EFFECTS OF A TRANSMISSION LINE ON BIRD POPULATIONS IN THE RED LAKE PEATLAND, NORTHERN MINNESOTA

GERALD J. NIEMI AND JOANN M. HANOWSKI

Lake Superior Basin Studies Center and Department of Biology, University of Minnesota, Duluth, Duluth, Minnesota 55812 USA

ABSTRACT.—The effects of a 500-kV transmission line on bird populations were assessed by comparing paired treatment areas [which included a transmission line and right-of-way (ROW)] with similar control areas in six different habitat types during the breeding and migration seasons. Habitat structure was measured to examine the inherent differences between control and treatment areas. Using two census methods, territorial mapping and transect counts, we determined that Sedge Wrens and LeConte's Sparrows had lower breeding-population densities in treatment areas than in control areas. LeConte's Sparrows and Connecticut Warblers occurred at greater mean distances from the transmission line in treatment areas than from a similarly positioned line in control areas. Fifteen paired *t*-tests (five habitats in 3 yr), in which territorial mapping data were used, revealed that community densities were lower in one treatment habitat (high shrub) in 1 of 3 yr ($P < 0.05$). A two-way analysis of variance with transect counts, however, was not confirmatory when yearly variation was included. Transect counts revealed lower population densities in one treatment habitat (low shrub) in 2 of 3 yr ($P < 0.05$). In contrast, we observed greater species richness ($P < 0.05$) in two treatment habitats (closed spruce and sedge fen) than in controls. Treatment habitats were most similar in habitat structure to their paired control habitats, but each habitat of the pair was significantly different ($P < 0.05$) from the other in at least 2 of 10 habitat characteristics analyzed. We suggest that the avian differences observed between paired areas were primarily attributable to (1) the inherent habitat differences between control and treatment areas, and (2) the new habitat created under the transmission line. Our data indicated negligible effects of this transmission line on bird populations, but interpretations are difficult, because the effects varied with (1) habitat, (2) season, and (3) method considered. Postimpact studies, which compare control and treatment areas, are less effective than before-and-after studies, because differences in habitat structure exist between any two areas. *Received 9 May 1983, accepted 6 February 1984.*

MANY investigators (e.g. Anderson et al. 1977, Stahlecker 1978, Lee and Griffith 1978, Anderson 1979, Lee et al. 1979, Meyers and Provost 1979, Stapleton and Kiviat 1979, Bell 1980, Kroodsma 1982) have studied the effects of transmission lines on bird populations, but few (e.g. Meyers and Provost 1979) have attempted to test these effects specifically. We examined postimpact effects on bird populations by comparing treatment areas, or those with a transmission line and right-of-way (ROW), with similar control areas. Because birds are thought to select their breeding habitats on the basis of vegetation structure (Lack 1933, Hildén 1965, James 1971, Anderson and Shugart 1974), we also examined the habitat similarity between control and treatment areas. We assumed that the effects of the transmission line on bird populations consisted of vegetation changes due to ROW clearing, audible noise generated from electrical transmission, and the presence of the towers and lines, but we did not consider bird collisions with the transmission line. We tested for differences between treatment and control areas in (1) densities of individual species; (2) distances of species territories from the transmission line as a measure of repulsion or attraction effects; (3) community composition, as measured by the number of species (richness) and density; and (4) vegetation structure.

METHODS

Study areas.—The Red Lake Peatland (about 48°N, 95°W) is about 1,500,000 ha and lies in the bed of Glacial Lake Agassiz (Wright 1972). The Peatland has little relief (less than 1 m/km), and its vegetational characteristics are presumably related to drainage patterns and water chemistry (Heinselman 1963, 1971; Glaser et al. 1981).

The ROW was cleared in 1979 to a width of 55 m in forested areas and 30 m in other areas. The transmission line, erected during the winter of 1979–1980, spans an area from northern Manitoba to eastern Minnesota. Towers, aluminum structures (delta configuration) with a single foundation anchor and four guy wires, are about 46 m high. Distances between towers vary from 366 to 427 m, and the minimum clearance between ground and conductors is 11 m.

Following an aerial reconnaissance of the sighting line before placement of the transmission line, we identified six habitat types for treatment areas. These were (1) sedge fen, (2) low shrub, (3) high shrub, (4) open black spruce (*Picea mariana*) forest, (5) closed black spruce forest, and (6) tamarack (*Larix laricina*) forest. The first five habitat types have been previously described (Niemi 1983, Niemi et al. in press). The tamarack forest was dominated by tamarack trees (3–12 m high). There were also scattered black spruce trees, a mixed-shrub layer of willow (*Salix* spp.), birch (*Betula papyrifera* and *B. pumila*), and alder (*Alnus* spp.), a dense forb layer (primarily Ericaceae), and an extensive ground cover of moss. We selected control areas that were similar to the treatment areas in vegetational structure and plant-species composition. Control areas were adjacent to but not contiguous with treatment areas and at least 175 m from the transmission line.

