

Artificial nest predation in bogs: Does peat harvest increase risk?¹

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Abstract: Bogs in southern Québec are facing significant and growing industrial pressure. Peat moss harvesting results in bog fragmentation and in edge increase between harvested areas and remaining natural patches. The objective of our study was to assess the effects of harvesting on nesting success of songbirds in adjacent undisturbed sites. We determined whether exposure of nests to predators was edge-dependent in harvested bogs and compared the risk of nest predation in harvested and undisturbed bogs. Over three summers, we placed a total of 480 artificial nests at various distances (≤ 450 m) from edges in five harvested and nine unharvested bogs. Mean nest predation rate was significantly higher (62.7%) and more variable in harvested bogs, compared to unharvested bogs (8.6%). However, we found no relation between nest fate and distance to exploitation edge in harvested bogs. We suggest factors associated with harvesting that may attract nest predators to remaining unharvested sites, thereby increasing risk of nest predation and ultimately lowering reproductive success.

Keywords: nest predation, bogs, edge effect, peat harvest, artificial nests.

Résumé : Les tourbières du Québec méridional font face à une pression d'utilisation significative et croissante. La récolte de la mousse de tourbe engendre le morcellement de cet écosystème et crée des bordures entre les sites exploités et les sites non perturbés avoisinants. L'objectif de cette étude était d'évaluer l'impact de l'exploitation sur le succès de nidification des oiseaux des sites non perturbés avoisinants. Ainsi, nous avons déterminé si la pression de prédation sur les nids dépendait de leur distance depuis la bordure dans les tourbières exploitées; nous avons aussi comparé les risques de prédation entre les tourbières exploitées et les tourbières non perturbées. Au cours de trois étés, nous avons placé un total de 480 nids artificiels à diverses distances (≤ 450 m) des bordures, dans cinq tourbières exploitées et dans neuf tourbières non perturbées. Le taux de prédation moyen était significativement plus élevé dans les tourbières exploitées (62,7 %) que dans les tourbières non perturbées (8,6 %). De plus, les taux de prédation ont démontré une grande variabilité entre les différentes tourbières exploitées. Le sort des nids ne dépendait pas de leur distance depuis la bordure dans les tourbières exploitées. Nous suggérons certains facteurs, associés à la récolte, qui pourraient attirer des prédateurs de nids et, par conséquent, augmenter le risque de prédation des nids, ce qui engendrerait une diminution du succès reproducteur.

Mots-clés : prédation de nids, tourbière, effet de bordure, récolte de tourbe, nids artificiels.

Introduction

Habitat loss is generally accompanied by fragmentation and an increase in edges (Ranney, Bruner & Levenson, 1981; Kroodsma, 1984; Laurance & Yensen, 1991). As the ratio between edge and area increases, habitat fragments and their wildlife communities are subject to a greater influence from the surrounding matrix (Angelstam, 1986; Nour, Matthysen & Dhondt, 1993). Breeding birds become particularly vulnerable to nest predators that are often associated with edges and man-induced changes in the environment (Ambuel & Temple, 1983; Wilcove, 1985; Andrén *et al.*, 1985; Andrén & Angelstam, 1988; Andrén, 1992). Because nest predation is usually the main cause of reproductive failure in breeding songbirds (Ricklefs, 1969; Martin, 1992), there is concern about the viability of avian populations in fragmented habitats (Askins, Lynch & Greenberg, 1990; Robinson *et al.*, 1995).

Studies in a variety of habitats have sought to understand relationships between edges, the species they harbor, and nest predation risk (deciduous forests: Gates & Gysel, 1978; prairies: Burger, Burger & Faaborg, 1994; conifer forest:

Rudnický & Hunter, 1993). The results of nest predation studies are as varied as the regions in which they were conducted, highlighting the need for habitat-specific approaches. Various explanations have been proposed for this lack of consistency, such as methodological differences (Paton, 1994; Major & Kendal, 1996), habitat characteristics such as landscape matrix (Angelstam, 1986), assemblage of predator species (Nour, Matthysen & Dhondt, 1993), and type of edge (Ratti & Reese, 1988; Yahner, Morrell & Rachael, 1989; Pasitschniak-Arts & Messier, 1995).

