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**Impacts of Adjacent Land Use and Isolation on Marsh Birds**

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# Impacts of Adjacent Land Use and Isolation on Marsh Bird Communities

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**Abstract** Over the next half century the human population is expected to grow rapidly, resulting in the conversion of rural areas into cities. Wetlands in these regions are therefore under threat, even though they have important ecosystem services and functions. Many obligate marsh-nesting birds in North America have shown declines over the past 40 years, and it is important to evaluate marsh bird community response to increased urbanization. We surveyed 20 coastal marshes in southern Ontario, Canada, and found that obligate marsh-nesting birds preferred rural over urban wetlands, generalist marsh-nesting birds showed no preference, while synanthropic species showed a trend towards increased richness and abundance in urban marshes. The Index of Marsh Bird Community Integrity (IMBCI) was calculated for each wetland and we found significantly higher scores in rural compared to urban wetlands. The presence of a forested buffer surrounding the marsh was not an important factor in predicting the distribution of generalists, obligates, synanthropic species, or the IMBCI. More isolated marshes had a lower species richness of obligate marsh-nesters and a lower IMBCI than less isolated marshes. Based on our results, we recommend that urban land use is not the dominant land use within 1000 m from any wetland, as it negatively affects the abundance and richness of obligate marsh-nesters, and the overall integrity of the avian community. We also recommend that all existing wetlands be conserved to mitigate against isolation effects and to preserve biodiversity.

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**Keywords** Urban · Rural · Wetland-dependent birds · Index of marsh bird community integrity · Forest buffer

## Introduction

Land transformations, specifically through urbanization, are considered to be the most important factor contributing to species extinction rates during this century (Marzluff and others 2001). Since almost 60% of the world's population lives within 100 km of the coast (Vitousek and others 1997), land transformations in these regions may have deleterious effects on extremely sensitive systems. Coastal wetlands are unique environments at the interface between aquatic and terrestrial systems and are some of the first habitats impacted by landscape disturbance and upstream pollution (Uzarski and others 2005, Seilheimer and Chow-Fraser 2006). Wetlands were once considered useless wastelands but are now recognized for their many important functions including local and global climate stabilization, erosion protection, flood attenuation, and sediment and water quality control (Williams 1991, Burbridge 1994). In addition to these ecosystem functions, they provide important habitat for many species including fish, invertebrates, mammals, and birds.

Concern over recent declines in many wetland-dependent bird species has led to an investigation into land use practices and the potential role they play in this decline. Secretive wetland birds, such as the American Bittern (*Botaurus lentiginosus*), American Coot (*Fulica americana*), Common Moorhen (*Gallinula chloropus*), King Rail (*Rallus elegans*), Least Bittern (*Ixobrychus exilis*), Pied-billed Grebe (*Podilymbus podiceps*), Sora (*Porzana carolina)*, Virginia Rail (*Rallus limicola)*, and Yellow Rail (*Coturnicops noveboracensis*), are quite sensitive to wetland changes because they are marsh obligates and require this habitat for both nesting and feeding (Peterson and Niemi 2007). The King Rail, Yellow Rail, and Least Bittern have been designated species at risk and are listed federally in Canada as endangered, of special concern, and threatened, respectively (COSEWIC 2000, 2001a, 2001b) and the King Rail and Yellow Rail are listed as species of high concern by the North American Waterbird Conservation Plan. The North American Breeding Bird Survey shows continental-scale declines for wetland obligates including the King Rail, American Bittern, Black Tern (*Chlidonias niger*), American Coot, and Common Moorhen between 1966 and 2007 (Sauer and others 2008). The Least Bittern and Sora populations appear to be stable, while the Swamp Sparrow (*Melospiza georgiana*), Marsh Wren (*Cistothorus palustris*), Virginia Rail, and Pied-billed Grebe show significant increases (Sauer and others 2008).

Landscape alteration primarily affects birds by clearing habitat and potential nest sites, but it can also increase the abundance of predators and nest parasites (Robinson and others 1995) including domestic cats (*Catus silvestris*) and racoons (*Procyon lotor*), along with a suite of synanthropic avian species such as the European Starling (*Sturnus vulgaris*), House Sparrow (*Passer domesticus*), and Rock Dove (*Columba livia*; Marzluff 2001). Urbanization has also been shown to elicit behavioural changes in birds such as human habituation (Donaldson and others 2007) and changes in song frequency in response to noise in urban environments (Slabbekoorn and Peet 2003).

Land-use studies focussing on birds have increased greatly since the 1980's, although studies are still lacking in coastal systems (Marzluff and others 2001). Most studies examine the impact of an urbanization gradient on the land-bird community (Blair 1996, Reynaud and Thioulouse 2000, Mackey and Currie 2001, Schulze and others 2004, Miller and others 2007), and the general finding is that with increased urbanization there is an increase in the density of birds and a decrease in the avian species richness (Blair 1996, Marzluff 2001). Few studies have looked at wetlands within the urban context (but see DeLuca and others 2004, Pearce and others 2007), and there is a pressing need for studies examining the impacts of land use, specifically urbanization, on coastal wetland birds throughout southern Ontario (Miller and others 2001).

DeLuca and others (2004) developed and used the Index of Marsh Bird Community Integrity (IMBCI) to examine the influence of land use at varying spatial scales surrounding wetlands on marsh birds of Chesapeake Bay, USA. High values of this index reflect a high integrity community consisting of species whose attributes represent undisturbed areas and species with marsh-specialist life history traits (O'Connell and others 2000). The IMBCI scores were reduced significantly when urbanization reached 14% at the 500 m scale and 25% at the 1000 m scale (DeLuca and others 2004). One hypothesis to explain this pattern is that high levels of urbanization in close proximity to the wetland create habitat for generalist species (Blair 1996), and these generalists could then invade marsh habitat and subsequently lead to increased interspecific competition (DeLuca and others 2004). We wanted to test this hypothesis by examining patterns of generalist species richness, obligate species richness, and associated IMBCI scores in wetlands bordered by varying degrees of disturbance.

In addition to urbanization, marsh isolation is an important factor influencing bird communities. Isolation could be the result of infilling or draining for either urban development or various rural land uses including agriculture. Marsh isolation limits the amount of potential nesting and feeding habitat nearby, and could influence metapopulation dynamics such as source-sink relationships (Semlitsch and Bodie 1998). Populations in more isolated wetlands have a lower probability of rescue effects because the chance of migration and recolonization is lower, and therefore are less likely to be rescued from extinction (Semlitsch and Bodie 1998). More isolated marshes tend to have a lower avian species richness than less isolated marshes, and wetland-complexes hold more species than more isolated wetlands (Brown and Dinsmore 1986, Naugle and others 2001). In this study, we determined the effect of marsh isolation on wetland bird communities. Therefore, the specific objectives of this study are to determine how (1) adjacent land use, and (2) marsh isolation, influences wetland bird communities in southern Ontario coastal marshes.

