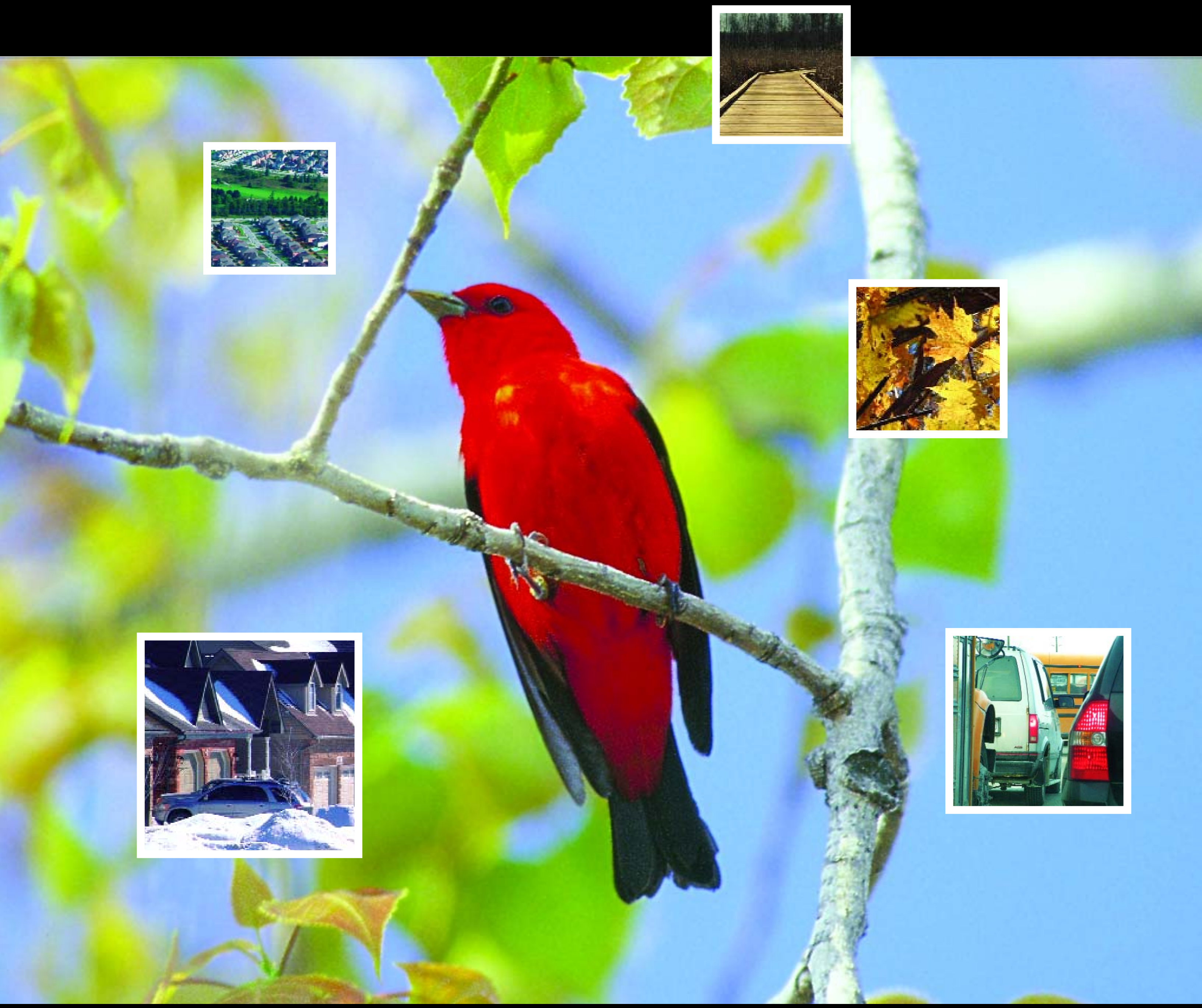
Area-Sensitive Forest Birds in Urban Areas



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About Environment Canada

Environment Canada manages wildlife matters that are the responsibility of the federal government. These include the protection and management of migratory birds, nationally significant habitat and species at risk, as well as work on other wildlife issues of national and international importance. In addition, the department does research in many fields of wildlife biology and provides incentive programs for wildlife and habitat stewardship.

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Executive Summary

Birds are perhaps the most easily studied and surveyed group of vertebrates and are often used as surrogates for the status of other wildlife species or natural communities. The life cycle requirements of forest birds were used in setting restoration guidelines for forests in *How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern* (Environment Canada 2004). There is increased interest in determining the applicability of the guidelines, and the breeding viability of area-sensitive forest birds, in an urban setting. The abundance and species richness of area-sensitive forest birds in urban areas are affected by numerous factors such as urban stressors, regional forest cover and the quality and extent of forest patches.

Thirteen major urban stressors were identified for forest birds in urban areas. The stressors thought to have the most impact on forest-bird breeding are: disruption of ecosystem processes, predation by urban-sponsored native predators, noise, and barriers to connectivity. Coupled with these forest-bird stressors, area-sensitive forest birds are also heavily dependent on other forest habitat metrics, in particular per cent forest cover and forest quality. *Framework* forest guidelines follow the principles behind these and other criteria. Patch size, one of the other metrics, appears to be dependent on forest cover, becoming more important in areas with less than 30 per cent forest cover.

The inability to restore total forest cover in an urban matrix raises doubts about the ability of urban systems to support area-sensitive forest-bird species. In terms of the gap between potential and actual bird richness: of 43 potential area-sensitive forest breeding birds in Toronto only 14 occur as breeding birds with any regularity in the urban environment, and 29 species have been lost or have not expanded into the urban forests.

