Effects of Recreational Use of Shorelines on Breeding Bird Populations

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Field studies were conducted at six lakes in southern Ontario to investigate the effects on breeding bird populations of the disturbance caused by recreational use of shorelines. The degree of land development observed created extensive edge habitat but had only moderate effects on other vegetation characteristics. Although disturbed areas had significantly more birds, they tended to have lower species diversity than more natural areas. Species richness remained fairly constant in both disturbed and isolated study areas whereas species evenness was significantly lower in the former. The species composition of bird populations in study areas was also affected by disturbance. Nesting success of Common Loons (*Gavia immer*) and Eastern Kingbirds (*Tyrannus tyrannus*) was lower in disturbed areas.

Key Words: birds, recreation, land development, species diversity, nesting success, breeding, beaches, environmental effects, community composition, Ontario, Rideau Lakes.

Recent decades have seen a marked and continuous rise in outdoor recreational activity. Unfortunately, the heavy use of natural landscapes for recreation sometimes threatens the resources (e.g., lakes, forests) that people are seeking. To determine the capacity of a natural environment for recreational activity, as is necessary for adequate planning and control, a quantitative knowledge of the effects of such use on the environment and the biota is required. The objective of this study was to investigate the impact of recreational use of land and water on the breeding bird assemblages of shoreline communities. The avian component of the community was selected for analysis because it represents a portion of the biological environment which (*a*) is particularly attractive to many users of recreational areas, (*b*) is often conspicuous and thus vulnerable to human activity, and (*c*) is sensitive to the changes in vegetation structure and other habitat variables which may result from development of cottage property (MacArthur 1964; Willson 1974).

Methods

Study Areas

Shorelines of six of the Rideau Lakes in southeastern Ontario were chosen for study because of their location in a popular recreational area, with use of shorelines varying from light to heavy (Figure 1). Indian (44°35′N, 76°19′W) and Sand (44°34′N, 76°20′W) lakes are both densely surrounded by cottages, and along with Lake Opinicon (44°34′N, 76°20′W) are connected via locks as part of the Rideau Waterway. They are thus subject to heavy non-resident boat use as well as local traffic. Crow (44°32′N, 76°19′W) and Lower Rock (44°31′N, 76°19′W) lakes, on the other hand, with large portions of unused land, have only small numbers of cottages and reduced levels of boat use. Hart Lake (44°32′N, 76°20′W) is landlocked and has no access road; it is therefore without buildings and is subject only to the traffic of those boats that may be portaged. Although Lake Opinicon is part of the Rideau Waterway, it is extensive and borders large undisturbed tracts of land, in the vicinity of which boat use is limited.

Twenty-five study areas, each 400 m long and 50 m wide (2 ha) running parallel and adjacent to the lakeshore, were selected for comparative purposes. Some were located in highly disturbed areas on Sand and Indian lakes as well as on portions of Lake Opinicon, while others were on the more isolated regions of Opinicon and on Hart, Crow, and Lower Rock lakes. Each study area was given a disturbance rating based on the intensity of use in three categories: (1) density of cottages in the study area, (2) proximity of roads to the study area, and (3) boat traffic adjacent to the shoreline of the study area. Serving as one measure of the level of human activity, this last factor was investigated by assessing relative boat traffic within 25 m of the shoreline of each study area during 4 consecutive days in early July 1976. Scores were assigned for each of these use categories as shown in Table 1. The overall disturbance level of a study area was determined by summing the values in the three categories. Disturbance scores ranged from 1 to 11 with increasingly heavy use. Areas scoring 1 or 2 were considered undisturbed; those scoring ≥ 3 were considered disturbed. Scoring was done prior to the analysis of impact data in order to avoid biasing the interpretation of results.