In southern Québec, ombrotrophic peatlands or bogs occur as naturally fragmented wetland ecosystems, usually bordered by forested habitat. Information concerning the breeding avifauna of these ecosystems is scarce (Clarke-Whistler *et al.*, 1983; Stockwell, 1994), and a large number of bogs have been reclaimed or harvested (Keys, 1992). Despite the relatively low species richness of bogs (Rocheffort & Quinty 1996), their ecological importance is undeniable and is owed to their characteristic species composition, and to specialized species which are highly dependent on bog habitats (Clarke-Whistler *et al.*, 1983). This is exemplified by the palm warbler (*Dendroica palmarum* Gmelin), which in southern Québec nests almost exclusively in bogs (Ibarzabal & Morrier, 1995).

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During harvesting for peat moss, all living vegetation is removed, leaving only bare peat moss. This process produces large open areas in the center of the bog and creates new edges between harvested areas and the remaining natural areas that surround them. In a three-year field experiment covering most of southern Québec, Canada, we used artificial nests to measure the association between both presence and distance of peat harvest and risk of nest predation in adjacent natural sites.

Material and methods

STUDY AREAS

The study was conducted during the summers of 1994, 1995, and 1996, in five harvested and nine unharvested bogs (Table I, Figure 1). Bogs ranged in size from 173 ha to 2251 ha. In 1994, artificial nests were placed in three harvested bogs (1, 2, 3; Table I, Figure 1) between May 23 and 27. In 1995, the experiment was repeated in the same three harvested bogs used in 1994, as well as in two new harvested bogs (4, 5; Table I, Figure 1), and in five unharvested bogs (6, 7, 8, 9, 10; Table I, Figure 1). The experiment was initiated between May 18 and May 23 in harvested bogs, and from June 13 to June 22 in natural bogs (see discussion). In 1996, artificial nests were set out between May 31 and June 11 in the five harvested bogs used in 1995, as well as in two of the natural bogs used in 1995, and in four new natural bogs (11, 12, 13, 14; Table I, Figure 1).

Bog vegetation was mainly composed of black spruce (*Picea mariana* [Mill.] BSP.), larch (*Larix laricina* [Du Roi] K. Koch), ericaceous shrubs such as *Ledum groenlandicum* Retzius and *Kalmia angustifolia* L., and grasses, mainly *Carex spp.* and *Eriophorum spp.* Nesting songbirds typically found in these bogs included palm warbler, common yellowthroat (*Geothlypis trichas* L.), hermit thrush (*Catharus guttatus* Pallas), white-throated sparrow (*Zonotrichia albicollis* Gmelin), Lincoln's sparrow (*Melospiza lincolnii* Audubon), and savannah sparrow (*Passerculus sandwichensis* Gmelin). Avian nest predators observed near our study sites included blue jay (*Cyanocitta cristata* L.), American crow (*Corvus brachyrhynchos* Brehm), common raven (*Corvus corax* L.), and common grackle (*Quiscalus quiscula* L.).

