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Effect of Sewage Effluent on Bird Abundance and Species Composition in a Northern Minnesota Wetland†

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Abstract

Bird abundance was monitored before (1985 and 1987) and after (1989) sewage wastewater effluent was added to a northern Minnesota wetland. Community parameters (i.e., number of individuals and species richness) varied annually, but, overall bird communities in 1985 and 1989 were more similar to each other than they were to the 1987 community. Relative abundance of 35 bird species was unchanged between years and species abundance ranks were not different between years. Distribution of numbers of individuals (relative percent) within nesting and foraging guilds (species that have similar nesting or feeding requirements) was similar among years. Numbers of species that increased or decreased between years was independent of nesting or foraging location (e.g., ground or above ground). Overall, no differences were detected in the bird community that could be attributed to addition of sewage effluent to the wetland up to two years after treatment (1987 to 1989).

Introduction

Use of wetlands for sewage treatment has increased in recent years, particularly in Minnesota and Wisconsin where wetlands are abundant (1). Biwabik, Minnesota began discharging secondary sewage effluent into a 40 ha wetland in the fall of 1987. Potential ecological effects of adding effluent to wetlands on wildlife are not fully understood (2). However, it is known that changes in animal communities may result from shifts in plant community composition, from changes in duration and frequency of flooding, or from changes in water quality (1). Our objectives were to assess the effects of adding sewage effluent to this wetland on bird species and communities in the wetland. We made comparisons before treatment (1985 and 1987) and after treatment (1989).

Materials and Methods

The study area was located about one km south of Biwabik, Minnesota between State highway 135 on the west side and county road 4 on the east side (3) (Figure 1). The wetland supported four distinct habitat types: shrub swamp, ash (*Fraxinus nigra*) forest, open coniferous forest, and closed coniferous forest (Figure 2). An upland mixed coniferous-deciduous forest bordered the east and south edges and an open meadow borders the north edge. The shrub portion of the wetland was about 4 ha and the dominant species were alder (*Alnus* spp.) and willow (*Salix* spp.). The shrub wetland graded into an ash swamp to the south. This habitat type was about 6 ha and the dominant understory vegetation was alder, willow, cattail (*Typha* spp.), wild calla (*Calla palustris*), and wild iris (*Iris versicolor*). The main portion of the wetland, about 28 ha, was comprised of a densely populated spruce/tamarack forest (*Picea mariana* and *Larix laricina*). A sparsely populated spruce/tamarack forest occupied the central portion of the wetland (about 2 ha). Dominant understory plant species in the open areas included leatherleaf (*Chamaedaphne calyculata*), bog laurel (*Kalmia polifolia*), small cranberry (*Oxycoccus microcarpa*), and cotton grass (*Eriophorum* spp.). Labrador tea (*Ledum groenlandicum*), three-leaved false Solomon's seal (*Smilicina trifolia*), and sedges (*Carex* spp.) were common in the closed canopy areas. See Schimpf (4) for a more quantitative description of the forested habitats.

Secondary sewage effluent from a settling pond was first discharged into the wetland in October of 1987. A total of 12.6 million gallons was discharged in 1987, 53.2 million gallons in 1988, and 37.8 million gallons (through June) in 1989. Average phophorous

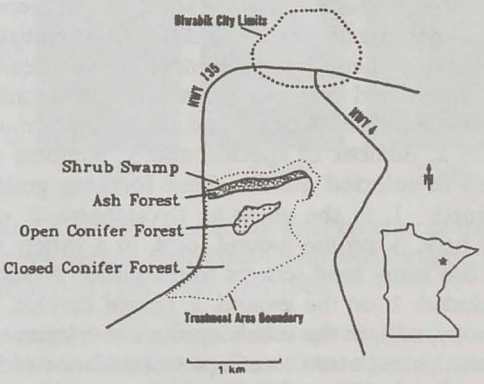

Figure I. Location of study area.