Given the impracticality of establishing large enough forest blocks within an urban area, an alternative approach that seeks to identify and protect existing forest cover well above the minimum 30 percent threshold, before significant pressures of urbanization arrive, is the most practical and appropriate means to provide habitat for area-sensitive forest birds. Achieving *Framework* guidelines such as minimum 30 per cent forest cover can still be largely accomplished within the non-urbanized portions of watersheds. This does not preclude restoration within urban areas: many of the efforts to improve habitat for marginal area-sensitive forest breeding birds can also improve habitat for other native forest species within the urban matrix, as well as provide habitat for migrating area-sensitive forest breeding birds. The urban forest also provides many critical ecological services and human benefits. There are eight actions, including increasing vegetation layers, maintaining native vegetation and deadwood and providing adequate critical function zones that would be of benefit.

There is also a continued need for further research in key areas to better understand forest birds within urban areas.

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1. Introduction

Environment Canada recently published *How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern*, 2nd Edition (2004). That report provides guidelines, and the rationale behind these guidelines, for restoring and maintaining wetland, riparian and forest habitats. The forest habitat guidelines from that report include the amount of forest cover in a region, as well as the size, shape and landscape location of forest patches. Many of these forest guidelines are based on the requirements of forest breeding birds.

Birds are perhaps the most easily studied and surveyed group of vertebrates and are often used as surrogates for other wildlife species. Some forest birds are considered to be area-sensitive. This indicates that either they require a relatively large forest patch within which to live, or they occur in higher densities in larger patches. The abundance and species richness of breeding forest birds during the breeding season are affected by numerous factors such as regional forest cover and the quality and extent of forest patches. There is increased interest in determining the viability of protected forests within an otherwise urban or suburban matrix of land use.

A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (the *Framework*) was first prepared by Environment Canada's Canadian Wildlife Service and the Great Lakes 2000 Cleanup Fund (now known as the Great Lakes Sustainability Fund), the Ontario Ministry of Natural Resources and the Ontario Ministry of the Environment and released in 1998. *How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern, 2nd Edition* was released in 2004. The *Framework* provides guidance in selecting where wetland, riparian and forest habitat can be restored most effectively and efficiently. The key parts of the *Framework* are its 18 guidelines, which can be adopted or adapted for local watersheds, and background information based on existing literature and practices.

The *Framework* was intended to provide guidance for restoration activities in Great Lakes Areas of Concern. However, since its release, the *Framework* has also been used to guide and inform habitat restoration and protection outside of Areas of Concern. It helps guide decisions regarding:

- how much habitat is needed to support a natural, functioning ecosystem, and;
- priority locations for wetland, riparian and forest rehabilitation and protection across a watershed or landscape.

The *Framework* is meant to guide, not dictate, local decisions. It provides general guidance; is not landscape-specific; and is meant to be adapted to local conditions. The *Framework* and additional information are available from Environment Canada – please see contact information.

The goal of this report, *Area-Sensitive Forest Birds in Urban Areas*, is specifically to provide information to guide expectations for the use of urban forests[1] by area-sensitive forest breeding bird species.

The primary objectives are to:

a) Identify the primary characteristics of forest patches that would provide habitat for area-sensitive forest breeding birds within a matrix of large urban centres.

b) Identify the types of mitigation and habitat compensation that would be required to offset urban impacts on these birds and how practical this mitigation might be, and provide some guidance on possible restoration activities for other forest species.

c) Identify which area-sensitive forest birds have been lost from Toronto.

d) Discuss the utility of *A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern* (the *Framework*) forest habitat guidelines within an urban matrix.

The integrity of forest patches for other wildlife groups and the social and economic benefits that humans may receive from forested lands in the urban matrix are not the focus of this report. However a summary is provided on page 3.

Forest Birds (Forest associated birds, Forest breeding birds): Forest birds are those which occur regularly in forested habitats. A list of forest-bird species is maintained by the Canadian Wildlife Service for the Forest Bird Monitoring Program.

Area-sensitive breeding birds: Area-sensitive breeding birds that require a relatively extensive habitat patch in which to successfully reproduce, or occur in higher densities in such patches.

[1] *"Urban forests" and "urban forest fragments" in this document refer to woodland features that remain within the urban or urbanizing matrix and not to the broader definition of urban forest which generally refers to trees, forest and greenspace in and around cities and communities.*

The Ecological Values and Services of Urban Forests Beyond Area-Sensitive Forest Breeding Bird Habitat – A Summary

Urban forests have many values, provide a multitude of benefits and ecological services and are necessary contributors to the maintenance of biodiversity.

Trees provide habitat and food sources for wildlife such as birds, insects, small mammals and fish (Friesen *et al.* 1995; Tilghman 1987). Urban forests can cool watercourses and mitigate noise and dust (Harris 1992) that add stress to wildlife populations and humans. Trees improve air quality by producing oxygen, absorbing pollutants and sequestering carbon (McPherson and Simpson*.* 1999; Nowak 1992; Rowntree and Nowak 1991). Trees help to conserve energy by indirectly mitigating climatic effects through providing evaporative cooling, windbreak and shading functions, thus reducing human dependence on power generation (McPherson 1994; Pouyat and McDonnell 1991; Nowak 1994). Trees can also contribute to water quality and quantity improvement through storm water control, attenuation of peak flows, maintenance of base flow, erosion control and rainfall interception (Peck and Callaghan 1999; Bernatzky 1983; Xiao *et al.* 1998). Other benefits are associated with physical, mental and social health (Sorte 1995; Dwyer *et al.* 1992; Grahn and Stigsdotter 2003; Kuo 2003), as well as economic benefits such as higher property values and an impact in real estate consumer preference (City of Toronto 2003). While most people identify with these benefits at some level, there is a need for better awareness and appreciation of them.

Understanding the functions, values and services that urban forests provide is integral to their successful management (Nowak 2002). There are many ways to conserve and enhance urban forests so that they continue to provide ecological value and enrich the lives of city-dwellers, both human and non-human. These include ecological restoration and stewardship; appropriate planning and management; favourable tree by-laws and legislation, and public education.