TABLE I. Study sites in Québec, Canada

No	Locality	Location	Area (ha) ^a	Status	Years	Dominant landscape
1	Saint-Charles	46° 47' N; 71° 00' W	343	Harvested	1994, 1995, 1996	Agricultural
2	Rivière-Ouelle	47° 29' N; 69° 57' W	470	Harvested	1994, 1995, 1996	Agricultural
3	Sainte-Marguerite-1 ^b	48° 49' N; 72° 08' W	2251	Harvested	1994, 1995, 1996	Agricultural
4	Cap Bon-Désir	48° 19' N; 69° 28' W	275	Harvested	1995, 1996	Forested
5	Manicouagan	49° 08' N; 68° 15' W	1512	Harvested	1995, 1996	Forested
6	Villeroy	46° 23' N; 71° 53' W	843	Unharvested	1995, 1996	Forested
7	Sainte-Marie-de-Blanford	46° 19' N; 72° 11' W	527	Unharvested	1995, 1996	Mixed
8	Sainte-Anastasie	46° 22' N; 71° 35' W	457	Unharvested	1995	Forested
9	Dosquet	46° 30' N; 71° 31' W	195	Unharvested	1995	Agricultural
10	Sainte-Croix	46° 36' N; 71° 43' W	222	Unharvested	1995	Agricultural
11	Grande Plée Bleue	46° 47' N; 71° 04' W	364	Unharvested	1996	Agricultural
12	Sainte-Marguerite-2 ^b	48° 47' N; 72° 11' W	2251	Unharvested	1996	Agricultural
13	Escoumins	48° 24' N; 69° 21' W	173	Unharvested	1996	Forested
14	Pointe-aux-Outardes	49° 06' N; 68° 22' W	1083	Unharvested	1996	Forested

^a This measure takes into account only the undisturbed portion of the bogs.

^b The Sainte-Marguerite bog was the largest in the study group, with harvested and unharvested sites separated by approximately 6 km. We thus considered these two sites to be independent.

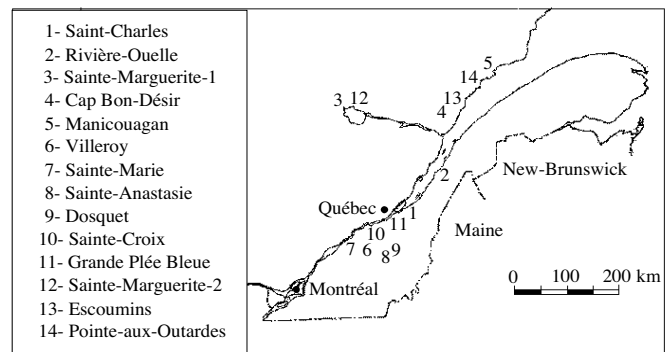


FIGURE 1. Geographic location of the 14 bogs in the experiment.

Mammalian predators were striped skunk (*Mephitis mephitis* Schreber), raccoon (*Procyon lotor* L.), red fox (*Vulpes vulpes* L.), red squirrel (*Tamiascurius hudsonicus* Erxleben), and a variety of mice and voles.

ARTIFICIAL NESTS

In each study site, artificial nests made of dry grasses with two Japanese quail (*Coturnix coturnix japonica* L.) eggs, were laid out on the ground along two transect lines. Transect lines were located at least 500 m apart, and were perpendicular to harvest edges in harvested bogs or forested edges in natural bogs. Nest transects extended from edges, 450 m into undisturbed bog surfaces. The first nest was placed on the edge, *i.e.*, at 0 m and subsequent nests were placed at intervals of 50 m, for a total of 10 nests on each transect and 20 nests in each bog. Altogether, we placed a total of 480 nests over the course of the experiment.

Nests were marked by flags 3 m to the north, and metal tags were hidden under nests to facilitate relocation if they were missing or damaged. Nest fate was determined 14 days after placement. Fourteen days is representative of the typical incubation period for bog nesting songbirds. We considered a nest to have suffered predation if one or more eggs were missing from the nest or damaged. Vegetation structure was described in a radius of 3 m centered around the nest, by visually estimating percent of coverage of the following strata: forbs and other herbaceous plants, ericaceous shrubs, trees < 2 m, trees 2–5 m, and trees > 5 m.

HABITAT USE BY AVIAN PREDATORS

In 1996, we censused avian predators in five unharvested and 16 harvested bogs. All bogs in which we conducted nest experiments in 1996 were censused, except Sainte-Marguerite-2. Censuses were done during the course of nest installation or subsequent visits by counting the number of individuals seen or heard during each interval of time an observer spent in a bog. We performed a one-tailed Mann-Whitney *U*-test to determine if the number of individuals recorded per minute was greater in harvested than in unharvested bogs.