Bird censuses.—We used two bird-censusing methods, territorial mapping (Williams 1936, Robbins 1978) and line transects (Emlen 1971, Järvinen and Väisänen 1975), during the breeding season but only line transects during the migration season to assess bird populations. Plots in treatment areas for territorial mapping were centered over the transmission line and were as large and square as the habitat would allow. All plots were at least 25 m from another habitat type and paired plots were equal in size and shape. Plot sizes were 15 ha in the sedge fen, 10 ha in the low shrub, 12.5 ha in the high shrub, 6 ha in the open black spruce, and 17.5 ha in the closed black spruce. No plots were established in the tamarack forest, because access to this area was difficult. We censused plots and interpreted territorial mapping data following the guidelines of the International Breeding Bird Census Committee (Anonymous 1970). We censused each plot eight times from mid-May to mid-July in 1980 and 1981 (Nevers et al. 1981, Hanowski et al. 1982). In 1982 seven censuses were completed in the open spruce and high shrub habitats and eight censuses in the other types between mid-May and 24 June (Hanowski and Niemi 1983). Daily census routes within a mapping plot were 100 m apart, and routes were shifted by 50 m on alternate census days to equalize coverage within a plot.

Transect lines ran under the transmission line in treatment areas and in the same relative position through the territorial mapping control plots. Transect lines were 1 km long, except in the low shrub and open spruce habitats, where they were 0.6 km and 0.4 km, respectively. Transect counts were run and divided into the following periods for analyses: (1) 5 fall migration censuses between mid-July 1979 and late September 1979 (pre-transmission-line placement); (2) 4 spring migration censuses between late April 1980 and mid-May 1980; (3) 4 fall migration censuses between late July 1980 and mid-September 1980; (4) 3 spring migration censuses between late April 1981 and mid-May 1981; and (5) 4 breeding censuses between mid-May and mid-July in 1980, 1981, and 1982.

All census data were gathered in early morning hours (0430–1030) on days without precipitation and with wind speeds less than 20 km/h. All censuses in paired habitat types were gathered simultaneously (±5 min); observers and directions were alternated for consecutive counts. The rate of movement in all censuses was 17 m/min in the low shrub, high shrub, open spruce, and closed spruce, and 20 m/min in the sedge fen.

Statistical analyses: territorial mapping data.—Differences in species densities between paired control and treatment plots were tested for each year with a paired *t*-test. We examined repulsion from or attraction to the transmission line of individual species by comparing distances from the transect line to the center of a species' territory in paired plots. Greater distances in treatment plots indicated repulsion from the transmission line, whereas lesser distances indicated attraction. We used two-way analyses of variance to identify differences in these distances between paired plots and between years. All statistical analyses were calculated with the Statistical Package for the Social Sciences (Nie et al. 1975).

Statistical analyses: transect data.—We examined control and treatment areas for differences in (1) number of individuals (those species with >25 observations in at least one paired transect for the breeding seasons), (2) total number of individuals, and (3) total number of species observed along each transect. To obtain replicates, each transect was divided into 100-m segments with a 25-m buffer between each segment. We included all observations up to 125 m laterally from the transect; therefore, each segment of the transect covered a rectangular area of 100 × 250 m (2.5 ha). We used two-way analyses of variance with the number of individuals or species observed during the census periods to examine differences between paired transects and between years for transects 1 km long. For transects less than 1 km, we used Mann-Whitney *U*-tests. Analyses were separated into breeding and migration periods.