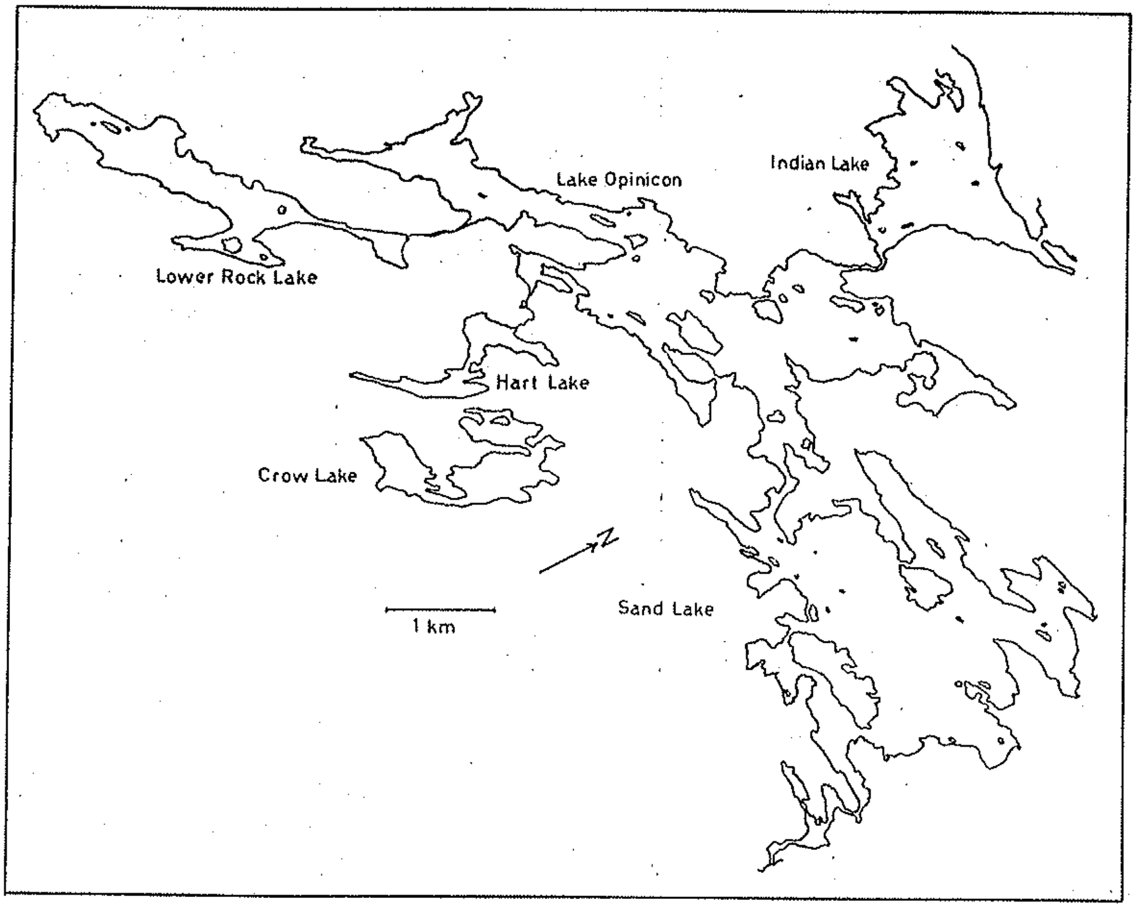

FIGURE 1. Map of the six lakes employed in the study, Frontenac County, Ontario.

Vegetation Analysis

The point-centered quarter method (Cottam and Curtis 1956), with points at 20-m intervals, was used to assess canopy density and tree species composition along a transect through the long axis of each study area. In addition, strip transects (3 × 50 m) perpendicular to the shoreline in each study area were used to determine foliage height diversity (FHD) (MacArthur 1961, 1964) in five vertical layers of vegetation. The amount of edge formed by cottage lots, roads, telephone line cuts, and/or more natural openings, but not including the shoreline, was determined by measuring the length of all edges between forested and open habitat in each study area.

TABLE 1—Scoring scheme for disturbance in three categories

Use category			Score
Roads	Cottages	Boats/hr	
None	None	0	0
Adjacent to study area	Isolated (1 or 2 only)	1-3	1
Through study area	Scattered (several along transect)	4-7	2
	Continuous; ⩾ 25 m between cottages	8-11	3
	Continuous; < 25 m between cottages	12-15	4
		16	5

Bird Censusing

Bird populations of the 25 study areas were censused by the strip transect method (Merikallio 1958; Järvinen and Väisänen 1975; "method D" *in* Emlen 1971). Censuses were conducted by walking 400 m along a transect parallel to and 25 m in from the shore at each study area. Stops of 3-5 min were made every 40 m and all males seen and/or heard were counted. A lateral distance of 25 m on either side of the observers was considered to be the maximum range over which the quieter birds could be detected as readily as were the more conspicuous ones. All censuses were conducted between 05:00 and 09:30 under favorable weather conditions during the period 17 May to 6 July. Each transect was censused 3 times, once during the first third, once in the middle, and once near the end of this period. The majority of the work was carried out after 23 May in order to reduce the possibility of migrants being included in samples. In addition, equal numbers of disturbed and undisturbed transects were censused early in the season so that the presence of migrants (if any) would have had an equal effect on both types of study area.

