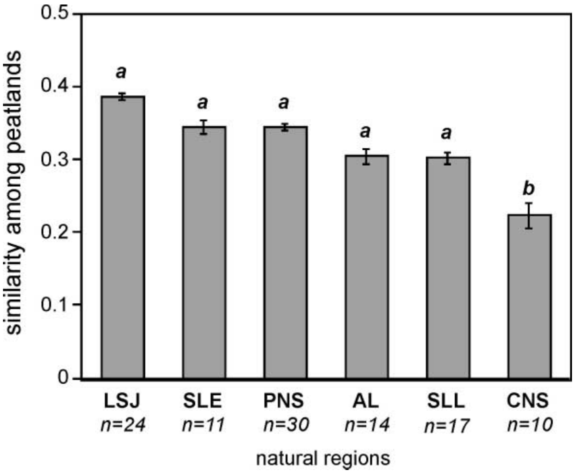

Fig. 3. Similarity of bird species assemblages among peatlands, for eight regions of Québec. Vertical lines represent standard errors. The same letter above bars indicates that regions did not differ at $P = 0.05$ (Tukey–Kramer's test). See caption of Fig. 1 for natural region codes.

Table 2
Coefficients of correlation between peatland characteristics and the first three principal coordinates according to the PCoA

Environmental variables	Principal coordinates		
	PCo1	PCo2	PCo3
Longitude (UTM)	−0.80**	−0.11 ns[a]	0.25**
Latitude (UTM)	0.58**	0.03 ns	−0.25**
Peatland area (ha)	0.04 ns	−0.13 ns	0.02 ns
Trees (% cover)	−0.40**	−0.01 ns	0.17*
Non-ericaceous shrubs (% cover)	−0.38**	−0.12 ns	−0.29**
Ericaceous shrubs (% cover)	−0.37**	0.60**	0.20*
Herbs (% cover)	0.25**	−0.61**	−0.05 ns
Lichens (% cover)	0.28**	0.48**	0.19*
Mosses (% cover)	−0.31**	−0.43**	0.18*
Open water (pools) (%cover)	0.64**	−0.22**	−0.06 ns

[a] ns, $P > 0.05$.
* $P \leqslant 0.05$.
** $P \leqslant 0.01$.

(Conservation responsibility score of 5; Table 1). Palm warblers were not only more commonly found in peatland than in other habitats throughout the study area, but their presence is also known to be more likely in large peatlands that are part of peatland networks (Calmé and Desrochers, 1999). Lincoln's sparrow is not as restricted to peatlands as palm warbler, but it nevertheless occurs almost exclusively in peatlands in the Lowlands of the Saint Lawrence River (Calmé and Desrochers, 1999), although the species is relatively widespread in the brushy and humid habitats of the boreal forest (Langevin, 1996). Thus, the contribution of peatlands to Lincoln's sparrows is far more important in the southern regions than in boreal regions. The importance of peatlands to white-winged crossbill is similar to that for Lincoln's sparrows, because in contrast to the regions we studied, this species can be found in a wide variety of ecosystems north of the Saint Lawrence lowlands. Furthermore, as palm warblers, white-winged crossbills are priority species for conservation according to Downes et al. (2000; Table 1).

Our study area encompassed eight natural regions, which comprised a wide array of ecosystems, ranging from deciduous broad-leaf forests in the south to black spruce forests in the north, and including shore habitats and agricultural ecosystems. It is no surprise that along this gradient, bird species varied greatly. Peatland physiognomy varied along this gradient (Table 2), but it was essentially due to peatlands of the North Shore, and especially those of the Cuestas. As suggested by the latter and similarity analyses, the variation in bird assemblages was probably closely related to structural variation in peatlands, which is consistent with Stockwell's (1994) finding that peatland vegetation structure is a good predictor of bird species occurrence. This is an important issue when selecting peatlands for conservation, or rehabilitating formerly exploited peatlands, because vegetation features within peatlands will set which species cannot be found.

The most parsimonious explanation for an increasing contrast between peatland and regional avifaunas from North to South can be found outside, rather than inside peatlands. Indeed, the peatland avifauna in the Cuestas could not differ much from that of the surroundings, because peatlands dominated the landscape at the spatial scale we selected. In this region, the low similarity between avifaunas in peatlands and surroundings probably resulted from markedly low similarity among peatland avifaunas themselves. On the other hand, peatlands in the St Lawrence Lowlands contrasted with the surrounding habitats (farmlands and deciduous forests). As a result, it was also the region where similarity between bird assemblages of peatlands and surrounding habitats was lowest.

5.2. Conservation of peatlands

Peatlands are not well represented in the worldwide system of protected areas (Ramsar Convention, 1996). In Canada, three sites have been recently recognized as Wetlands of International Importance, but together cover less than 10,000 ha. Only one National Park, Kouchibougac, in New Brunswick, supports a large area (3000 ha) consisting of peatlands. The Province of Québec also protects some 30,000 ha of peatland habitat (Poulin and Pellerin, 2001), but those areas are generally scattered in small patches (< 500 ha). Our study shows clearly southernmost regions are those where peatlands have most to offer towards regional avian diversity.

Virkkala et al. (1994) argued that the conservation status of a given location should be justified by its significance for certain species, either because an important proportion of their regional population is found at this location or because they are rare and vulnerable. Among the 17 species associated with peatlands in the present study, none is endangered. Furthermore, no southern peatland would likely support enough individuals of those species to justify in itself its protection. Despite the latter caveats, the case for conserving peatlands in "avianscapes" such as SLL where peatlands are rare and threatened is made stronger by our findings, given the commitment of governments to protect biodiversity at the regional level, and the presence of a substantial number of boreal and peatland specialists in those regions.

Despite the special concern for southernmost peatlands, it remains that both peatlands and their associated avifauna changed along the geographical gradient we sampled, and that peatland avifaunas were always very dissimilar to regional ones. Thus, special efforts should be made not only to conserve southern peatlands, but also to conserve them along the full biogeographical gradient as in other countries (e.g. Virkkala and Rajasärkkä, 2001).

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