Habitat data.—Point samples were randomly selected and gathered within each study plot in July of 1980 and 1981 [a method modified from Wiens (1969) and Wiens and Rotenberry (1981) and fully described in Niemi (1983) and Niemi and Hanowski (MS)]. Briefly, for these point samples we: (1) estimated the mean overall height (m) of the predominant vegetation in a 10-m-radius circle surrounding the point; (2) estimated the density of trees (>2.5 cm dbh), shrubs (those >30 cm high but <2.5 cm dbh), forbs (mostly Ericaceae species and those >10 cm high), and graminoids (hereafter termed sedges because they were predominant) with the point-centered quarter method (Cottam and Curtis 1956); (3) counted the number of contact hits of shrubs (including trees), forbs, and sedges at 10-decimeter intervals on a 10-mm-diameter rod dropped from the ends of four diagonals (see Wiens 1969); (4) measured the height (cm) of the four shrubs measured in (2) above; and (5) estimated the percentage of green vegetation <10 cm high (mostly moss) in the m^2 surrounding the point. We used 10 habitat variables: overall height, tree density, shrub density, forb density, sedge density, percentage ground cover, shrub height [mean of four shrubs measured in (4)], and the total number of shrub hits, forb hits, and sedge hits in the 0-30-cm height interval. We used Wilks stepwise discriminant function analysis (DFA) (Tatsuoka 1971) to identify differences in vegetation structure among all plots and between paired control and treatment plots. Point samples within the ROW of the closed black spruce treatment plot were not included in these comparisons. No vegetation data were gathered in the tamarack habitat. In other habitats, clearing was minimal and limited to the tall shrubs in the ROW. Therefore, inherent differences between paired areas were analyzed in the habitat comparisons.

RESULTS

Territorial mapping.—Species-composition differences existed between each paired control and treatment plot (Table 1), but paired t-tests revealed that densities were lower ($t = 2.6$, df = 10, $P < 0.05$) only in the high-shrub treatment area in 1981 (Table 1). This difference was primarily due to higher densities of Sedge Wrens (*Cistothorus platensis*), Common Yellowthroats (*Geothlypis trichas*), Bobolinks (*Dolichonyx oryzivorus*), and LeConte's Sparrows (*Ammodramus leconteii*) in the control plot than in the treatment plot. In the closed spruce habitat, ROW clearing created suitable conditions for Eastern Kingbirds (*Tyrannus tyrannus*), Savannah Sparrows (*Passerculus sandwichensis*), and LeConte's Sparrows. This may have resulted in lower populations of some forest-dwelling species in the treatment plot [e.g. Hermit Thrush (*Catharus guttatus*) and Nashville (*Vermivora ruficapilla*), Yellow-rumped (*Dendroica coronata*), and Connecticut (*Oporornis agilis*) warblers], but there was no trend, because some forest-dwelling species had higher populations in the treatment plot [e.g. Yellow-bellied Flycatcher (*Empidonax flaviventris*), Boreal Chickadee (*Parus hudsonicus*), and Palm Warbler (*Dendroica palmarum*)].

Connecticut Warblers in the closed spruce and LeConte's Sparrows in the low shrub were at greater mean distances from the transect line in treatment plots than in control plots (Table 2). Results from other habitats (e.g. sedge fen and high shrub) where LeConte's Sparrows occurred, however, were inconsistent with these findings.

Transect counts.—We observed fewer Connecticut Warblers, Sedge Wrens, and LeConte's Sparrows, but more Yellow Warblers (*Dendroica petechia*), in treatment transects than in control transects (Table 3). Significantly fewer Sedge Wrens were present in treatment than in control areas in 2 of the 3 habitats where they occurred, and, although there was no significant difference between plots in the third habitat (sedge fen), this trend was upheld (Table 3). Fewer observations of LeConte's Sparrows in treatment transects in 2 of the 4 habitats where they occurred suggested a similar pattern.

More species were observed in treatment transects during the breeding season in the closed spruce and sedge fen habitats, whereas more individuals were observed in the low shrub control transect in 1981 and 1982 (Table 4). The higher populations in the low shrub control area were attributable to high populations of Sedge Wrens and LeConte's Sparrows (e.g. see Table 1). The greater number of species in the closed spruce treatment area was at least partially attributable to the colonization of the ROW by several species.

The number of species observed on the transects was lower during the 1979 fall migration period in the high shrub treatment area than in the control area (Table 5). During the 1980 spring, however, there were more individuals observed in the high shrub treatment area than in the control area. Fewer individuals were observed in the low shrub treatment transect during the fall of 1980 (Table 5), which was consistent with some of the observations made during the breeding season. In general, few patterns were evident during the migration periods.

Habitat differences between control and treatment plots.—The DFA of all plots revealed that in all habitats treatment areas were most similar to control areas (Fig. 1). DFA between each paired

TABLE 1. Mean population densities (pairs/10 ha) and ranges (in parentheses) in the control (C) and treatment (T) plots for five habitat types over a 3-yr period (1980–1982) based on territorial mapping.