Censuses were carried out by two or occasionally three observers, providing a thorough check on species identification. One member of each census team was present during all censuses conducted on any particular transect while the other member(s) varied.

Data on bird species occurrence and relative abundance were used to determine the species diversity for each transect. The diversity index used was the information theory measure H′, in which $-\sum_{i=1}^{s} p_i \log p_i$ where p_i represents the proportion of the total number of individuals that belong to the i^{th} species (Shannon and Weaver 1949). S denotes species richness and refers to the total number of species present. Evenness (J'), which is defined by $J' = H'/\log S$ is a measure of the relative distribution of individuals amongst the species. Both richness and evenness contribute to the relative magnitude of H′. The reader is referred to Pielou (1966, 1975) for derivation of these formulae.

Qualitative observations suggested that the characteristic avifaunas of highly disturbed study areas were different from those of less disturbed plots. To quantify this difference we compared the species composition of each transect to that of the most disturbed transect (Mustard Point on Sand Lake, transect #12) by computing Coefficient of Community (CC) and Percentage Similarity (PS) values (Pielou 1975). These indices estimate the similarity between the avifauna of the Mustard Point area and that of each of the other transects. The Coefficient of Community is defined as $CC = 200 S_{xy}/S_x + S_y$ where S_x and S_y are the numbers of species found in each of the two study areas being compared (Mustard Point with each of the 24 others in this case) and S_{xy} is the number of species common to both areas. Percentage Similarity is determined by $PS = 200 \Sigma_{min}(P_{i_x}, P_{i_y})$ where P_{i_x} and P_{i_y} are the quantities of species i on transects x and y expressed as proportions of the total number of all S species in the two study areas combined.

Nesting Success

Nests of Common Loons (*Gavia immer*) located in shoreline areas throughout the study lakes were monitored weekly to determine nesting success. Eastern Kingbirds (*Tyrannus tyrannus*) breeding in shoreline areas commonly build nests in cedar (*Thuja occidentalis*) trees on the water's edge. These nests are frequently less than 3 m above the ground and are often built in branches overhanging the water. Thus, like the nests of loons, they were considered to be particularly vulnerable to disturbance from nearshore boating and/or camping activity. Kingbird nests on the shores of Sand and Opinicon lakes were visited every 3 days until fledging or nest failure occurred. Nests were considered successful if they fledged at least one young. For loons, a breeding attempt was considered successful if any young loons were still alive at the termination of the project on 10 August.

Nests of both species were scored for disturbance with respect to boat use and general activity in the area. The former factor was estimated as described previously. The intensity of human activity was estimated by noting the presence and number of picnic tables, camp sites, and/or cottages within 25 m of the nest. A nest subject to high levels of activity was assigned a score of 3, whereas one in an isolated, uninhabited area scored 1. The total disturbance designation for a nest was the sum of the scores in these two categories. Values ranged from 1 to 8, with nests scoring less than 4 being considered 'undisturbed,' and those with scores of 4 or greater considered 'disturbed.'

All field work for the project was conducted by a five-person team during the period May through August 1976.

Results

Vegetation Analysis

Eighteen genera of canopy trees were found to be present on the 25 transects; 10 of the taxa comprised 95% of all the trees present. No significant difference was found between the average amounts of each genus in disturbed (disturbance level $\geqslant 3$) and undisturbed study areas (Mann-Whitney U-test, $P \geqslant 0.05$; Table 2). There was no correlation between the abundance of a particular genus on any transect and the bird species diversity, species evenness, or species richness of that transect.

Foliage height diversity (FHD) values were generally lower in disturbed areas although the trend was not significant ($P > 0.05$) (Table 3). A significant positive correlation was found, however, between disturbance and the amount of edge present within a study area (Kendall Rank Correlation, $P \leqslant 0.05$). The average amount of edge in undisturbed areas was only 188 m compared to a mean of 455 m in disturbed locations. This relationship is not surprising in light of the factors that comprise the disturbance score, as the

TABLE 2—Vegetation composition of disturbed (disturbance) level ≥ 3) and undisturbed study areas: average percentage of total canopy trees on each transect belonging to the 10 most common tree genera

Tree genera	Average per transect (%)	
	Disturbed	Undisturbed
Pinus	23.2	23.2
Acer	17.7	14.2
Quercus	20.8	22.2
Betula	3.8	2.7
Carya	2.6	8.2
Fraxinus	7.9	12.2
Populus	2.4	1.2
Tilia	3.9	7.3
Ulmus	3.1	1.9
Ostrya	5.3	3.7

presence of roads and the number of cottages are both partial determinants of the amount of edge habitat in a study area.