To this end, recommendations for urban-forest conservation and management have been described (Kenney 1996; Nilsson *et al.* 2000; Konijendijk 1999; Tschantz and Sacamano 1994; Pouyat and Zipperer 1992; Matheny and Clark 1998) and include: increasing the number of healthy trees and sustaining existing canopy cover; building a basic understanding of ecological principles within the human community; establishing region wide policies and standards for best management practices; developing and implementing strategic management plans based on tree inventories and GIS technologies; undertaking more research on the value of the ecological benefits provided by the urban forest; and implementing functional urban design strategies that consider benefits such as ecological connectivity and shade.

(Ambrosia 2005)

2. Potential Urban Stressors on Area-Sensitive Forest Birds

In considering the primary objectives, it was determined that an appropriate first step in these investigations would be to consider what types of stressors on area-sensitive forest birds might be anticipated within an urban matrix[2]. Table 1 presents a list of potential stressors, based on relevant literature and scientific deduction within the urban environment.

Table 1. Potential Stressors for Area-Sensitive Forest Associated Breeding Birds in an Urban Environment

1. Barriers to Connectivity	**8. Nest Parasitism**
2. Contaminants	**9. Noise**
3. Direct Disturbance and Trails	**10. Predation by Urban-sponsored Native Predators**
4. Disruption of Ecosystem Process	**11. Predation by Urban-sponsored Non-native Predators**
5. Food Supply Changes	**12. Psychological and Social Behaviour**
6. Habitat Alteration	**13. Removal of Top Predators**
7. Artificial Light	

A review of the literature was undertaken. It was not an exhaustive review; the objective was to highlight key stressors and to gain some understanding (if possible) of the relative importance of these stressors, or to identify knowledge gaps. The following subsections discuss each of these potential stressors.

Marzluff and Ewing (2001) provide an insightful review of urban effects, as they are expressed through anthropogenic habitat fragmentation, and consider two primary attributes of the landscape that influence the effects. The first is the frequency and spatial extent of natural disturbance regimes. These are low in southern Ontario such that many native species are not adapted to rapid change. The second factor is the similarity of the land cover created by humans to natural cover. The change in land use from forest to row crop and pasture, or to urban, results in a loss of regional bird-community diversity. As is characteristic of biotic homogenization, urban fragmentation can increase local diversity (e.g., by adding species associated with humans or edge specialists), but decrease regional avifaunal diversity (Case 1996 *in* Crooks *et al.* 2004).

This document concentrates on urban effects. It is important to note that the non-urban or agricultural matrix also has an important influence on birds in terms of stressors. This is

[2] *In this report "urban", "urban environment", and "suburban" are used as synonyms; to avoid unnecessary precision a rigorous definition of urban is not presented. Such a definition would be problematic to establish as studies reviewed in this document use a wide variety of parameters to define "urban" limits.*

particularly relevant as almost one-third of the earth's land surface is planted in row crops or pastures and in southern Ontario, like many parts of the world, agricultural practices have intensified. Agriculture often converts land to a matrix that is as different (or even more different) from the natural matrix, as is the urban matrix. While an agricultural matrix may provide some vegetation cover that an urban land matrix may not, stresses such as disruption of nutrient cycles, the addition of pollutants and pesticides and the introduction or encouragement of non-native flora and fauna occur with conversion to an agricultural matrix (Newton 1998 *in* Marzluff and Ewing 2001). Perhaps the greatest difference between agricultural and urban matrices is that the latter seldom reverts to natural habitat.

2.1 Barriers to Connectivity

Within a non-forest matrix, forest-associated breeding birds face the challenge of dispersal or replenishment from one habitat patch to another. While it is generally accepted that landscape connectivity promotes the movement of animals among habitat patches (including non-desirables such as invasive species and pathogens), little research has been published on the relative ease with which forest-associated animals (or plants) move through or over the non-forest matrix.

At one end of the dispersal-ability scale, species that rarely move more than a very small distance, with or without connecting habitat, are unlikely to be assisted by, for example, connecting hedgerows. Being non-dispersers by strategy, they are unlikely to be affected by habitat isolation *per se*. For highly mobile species, it is assumed that a series of habitat patches can, depending on proximity and species characteristics, support either one large population or a related series of discrete populations. For non-dispersers and highly mobile species, it is likely that ensuring the maintenance of quality habitat becomes more important, rather than considerations to do with the precise distribution of habitat (Dawson 1994).

It is reasonable to suppose that species with intermediate powers of movement depend upon dispersal to replenish isolated populations (Dawson 1994). However, there is little direct scientific support for calculating the relative mobility of wildlife species that fall between these two extremes. It is particularly difficult to directly assess the movement potential of forest-associated breeding birds. In the temperate zone, most of these species can migrate hundreds of kilometres in just one evening, hundreds of individuals may pass through an isolated woodlot on migration, and key points in the mobility calendar are poorly understood (e.g., the diurnal movement of migrants or the post-breeding dispersal of adult and young birds). Therefore, it does not necessarily follow that a forest understorey area-sensitive species such as Black-throated Blue Warbler is incapable of crossing inhospitable habitat although the presence of appropriate natural cover may assist some movements or dispersal strategies.

Recent empirical research has challenged the notion that area-sensitive species avoid edge habitat or crossing open habitats or that they require corridors to move between forest patches. Indeed, it has been shown that male (although not female) Hooded Warblers (*Wilsonia citrina)* will cross up to 465 m of open field and travel up to 2.5 km away from their resident forest patch, primarily to solicit covert extra-pair copulations (Norris and Stutchbury 2001). The presence of successfully-nesting Hooded Warblers in 20 ha woodlots in Haldimand-Norfolk may be predicated on the contagion effect of adjacent woodlands, especially the "Big Woods" (in this case, Wilson Tract) (Stephanie Melles and Lyle Friesen pers. comm.).