## Methods

### Study Area

From 2006–2007, we conducted point counts in 20 coastal wetlands of Lake Erie and Lake Ontario, Ontario, Canada (Fig. 1). This shoreline contains the remnants of a once extensive coastal wetland system that has succumbed to the pressures of a growing human population. Between 1800 and 1985, over 80% of wetlands in southern Ontario have disappeared due to agricultural or urban development (Snell 1987). These marshes are now primarily eutrophic systems with dominant emergent vegetation such as native, alien and putative hybrid species of cattails (*Typha* spp.), the exotic species of common reed (*Phragmites australis*), and several native species of bulrush (*Schoenoplectus* spp.).

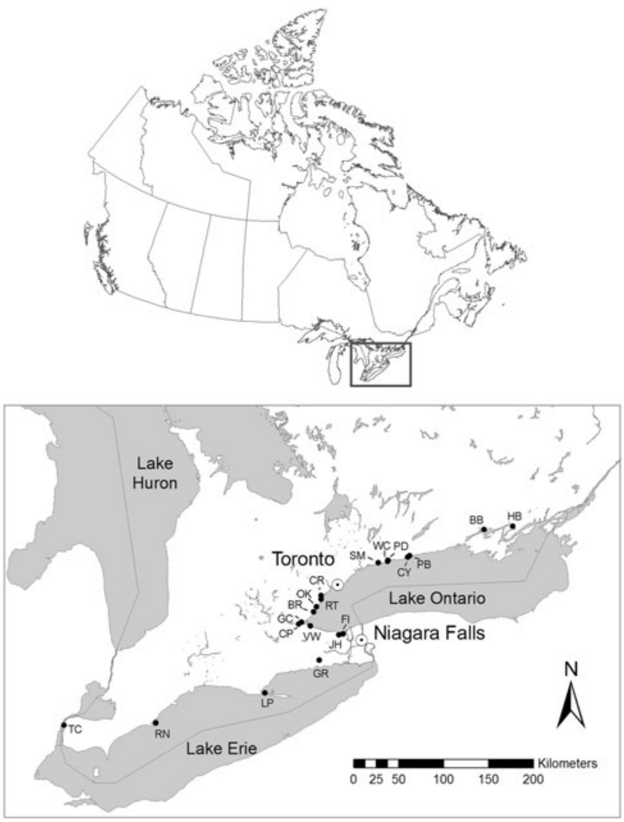


**Fig. 1** A map of 20 coastal wetland study sites in southern Ontario, Canada surveyed between 2006 and 2007

Avian Sampling

All point counts were sampled from a canoe between 1 May and 27 July, 2006 and 2007. Each count was conducted twice throughout the season at least 10 days apart and the results of each survey were averaged (Siegel and others 2001). All counts were conducted between sunrise and four hours after sunrise, and surveys were not conducted in high winds (>20 km/h) or during periods of rainfall (Krzys and others 2002, Hanowski and others 2007). Point counts were 10 min in length and a 25 m radius full circle was used. We located our first sample point at the emergent vegetation-water interface closest to the canoe launch point but at least 25 m from the shore. Once we arrived at the point count, one minute was allowed for birds to settle. We recorded all birds seen and heard regardless of age (immature vs. adult) or sex. We counted all individuals which were landing, flushing, wading, perching, or calling within the point count area. If the bird was foraging in the wetland (e.g., swallows, swifts, terns, gulls, birds of prey) they were included in the point count if they were <25 m above the wetland. If birds were flushed upon our approach (e.g., herons or egrets), they were included in the count.

To increase the responsiveness of secretive wetland bird species, we broadcasted the songs of the American Coot, American Bittern, Least Bittern, Pied-billed Grebe, Sora, Virginia Rail, Common Moorhen, King Rail, and Yellow Rail in that order following the 10 min passive period (Gibbs and Melvin 1993). Calls were broadcast at a sound level of 70–85 dB at a distance of 1 m from the front of the speakers which were oriented to broadcast directly into the patch of emergent vegetation. Speakers were held at a height of 0.75 m above the water surface.

In the broadcast sequence, each species' call varied in length (35–110 s), but each species' call was separated by a 30 s pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts for us to listen for responses. Subsequent point counts were located by paddling further into the wetland and were located at least 200 m apart to ensure sample independence (Rehm and Baldassarre 2007). We conducted more point counts in larger wetlands surveying as many points as possible during the morning sampling period, or until we surveyed the entire wetland.

Land Use Classification

Land use analysis was performed using the Southern Ontario Land Resources Information System (SOLRIS; OMNR 2008). SOLRIS is a geographical information system platform consisting of digital polygons for 23 different land use classes for all of southern Ontario (OMNR 2008). For analysis, we grouped these 23 land use classes into 5 subclasses: forest, rural/wildlands, marsh, urban, and open water. It is important to note that SOLRIS was created based on aerial images from 2000–2002, whereas our study will utilize information collected from 2006–2007. We updated known land use changes using 2005 Ministry of Natural Resources shapefiles and Google Earth satellite images. To determine the extent of unknown changes we randomly selected five sites and identified changes in land use since 2000–2002 using Google Earth images from 2004–2007. Since changes involved the conversion of on average 0.23% of the land at varying scales from either rural/wildlands or forest to impervious urban areas or roads, we concluded that they were negligible and did not modify information for the remaining wetlands.

For analysis, we used the proportion of each land-based sub-class (including marsh) out of the total amount of land in the sample. To determine if the wetlands were buffered by a forest or not, we visually inspected GIS images, but also looked at the proportion of forest cover within the 500 m radius. If forest composed >20% of the land at the 500 m scale, sites were considered to be buffered. To determine adjacent land use, we selected the land use (other than forest) that composed the majority of land at the 1000 m scale. Therefore, sites could be placed into four categories: urban buffered, urban no buffer, rural buffered, and rural no buffer (Table 1). To measure isolation we used the amount of marsh within 4000 m from the edge of the wetland of interest because birds are highly mobile and are more likely influenced by isolation at a large spatial scale (Brown and Dinsmore 1986). Turkey Creek wetland was removed from this analysis because at the 4000 m scale, part of the area entered into a region for which we did not have GIS data.

### Statistical Analyses

To determine the influence of forested buffers and adjacent land use on the wetland bird community, we used a two-factor analysis of variance. The first factor was the presence or absence of a forested wetland buffer, and the second factor was the land use adjacent to the buffer (rural/wildlands or urban areas). We tested the effects on both the richness and abundance of obligate and generalist marsh-nesting birds (Appendix 1). Richness was calculated as the overall site presence/absence and abundance was averaged between the two seasonal point count visits and then averaged for the total number of point counts at each wetland. We tested for species-specific trends in abundance between urban and rural, and buffered and non-buffered sites for the Red-winged Blackbird (*Agelaius phoeniceus*), Song Sparrow (*Melospiza melodia*), Yellow Warbler (*Dendroica petechia*), Common Yellowthroat (*Geothlypis trichas*), Marsh Wren, Swamp Sparrow, Virginia Rail, and Mute Swan (*Cygnus olor*).