Canopy density (CD) was not significantly correlated with either disturbance or amount of edge, although a general trend toward a decrease in CD with an increase in edge was observed. This result also is as expected: CD values averaged over several sampling points along transects which include extensive edge habitat will likely reflect the reduction in tree density which is implied by the existence of these edges.

Relative Bird Abundance and Species Diversity

The relative abundance of birds in each study area (the total number of birds recorded during the three replicate censuses of each transect) was positively correlated with disturbance (Kendall Rank Correlation, $P \leq 0.001$; Table 4). Population densities of birds tend to be greater across ecotones (Kendeigh 1944; Odum 1971); since in this study amount of edge or ecotone was positively correlated with disturbance, bird abundance was examined in relation to the amount of edge in each study area. The number of individual birds in each area was positively correlated with edge as well as with disturbance (Kendall Rank Correlation, $P \leq 0.001$). A nonsignificant tendency toward decreasing diversity with increasing development was also indicated: the average H′ for disturbed transects was only 4.053 compared to a value of 4.214

TABLE 3—Structure of the vegetation on each transect: amount of edge, foliage height, and canopy density in relation to disturbance

Disturbance level	Amount of edge (m)	Foliage height diversity	Canopy density (1/m²)	Transect number
1	0	2.036	0.038	15
1	150	1.884	0.073	1
1	250	1.612	0.051	16
1	300	1.667	0.034	8
2	25	1.893	0.062	14
2	50	1.715	0.022	21
2	75	1.924	0.036	19
2	150	2.049	0.021	22
2	150	1.896	0.033	18
2	200	1.868	0.035	25
2	200	1.594	0.023	23
2	400	1.909	0.038	6
2	500	1.612	0.037	20
3	150	2.011	0.054	10
3	300	1.696	0.006	17
3	700	1.527	0.007	11
4	250	1.746	0.048	5
5	50	1.587	0.087	24
5	110	1.587	0.085	2
7	300	2.126	0.034	13
7	1000	2.043	0.075	9
8	400	1.836	0.064	4
8	800	1.630	0.045	7
9	650	1.445	0.010	3
11	750	0.465	0.005	12

TABLE 4—Avian community characteristics: the bird abundance, species diversity, species richness, species evenness, Coefficient of Community, and Percentage Similarity values for each transect

Disturbance level	Bird abundance (total individuals counted)	H'	S	J'	Coefficient of Community (%)	Percentage Similarity (%)	Transect number
1	109	4.371	28	0.909	70.34	57.60	15
1	49	4.027	21	0.917	59.57	20.56	1
1	63	4.334	25	0.933	47.06	26.38	16
1	103	4.022	22	0.902	70.83	34.14	8
2	43	4.344	24	0.947	60.00	22.52	14
2	113	4.426	29	0.911	58.18	42.98	21
2	65	3.904	21	0.889	51.06	24.42	19
2	106	4.271	26	0.909	57.69	36.14	22
2	87	4.022	21	0.911	63.84	35.16	18
2	112	4.270	26	0.909	80.72	70.28	25
2	84	4.105	23	0.907	53.06	32.36	23
2	116	4.474	34	0.879	63.33	41.98	6
2	65	4.214	25	0.907	66.67	28.36	20
3	61	4.094	23	0.905	61.22	29.34	10
3	116	4.118	29	0.862	58.18	47.82	17
3	112	3.958	25	0.852	66.67	55.65	11
4	72	4.048	21	0.922	59.57	31.26	5
5	75	3.933	22	0.882	62.50	29.34	24
5	74	4.035	24	0.880	64.00	36.14	2
7	117	4.096	26	0.871	84.62	82.00	13
7	104	3.759	21	0.856	68.09	73.20	9
8	104	4.277	24	0.933	76.00	56.62	4
8	143	4.136	28	0.860	74.07	73.24	7
9	169	4.103	24	0.895	72.00	95.60	3
11	156	4.079	26	0.868	100.00	100.00	12

for more isolated areas.