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Figure 2. Habitat types in the study area near Biwabik, Minnesota.

concentrations measured in the wetland was 0.65 mg L^{-1}, 1.23 mg L^{-1}, and 1.3 mg L^{-1} in 1987, 1988, and 1989 respectively. Average phophorous concentrations in Bog Creek (point where water is discharged from wetland) were 0.14 mg L^{-1}, 0.15 mg L^{-1}, and 0.22 mg L^{-1} in 1987, 1988, and 1989 respectively.

We used a modified line transect method (5) to make four counts of breeding birds (June to early July) in 1985, 1987, and 1989 (3). Census data were gathered by observers trained in the identification of birds by sight and sound, during early morning hours (0445-0930 Central Daylight Savings Time), on days with little wind (< 10 km hr^{-1}), and no precipitation. One observer walked a predetermined route (about 4 km) through the wetland and recorded bird species and approximate distance to the individual (either > or < 25 m from the route). Routes traversed all habitats of the wetland and the habitat affinity of each species was noted.

We used the maximal values from the four censuses in each year to make before and after comparisons. With this method we attempted to record the maximal number of breeding individuals to partially control for song phenology differences between early and late nesters and between years (6). Community parameters examined included: 1. number of individuals; 2. number of species; and 3. numbers of individuals in selected guilds. Four foraging guilds were defined: 1. in the air (e.g., flycatchers), 2. on foliage or bark, 3. on the ground, or 4. in a variety of places or use many food sources (omnivores). Nesting guilds included: 1. on the ground, 2. in tree cavities, 3. in the canopy, or 4. in the subcanopy or shrub layer.

We used paired t-tests to compare abundance of 35 species between 1985 and 1987; 1985 and 1989; and 1987 and 1989. We chose species that were present in all years, generally eliminating those that were observed only one time in any year (see Appendix 1). The maximal value for each species observed during the four census periods in each year were used for these tests. Spearman's rank correlation test (7) was used to examine whether species abundance patterns were similar among years. In addition, we used Fisher's exact test of independence (2 x 2 table) to determine whether increases or decreases in species numbers between years was independent of the species' nesting or foraging location (7). For this analysis we classified species into ground or above ground categories and included species that showed >10% change in numbers among years. This was done to eliminate the uncommon species that were recorded primarily in 1987.

Results

Number of individuals and species observed in the wetland varied annually (Appendix 1). Overall, total individuals and number of species observed were more similar in 1985 and 1989 than they were in 1985 and 1987 or in 1987 and in 1989. Five species were observed in 1985 and 1987 but not in 1989 (Northern Flicker, Olive-sided Flycatcher, Eastern Kingbird, American Crow, and Red-breasted Nuthatch). The Sharp-shinned Hawk, Black-billed Cuckoo, Ruby-crowned Kinglet, and Solitary Vireo were counted in 1985 and 1989 but not in 1987. In addition, six species were seen both in 1987 and 1989 but not in 1985. These were Northern Harrier, Common Snipe, Downy Woodpecker, American Robin, Pine Siskin, and American Goldfinch (Appendix 1). Only one species, the Black-backed Woodpecker was observed exclusively in 1985. Conversely, 28 species were observed only in 1987 (Appendix 1).

Abundance of 35 species that were observed in all three years did not differ between years (paired t-test; $T < 1.43$; $P > 0.21$). In addition, ranked correlation tests of these species indicated significant correlations (Spearman's rank correlation; $R > 0.64$; $P < 0.01$) in abundance among years.

Although total number of individuals fluctuated annually, number of individuals within nesting and

foraging guilds were not different among years (paired t-test; $T < 1.82$; $P > 0.14$) (Figure 2). In addition, number of species that increased or decreased between years was independent of nesting or foraging location (ground or above ground). For instance, numbers of ground nesting or ground foraging species that decreased (or increased) was not different from the number of above ground nesting or above ground foraging species that declined (or increased) between years (Fisher's exact test 2-tail; $P > 0.05$).