Species	Habitats									
							Spruce			
	Sedge fen		Low shrub		High shrub		Open		Closed	
	C	T	C	T	C	T	C	T	C	T
Mallard (*Anas platyrhynchos*)			0.3 (0–1.0)	0.3 (0–1.0)			0.6 (0–2.0)		0.2 (0–0.6)	
American Bittern (*Botaurus lentiginosus*)					1.0 (0.6–1.6)	0.3 (0–0.8)				
Yellow Rail (*Coturnicops noveboracensis*)					0.8 (0.8–1.6)	0.3 (0–0.8)				
Common Snipe (*Gallinago gallinago*)					0.8 (0.8)	1.1 (0–2.4)				
Northern Harrier (*Circus cyaneus*)									0.3 (0–1.0)	
Eastern Kingbird (*Tyrannus tyrannus*)							1.3 (0–2.0)			0.2 (0–0.6)
Yellow-bellied Flycatcher (*Empidonax flaviventris*)							0.2 (0–0.5)		1.5 (1.2–1.7)	1.9 (1.1–2.3)
Alder Flycatcher (*Empidonax alnorum*)					2.6 (0.8–4.5)	3.0 (1.6–5.1)				
Tree Swallow (*Tachycineta bicolor*)						0.3 (0–0.8)				
Blue Jay (*Cyanocitta cristata*)									0.1 (0–0.2)	0.6 (0.5–0.6)
Gray Jay (*Perisoreus canadensis*)									0.6 (0.6)	0.6 (0.6)
Boreal Chickadee (*Parus hudsonicus*)									0.2 (0–0.5)	0.5 (0.6–1.0)
Black-capped Chickadee (*Parus atricapillus*)					0.3 (0–0.8)	0.3 (0–0.8)				

TABLE 1. Continued.

Species	Sedge fen C	Sedge fen T	Low shrub C	Low shrub T	High shrub C	High shrub T	Spruce Open C	Spruce Open T	Spruce Closed C	Spruce Closed T
Sedge Wren (*Cistothorus platensis*)	9.1 (5.3–13.8)	4.0 (0.7–6.0)	19.6 (15.0–23.7)	2.6 (1.0–5.3)	22.4 (19.2–28.6)	17.1 (16.0–19.2)				
Veery (*Catharus fuscescens*)						1.6 (0.8–3.2)				
Hermit Thrush (*Catharus guttatus*)									1.6 (1.1–2.1)	1.3 (1.1–1.8)
Golden-crowned Kinglet (*Regulus satrapa*)									0.4 (0–0.6)	
Black-and-white Warbler (*Mniotilta varia*)						0.8 (0–2.4)				
Nashville Warbler (*Vermivora ruficapilla*)					0.5 (0–1.6)	0.5 (0–1.6)	1.5 (0–2.4)		4.8 (4.1–5.8)	4.4 (2.9–6.6)
Yellow-rumped Warbler (*Dendroica coronata*)							0.5 (0–1.5)	0.7 (0–2.0)	3.2 (2.9–3.4)	2.6 (2.3–2.8)
Palm Warbler (*Dendroica palmarum*)							1.4 (0.3–2.0)		5.0 (4.6–5.8)	5.8 (4.6–6.5)
Yellow Warbler (*Dendroica petechia*)					2.3 (1.6–3.0)	6.3 (3.2–8.0)				
Common Yellowthroat (*Geothlypis trichas*)			7.7 (4.0–13.0)	9.3 (4.0–15.1)	14.7 (12.8–15.9)	11.5 (8.8–14.5)		0.4 (0–1.3)		
Connecticut Warbler (*Oporornis agilis*)									4.2 (2.9–5.6)	2.1 (1.7–2.7)
Bobolink (*Dolichonyx oryzivorus*)	5.3 (4.7–6.0)	6.6 (6.0–7.0)	4.3 (3.5–5.0)	1.3 (1.0–2.0)	3.7 (3.2–4.0)		0.5 (0–1.6)	1.7 (0–3.5)		
Brewer's Blackbird (*Euphagus cyanocephalus*)								1.4 (0–4.2)		

TABLE 1. Continued.