When the two components of species diversity were examined separately, species richness was not correlated with disturbance, amount of edge, FHD, or canopy density. The evenness component (J'), on the other hand, was significantly and negatively related to disturbance and amount of edge (Kendall Rank Correlation, $P \leq 0.01$).

Coefficient of Community and Percentage Similarity values relative to the highly disturbed Mustard Point transect were positively correlated with disturbance (Kendall Rank Correlation, $P \leq 0.01$; Table 4). In effect, the more disturbed an area, the closer the species composition of its avifauna resembled that of Mustard Point. In general, species common in urban areas, such as American Robins (*Turdus migratorius*), were found more frequently and in greater abundance in disturbed study areas. In contrast, other species such as Blackburnian (*Dendroica fusca*), Cerulean (*D. cerulea*), and Black-and-White (*Mniotilta varia*) Warblers were found more commonly or only in undisturbed areas. This was illustrated not only by the PS and CC values, but also by a comparison of disturbed and undisturbed transects with regard to the distribution of the 20 most common species (Table 5).

Nesting Success

Common Loons nesting in undisturbed areas appear to have had higher success than those nesting in disturbed locations. Although the sample size is too small for statistical testing, four out of six nests with low disturbance scores (< 4) fledged at least one young, while in disturbed areas only two out of seven nests were successful.

The same trend is apparent for Eastern Kingbirds. Nine of 13 nests in undisturbed areas were successful, while only 5 out of 13 nests in disturbed areas fledged any young. A larger percentage of the total number of eggs laid hatched in undisturbed than in disturbed locations (73.8% vs. 53.6%; chi-square test, $P \leq 0.10$). Nests in undisturbed areas produced significantly more fledglings as a proportion of the total number of eggs laid than did nests in disturbed areas (50% vs. 25%; chi-square test, $P \leq 0.05$). There was no differ-

TABLE 5—Distribution of the 20 most common bird species. Ci-square test; $*P \leqslant 0.05$, $**P \leqslant 0.005$

Species	No. in disturbed study areas	No. in undisturbed study areas
Molothrus ater	142	113
Melospiza melodia	91	80
Vireo olivaceus	63	85
Turdus migratorius	111	28**
Spizella passerina	75	64
Icterus galbula	72	50*
Spinus tristis	31	60**
Dendroica petechia	74	15**
Vireo gilvus	69	15**
Contopus virens	43	28
Parus atricapillus	29	38
Myiarchus crinitus	16	47**
Troglodytes aedon	60	2**
Tyrannus tyrannus	41	18**
Quiscalus quiscala	28	29
Bombycilla cedrorum	32	20
Dendroica pinus	27	22
Setophaga ruticilla	10	34**
Piranga olivacea	12	29*
Mniotilta varia	1	37**

ence in mean clutch size between the two habitat groups.

Discussion

Nesting Success

A variety of factors might be responsible for the reduced nesting success of kingbirds and loons in disturbed areas. Human activity (e.g., fishermen, picnickers) was observed to frighten birds off their eggs during incubation. Such repeated disturbance could result in chilling of the eggs or nestlings or increased exposure of the nest to predators. Also the increased abundance of Raccoons (*Procyon lotor*) and Eastern Chipmunks (*Tamius striatus*) often associated with human disturbance (i.e., with garbage cans and picnic areas) might result in greater predation of nests in such areas. In addition, located as they are on the ground close to the water's edge, loon nests are often vulnerable to waves caused by large watercraft such as those which travel the Rideau Waterway (cf., Vermeer 1973).

The abundance, larger clutch size, and broad habitat distribution of kingbirds reduces the likelihood that reduced nesting success in disturbed shoreline areas will appreciably affect their population size. For loons, with many fewer nests per lake, the risk is much greater that some factor resulting from disturbance could, over a period of years, eliminate the entire population of an area. These birds show a strong attachment to their nesting site, returning to it year after year, even after repeated failure (Bent 1919; Webb 1963). The disappearance of loons from several Rideau lakes on which they had nested previously and a decline in the number of nesting pairs on other lakes has been noted by several authors (e.g., Quilliam 1973). The absence of breeding loons from some of the densely populated lakes in Minnesota (Ream 1976; personal observation) may be further evidence of the vulnerability of this species.