We also tested the effect of land use and buffer presence on the IMBCI scores using a two-factor analysis of variance (DeLuca and others 2004). This index is modelled after the Index of Biotic Integrity (IBI) proposed by Karr and Dudley (1981), where biotic integrity measures the ability of an area to support and maintain an adaptive species community and function similar to the natural habitat of the area. High integrity scores indicate marsh bird communities with many wetland-specialized species, and few generalists. The index is calculated using a guild-based approach and specifically includes foraging, nesting, and migratory guilds, along with breeding range. Scores for individual species are shown in Appendix 1 and are produced by simply adding each life history trait. Next, a total $W_{IMBCI}$ value can be calculated for the wetland as:

$$W_{IMBCI} = \left[\left(\frac{\sum S_{IMBCI}}{S_N}\right) + MO_N\right] - 4$$

DeLuca and others (2004)

where $S_{IMBCI}$ is each species' individual score, $S_N$ is the total number of species, $MO_N$ is the number of marsh obligate nesters detected. Four is subtracted to keep a scoring scale that starts at zero and is constant (DeLuca and others 2004). We also examined land use impacts on the overall site species richness, and the species richness and abundance of synanthropic species (Johnston 2001).

We used simple linear regression to determine the effect of isolation on obligate richness and abundance, generalist richness and abundance, the IMBCI, and overall site species richness. The proportion of surrounding marsh within 4000 m was used as our measure of isolation and was ArcSin(squareroot) transformed for all analyses. Graphs show non-transformed data and all $R^2$ values reported are adjusted $R^2$ values.

A confounding factor in many wetland-land use studies is the influence of wetland area, which has been well documented in the literature (Brown and Dinsmore 1986, Findlay and Houlahan 1997, DeLuca and others 2004, Benassi and others 2007). We performed a two-factor ANOVA using the same independent treatment groups, but this time with marsh size as the dependent variable to see if our land use categories were grouping larger marshes together or smaller marshes together. We also looked for a potentially confounding relationship between isolation and marsh size using correlation. We found that more isolated marshes tended to be smaller ($r = 0.442$, $P = 0.058$), and therefore we used Partial Mantel tests to look at the effect of marsh isolation on the dependent variables that yielded significant regressions. Partial Mantel tests determine the effect of one independent variable (marsh isolation), while holding the effect of the other correlated independent variable constant (marsh size).

All dependent variables were normally distributed and were checked for heteroscedasticity for analyses of variance. We squareroot(x + 1) transformed the $W_{IMBCI}$ data, but it continued to show slight heteroscedasticity (Bartlett's test $P = 0.012$). We also squareroot(x + 3/8) transformed obligate abundance and it also still showed heteroscedasticity (Bartlett's test $P = 0.0016$). Obligate species richness showed no variance for urban, buffered sites, which always contained only one obligate species. Variances between urban/non-buffered, rural/buffered, and rural/non-buffered were homogeneous for obligate species richness. We squareroot(x + 1) transformed the Mute Swan abundance data to bring it closer to normal for the buffered/rural grouping. We decided to proceed with the parametric tests for these analyses due to the robustness in analysis of variance tests, and the fact that our samples sizes for each treatment group were relatively similar.

## Results

### Adjacent Land Use

There was no significant relationship between land use ($F_{1,16} = 0.548$, $P = 0.470$) or buffer presence ($F_{1,16} =$

**Table 1** Sites categorized as buffered or not buffered, and adjacent land as urban or rural

| Site | Category (B = buffered, N = no buffer, U = urban, R = rural) | GIS proportion forest cover within 500 m | Visual inspection if buffered | GIS proportion adjacent urban 1000 m | GIS proportion adjacent rural 1000 m | Proportion marsh ($\times 10^{-4}$) |
|---|---|---|---|---|---|---|
| Van Wagners (VW) | NU | 0.030 | No | 0.726 | 0.254 | 37.51 |
| Westside Creek (WC) | NR | 0.058 | No | 0.520 | 0.385 | 68.34 |
| Oakville Marsh (OK) | NU | 0.076 | Partial | 0.939 | 0.004 | 0 |
| Port Darlington (PD) | NR | 0.108 | No | 0.464 | 0.392 | 100.28 |
| Turkey Creek (TC) | NU | 0.110 | No | 0.729 | 0.128 | – |
| Bronte Creek (BR) | NU | 0.132 | Partial | 0.803 | 0.051 | 3.37 |
| Second Marsh (SM) | NU | 0.183 | Partial | 0.496 | 0.358 | 53.11 |
| Crysler Point (CY) | NR | 0.200 | Partial | 0.490 | 0.276 | 87.91 |
| Jordan Harbour (JH) | BR | 0.211 | Yes | 0.210 | 0.616 | 50.46 |
| Long Point (LP) | BR | 0.212 | Yes | 0.099 | 0.712 | 64.59 |
| Credit River (CR) | BU | 0.216 | Partial | 0.833 | 0.027 | 17.81 |
| Grand River (GR) | BR | 0.227 | Yes | 0.140 | 0.643 | 23.60 |
| Port Britain (PB) | BR | 0.250 | Yes | 0.053 | 0.784 | 58.58 |
| Fifteen Mile Creek (FI) | BR | 0.250 | Yes | 0.201 | 0.614 | 87.95 |
| Grindstone Creek (GC) | BU | 0.275 (>0.2) | Yes | 0.388 | 0.349 | 97.26 |
| Hay Bay (HB) | BR | 0.299 (>0.2) | Partial | 0.021 | 0.704 | 223.55 |
| Rattray (RT) | BU | 0.435 (>0.2) | Partial | 0.694 | 0.006 | 37.51 |
| Cootes Paradise (CP) | BU | 0.501 (>0.2) | Yes | 0.488 | 0.138 | 36.90 |
| Blessington Bay (BB) | BR | 0.597 (>0.2) | Yes | 0.196 | 0.255 | 385.38 |
| Rondeau (RN) | BR | 0.841 (>0.2) | Yes | 0.075 | 0.118 | 726.23 |

GIS land use measurements at Westside Creek, Port Darlington, Crysler Point, and Blessington Bay were overridden by visual data due to habitat configuration surrounding the wetland at the 1000 m scale. Proportion marsh indicates the proportion of the land within 4000 m of the wetland that is marsh habitat

0.563, $P = 0.464$) and wetland area. We found a higher richness ($F_{1,16} = 6.85$, $P = 0.019$) and abundance ($F_{1,16} = 8.42$, $P = 0.010$) of obligate marsh-nesting birds in rural sites as compared to urban sites (Fig. 2a, b). There was no effect of a forested buffer on the richness ($F_{1,16} = 0.428$, $P = 0.522$) or abundance ($F_{1,16} = 3.09$, $P = 0.098$) of obligate marsh-nesters.