STATISTICAL ANALYSES

We performed two distinct nest predation analyses. First, we determined if the occurrence of nest predation was dependent on bog type (harvested *versus* undisturbed) using a logistic regression, with data from 1995 and 1996. 1994 was excluded from this analysis because of the absence of data from undisturbed bogs. We considered an independent observation to be the proportion of nests that suffered depredation after 14 days in each of the bogs in each year ($n = 21$ bogs). Data from a bog that was sampled in both 1995 and 1996 were considered to be independent since there was no strong correlation between results from one year to the next in bogs that had been sampled in both years ($r_s = 0.19$, $n = 7$ bogs). Second, with logistic regression, we examined the effects of nest distance to peat harvest, vegetation structure around the nests, and sites (individual bogs), using the data from harvested bogs (1994, 1995, and 1996) with predation rates between 10% and 90% ($n = 6$ bogs). Bogs with predation rates under 10% and above 90% were not included in the analysis since the outcome of the nests within these bogs showed little variability, and therefore they could not provide any information as to the effects of distance to peat harvest, or vegetation structure.

Results

EFFECT OF BOG TYPE

Artificial nests in harvested bogs suffered high levels of predation in the first two years of the study, with rates of 72% (43/60) and 87% (87/100) for 1994 and 1995, respectively. In 1996, the predation rate was lower, with 33% of nests ($n = 100$) lost to predation, bringing the overall predation rate for harvested bogs to 62.7%. Nests in unharvested bogs experienced a predation rate of 8.6% over the course of two years, with rates of 9.0% (9/100) in 1995 and 8.3% (10/120) in 1996.

Logistic analysis produced a model with an adjusted $R^2 = 0.53$ (Nagelkerke, 1991). There was a strong bog type \times year interaction ($\chi^2 = 17.3$, $df = 1, 17$, $p < 0.001$). In both 1995 and 1996, however, predation rates were higher in harvested than in unharvested bogs (Figure 2). Nest predation rates among harvested bogs were more variable than among unharvested bogs ($F = 15.98$, $df = 9, 10$, $p < 0.005$).

TABLE II. Avian nest predators observed in bogs in 1996

	Blue jay	Common grackle	American crow	Raven	Observation time (min.)	Predators/hour
Harvested	4	49	36	24	4946	1.68
Unharvested	1	32	9	2	1699	1.56

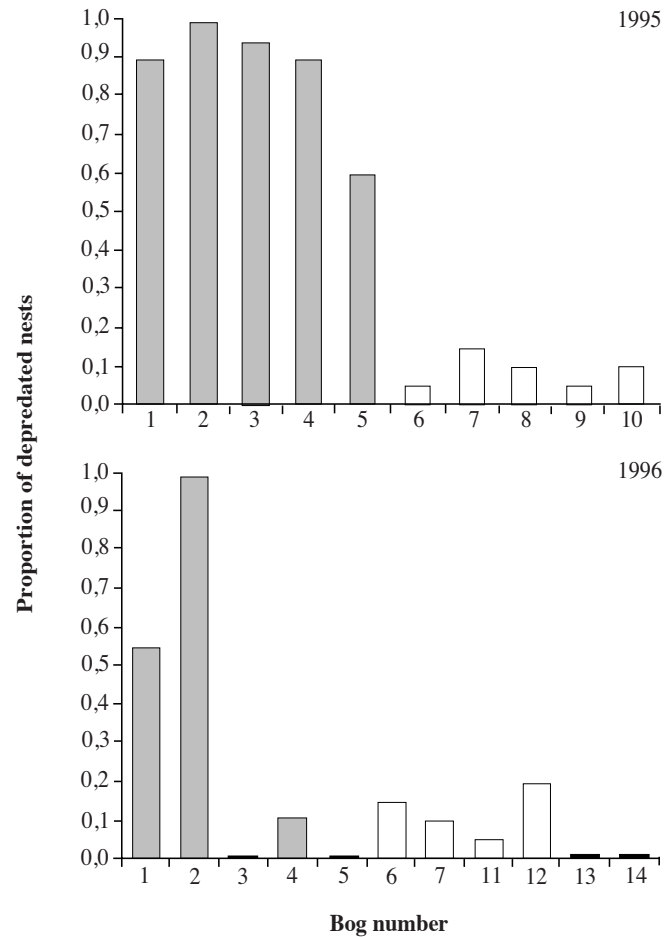


FIGURE 2. Rate of nest depredation in harvested and undisturbed bogs in 1995 and 1996. Hatched bars represent harvested bogs and open bars represent unharvested bogs. See Table I for descriptions of bogs.