Another important study, using radio-tracking techniques, has found that Scarlet Tanagers (*Piranga olivacea)* made extensive and frequent movements among forest fragments in Pennsylvania (Fraser and Stutchbury 2004). In the words of those authors:

> *To date three of three 'area-sensitive' birds studied…are actually not area-sensitive in terms of movements. Nonetheless, species may still be considered area-sensitive if their probability of occurrence increases with habitat patch size…area-sensitive species should not be assumed to avoid edge habitat, rely on corridors or avoid crossing open fields.*

A few small-scale gap-crossing experiments have been instigated for birds (e.g., Desrochers and Hannon 1997; Grubb and Doherty 1999) but these too have examined woodland birds crossing non-urban gaps. Whether any of these studies, which have been primarily aimed at movements in the non-urban matrix, relate well to the urban matrix is unknown.

In the urban matrix, roads can be an effective barrier to wildlife movement (Clarke *et al.* 1998). Roads create a barrier effect from a combination of disturbance and avoidance (behavioural), physical hindrances and roadkill. This barrier effect can also disrupt broader natural processes such as groundwater flow, fire spread, plant dispersal and animal movements (Seiler 2001). However, relatively little research or few studies have examined ecological thresholds regarding roads as barriers. Most of that science which is available has focussed on reptiles, amphibians and large rare mammals, groups of taxa that are more susceptible to road effects, and not on birds.

There is no evidence that a subdivision, or other urban land use, is necessarily more or less effective as a barrier than a road. Many of the characteristics of roads (e.g., noise, physical hindrances and mortality) can equally apply to other urban features, and some stressors may be enhanced. One study (Boal and Mannan 1999) found that almost 70 per cent of urban mortality of Cooper's Hawks (*Accipiter cooperi)* in the urban environment was caused by collisions, primarily with windows.

In a review of the effects of habitat fragmentation, Andren (1994) noted that in landscapes with highly fragmented habitat, patch size and isolation (the inverse of connectivity) will complement the effect of habitat loss. Andren suggested that evidence points towards a change in the relative importance of pure habitat loss versus patch size or isolation depending on the landscape, with a break at around 30 per cent.

In summary, barrier effects occur in urban environments, but the extent to which they are ecologically limiting is largely unknown. Furthermore, the function of corridors to mitigate the effects of isolation is poorly established and there is increasing evidence that some species at least (e.g., area-sensitive forest birds) can travel among habitat patches without the aid of habitat corridors, at least across an agricultural matrix. Whether connectivity is a limiting factor during the breeding season or also during periods of dispersal, is less clear and is likely species-specific. The role of connectivity in facilitating social interaction is just beginning to be explored. It is likely that connectivity (and patch size) becomes more important when forest cover falls below 30 per cent.

2.2 Contaminants

Contaminants are usually measured in top predators due to the fact that metals and other contaminants bio-magnify as they move up the food chain. Consequently, contaminants such as metals are usually in low levels and have short residence in birds such as passerines, which are low in the food chain. They can accumulate through drinking and geophagy (Hui and Beyer 1998). Metals and pesticides are only a few of the contaminants that can become common stressors for birds in human-influenced urban landscapes. Bioaccumulation of metals in birds can negatively influence reproductive success or ultimately the survival of species.

A study by Burger *et al*. (2004), reported local exposure to contaminants by analyzing concentrations of metals and metalloids in the eggs of Florida Scrub Jays (*Aphelocoma coerulescens)* from a residential subdivision. The influence of housing density on contaminant levels was analyzed and contaminants found in suburban-area birds versus birds in a biological reserve were compared. Unexpected results indicated that housing density showed no significant differences between contaminant levels except for mercury. Surprisingly, mercury levels were lower in high housing densities and higher in intermediate housing densities. It was also discovered that levels of cadmium, lead, manganese and selenium were significantly lower in the eggs collected in the suburban study area compared to those at the reserve (Burger *et al*. 2004). Nest success did not differ between the two areas. However, hatching failure in nests in the suburbs was twice that of the reserve. Overall, contaminant-level studies are difficult to interpret since one must take many considerations into account including food-chain susceptibility, contaminants in the eggs versus the feathers, surrounding natural features and the specific metals or metalloids being measured.

Lead is another known contaminant in urban environments, which poses a health risk to wildlife, including birds. In disturbed (urban/altered) habitat, lead concentrations in the atmosphere and soil are higher than in non-urban habitats. A study was conducted by Chandler *et al.* (2004), to determine the threat of lead exposure to the Sharp-shinned Hawk (*Accipter striatus)*. Lead blood concentrations of the House Sparrow (*Passer domesticus)*, the preferred prey of the hawk, were measured to determine if hawks were at risk. Lead blood concentrations of the House Sparrow were 4.5 fold higher in urban areas than in the exurban (in this case agricultural) control group. Therefore, Sharp-shinned Hawks may have been at risk of exposure to lead. Although results of the study signify that the hawks are potentially exposed to high lead levels, the degree to which the exposure became an actual threat remained unclear for the urban dwelling raptors.

Assessing the risk to wildlife of contaminant exposure remains relatively uncertain because empirical data are lacking and the science of ecological risk assessment is relatively new.

2.3 Direct Disturbance and Trails

It is reasonable to assume that more people use wooded areas within an urban matrix than forested areas within non-urban matrices. The presence of people, whether along the edges of wooded areas, on-trail, or off-trail within wooded areas, can result in disturbance to forest birds. Almost all forest-bird species will move away (flush) from a human if he/she approaches too close, as the human is presumably seen as a threat or potential predator. Increased disturbance results in less time for crucial activities such as feeding, territory maintenance and care of young. Trails may also create habitat edges which can increase nest predation, result in trampling and soil compaction or erosion. Also, human activities (e.g., bird feeding) can attract resident wildlife species that become predators during the breeding season.

In wooded parks in Madrid, Spain, Fernández-Juricic (2000) found that increased numbers of people led to lower species richness of forest birds and lower overall abundance of the common species within a forest fragment. After taking into account fragment size, it was also found that between forest fragments, larger numbers of pedestrians resulted in lower species richness. Sixteen of 17 species were negatively affected by an increasing pedestrian rate.