Generalist marsh-nesters showed no apparent preference between urban and rural sites (richness: $F_{1,16} = 0.336$, $P = 0.571$; abundance: $F_{1,16} = 2.54$, $P = 0.131$), or between buffered and non-buffered sites (richness: $F_{1,16} = 2.60$, $P = 0.126$; abundance: $F_{1,16} = 1.09$, $P = 0.312$; Fig. 2c, d). Synanthropic species showed a trend towards higher richness ($F_{1,16} = 2.59$, $P = 0.127$) and abundance ($F_{1,16} = 2.37$, $P = 0.143$) in urban areas, although the results were not significant (Fig. 2e, f). There was no effect of a forested buffer on the richness ($F_{1,16} = 1.20$, $P = 0.290$) or abundance ($F_{1,16} = 0.004$, $P = 0.949$) of synanthropic birds.

The $W_{IMBCI}$ scores were significantly higher in rural sites than urban sites ($F_{1,16} = 7.12$, $P = 0.017$), although there was no significant effect of a forested buffer ($F_{1,16} = 0.404$, $P = 0.534$; Fig. 3). There was no difference in overall wetland species richness between urban and rural sites ($F_{1,16} = 0.141$, $P = 0.712$), and buffered and non-buffered sites ($F_{1,16} = 1.56$, $P = 0.230$).

Species-specific results suggest that the Red-winged Blackbird, Song Sparrow, Marsh Wren, and Swamp Sparrow are sensitive to adjacent land use practices (Table 2). The Red-winged Blackbird and Song Sparrow were found in higher abundances in urban contexts regardless of the presence of a forested buffer ($F_{1,16} = 0.462$, $P = 0.507$; $F_{1,16} = 0.410$, $P = 0.531$; respectively). The Marsh Wren and Swamp Sparrow preferred rural wetlands, and also showed no significant preference for buffered or non-buffered sites ($F_{1,16} = 4.03$, $P = 0.062$; $F_{1,16} = 0.132$, $P = 0.721$; respectively).

### Isolation

The amount of marsh habitat within 4000 m of the wetland significantly influenced the bird community at the study site. Sites with more surrounding marsh habitat (less isolated wetlands), had a higher $W_{IMBCI}$ value than those more isolated wetlands, even when holding the influence of wetland area constant (Mantel r = 0.290, $P = 0.001$; Fig. 4a). Less isolated wetlands also contained significantly more obligate marsh-nesting species (Mantel r = 0.295, $P = 0.004$; Fig. 4b), even when controlling for wetland area. There was no effect of isolation on generalist richness ($R^2 = 0.00$, $P = 0.860$; Fig. 4c), obligate abundance ($R^2 = 0.068$, $P = 0.147$), generalist abundance ($R^2 = 0.00$, $P = 0.706$), or overall site species richness ($R^2 = 0.00$, $P = 0.596$).

## Discussion

This study illustrates the far-reaching effects that urbanization can have on nearby natural systems. Even though each wetland unit was relatively void of immediate human presence, the influence of the adjacent land use was still apparent as shown by changes in the bird community. Our findings contribute to the growing body of evidence that suggests obligate marsh-nesters prefer wetlands in more undisturbed landscapes, and less isolated wetlands.

We found a tendency towards more synanthropic species and individuals in urban wetlands compared to rural wetlands and this is consistent with previous research showing that some species form symbiotic relationships with humans through urban environments (Johnston 2001). Generalist marsh-nesters showed no preference between urban and rural habitats demonstrating their ability to use both urban environments and un-urbanized areas. There were fewer obligate species and individuals occupying urban wetlands compared to rural wetlands, and this finding is consistent with previous literature (DeLuca and others 2004). Avoidance of urban wetlands could be due to many factors including increased competition from generalists (DeLuca and others 2004), changes in predator communities (Hoffmann and Gottschang 1977, Haskell and others 2001) or noise pollution (Slabbekoorn and Peet 2003, Patricelli and Blickley 2006).

Although we cannot directly demonstrate that competition between generalists and obligates led to the segregation of niches between urban and rural sites, it may be one of many factors influencing habitat selection (Marzluff 2001, DeLuca and others 2004). Anthropogenic niche differentiation could be directly demonstrating the ability of generalists to live in, or close to, human environments and the inabililty of obligates to occupy these environments. Many bird species once adapted to natural environments have taken to human-dominated habitats for either nesting or feeding. For example, many cliff-nesting species such as swallows now use human structures for nesting, while gulls and corvids exploit human environments for food (Johnston 2001). It is extremely unlikely that species such as marsh-obligate nesters would be able to use human-associated habitats, as they rely solely on aquatic habitat, which is often altered by human development through drainage or other activities that alter marsh vegetation.

The fact that birds are adapting to live with humans appears to be natural, and a part of evolution. For example, some European synanthropes, who have been living with humans for close to 1000 years, show increased fecundity and decreased longevity compared to their North American counterparts (Martin and Clobert 1996). This shift could be due to an adaptation to increases in human and associated