Species	Habitats									
	Sedge fen		Low shrub		High shrub		Spruce: Open		Spruce: Closed	
	C	T	C	T	C	T	C	T	C	T
Brown-headed Cowbird (*Molothrus ater*)					0.8 (0–2.4)	2.1 (1.6–3.2)				
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)						0.2 (0–0.6)				
Savannah Sparrow (*Passerculus sandwichensis*)	0.5 (0–0.7)	4.4 (3.3–6.2)		0.3 (0–1.0)			11.0 (8.0–14.2)	10.6 (8.0–14.1)		0.9 (0.6–1.2)
LeConte's Sparrow (*Ammodramus leconteii*)	20.2 (15.1–26.8)	13.4 (12.2–15.3)	11.7 (7.2–14.0)	4.6 (2.6–7.0)	9.0 (6.8–10.7)	7.5 (6.2–8.8)	0.7 (0–2.0)	1.3 (0–4.0)		0.2 (0–0.6)
Dark-eyed Junco (*Junco hyemalis*)									1.3 (1.1–2.1)	1.4 (1.1–2.3)
Chipping Sparrow (*Spizella passerina*)									0.6 (0.4–0.7)	1.0 (0.6–1.7)
Clay-colored Sparrow (*Spizella pallida*)			4.7 (1.7–9.1)	7.2 (6.8–8.0)	1.7 (0–2.5)	0.2 (0–0.4)	1.3 (0–2.0)	1.6 (0.5–2.2)		
White-throated Sparrow (*Zonotrichia albicollis*)									0.2 (0–0.6)	0.2 (0–0.6)
Lincoln's Sparrow (*Melospiza lincolnii*)				1.3 (0–3.0)			5.0 (2.0–7.6)	2.2 (1.6–3.0)		0.5 (0.4–0.6)
Swamp Sparrow (*Melospiza georgiana*)		0.4 (0–1.3)	6.0 (5.0–10.2)	5.5 (1.0–9.5)	15.0 (10.4–17.6)	14.8 (9.6–18.4)				
Song Sparrow (*Melospiza melodia*)				0.8 (0–2.3)						
Total density	35.1 (28.0–47.3)	28.8 (22.7–35.5)	54.3 (45.0–74.7)	33.2 (25.0–39.8)	75.6 (64.8–81.1)	67.9 (51.2–82.5)	24.0 (16.0–32.2)	20.2 (17.0–24.4)	23.9 (22.3–28.2)	24.2 (20.1–27.8)

TABLE 2. Mean distances and F-statistics from two-way analysis of variance tests [treatment (Plot), year (Yr), and interaction (Plot/yr)] between control and treatment areas for the perpendicular distances from the center of a species' territory to the transect line (see text for details).

		Mean distance						
		Control		Treatment		F		
Habitat	Species	(m)	(n)	(m)	(n)	Plot[a]	Yr[a]	Plot/yr[a]
Closed spruce	Palm Warbler	102	(31)	120	(31)	2.5	0.1	1.3
	Yellow-rumped Warbler	94	(17)	107	(16)	1.2	1.3	0.1
	Connecticut Warbler	108	(24)	144	(13)	4.3*	3.0	1.8
	Nashville Warbler	110	(27)	102	(25)	0.2	0.4	0.1
High shrub	Sedge Wren	63	(86)	62	(45)	1.6	4.7*	0.1
	Common Yellowthroat	72	(55)	64	(42)	0.1	0.5	0.2
	Swamp Sparrow	75	(57)	71	(60)	0.0	0.2	0.9
	LeConte's Sparrow	68	(26)	58	(27)	0.6	0.3	0.2
Low shrub	Common Yellowthroat	92	(34)	74	(31)	0.1	0.2	0.1
	Swamp Sparrow	96	(23)	81	(21)	0.2	1.8	1.3
	LeConte's Sparrow	52	(38)	85	(10)	9.9**	0.0	5.6*
Sedge fen	Sedge Wren	89	(44)	103	(15)	1.0	0.7	1.5
	LeConte's Sparrow	83	(102)	82	(64)	1.4	3.0	0.5

[a] * = $P < 0.05$; ** = $P < 0.01$.

TABLE 3. Mean number of individuals observed in 100- × 250-m segments during four transect counts run in 1980, 1981, and 1982 for bird species in five peatland habitats. Two-way analysis of variance was used for species in plots where $n = 8$, and Mann-Whitney U-tests were used in plots where $n = 5$.