The distance which a perched bird flies upon disturbance is called flight-initiation distance or flush distance. Flush distance varies significantly between species, with larger species tending to be less tolerant of disturbance (Blumstein *et al.* 2003; Wang *et al.* 2004; Fernández-Juricic *et al.* 2001, 2004).

An investigation by Miller *et al*. (1998), studied the influence of recreational trails on breeding-bird communities in North America. Species composition, nest predation and brood parasitism by the Brown-headed Cowbird (*Molothrus ater)* were considered. It was discovered that control transects housed significantly more birds than were along trails. However, some generalist species such as American Robins (*Turdus migratorius)* were found to be much more abundant along trails than in the forest. Results from that study also indicated that there was a significant positive correlation between distance from trails and nest survival. The zone of influence from trails into the forest was estimated at approximately 75 m and elevated rates of nest predation were evident. In a similar study, findings indicated that a single pedestrian moving through the territory of a specific bird may have a negative effect, such that it could reduce the occurrence and consistency of its primary song (Gutzwiller *et al.* 1994 *In* Miller *et al.* 1998).

The literature suggests that the larger area-sensitive forest species (such as hawks and owls) might be disturbed frequently enough by humans that they do not occur or that it is not possible for them to successfully reproduce in certain human visited woodlots. Furthermore, more disturbance-sensitive smaller species could also have lower rates of productivity. The effects of faster-moving disturbance (e.g., all-terrain bicycles) might be different, although no specific studies were noted.

Of interest is research that shows that at least some species can habituate to human disturbance (Miller *et al.* 2001; Fernández-Juricic *et al.* 2002) This includes habitat generalists and urban associated species such as Blackbirds (*Turdus merula)* (an ecological equivalent of American Robin) and House Sparrows. American Robins near Boulder Colorado, were more tolerant of disturbance when the person was on a trail (flew at ~10 m from person), than when a person was off a trail (flew at ~14 m from person) (Miller *et al.* 2001). On the other hand, human disturbance appears to be sufficiently 'disturbing' that some relatively sensitive species (Western Wood-Pewee *Contopus sordidulus*, Chipping Sparrow *Spizella passerina*, Pygmy Nuthatch *Sitta pygmaea*, Solitary Vireo *Vireo solitarius* and Townsend's Solitaire *Myadestes townsendi*) occur much less frequently near trails (Miller *et al.* 1998).

Overall, it appears as if direct disturbance is detrimental to all but a few very tolerant species, and that the disturbance may be such that it contributes to the actual loss of some species from urban forest fragments.

2.4 Disruption of Ecosystem Processes

Marzluff and Ewing (2001) argue that the greatest long-term effect on birds is human disruption of nutrient and water cycles and the diversion of primary productivity. The suppression of natural processes such as fire, the overuse of water resources and the alteration of nutrient pathways have had wide-ranging effects on many habitats both close to and further away from urban areas. An example of the far-reaching effects is that some habitats (e.g., nutrient-poor fens and bogs) may not be reproducible in southern Ontario because of the atmospheric deposition of nutrients. Disruption of these processes (e.g., increases in nutrient availability) may help to explain why some invasive non-native plants have such competitive advantages in urban-influenced landscapes over species that have, for example, adapted to low-nutrient environments.

2.5 Food Supply Changes

Many small and medium-sized forest birds feed on insect and other arthropod prey. It is possible that forest fragmentation also affects these organisms, in turn influencing bird food supply.

Gunnarsson and Hake (1999) examined the effect of bird predation of tree canopy arthropod communities in Swedish city parks. Generally, bird predation significantly reduced the numbers of arthropods on birch and oak tree branches. Although there was some site-to-site variation, they concluded that bird predation, as a part of the canopy food web, was not seriously affected by the urban environment.

In urban Sydney, Australia, forest patch size was examined for effects on arthropod-communities (Gibb and Hochuli 2002). Large (greater than 80 km^2) and small (less than 4 km^2) fragments had a similar number of species per unit area for most groups of arthropods, and small fragments actually contained more species of ants. However the species found in the woodlands were not always the same; significantly different assemblages of spiders and ants were found in large versus small fragments. This study did not examine abundance of arthropods. Zanette and Jenkins (2000), also in Australia, found that invertebrate biomass in small fragments (less than 55 ha) was about half that of large forests (greater than 400 ha). Perhaps more importantly, nesting females of the Eastern Yellow Robin (*Eopsaltria australis)* in small forests, received about 40 percent less food from males, left their nests more frequently to forage, and fed their nestlings less food, among other related effects.

The effects of forest fragmentation on web spider communities in urban areas in Japan were studied by Miyashita *et al.* (1998). Smaller fragments had fewer species per unit area than the larger fragments. Perhaps of greater importance, the smaller fragments contained a lower density of individuals. Additionally, for the same size fragment, there were more species in the less isolated fragments of Yokohama than in the more isolated fragments of Tokyo. The body size of a common spider species was smaller in the small fragments, which it was hypothesized may be due to a lower abundance of flying insects in 1 ha versus 10 ha fragments (Miyashita 1990 *In* Miyashita *et al.* 1998). In other words, they found that patch size, isolation (forest cover), and in turn a decrease in spider prey, all affected the web spiders.

Burke and Nol (1998) found that the biomass of litter invertebrates (as collected by leaf litter sifting) was significantly higher within larger (greater than 20 ha) woodlots than smaller patches. Within Ovenbird territories, prey biomass collected in this manner was 10 to 36 times higher in large woodlots than in small woodlots. The authors presented evidence and argument that this effect was linked to the desiccation of arthropods in leaf litter when edge effects were prevalent, and to the higher connectivity of forested landscapes maintaining populations of litter-inhabiting arthropods.