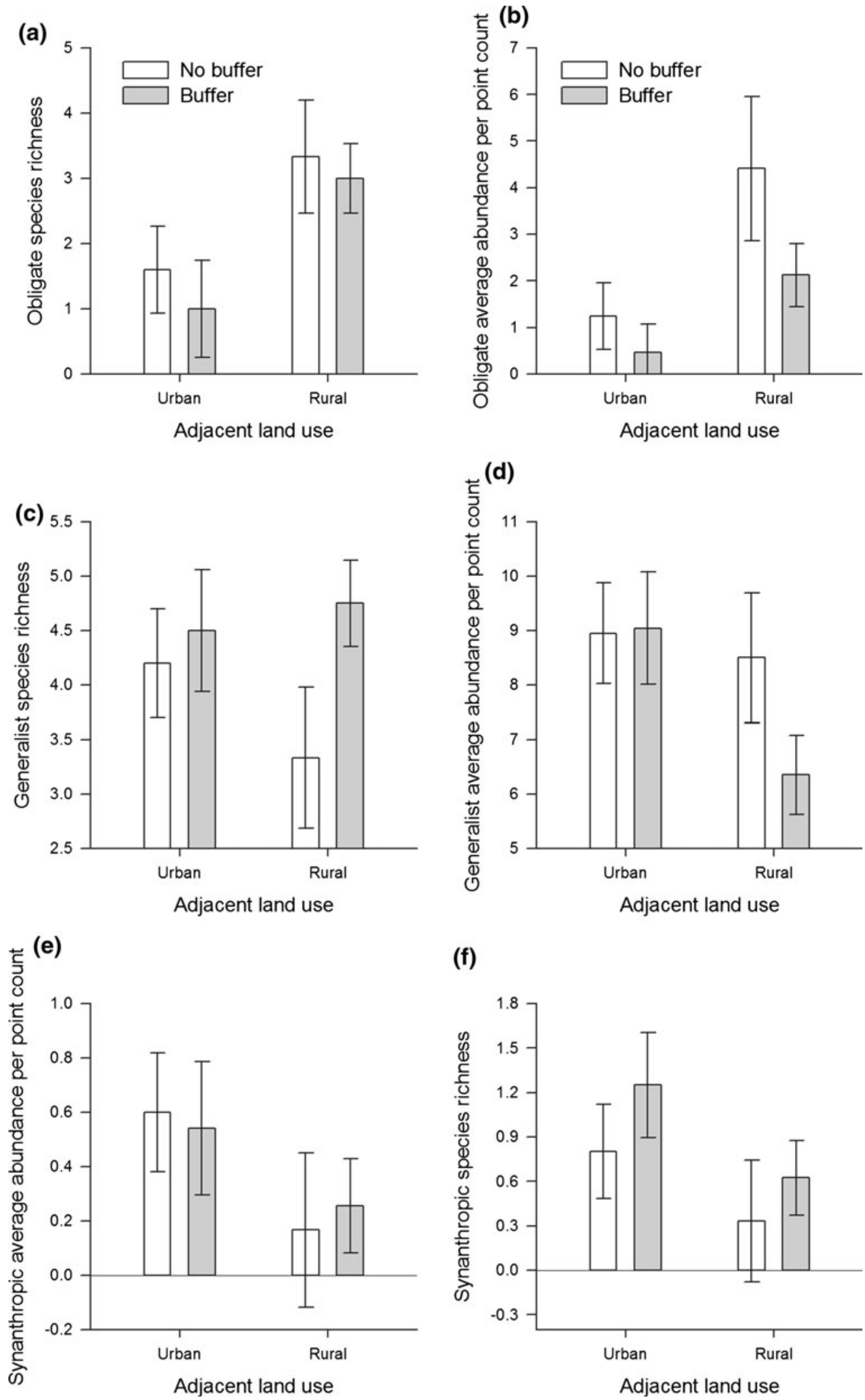


**Fig. 2** Variation in obligate richness and abundance (**a**, **b**), generalist richness and abundance (**c**, **d**), and synanthropic species richness and abundance (**e**, **f**) between urban and rural, and buffered and non-buffered sites. Shown are means ± 1SE. Back-transformed data are shown for obligate abundance

predators. Those individuals able to quickly reproduce more young may be at an advantage, and therefore pass on more of their genes (Martin and Clobert 1996). It is important to stress that while the evolution of synanthropism may be a natural process to coping with the increasing human presence for some species, it is not a solution

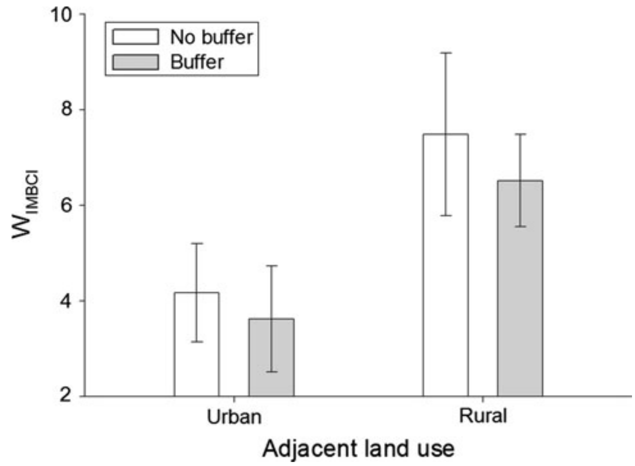


**Fig. 3** The effect of adjacent land use and the presence of a forested buffer on the Index of Marsh Bird Community Integrity at 20 coastal marshes in southern Ontario. Back-transformed data are shown

(Johnston 2001). If species are forced to evolve too quickly, as is the current situation with the exponential human population growth and required infrastructure, extinctions may result instead of evolution (Johnston 2001, Cohen 2003).

Based on the results of this study, we recommend that urban development should not be the dominant land use within 1000 m of any wetland since it negatively affects the abundance and richness of obligate marsh-nesters, and the overall integrity of the avian community. These results are consistent with previous research using IBI's to indicate land use and disturbance for many taxa including fish (Seilheimer and Chow-Fraser 2006), plants (Croft and Chow-Fraser 2007) and birds (DeLuca and others 2004, Howe and others 2007). This study also provides evidence that the IMBCI developed by DeLuca and others (2004) in Chesapeake Bay, USA, can also be used to accurately reflect adjacent land use in Great Lakes coastal marshes along the north shores of Lake Ontario and Lake Erie. Future research should be conducted to determine the performance of this indicator on a basin-wide scale.

Even though urban marsh habitat does not seem to be the most suitable for obligate marsh-nesting birds, it is still important for generalist marsh-nesters. Many of these generalist species are Neotropical migrants, and already face many difficulties including habitat destruction on breeding and wintering grounds (Sarmiento 2000), and danger associated with migration (Newton 2006). It is important to recognize the importance of all wetlands, including existing urban wetlands, because they provide habitat for generalist species, which are also important for ecosystem functioning.

The presence of a forested buffer (defined in our study as forest cover of >20% within 500 m from the wetland edge) does not appear to be as important in predicting species richness as the land use adjacent to the buffer. This finding for marsh birds is quite different from the current literature that shows wetland buffers are important for controlling water quality and conserving habitat for other wetland-associated organisms (Carter 1996, Norman 1996, Crosbie and Chow-Fraser 1999, Robichaud and others 2002, Houlahan and Findlay 2004, Bried and Ervin 2006, Gamble and others 2006). One study by Pierluissi and King (2008) found that the proportion of tree cover within 1000 m of rice fields containing nesting King Rails was not important in predicting nest density. More research needs to be conducted to uncover the reason why wetland birds respond differently than other species to the presence or absence of a forested buffer.

We also recommend that all existing wetlands be conserved to mitigate against isolation effects and that future restoration work should focus on reducing isolation of

**Table 2** Species-specific changes in abundance between primarily urban or rural adjacent land uses

| Species | Urban ($n = 9$) | Rural ($n = 11$) | $F_{1,16}$ | $P$ |
|---|---|---|---|---|
| Red-winged Blackbird | 5.57 ± 0.325 | 4.14 ± 0.409 | 4.45 | 0.051 |
| Song Sparrow | 0.630 ± 0.102 | 0.417 ± 0.097 | 3.80 | 0.069 |
| Yellow Warbler | 0.324 ± 0.135 | 0.330 ± 0.064 | 0.0003 | 0.987 |
| Common Yellowthroat | 0.213 ± 0.109 | 0.504 ± 0.170 | 1.06 | 0.319 |
| Marsh Wren | 0.500 ± 0.333 | 1.33 ± 0.336 | 5.40 | 0.034 |
| Swamp Sparrow | 0.296 ± 0.197 | 0.879 ± 0.107 | 6.36 | 0.024 |
| Virginia Rail | 0.250 ± 0.132 | 0.296 ± 0.154 | 0.293 | 0.596 |
| Mute Swan | 0.395 ± 0.173 | 0.084 ± 0.058 | 2.61 | 0.126 |

All interaction effects and effects of the presence/absence of a forested buffer were not significant. Abundance represents the average abundance/wetland and data shown are means ± 1SE (back-transformed values for the Mute Swan)