Discussion

Addition of sewage effluent to uplands and wetlands can alter plant communities within one to two years after treatment (1) and therefore, indirectly affect breeding bird species and communities. Previous studies reported that upland bird communities were affected shortly after treatment (e.g., 1-2 years) whereas, wetland bird communities exhibited little change within the first few years after treatment. For example, Beaver (8) reported that habitat changes associated with added wastewater in oldfields in Michigan increased species richness and densities of wetland species (e.g, Red-winged Blackbirds), but densities of upland species [e.g., Field Sparrow *(Spizella pusilla),* Savannah Sparrow] decreased within three years after treatment. Number of bird species in irrigated upland forests increased after treatment with municipal wastewater (9). In contrast, Rabe (10) found no changes in bird species diversity attributable to sewage effluent in a northern Michigan wetland. Kent and Anderson (11) also found no short-term effects on relative abundance and species diversity of birds in a bog near Drummond, Wisconsin that received sewage effluent in a manner similar to the Biwabik Bog.

Results of our investigation agree with previous studies that assessed short-term effects of added sewage effluent on wetland bird species and communities. We found that some characteristics of the bird community varied among years, but that communities in 1985 (pre-treatment) and 1989 (treament) were more similar than communities in 1987 (pre-treatment). Differences (e.g., lower numbers and more species in 1987) are attributed to natural annual variation in bird communities (11). Annual variation of bird populations in the wetland parallel results of censuses conducted in northern Wisconsin and Michigan wetlands over the same years. Bird numbers in both states declined steadily from 1985 to 1988 and then increased slightly in 1989 in Wisconsin (2).

Changes in water levels in wetlands treated with sewage effluent may not affect all bird species in the same way. Flooding may reduce habitat available for ground nesters or foragers, but not affect birds that nest or feed above the forest floor. If this occurred, we would expect a shift in the composition of the

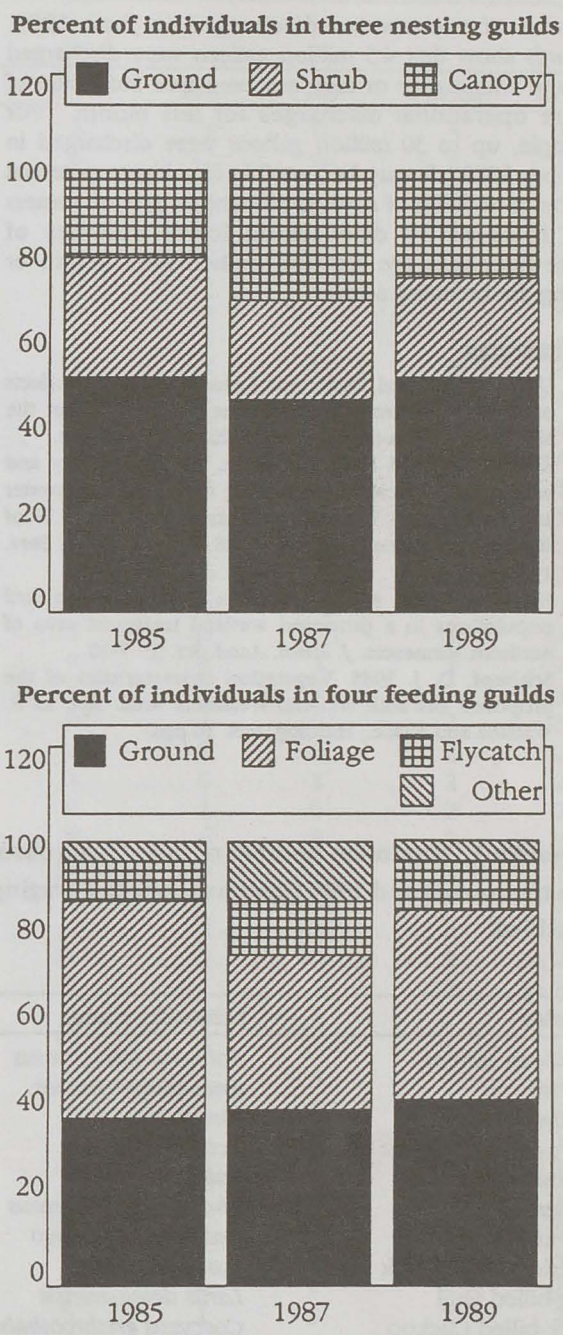

Figure 3. Relative percent of total number of individuals in three nesting guilds (top), and four foraging guilds (bottom) in 1985, 1987, and 1989.