In recent years, concerns have been raised regarding a number of aerial foragers that have apparently declined (i.e., swallows, Whippoorwill (*Caprimulgus vociferus)*, Common Nighthawk (*Chordeiles minor)* and Chimney Swift (*Chaetura pelagica)*). It is possible that poor air quality in general (i.e., in urban environments and elsewhere) is impairing the quality or quantity of food that is available to these aerial insectivores. In the U.K., concerns have been raised over general declines in Lepidoptera (particularly moths), that may reflect similar issues. Research is currently underway looking at the effects of air quality on flora and fauna in southern Ontario and it may yet shed some light on this area of concern; clearly research on subsequent effects on forest breeding birds would be useful.

There is increasing support for the notion that arthropod communities are depressed in smaller urban-forest fragments (less than 20 to 50 ha). It is less than certain, to what extent a changing prey-species composition would affect forest birds as it is unlikely that most forest birds are species-specific in their prey requirements. However, it appears that a decrease in the overall biomass of arthropods in urban fragments in Ontario should be expected, and that this in turn can be expected to affect the productivity and presence of certain forest breeding birds.

2.6 Habitat Alteration

In urban forests human use causes habitat alteration due to physical changes in the vegetation. The effect of this disturbance is most likely to reduce the vertical complexity of the forest. Forests with well-developed ground cover, low and tall shrubs, understorey and canopy trees generally provide a wider variety of habitat niches for forest birds, and nest predators have more difficulty finding well-concealed nests.

The following sections address three aspects of habitat alteration. Other aspects are more related to general physical degradation and less associated with direct effects on breeding area-sensitive forest birds (e.g., soil compaction and erosion).

2.6.1 Loss of Vegetation and Woody Debris

Forest fragments within the urban matrix are susceptible to vegetation trampling due to the presence of many pedestrians (and sometimes the additional presence of dogs) who are not constrained to trails. This results in the loss of low vegetation as well as a decrease in the recruitment of new seedlings of all types of plants, which in turn is likely to result in the physical decrease in habitat for some species of forest birds. Blakesley and Reese (1988) found when comparing the riparian breeding birds of campgrounds and similar non-campground areas, six ground or shrub nesting or ground foraging species were not found in the campgrounds. This was presumed to be due to differences in shrub and sapling density, litter depth and amount of woody debris. The apparent human desire to tidy-up and the associated removal of dead wood and detritus for activities such as campfires can affect a wide-range of organisms from fungi and detritivores, through insects and vertebrates.

For example, in the Greater Toronto Area (GTA) at Altona Forest, Pickering, trees and saplings have been cut, tree houses and fire pits constructed and so on. The use of all-terrain bicycles on wet soils (e.g., trails and jumps) has exacerbated the trampling of plants and soil disturbance.

Loss of structural diversity in forest communities (e.g., shrub layers and ground cover) whether directly by human disturbance or indirectly by factors such as overgrazing by White-tailed Deer (which are often in elevated densities in woodlots in suburban areas), leads to a reduction in the density and species-richness of forest breeding birds (Allombert *et al*. 2005) .

A relatively undocumented but potentially important effect might be the lack of serial stages and the full canopy closure that occurs in many urban forests that are simply left relatively unmanaged (save perhaps for snag removal). This could affect a wide range of species (e.g., Wood Thrush (*Hylocichla mustelina)* that require a well-developed understorey including saplings or thickets).

2.6.2 Invasive Species and Exotic Plants

Non-native (exotic) plant species, especially invasive ones, are likely to be found in urban forest fragments, due to the proximity of nearby gardens and the physical introduction of plants along trail systems. These species may also be encouraged where soil conditions, including nutrient levels, are affected by human use.

In general, there is a much higher abundance of non-native plants in urban versus rural areas. For example, in California, urbanized coastal plant communities are 40 per cent exotic, in contrast with 5 per cent exotic in interior mountain regions (Mooney *et al.* 1986 *In* Smallwood 1994).

Studies have shown differing results regarding the effects of exotic plants on bird communities, often negative but sometimes neutral. Most relevant is Schmidt and Whelan's (1999) study of the effect of a non-native Honeysuckle (*Lonicera maackii)* and Common Buckthorn (*Rhamnus cathartica)*, both shrub species present in southern Ontario, on nest predation rates. They found that predation of American Robin and Wood Thrush nests was greater when the nests were in the non-native shrubs versus the native species. They theorized that the exotic species either lacked the protection afforded by the thorns of the native hawthorns (*Crataegus* sp*.)* or that they had a different plant structure that made it easier for the predators to reach the nests.

In a study that examined a gradient of urban through rural areas in the Seattle, Washington region, native forest-bird species decreased with increasing amounts of exotic ground and shrub cover. Although the effect associated with landscape was explained by exotic ground and shrub cover it was unclear whether some correlated urban factor(s) was the cause (Donnelly and Marzluff 2004). In suburban Australia, native nectar producing plants produced more nectar and were the preferred foraging sites of nectarivorous birds in contrast with non-native nectar producing plants (French *et al.* 2004). Although this study is of less relevance for southern Ontario, as the ecosystem is very different in Australia and there are few nectarivorous species in Ontario, it is another example of non-native plants being less suitable for native birds. In contrast, in the different riparian habitats in the Mojave desert, the presence of an invasive plant did not affect the species richness of native birds (Fleishman *et al.* 2003).

In southern Ontario, studies that examine the influence of common invasive species (such as Garlic Mustard (*Alliaria petiolata)* and Common Buckthorn) on species such as the Wood Thrush and the Ovenbird would be a useful contribution.

2.6.3 Snags and Cavity Nesting Competitors

The majority of cavity nesting birds (e.g., nuthatches, woodpeckers) require snags within which to situate their nests. Cavity nesting birds might face steeper competition for cavities in urban areas due to either: the presence of non-native, highly abundant cavity-nesters such as the European Starling (*Sturnus vulgaris)* or the paucity of snags due to removal for public safety reasons.