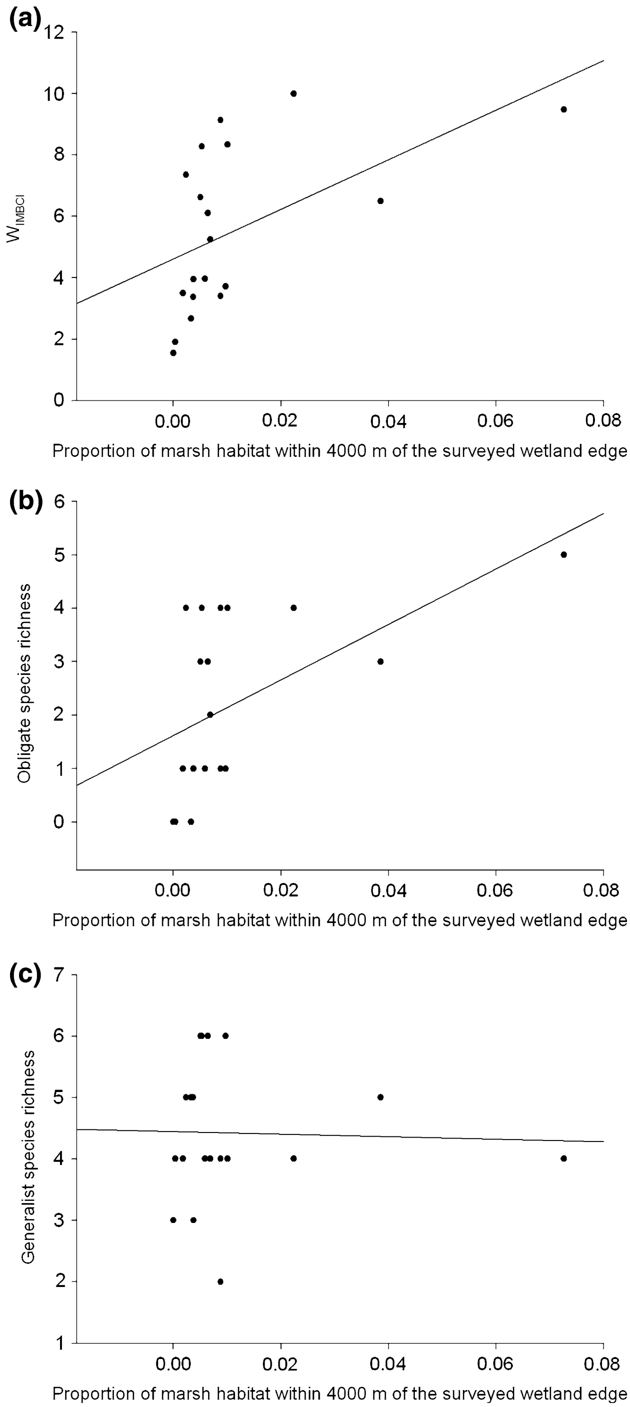


**Fig. 4** The effects of isolation on the $W_{IMBCI}$, obligate species richness, and generalist species richness for 19 coastal marshes in southern Ontario

remaining wetlands using a landscape approach to preserve biodiversity. Less isolated wetlands were associated with higher integrity values and obligate species richness, but it is important to point out that some of the more isolated marshes had equally high values. This indicates that small, isolated wetlands are not expendable (Semlitsch and Bodie 1998) and should be included with larger marshes in wetland protection legislation because they also provide important habitat for marsh birds. Future research should strive to determine the reason for urban-avoidance in obligate marsh birds. Low-frequency urban noise from traffic and machinery is thought to interfere with avian communication, and can lead to lower densities of breeding birds near roads (Reijnen and others 1995, Reijnen and others 1996, Forman and Alexander 1998). Marsh-birds primarily communicate using low frequency sounds to facilitate long-distance transmission through dense marsh habitat (Cosens and Falls 1984), and human noise could be interfering with communication in urban environments (Slabbekoorn and Peet 2003). In-depth long-term studies are also needed to monitor nest survival rates, predator communities, and food abundance within the context of varying land uses surrounding wetlands to determine other potential mechanisms of urban-avoidance.

It is important to preserve the remaining wetlands in southern Ontario, and the undisturbed land surrounding them, to ensure that natural ecosystem processes and services continue to function. The continued functioning of wetlands in this region is not only important for our future benefit, but also for those species that require marsh habitat for their survival, and are integral in the proper functioning of these ecosystems. It is our hope that these remaining wetlands will stay undisturbed through the implementation and development of policy, future wetland research, and monitoring for early detection of changes and potential threats to these sensitive, yet powerful, ecosystems. This article is another stark reminder of the tumultuous impact that humans are having on bird communities, as they are forced into environments far away from the human presence.

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## Appendix 1

See Table 3.