			Control			Treatment			Significance[a]	
Habitat	Species	n	80	81	82	80	81	82	Year	Plot
Closed spruce	Nashville Warbler	8	1.4	2.8	2.5	1.1	4.4	2.1	**	—
	Palm Warbler	8	2.8	3.4	2.4	2.5	3.4	2.4	—	—
	Connecticut Warbler	8	1.1	2.9	1.4	0.5	1.3	1.4	**	*
Tamarack forest	Nashville Warbler	8	1.8	2.5	2.4	0.8	1.6	2.0	—	—
	Palm Warbler	8	2.0	2.9	3.5	1.6	2.5	3.4	—	—
High shrub	Alder Flycatcher	8	1.0	2.4	1.9	1.8	2.8	1.6	—	—
	LeConte's Sparrow	8	2.5	2.9	2.8	2.4	2.4	3.0	—	—
	Swamp Sparrow	8	5.6	7.6	5.3	7.5	7.1	5.8	*	—
	Yellow Warbler	8	1.0	1.8	1.9	2.1	3.0	2.3	—	*
	Common Yellowthroat	8	3.9	5.6	4.5	4.3	5.1	4.1	—	—
	Sedge Wren	8	9.8	6.4	8.9	5.0	6.4	7.1	—	*
Low shrub	LeConte's Sparrow	5	5.0	5.0	5.4	1.2	2.2	1.4	—	** (80) * (82)
	Clay-colored Sparrow	5	1.4	2.6	1.8	1.8	2.2	2.4	—	—
	Swamp Sparrow	5	2.6	5.4	2.0	4.0	3.2	0.6	—	—
	Common Yellowthroat	5	2.2	4.0	4.4	3.0	5.8	3.4	*	—
	Sedge Wren	5	5.4	7.2	5.6	0.6	1.6	0.2	—	** (80) ** (81) ** (82)
Sedge fen	Bobolink[b]	8	3.1	3.6	3.6	3.3	4.1	4.1	—	—
	LeConte's Sparrow	8	6.6	7.1	8.9	3.0	4.5	8.5	**	**
	Sedge Wren[b]	8	1.9	3.5	3.5	1.6	3.0	1.6	—	—
	Savannah Sparrow	8	0.8	1.5	1.3	1.3	3.0	1.8	—	—

[a] * = $P < 0.05$; ** = $P < 0.01$.
[b] Log (natural) transformed before testing.

TABLE 4. Mean number of species (A) and number of individuals (B) observed in four censuses in each of three breeding seasons (1980, 1981, and 1982) in a 100- × 250-m segment of a line transect. Those habitats with $n = 8$ were tested with analysis of variance and those with $n = 4$ or 5 with a Mann-Whitney U-test.

		Control			Treatment			Significance[a]		
Habitat	n	80	81	82	80	81	82	Year	Plot	Year/plot
A. Number of species										
Closed spruce	8	6.3	7.0	4.5	6.5	8.5	8.1	*	**	*
Tamarack forest	8	8.6	7.5	7.3	7.1	7.1	6.4	a	a	a
Open spruce	4	4.8	6.0	4.3	4.8	5.0	3.0	a	a	b
Low shrub	5	5.8	6.4	6.0	5.6	6.8	5.0	a	a	b
High shrub	8	6.3	8.6	9.8	7.0	8.3	7.8	*	a	a
Sedge fen	8	3.3	3.0	3.3	3.5	4.6	4.0	a	*	a
B. Number of individuals										
Closed spruce	8	9.9	17.4	9.9	10.4	18.3	13.8	*	a	a
Tamarack forest	8	13.5	15.6	15.9	14.0	14.3	15.5	a	a	a
Open spruce	4	12.0	13.3	6.3	12.5	9.8	6.5	a	a	b
Low shrub	5	18.0	27.2	24.4	12.4	18.4	10.4	*	* (81) ** (82)	b
High shrub	8	23.9	28.4	28.9	24.8	31.9	27.4	a	a	a
Sedge fen	8	12.8	15.8	17.8	10.5	15.4	16.3	*	a	a

[a] * = $P < 0.05$; ** = $P < 0.01$; a = not significant; b = not examined.

plot, however, revealed that there were significant differences ($P < 0.01$) between each pair in at least 2 of the 10 variables in vegetation structure analyzed (Table 6).

DISCUSSION

Habitat.—An underlying problem in attempting to analyze post-impact differences between control and treatment plots is the existence of subtle differences in habitat structure. Because habitat structure is important in determining the distribution and abundance of breeding birds (i.e. Lack 1933, Hildén 1965, James 1971, Anderson and Shugart 1974), it is important to identify these differences in order to isolate the effects of inherent habitat differences from those due to the transmission line. To explain the inherent differences, we view peatland habitats as a complex matrix of life

TABLE 5. Mean number of species (A) and number of individuals (B) observed in transect counts during four migration periods in 100- × 250-m segments in control (C) and treatment (T) areas. Those habitats with $n = 8$ were examined with a t-test and those with $n = 4$ or 5 with a Mann-Whitney U-test. The number of times a segment was censused during the respective period is shown in parentheses.