There are numerous observations of European Starlings competing with other cavity nesting birds for nesting sites (Koenig 2003). Koenig examined 27 cavity nesting birds occurring across North America using Christmas Bird Count and Breeding Bird Survey data to see if populations of these 27 species changed after the arrival of the European Starling in a given area. Surprisingly, only one species (the sapsucker group) showed a population decline that might be attributable to European Starlings. Rohila and Marzluff (2002) found that competition from European Starlings interfered with Red-breasted Sapsucker (*Sphyrapicus ruber)* productivity within residential areas of Seattle, but found that the same was not the case in forest fragments within an urban matrix. This competition might explain a possible decline in sapsucker populations, but on the other hand shows that, at least in one region, starlings were not major competitors for cavities in forest fragments. In Ontario, this might not be the case as, contrary to Rohila and Marzluff (2002), starlings are frequently seen in urban forest fragments, and they have been observed in competition with Red-headed Woodpeckers (*Melanerpes erythrocephalus)* for nesting sites (B. Henshaw pers. comm.).

Rohila and Marzluff (2002) examined snag densities in forest fragments in urban through to non-urban areas and did not find a difference in snag density. This suggests that snag loss per unit of forest does not necessarily occur in urban forest fragments. In addition, some jurisdictions in Ontario have changed their practices (i.e., the removal of dead standing wood) to increase snag density. However, according to one Ontario source, even well-managed forests in non-urban areas may have depressed snag counts (Elliott 2004) thereby potentially negatively affecting forest cavity nesting birds.

2.7 Artificial Light

The scientific literature on the effects of artificial light on flora and fauna in natural habitats in general, and on breeding birds in particular, is sparse. In a summary of the topic, Outen (2002) suggests that there exists potential for behavioural changes particularly those behaviours relating to the photoperiodic control of reproduction and opportunities for illuminated foraging. Outen also noted that nocturnal species (e.g., owls) are more likely to be disturbed by the presence of bright illumination.

Most of the literature relating to light deals with birds attracted to lit towers and it is well-known that migrant birds can be fatally attracted to tall lit buildings. Birds can be affected by artificial light (e.g., habitat-quality change, attraction/repulsion/disorientation, disruption of biological rhythms) and the effect is likely to be influenced by the susceptibility of individual species, effects on food supply and potential nest predators and the characteristics of the light (e.g., intensity, duration and wavelength). Currently, considerably more research is available regarding the effects of artificial light on insects; for most other wildlife groups and in most circumstances, more research is required.

2.8 Nest Parasitism

Human disturbance of natural habitat is often the cause of decreased patch size and consequently, increased openings and forest edges. This exposure can leave area-sensitive breeding birds vulnerable to brood parasitism, nest predation and competition. In Ontario, the Brown-headed Cowbird is the only obligate brood parasite. The cowbirds lay their eggs in the nests of host species who then raise the cowbird young often at the expense of their own reproductive fitness.

When Brown-headed Cowbirds select potential breeding habitat, they focus on mainly deciduous forest-brush edges along clearings, stream corridors, power lines or roads. The preferred breeding habitat has a large number of seedlings, saplings and snags; more than what would typically be found in forest interior greater than 250 m from an edge (Gates and Evans 1998). Although, recent studies have indicated that there was an increased parasitism rate in forest-interior bird communities rather than along edges suggesting that cowbirds may switch habitats (Miller *et al.* 1998).

In one Ontario study two species (Red-eyed Vireo and Ovenbird) suffered high rates of cowbird parasitism (and this varied from zero to 29 per cent depending on fragment extent), although complete nest failure due to cowbirds was low. Parasitism rates were higher within 100 m of forest-patch edge (Burke and Nol 2000). Also in Ontario, cowbird parasitism on Wood Thrushes increased when houses were located within woodlots, although in all cases, rates of brood parasitism were not sufficient to impact rates of nest success. However, in one of two study regions (Peterborough, Ontario) reductions in productivity (lower numbers of fledglings) due to cowbirds were noted in developed woodlots (Phillips *et al.* 2005).

It has also been suggested that cowbirds are attracted to urban areas for food resources (e.g. bird feeders and short, moist grass lawns in residential areas) (Chace *et al*. 2003). It is also possible that an abundance of perching structures attract this species. Some authors have suggested that urban areas be made less attractive to cowbirds by restricting lawn watering, increasing lawn grass-length and curtailing bird feeding during the breeding season (Mayfield 1965; Goguen and Mathews 1999), although intuitively these mitigative suggestions seem unlikely to be a successful strategy given the apparent adaptability of cowbirds.

Cowbirds may choose to parasitize within forest interior habitats or along edges depending on the urban context. If open areas exist within forest patches in urban areas, they can act as corridors, which may encourage female cowbirds into forest interiors. However, it is also known that cowbirds will travel into extensive forest areas to find nests.

It is well-established that cowbirds can reduce host productivity in some species and in certain landscape contexts. In the context of other urban-related stressors, this could be an important additive effect. There is also evidence that, in some regions at least, the effect of cowbirds may be enhanced when urban development is present.

2.9 Noise

Sudden unpredictable anthropogenic noise can elicit a flight or alert response in birds, and in some cases this behavioural trait is often used for management of pest species. Whether birds that nest in the urban environment adapt to these disturbances, or whether the only remaining species in urban forests are those that are noise-tolerant is an unanswered question. Regardless, there is mounting scientific evidence that vehicular traffic noise is an important stressor, at least for many breeding birds (forest and non-forest), although a direct causal link has not yet been established. Traffic volume appears to be a critical factor in determining the magnitude and geographic extent of disturbance zones (Reijnen and Foppen 1994a; 1994b; 1995 and Forman *et al.* 2002, summarized *In* Reijnen *et al.*1997).

A study in Massachusetts found that grassland bird breeding success was unaffected in the vicinity of a road with 3,000 to 8,000 cars per day. However, reduced breeding success occurred at 400 m from the road with 8,000 to 15,000 cars per day; 700 m from the road with 15,000 to 30,000 cars per day; and 1,200 m from the road with more than 30,000 cars per day (Forman *et al.* 2002). Similarly, in the Netherlands, grassland-bird populations showed decreased density along roadsides with estimated population losses of 12 per cent to 56 per cent within 100 m of roads with 5,000 cars per day, and 12 per cent to 52 percent within 500 m with 50,000 cars per day. Some species showed reduced densities up to 3.5 km from the road (Reijnen *et al.* 1996).