**Table 3** Individual species scores for calculation of the Index of Marsh Bird Community Integrity (IMBCI)

| Common name | Scientific name | Foraging habitat | Nesting substrate | Migratory status | Breeding range | $S_{IMBCI}$ |
|---|---|---|---|---|---|---|
| American Goldfinch | *Carduelis tristis* | 1 | 1 | 1 | 1 | 4 |
| Mourning Dove | *Zenaida macroura* | 1 | 1 | 1 | 1 | 4 |
| European Starling[d] | *Sturnus vulgaris* | 1 | 1 | 1 | 1 | 4 |
| American Robin | *Turdus migratorius* | 1 | 1 | 1 | 1 | 4 |
| Northern Cardinal | *Cardinalis cardinalis* | 1 | 1 | 1 | 1 | 4 |
| Herring Gull | *Larus argentatus* | 1 | 1 | 1 | 1 | 4 |
| Ring-billed Gull | *Larus delawarensis* | 1 | 1 | 1 | 1 | 4 |
| Gull spp. | *Larus* spp. | 1 | 1 | 1 | 1 | 4 |
| Cedar Waxwing | *Bombycilla cedrorum* | 1 | 1 | 1 | 1 | 4 |
| Northern Flicker | *Colaptes auratus* | 1 | 1 | 1 | 1 | 4 |
| Turkey Vulture | *Cathartes aura* | 1 | 1 | 2.5 | 1 | 5.5 |
| Double-crested Cormorant | *Phalacrocorax auritus* | 1 | 1 | 2.5 | 1 | 5.5 |
| Mute Swan[d] | *Cygnus olor* | 1 | 2.5 | 1 | 1 | 5.5 |
| Canada Goose[c] | *Branta Canadensis* | 1 | 2.5 | 1 | 1 | 5.5 |
| Song Sparrow[c] | *Melospiza melodia* | 1 | 2.5 | 1 | 1 | 5.5 |
| Mallard | *Anas platyrhynchos* | 2.5 | 1 | 1 | 1 | 5.5 |
| Wood Duck[c] | *Aix sponsa* | 2.5 | 1 | 1 | 1 | 5.5 |
| Duck spp. | Family: Anatidae | 2.5 | 1 | 1 | 1 | 5.5 |
| Common Grackle[c] | *Quiscalus quiscula* | 1 | 2.5 | 1 | 2 | 6.5 |
| Brown-headed Cowbird | *Molothrus ater* | 1 | 1 | 4 | 1 | 7 |
| Chimney Swift[d] | *Chaetura pelagica* | 1 | 1 | 4 | 1 | 7 |
| Killdeer | *Charadrius vociferous* | 1 | 1 | 4 | 1 | 7 |
| Spotted Sandpiper | *Actitis macularia* | 1 | 1 | 4 | 1 | 7 |
| Lesser Yellowlegs | *Tringa flavipes* | 1 | 1 | 4 | 1 | 7 |
| Semipalmated Plover | *Charadrius semipalmatus* | 1 | 1 | 4 | 1 | 7 |
| Tree Swallow | *Tachycineta bicolour* | 1 | 1 | 4 | 1 | 7 |
| Barn Swallow | *Hirundo rustica* | 1 | 1 | 4 | 1 | 7 |
| Purple Martin[d] | *Progne subis* | 1 | 1 | 4 | 1 | 7 |
| Bank Swallow | *Riparia riparia* | 1 | 1 | 4 | 1 | 7 |
| Cliff Swallow | *Petrochelidon pyrrhonota* | 1 | 1 | 4 | 1 | 7 |
| Northern Rough-winged Swallow | *Stelgidopteryx serripennis* | 1 | 1 | 4 | 1 | 7 |
| Swallow spp. | Family: Hirundinidae | 1 | 1 | 4 | 1 | 7 |
| Caspian Tern | *Sterna caspia* | 1 | 1 | 4 | 1 | 7 |
| Baltimore Oriole | *Icterus galbula* | 1 | 1 | 4 | 1 | 7 |
| Belted Kingfisher | *Ceryle alcyon* | 1 | 1 | 4 | 1 | 7 |
| Yellow Warbler[c] | *Dendroica petechia* | 1 | 1 | 4 | 1 | 7 |
| Willow Flycatcher | *Empidonax traillii* | 1 | 1 | 4 | 1 | 7 |
| Eastern Kingbird | *Tyrannus tyrannus* | 1 | 1 | 4 | 1 | 7 |
| Sedge Wren[c] | *Cistothorus platensis* | 1 | 2.5 | 2.5 | 1 | 7 |
| Red-winged Blackbird[c] | *Agelaius phoeniceus* | 1 | 2.5 | 2.5 | 1 | 7 |
| Common Loon | *Gavia immer* | 1 | 2.5 | 2.5 | 1 | 7 |
| Great Egret | *Ardea alba* | 2.5 | 1 | 4 | 1 | 8.5 |
| Common Moorhen[a,b] | *Gallinula chloropus* | 2.5 | 2.5 | 2.5 | 1 | 8.5 |
| Common Yellowthroat[c] | *Geothlypis trichas* | 1 | 2.5 | 4 | 1 | 8.5 |
| Gray Catbird | *Dumetella carolinensis* | 1 | 2.5 | 4 | 1 | 8.5 |
| Osprey | *Pandion haliaetus* | 1 | 2.5 | 4 | 1 | 8.5 |
| Common Moorhen/American Coot[a,b] | *Gallinula chloropus/Fulica Americana* | 2.5 | 3.25 | 2.5 | 1 | 9.25 |

**Table 3** continued

| Common name | Scientific name | Foraging habitat | Nesting substrate | Migratory status | Breeding range | $S_{IMBCI}$ |
|---|---|---|---|---|---|---|
| Common Tern | *Sterna hirundo* | 1 | 2.5 | 4 | 2 | 9.5 |
| Swamp Sparrow[a] | *Melospiza Georgiana* | 2.5 | 4 | 1 | 2 | 9.5 |
| Green Heron | *Butorides virescens* | 2.5 | 2.5 | 4 | 1 | 10 |
| Black-crowned Night Heron | *Nycticorax nycticorax* | 2.5 | 2.5 | 4 | 1 | 10 |
| Great-blue Heron[c] | *Ardea herodias* | 2.5 | 2.5 | 4 | 1 | 10 |
| American Coot[a,b] | *Fulica Americana* | 2.5 | 4 | 2.5 | 1 | 10 |
| American Bittern[a,b] | *Botaurus lentiginosus* | 2.5 | 4 | 4 | 1 | 11.5 |
| Marsh Wren[a] | *Cistothorus palustris* | 4 | 4 | 4 | 1 | 13 |
| Black Tern[a] | *Chlidonias niger* | 4 | 4 | 4 | 1 | 13 |
| Sora[a,b] | *Porzana Carolina* | 4 | 4 | 4 | 1 | 13 |
| Virginia Rail[a,b] | *Rallus limicola* | 4 | 4 | 4 | 1 | 13 |
| Least Bittern[a,b] | *Ixobrychus exilis* | 4 | 4 | 4 | 1 | 13 |

$S_{IMBCI}$ represents the score for each species. Each category ranges from one to four with one representing marsh-feeding generalists, non-marsh nesters, resident species, and those distributed throughout North America. Species with a category score of four are marsh obligates, Neotropical migrants, and have a distribution limited within North America

[a] Marsh-nesting obligates, [b] secretive species, [c] marsh-nesting generalists, [d] synanthropic species

## References


Benassi G, Battisti C, Luiselli L (2007) Area effect on bird species richness of an archipelago of wetland fragments in Central Italy. Community Ecology 8:229–237

Blair RB (1996) Land use and avian species diversity along an urban gradient. Ecological Applications 6:506–519

Bried JT, Ervin GN (2006) Abundance patterns of dragonflies along a wetland buffer. Wetlands 26:878–883

Brown M, Dinsmore JJ (1986) Implications of marsh size and isolation for marsh bird management. The Journal of Wildlife Management 50:392–397

Burbridge PR (1994) Integrated planning and management of freshwater habitats, including wetlands. Hydrobiologia 285: 311–322

Carter V (1996) Environmental gradients, boundaries, and buffers: an overview. In: Mulamoottil G, Warner BG, McBean EA (eds) Wetlands: environmental gradients, boundaries, and buffers. Lewis Publishers, Boca Raton, FL

Cohen JE (2003) Human population: the next half century. Science 302:1172–1175

Cosens SE, Falls JB (1984) A comparison of sound propagation and song frequency in temperate marsh and grassland habitats. Behavioral Ecology and Sociobiology 15:161–170

COSEWIC (2000) COSEWIC assessment and update status report on the King Rail *Rallus elegans* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +10 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

COSEWIC (2001a) COSEWIC assessment and status report on the Yellow Rail *Coturnicops noveboracensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 62 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

COSEWIC (2001b) COSEWIC assessment and update status report on the Least Bittern *Ixobrychus exilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 10 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Croft MV, Chow-Fraser P (2007) Use and development of the wetland macrophyte index to detect water quality impairment in fish habitat of Great Lakes coastal marshes. Journal of Great Lakes Research 33:172–197