		Migration season[a]							
		Fall 79(5)		Spring 80(4)		Fall 80(4)		Spring 81(3)	
		C	T	C	T	C	T	C	T
A. Number of species									
Closed spruce	8	3.1	4.6	4.0	3.9	1.6	2.1	3.8	4.5
Open spruce	4	0.8	0.3	2.0	1.0	3.0	2.0	4.0	3.5
Low shrub	5	4.0	2.8	2.8	3.8	3.2	1.8	4.8	5.0
High shrub	8	6.0	4.0*	2.0	1.5	3.9	4.8	6.1	7.5
Sedge fen	8	2.5	3.3	1.4	2.0	1.3	1.1	2.6	2.9
B. Number of individuals									
Closed spruce	8	4.5	8.6	7.8	8.5	2.3	4.0	4.8	7.6
Open spruce	4	1.0	0.8	3.5	1.3	4.5	4.3	5.3	5.3
Low shrub	5	12.0	8.2	3.8	5.4	7.4	4.2*	10.2	9.0
High shrub	8	19.0	18.6	5.3	7.9*	8.3	9.9	10.1	15.6
Sedge fen	8	9.0	7.5	1.8	3.1	1.8	2.3	5.9	4.9

[a] * = $P < 0.05$.

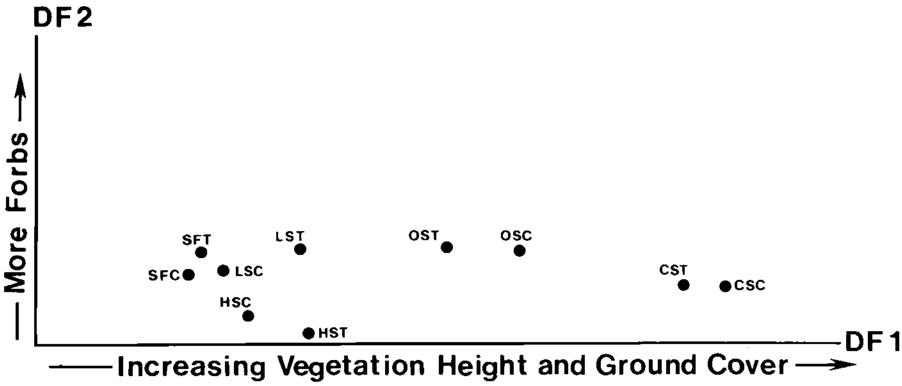

Fig. 1. Relationships, based upon nine habitat characteristics, among 10 territorial mapping plots according to the first two discriminant functions (Table 6). Plot codes are as follows: sedge fen control (SFC) and treatment (SFT), low shrub control (LSC) and treatment (LST), high shrub control (HSC) and treatment (HST), open spruce control (OSC) and treatment (OST), and closed spruce control (CSC) and treatment (CST).

TABLE 6. Overall *F* from discriminant analyses, mean (or median) values, and ranges (in parentheses) for the discriminating variables between control (C) and treatment (T) plots in five habitats. Only those variables that were significantly different ($P < 0.05$) between plots are shown.

		Habitat variables[a]							
Plots	Overall *F*	Overall vegetation height (m)	Tree density (stems/ 0.01 ha)[b]	Shrub density (stems/ 0.0025 ha)[b]	Forb density (stems/ 0.0001 ha)[b]	Forb hits in (0–30 cm) height interval	Sedge density (stems/ 0.0001)[b]	Sedge hits in (0–30 cm) height interval	Ground cover (%)
Closed spruce	2.7								
C		6.6**	45**						
		(4.5–10.0)	(5–256)						
T		5.5	23						
		(3.0–8.0)	(5–100)						
Open spruce	2.4**								
C		3.1**							95**
		(1.0–5.0)							(95)
T		2.1							90
		(1.0–4.0)							(75–95)
High shrub	7.4***								
C		1.4*		32*	0.4*	1**			
		(0.7–2.5)		(1–2,066)	(0–303)	(0–15)			
T		1.9		11	0.1	0			
		(1.0–3.5)		(0–658)	(0–15)	(0–1)			
Low shrub	5.7***								
C				19***	59**	5**	400**	26**	28**
				(3–434)	(3–331)	(0–11)	(124–10,000)	(10–68)	(10–60)
T				193	125	10	61	10	62
				(33–1,480)	(39–2,500)	(4–20)	(16–2,500)	(0–30)	(20–90)
Sedge fen	3.8***								
C				57**	52**	1**			36**
				(1–1,890)	(0–554)	(0–11)			(5–95)
T				119	125	4			58
				(0–2,380)	(0–2,500)	(0–9)			(10–95)

[a] * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$. All variables were log transformed before use in the discriminant analyses.
[b] Median.

forms (Dansereau and Segadas-Vianna 1952). A habitat may be dominated by one life form (e.g. *Carex* in the sedge fen or *Salix* in the high shrub), but there is variability caused by the presence of other life forms, as well as variation in stature, density, and patchiness of the predominant life form. If we assume that an area is represented by many life forms and each form varies temporally and spatially in density, in height, and in patchiness, then the number of possible combinations of these forms is enormous. It is not surprising to find differences between two areas.