Edge Effect, Bird Species Diversity, Species Composition

An edge or ecotone is essentially a transition zone between two different habitat types. Such a zone commonly contains some species found in each of the adjoining habitats as well as others characteristic of the ecotonal region itself. As a result, both population density and species richness may be increased in the vicinity of an edge (Pianka 1974). Examples of changes in community structure occurring as a result of an increase in edge are abundant, particularly for avian communities (e.g., Beecher 1942; Odum and Burleigh 1946). In the present investigation, however, species richness and/or diversity were not found to be higher in study areas that possessed increased amounts of edge, despite the greater number of individual birds observed to occur in these locations. This suggests that the edges formed as a result of cottage development are different in some respects from edges formed in other ways, such as between forest and field. They thus may not serve as interfaces between two habitats, both of which are capable of sustaining diverse avian communities; rather, they may be boundaries between wooded areas capable of supporting many avian species and developed (i.e., built up, cleared of much vegetation) spaces used by only a few hardy types. Thus, although the creation of this type of edge may typically influence certain aspects of the avian community (e.g., species composition, population abundance), its effect on other parameters (e.g., species diversity, species richness) may be minimal, quite different from that which might have been predicted on the basis of previous studies of edge habitat.

Past studies have shown that the substitution of edge habitat for portions of climax forest may result in the dislocation of many 'true forest' species (see Kendeigh 1944). Perhaps out-competed by those that preferentially inhabit such ecotones, or faced with detrimental changes in certain habitat variables, these forest species may withdraw into more isolated tracts of woodland. In our study several typically forest-dwelling species including the Yellow-billed Cuckoo (*Coccyzus americanus*), Yellow-throated Vireo (*Vireo *flavifrons*), Black-and-White and Cerulean Warblers, American Redstart (*Setophaga ruticilla*), and Pileated Woodpecker (*Dryocopus pileatus*) were more abundant in, or restricted to, the less disturbed transects which were characterized by reduced amounts of edge.

On the other hand, land development may result in an influx of other species more characteristic of open areas. For example, the construction of buildings on portions of this land provides conditions suitable for those birds that commonly nest in or around such structures (e.g., Barn Swallows, *Hirundo rustica* and Eastern Phoebes, *Sayornis phoebe*). The expected influx of new species as a result of such events may not be sufficient to outweigh the desertion of disturbed habitats by other species. Thus species richness and/or diversity might be expected to remain the same or even decline in areas where the cause of an increase in edge habitat is cottage development rather than some other factor. Such a trend is indeed indicated by our data.

The increase in edge on disturbed transects resulted in a few species being favored. For these characteristic edge species (e.g., American Robins and Northern Orioles, *Icterus galbula*), population densities rose to very high levels in disturbed areas, while for other species densities were the same as or less than they were in undisturbed locations. Consequently, the evenness with which individuals were distributed among species was reduced in disturbed areas. The decrease in average H' noted for transects with disturbance levels ≥ 3 may thus have been due to a reduction in J', since S remained fairly constant.

It is apparent from the data, and for the reasons discussed above, that the major effect of disturbance in the areas investigated has been on the actual species composition of the avian fauna. This is indicated by the PS and CC values in particular. The extent of land development on Mustard Point approached that of an urban or suburban situation; the abundance of buildings, the presence of two roads, and extremely high levels of boat traffic in the area were reflected in very low values for FHD, CD, H', and J'. The difference between the avifaunas of Mustard Point and those of the majority of other transects is an indication of the nature and extent of the influence that intensive land development can have on a once natural landscape. It is worthy of note that the only Rock Doves or domestic pigeons (*Columba livia*) observed during the study were seen on Mustard Point.

This investigation was conducted in an area in which land development, although extensive, is not generally as intensive as in some other recreational centers. Extreme habitat alteration such as on Mustard Point is rare on these lakes. Thus, although some canopy trees have been removed when cottages and roads were built, many remain, and much of the understory vegetation has been left untouched or replaced. This type of land use is in contrast to that encountered on many of the more populated lakes in Ontario and elsewhere: often several tiers of cottages extend back from the shoreline, lawns are manicured, and only scattered canopy trees remain. In the Rideau Lakes region, such high intensity land use fortunately continues to be rare.

Our results are thus generally indicative of a low level of disturbance, as might have been predicted. A magnification of the noted effects may be expected in situations of more intensive development. The results point to the need for further study as well as for careful planning and control to prevent higher intensity use from having seriously deleterious effects on breeding bird populations.

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