Crosbie B, Chow-Fraser P (1999) Percentage land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Science 56:1781–1791

DeLuca WV, Studds CE, Rockwood LL, Marra PP (2004) Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837–847

Donaldson MR, Henein KM, Runtz MW (2007) Assessing the effect of developed habitat on waterbird behaviour in an urban riparian system in Ottawa, Canada. Urban Ecosystems 10:139–151

Findlay CS, Houlahan J (1997) Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000–1009

Forman RTT, Alexander LE (1998) Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207–231

Gamble LR, McGarigal K, Jenkins CL, Timm BC (2006) Limitations of regulated "buffer zones" for the conservation of marbled salamanders. Wetlands 26:298–306

Gibbs JP, Melvin SM (1993) Call-response surveys for monitoring breeding waterbirds. The Journal of Wildlife Management 57:27–34

Hanowski JM, Danz NP, Howe RW, Regal RR, Niemi GJ (2007) Considerations for monitoring breeding birds in Great Lakes coastal wetlands. Journal of Great Lakes Research 33:245–252

Haskell DG, Knupp AM, Schneider MC (2001) Nest predatory abundance and urbanization. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA

Hoffmann CO, Gottschang JL (1977) Numbers, distribution, and movements of a raccoon population in a suburban residential community. Journal of Mammology 58:623–636

Houlahan JE, Findlay CS (2004) Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19:677–690

Howe RW, Regal RR, Hanowski J, Niemi GJ, Danz NP, Smith CR (2007) An index of ecological condition based on bird

assemblages in Great Lakes coastal wetlands. Journal of Great Lakes Research 33:93–105
Johnston RF (2001) Synanthropic birds of North America. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA
Karr JR, Dudley DR (1981) Ecological perspective on water quality goals. Environmental Management 5:55–68
Krzys G, Waite TA, Stapanian M, Vucetich JA (2002) Assessing avian richness in remnant wetlands: towards an improved methodology. Wetlands 22:186–190
Mackey RL, Currie DJ (2001) The diversity-disturbance relationship: is it generally strong and peaked? Ecology 82:3479–3492
Martin TE, Clobert J (1996) Nest predation and avian life-history evolution in Europe versus North America: a possible role of humans? The American Naturalist 147:1028–1046
Marzluff JM (2001) Worldwide urbanization and its effects on birds. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA
Marzluff JM, Bowman R, Donnelly R (2001) A historical perspective on urban bird research: trends, terms, and approaches. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA
Miller JR, Fraterrigo JM, Hobbs NT, Theobald DM, Wiens JA (2001) Urbanization, avian communities, and landscape ecology. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA
Miller C, Niemi GJ, Hanowski JM, Regal RR (2007) Breeding bird communities across an upland disturbance gradient in the western Lake Superior Region. Journal of Great Lakes Research 33:305–318
Naugle DE, Johnson RR, Estey ME, Higgins KF (2001) A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands 21:1–17
Newton I (2006) Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146–166
Norman AJ (1996) The use of vegetative buffer strips to protect wetlands in southern Ontario. In: Mulamoottil G, Warner BG, McBean EA (eds) Wetlands: environmental gradients, boundaries, and buffers. Lewis Publishers, Boca Raton, FL
O'Connell TJ, Jackson LE, Brooks RP (2000) Bird guilds as indicators of ecological condition in the central Appalachians. Ecological Applications 10:1706–1721
OMNR (2008) Southern Ontario Land Resource Information System Ver.1.2. Land Information Ontario, Ministry of Natural Resources, Queens Printer for Ontario, Toronto
Patricelli GL, Blickley JL (2006) Avian communication in urban noise: causes and consequences of vocal adjustment. Auk 123: 639–649
Pearce CM, Green MB, Baldwin MR (2007) Developing habitat models for waterbirds in urban wetlands: a log-linear approach. Urban Ecosystems 10:239–254
Peterson AC, Niemi GJ (2007) Evaluation of the Ohio Rapid Assessment Method for wetlands in the western Great Lakes: an analysis using bird communities. Journal of Great Lakes Research 33:280–291
Pierluissi S, King SL (2008) Relative nest density, nest success, and site occupancy of King Rails in southwestern Louisiana rice fields. Waterbirds 31:530–540
Rehm EM, Baldassarre GA (2007) Temporal variation in detection of marsh birds during broadcast of conspecific calls. Journal of Field Ornithology 78:56–63
Reijnen R, Foppen R, Ter Braak C, Thissen J (1995) The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. The Journal of Applied Ecology 32:187–202
Reijnen R, Foppen R, Meeuwsen H (1996) The effects of traffic on the density of breeding birds in dutch agricultural grasslands. Biological Conservation 75:255–260
Reynaud PA, Thioulouse J (2000) Identification of birds as biological markers along a neotropical urban-rural gradient (Cayenne, French Guiana), using co-inertia analysis. Journal of Environment Management 59:121–140
Robichaud I, Villard M, Machtans CS (2002) Effects of forest regeneration on songbird movements in a managed forest landscape of Alberta, Canada. Landscape Ecology 17:247–262
Robinson SK, Thompson FR III, Donovan TM, Whitehead DR, Faaborg J (1995) Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987–1990
Sarmiento FO (2000) Breaking mountain paradigms: ecological effects on human impacts in managed Tropandean landscapes. Ambio 29:423–431
Sauer JR, Hines JE, Fallon J (2008) The North American Breeding Bird Survey, Results and Analysis 1966–2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center. Laurel, Maryland, USA
Schulze CH, Waltert M, Kessler PJA, Pitopang R, Shahabuddin, Veddeler D, Muhlenberg M, Gradstein SR, Leuschner C, Steffan-Dewenter I, Tscharntke T (2004) Biodiversity indicator groups of tropical land-use systems: comparing plants, birds, and insects. Ecological Applications 14:1321–1333
Seilheimer TS, Chow-Fraser P (2006) Development and use of the Wetland Fish Index to assess the quality of coastal wetlands in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Science 63:354–366
Semlitsch RD, Bodie JR (1998) Are small, isolated wetlands expendable? Conservation Biology 12:1129–1133
Siegel RB, Desante DF, Nott MP (2001) Using point counts to establish conservation priorities: how many visits are optimal? Journal of Field Ornithology 72:228–235
Slabbekoorn H, Peet M (2003) Birds sing at a higher pitch in urban noise. Nature 424:267
Snell EA (1987) Wetland distribution and conversion in southern Ontario, Working paper No. 48. Canada Land Use Monitoring Program, Inland Waters and Lands Directorate, Environment Canada, Burlington, ON, Canada
Uzarski DG, Burton TM, Cooper MJ, Ingram JW, Timmermans STA (2005) Fish habitat use within and across wetland classes in coastal wetlands of the five great lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31:171–187
Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human domination of Earth's ecosystems. Science 277:494–499
Williams M (ed) (1991) Wetlands a threatened landscape. Basil Blackwell Ltd., Cambridge, MA