Postimpact studies are confounded by the difficulty in matching control and treatment areas, yet we are unaware of any studies that test the assumption that control areas can be found that are similar enough to treatment areas to make impact studies meaningful. Although avian species composition in the two closed spruce plots was generally similar, the differences that did exist could be explained by differences in habitat between the two areas. For example, species that preferred a high density of tall trees, like those found in the closed spruce control plot, were also likely to be more abundant there than in the treatment plot, where tree density and overall height were lower. This may explain why there were greater numbers of Connecticut Warblers in the control area. In contrast, we are confident that the greater numbers of Sedge Wrens and LeConte's Sparrows in control areas as compared with treatment areas in the sedge fen, low shrub, and high shrub are related to inherent habitat differences between the paired areas. Sedge Wrens preferred habitats with patchy, low (1–2 m high) shrubs intermixed with sedge. These habitats were most abundant in the low shrub control, high shrub control, and high shrub treatment areas (e.g. median shrub densities were between 11 and 32 stems/0.0025 ha, Table 6), and Sedge Wrens were abundant in these areas (e.g. >15 pairs/10 ha, Table 1). In the low shrub and sedge fen treatment areas, shrubs were dense (e.g. >100 stems/0.0025 ha, Table 6) and not as patchy as in the control areas. In these areas, there were fewer than 5 pairs of Sedge Wrens per 10 ha (Table 1). Similarly, LeConte's Sparrows were most abundant (≥7.5 pairs/10 ha, Table 1) in areas where the median sedge density was greater than 250 stems/0.0001 ha (e.g. in the sedge fen control and treatment plots, high shrub control and treatment plots, and in low shrub control plot) (Niemi and Hanowski MS). They were least abundant (<5 pairs/10 ha, Table 1) in areas where the median sedge densities were less than 75 stems/0.0001 ha (e.g. in the low shrub treatment and the two open spruce plots) (Niemi and Hanowski MS). We believe that the differences in the numbers of LeConte's Sparrows in the treatment areas of the sedge fen, low shrub, and high shrub are due to lower densities of sedges in the treatment areas than in the control areas.

Bird populations.—There are few patterns in the data presented here. In some habitats there were more species in the treatment areas (e.g. closed spruce), whereas in other habitats there were fewer individuals (e.g. low shrub). Furthermore, in some habitats, different methods resulted in different interpretations, as did results based on different years (e.g. high shrub). The difficulties of interpreting limited censusing schemes and the high variation of local populations have been discussed by Wiens (1981). Unfortunately, much work on the potential impact of transmission lines has been confined to one season, one year, or one census technique.

CONCLUSIONS

We have asked specific questions about the potential effects of transmission lines on bird populations. In a postimpact study, suitable control areas must be compared with areas upon which there might be a potential impact. Although compared habitats are often assumed to be similar (e.g. see Wiens 1983), we tested this assumption and found that all five paired plots were significantly different. We may be criticized for selecting unsuitable control areas, but in each habitat type our controls were adjacent to and not more than 100 m from treatment areas. Furthermore, we believe that the control areas represented the most reasonable areas for comparison. We now question whether or not it is possible to identify suitable control areas. If we accept the assumption of habitat similarity and compare the control and treatment areas, we find little basis for suggesting any negative or positive effects of this transmission line on breeding bird populations. The possible exceptions were fewer numbers of Sedge Wrens and LeConte's Sparrows in several treatment areas than in controls. In both cases, however, we believe that the population differences are due to inherent habitat differences between control and treatment areas rather than to the transmission line. Furthermore, LeConte's Sparrows colonized the cleared vegetation under the transmission line in the closed spruce forest, which may indicate a positive impact on this species, that of more suitable habitats having been created.

We have shown that a number of variables can influence the assessment and interpretation of the effects of transmission lines on bird populations: (1) differences in habitat structure between paired control and treatment areas, (2) different results from different habitats, (3) different results from different census techniques used in the same or in different habitats, (4) different results from different seasons, and (5) different results from different years. Given these results, the conclusions drawn from other postimpact studies of the effects of transmission lines on bird populations must be considered critically. Postimpact studies of transmission lines must be designed to assess these effects. Yet, the inherent differences that exist between paired areas may be difficult to resolve. We see two possible means of assessing impact effects: (1) the collection of standardized habitat and population data to understand better how bird populations vary with habitat characteristics on local, regional, and temporal scales, and (2) before-and-after impact studies that include sufficient sampling before impact in both treatment and control areas to evaluate differences between areas but also to identify normal fluctuations in populations. The latter is the better approach, but it requires the wisdom of planning years in advance.

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