This result is exemplified by the data from 1996 in which two of the five harvested bogs (Sainte-Marguerite-1 and Manicouagan) did not lose any nests to predation, whereas in one bog (Rivière-Ouelle), the predation rate was 100%. Furthermore, we observed considerable yearly differences in the depredation rates of four of the five harvested bogs. Sainte-Marguerite-1, for example, experienced high rates of nest predation in 1994 and 1995, whereas in 1996 no nests were lost to predators.

Despite the variation in nest predation rates, we found no difference between harvested and unharvested bogs in numbers of avian predators observed (Mann-Whitney *U*-test = 32.0, $p = 0.3$; Table II).

EFFECT OF DISTANCE, VEGETATION, AND SITES

To assess the effects of distance, vegetation, and sites, variables were entered into the regression model in three separate blocks. First we entered sites (individual bogs) as a categorical covariable which accounted for the combined

effects of the six bogs that were retained for the analysis. We then entered the five vegetation variables, and finally distance of nest to peat harvest. The variation in predation rates amongst harvested bogs was strong ($\chi^2 = 55.5$, $df = 5$, $114 p < 0.001$). After controlling for sites, vegetation variables were still correlated with nest predation ($\chi^2 = 12.6$, $df = 5$, $109 p < 0.05$). For all vegetation variables, cover was lower around depredated nests than around undepredated nests (Table III). Small trees (< 2 m) accounted for most of the effect of vegetation. After controlling for sites and vegetation, we found that distance of nest to peat harvest did not contribute to nest predation rate ($\chi^2 = 0.03$, $df = 1$, $108 p = 0.88$). The complete regression model had an adjusted $R^2 = 0.58$ (Nagelkerke, 1991).

Discussion

Overall, risk of nest predation was greater in harvested than unharvested bogs. A heightened risk of nest depredation will ultimately translate into lower nesting success (Ricklefs, 1969; Martin, 1992), and we conclude that peat harvesting is likely detrimental to this ecosystem's breeding birds. Furthermore, nest predation risk varied strongly among study sites (bogs). Part of this variability can be attributed to the geographic position and landscape surrounding the bog. The two harvested bogs located furthest north and surrounded mainly by a forested landscape (Cap Bon-Désir and Manicouagan), experienced lower depredation rates than the two southernmost harvested bogs surrounded by an agricultural landscape (Saint-Charles and Rivière-Ouelle). Few other studies have documented spatial heterogeneity in predation levels (Reitsma, Holmes & Sherry, 1990; Marini, Robinson & Heske, 1995). Spatial heterogeneity could result from small sample sizes, although unharvested bogs, with a comparable number of sites, experienced little spatial variability. Reitsma, Holmes & Sherry (1990) found uneven rates of nest predation between study plots and attributed this variation to patchily distributed nest predators and possibly to concentrated predation events when most nests on a plot were disturbed by a single nest predator. In the present study, spatial and yearly variations in predator distribution, density, and species composition seemed to occur at a greater rate in harvested bogs. This could account for their lower stability and predictability than their unharvested counterparts.