community away from those species that are ground nesters or foragers. Our data showed that guild composition and patterns of species that increased or decreased within ground nesting or feeding guilds did not change after effluent was added to the wetland. However, lack of an observed decline in birds that nest or feed on the ground in 1989 relative to the pre-treatment years could be due to the relatively low

volume of wastewater discharged in June 1989. Records show that 4.3 million gallons were discharged in June which may or may not be a true indication of future operational discharges for this month. For example, up to 30 million gallons were discharged in October 1988. It may be possible to mitigate potential effects of addition of sewage effluent on ground nesters and foragers by discharging lower volumes of wastewater into the wetland immediately before or during the breeding season.

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Appendix 1. Maximum number of individuals observed during four breeding bird censuses in 1985, 1987 (pre-treatment) and 1989 (post-treatment). Foraging[a] and nesting[b] categories for the guild analysis are also identified.

Species	Scientific Name	1985	1987	1989	Forage	Nest
American Bittern	*Botaurus lentiginosus*	0	1	0	4	1
Mallard	*Anas platyrhynchos*	2	2	1	4	1
Northern Harrier	*Circus cyaneus*	0	1	1	4	1
Sharp-shinned Hawk	*Accipiter striatus*	2	0	1	4	2
Virginia Rail	*Rallus limicola*	0	1	0	4	1
Killdeer	*Charadrius vociferous*	0	1	0	1	1
Common Snipe	*Gallinago gallinago*	0	1	1	1	1
American Woodcock	*Scolopax minor*	0	1	0	1	1
Ring-billed Gull	*Larus delawarensis*	0	1	0	4	1
Black-billed Cuckoo	*Coccyzus erythropthalmus*	3	0	1	2	3
Downy Woodpecker	*Picoides pubescens*	0	2	1	2	4
Hairy Woodpecker	*Picoides villosus*	0	2	1	2	4
Black-backed Woodpecker	*Picoides arcticus*	2	0	0	2	4
Northern Flicker	*Colaptes auratus*	1	2	0	2	4
Olive-sided Flycatcher	*Contopus borealis*	1	1	0	3	2
Eastern Wood-Pewee	*Contopus virens*	0	1	0	3	2
Yellow-bellied Flycatcher	*Empidonax flaviventris*	12	10	9	3	1
Alder Flycatcher	*Empidonax alnorum*	6	13	6	3	3
Least Flycatcher	*Empidonax minimus*	2	3	3	3	2
Eastern Phoebe	*Sayornis phoebe*	0	1	0	3	2
Great Crested Flycatcher	*Myiarchus crinitus*	0	2	0	3	4

Appendix I (continued)

Species	Scientific Name	1985	1987	1989	Forage	Nest
Eastern Kingbird	*Tyrannus tyrannus*	2	4	0	3	3
Tree Swallow	*Tachycineta bicolor*	0	12	0	3	4
Gray Jay	*Perisoreus canadensis*	3	5	2	3	2
Blue Jay	*Cyanocitta cristata*	4	11	5	4	2
American Crow	*Corvus brachyrhynchos*	7	8	0	4	2
Common Raven	*Corvus corax*	0	1	0	4	2
Black-capped Chickadee	*Parus atricapillus*	3	6	4	2	4
Boreal Chickadee	*Parus hudsonicus*	2	2	2	2	4
Red-breasted Nuthatch	*Sitta canadensis*	1	2	0	2	4
Brown Creeper	*Certhia americana*	0	6	0	2	4
House Wren	*Troglodytes aedon*	0	2	0	2	4
Winter Wren	*Troglodytes troglodytes*	0	1	0	2	4
Sedge Wren	*Cistothorus platensis*	8	2	4	2	3
Marsh Wren	*Cistothorus palustris*	0	1	0	2	3
Golden-crowned Kinglet	*Regulus satrapa*	6	11	5	2	2
Ruby-crowned Kinglet	*Regulus calendula*	2	0	4	2	2
Veery	*Catharus fuscescens*	9	6	5	1	1
Hermit Thrush	*Catharus guttatus*	10	18	9	1	1
American Robin	*Turdus migratorius*	0	6	1	1	2
Gray Catbird	*Dumetella carolinensis*	2	1	2	2	3
Brown Thrasher	*Toxostoma rufum*	0	1	0	2	3
Cedar Waxwing	*Bombycilla cedrorum*	0	9	0	2	2
Solitary Vireo	*Vireo solitarius*	2	0	1	2	2
Warbling Vireo	*Vireo gilvus*	0	1	0	2	2
Red-eyed Vireo	*Vireo olivaceus*	8	6	8	2	2
Nashville Warbler	*Vermivora ruficapilla*	58	35	41	2	1
Yellow Warbler	*Dendroica petechia*	6	3	4	2	3
Chestnut-sided Warbler	*Dendroica pensylvanica*	2	2	2	2	3
Yellow-rumped Warbler	*Dendroica coronata*	11	3	10	2	2
Black-throated Green Warbler	*Dendroica virens*	0	1	0	2	2
Blackburnian Warbler	*Dendroica fusca*	1	3	1	2	2
Palm Warbler	*Dendroica palmarum*	11	6	12	1	1
Black-and-white Warbler	*Mniotilta varia*	5	3	3	2	1
American Redstart	*Setophaga ruticilla*	4	1	5	2	2
Ovenbird	*Seiurus aurocapillus*	0	3	0	1	1
Connecticut Warbler	*Oporornis agilis*	14	15	12	2	1
Mourning Warbler	*Oporornis philadelphia*	0	2	0	2	1
Common Yellowthroat	*Geothlypis trichas*	17	15	12	2	3
Canada Warbler	*Wilsonia canadensis*	0	2	0	2	3
Scarlet Tanager	*Piranga rubra*	0	2	0	2	2
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	5	1	3	2	2
Indigo Bunting	*Passerina cyanea*	0	2	0	2	3
Chipping Sparrow	*Spizella passerina*	6	8	8	1	2
Clay-colored Sparrow	*Spizella pallida*	10	3	5	2	3
Savannah Sparrow	*Passerculus sandwichensis*	0	2	0	1	1
LeConte's Sparrow	*Ammodramus leconteii*	0	1	0	1	1
Song Sparrow	*Melospiza melodia*	9	8	8	1	3
Lincoln's Sparrow	*Melospiza lincolnii*	7	1	5	1	1
Swamp Sparrow	*Melospiza georgiana*	16	8	14	1	3
White-throated Sparrow	*Zonotrichia albicollis*	23	29	22	1	1
Dark-eyed Junco	*Junco hyemalis*	7	3	5	1	1
Red-winged Blackbird	*Agelaius phoeniceus*	2	3	3	1	3
Brown-headed Cowbird	*Molothrus ater*	5	2	3	1	3

Appendix I (continued)

Species	Scientific Name	1985	1987	1989	Forage	Nest
Purple Finch	*Carpodacus purpureus*	1	1	2	2	2
White-winged Crossbill	*Loxia leucoptera*	0	13	0	2	2
Pine Siskin	*Carduelis pinus*	0	1	2	2	2
American Goldfinch	*Carduelis tristis*	0	8	2	2	3
Evening Grosbeak	*Coccothraustes vespertinus*	0	2	0	2	2
Number of individuals		320	360	266		
Number of Species (total)		45	74	46		

Foraging Guilds[a]	Nesting Guilds[b]
1 Ground	1 Ground
2 Foliage or bark	2 Canopy
3 Aerial	3 Subcanopy
4 Omnivore	4 Cavity