The higher risk of nest depredation in harvested bogs indicates that a factor unique to, or more prevalent in, these bogs increased predation levels. Counts of avian nest predators did not differ significantly between harvested and unharvested bogs, suggesting that mammalian predators were responsible for the difference in predation rates between harvested and unharvested sites. We hypothesize that the daily presence of humans working in harvested area of the bogs attracted higher numbers of mammalian nest predators. Increased depredation rates have been associated elsewhere with human activities, and particularly with agriculture (Andrén *et al.*, 1985; Angelstam, 1986; Andrén, 1992). Moreover, once a bog has been harvested, it becomes easier for mammals to penetrate into the undisturbed areas of the bog via the harvested surfaces. Furthermore, the proximity of harvested areas drains part of the remaining

TABLE III. Effect of vegetation within 3 m on nest predation risk in harvested bogs in 1994, 1995 and 1996

	b^a	SE	Mean percent cover		
			predation	no predation	p
Trees > 5 m	-0.67	4.712	0.0	0.4	0.81
Trees 2-5 m	-0.09	0.055	1.0	4.5	0.10
Trees < 2 m	-0.03	0.015	12.8	17.3	0.05
Herbaceous	-0.02	0.021	11.1	17.0	0.32
Ericaceous	0.01	0.016	46.3	49.5	0.26

^a Parameter estimate from logistic regression.

undisturbed areas (Poulin, Rochefort & Desrochers, 1999) and dry surfaces may also facilitate penetration by terrestrial predators. In contrast, unharvested bogs may be more difficult for predators from surrounding forests to enter, since the ecotone between the two habitats often consists of densely vegetated (*e.g.*, reeds, alder) swampy areas known as the lagg zone (National Wetlands Working Group, 1988). This area may prove to be an obstacle for mammalian predators, and thus lower their numbers in bogs. Elsewhere, nest predation by mammalian predators has been reported to be lower in habitats with denser vegetation (Pasitschniak-Arts & Messier, 1995).

In 1995, there were initial differences between undisturbed and harvested sites, specifically in geographic position and timing of the experiment. Unharvested bogs were located further south than most harvested bogs and were mainly surrounded by agricultural land. This could have caused a bias in favor of higher predation levels in unharvested bogs (Andrén *et al.*, 1985; Angelstam, 1986), *i.e.*, a result opposite to that which we observed. It can also be argued that the later date of the experiment in unharvested bogs in 1995 could have resulted in lower predation as a consequence of changes in numbers and/or behaviors of predators. Previous studies have reported lower predation rates late in the breeding season (Yahner & Mahan, 1996; Yahner & Cyphe, 1987), although in Maine, Rudnický & Hunter (1993) found that nest predators were still active in early July. In southern Québec, crows and ravens remain on breeding territories until at least the first week of July (Pelletier, 1995; Roy & Bombardier, 1995), suggesting that they remained active throughout our experiment. Little is known, however, about an effect of season on ground predator activities in bogs. Sampling disparities between harvested and unharvested bogs were removed in 1996, and although predation rates in harvested bogs were lower than in the two previous years, they remained significantly higher than the rates obtained in undisturbed bogs.

In general, nests surrounded by greater cover are less likely to be depredated (Yahner & Scott, 1988; Martin, 1992; Leimgruber, McShea & Rappole, 1994). This finding was corroborated by our results. Vegetation was related to nest predation, and percent cover of all vegetation variables was higher around nests that had not suffered depredation. Small trees (mainly black spruce and larch) provide vertical layering and likely conceal nests from visual predators. Furthermore, high densities of small shrubs (in this case ericaceous shrubs and dwarfed trees) may deter ground predators, since they hinder their travel and foraging movements (Yahner & Wright, 1985).

The limitations of artificial nest experiments (Major & Kendal, 1996; Wilson, Brittingham & Goodrich, 1998), dictate caution in the interpretation of our results. Nonetheless, we concur with the critiques that this method remains a valuable tool for detecting major differences in nest predation risk. Given our study's broad geographical scope and duration, and its implication for conservation, we conclude that peat harvesting presents an additional risk to birds nesting in adjacent natural sites. These findings lead us to question the quality of harvested bog remnants as productive wetlands for nesting songbirds, and warrant the necessity for further studies to identify nest predators and thus acquire a better understanding of the relationship between breeding birds and nest predators in bogs.

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