A study on woodland species showed similarly broad effects: roads with 10,000 cars per day led to reduced breeding bird density up to 1.5 km from the road and roads with up to 60,000 cars per day led to reduced density up to 2.9 km away (Reijnen and Foppen 1994b). Based on measurements of stressors, traffic noise, rather than visual disturbance, air pollutants, or predators along roads, was identified as the primary cause for avian community change (Reijnen *et al.* 1997; Forman 2000).

Acoustic masking has been identified as one possible mechanism by which traffic noise can negatively affect songbird density (Rheindt 2003; Katti and Warren 2004). Hence, having a higher-pitched song with frequencies well above those of traffic noise may make certain bird species less susceptible to the disturbance effects of noise. There is evidence supporting this hypothesis, as some birds appear to be changing their song frequency in response to urban noise (Slabbekoorn and Peet 2003).

Noise in general, and traffic noise in particular, appears to be an important limiting factor for many breeding birds. This effect might be limited to busy roads (greater than 10,000 cars per day), especially roads used by commuters (e.g., in Ontario 400 series highways), where noise is constant, day and night, and the roads are busiest early in the morning, coinciding with important periods of birdsong.

2.10 Predation by Urban-sponsored Native Predators

Predation is generally acknowledged to be the largest cause of nest failure for many species of forest birds (Burke and Nol 2000). Predator intrusions alone have been shown to have the potential to induce critical patch-size effects for prey species (Cantrell *et al.* 2001).

Several important native nest predators, such as Raccoon (*Procyon lotor)*, Grey Squirrel (*Sciurus carolinensis)*, Red Fox (*Vulpes vulpes)*, American Crow (*Corvus brachyrhynchos)*, and Blue Jay (*Cyanocitta cristata),* thrive in urbanized environments (Sorace 2002). In many urban situations Common Grackle (*Quiscalus quiscala)*, Eastern Chipmunk (*Tamias striates)* and Red Squirrels (*Tamiasciurus hudsonicus)* may also be added to this list of key predators. Some of these species have been shown to be at their highest densities in urban and suburban environments. Raccoons, for instance, are much more common in urban areas than in rural areas (Ray 2000). One study noted Raccoon abundance in edge habitats three times higher in areas with houses than those without (Danielson *et al*. 1997 cited *In* Kluza *et al*. 2000). It has been shown that some predatory species such as American Crows, Common Grackles and Blue Jays reach their highest densities in edge habitats (Niemuth and Boyce 1997 *In* Kluza *et al*. 2000).

A large body of literature surrounds the effects of nest predation in forest fragments (see Chalfoun *et al.* 2002). However, scientifically robust data on the long-term nesting success rates in urban forests remains elusive. Much of the literature on effects of nest predation in forest fragments suggests that smaller fragments have higher nest predation rates (Keyser 2002) or that predation rates decreased with increases in forest cover (Hartley and Hunter 1998). Some of this literature has been criticized, either because only artificial nests with quail eggs were used (Haskell 1995), or because they were otherwise weak in their methods (Chalfoun *et al.* 2002). Also of particular relevance to this report is the criticism that most studies were undertaken in agricultural or forested matrices. Chalfoun *et al.* (2002) concludes that predator responses to fragmentation are taxon-specific and context dependent and thus management needs to be geared to local conditions.

There are a few recent studies of urban-fragmentation effects on nest predation, although they are not from northeastern North America. In an urban context in Florida, nest predation was higher in areas of higher-density housing versus lower-density housing (Thorington and Bowman 2003). And, in large urban Alabama forest fragments, predation was highest closest to the edge of the forest (one to 15 m versus 30 to 45 m) (Keyser 2002).

Supplemental food sources, particularly bird feeders, subsidize local populations of some predatory species. There is some support in the literature indicating the importance of this effect (i.e., Bock and Lepthien 1976 *In* Kluza *et al.* 2000). Morneau *et al.* (1999) postulated that bird feeders in Montreal parks played a major role in the increase of several species, including Blue

Jays and American Crows. These two species may be key avian nest predators in urban forests.

Shochat's (2004) discussion of urban nest predation states that it is difficult to assess whether urban predator abundance is lower or higher than in wild lands. It is likely that the species richness of predators will be lower in urban areas as some raptorial birds, snakes and mammals (such as weasels) might be absent or nearly so. However, the density of highly efficient nest predators that *prefer* urban and suburban environments may limit birds attempting to breed within forests in the urban matrix. To be productive, birds within urban forests such as High Park in the GTA, with its high populations of key predators (e.g., squirrels, Raccoons, Blue Jays, American Crows and Common Grackles), must be able to withstand potentially very high predation rates.

2.11 Predation by Urban-sponsored Non-native Predators

In southern Ontario, predation by urban-sponsored non-native predators is primarily the purview of pet cats that are permitted to range outdoors and perhaps rats. Various non-native pathogens that can affect survivorship and fitness of birds could also be included in this category.

While outdoor pet cats are clearly more abundant in urban areas than in rural areas (Lepczyk *et al.* 2003), their role as an important predator of forest birds is uncertain. Birds are generally cats' second-most-favoured prey group after mammals. Studies have found that birds constituted 24 per cent of prey items retrieved from cats (Woods *et al.* 2003; Gillies and Clout 2003). Most cats feed on at least some birds (47 per cent of cats caught birds according to Lepczyk *et al.* 2003 and up to 71 per cent caught birds according to Gillies and Clout 2003). The House Sparrow (a non-native, non-forest bird) is often the most frequent prey in urban areas (Gillies and Clout 2003). However, numerous other species have been recorded as being taken by cats (Gillies and Clout 2003; Lepczyk *et al.* 2003). In the latter study 23 bird species were taken in urban through rural Michigan. While most species identified were not forest area-sensitive species, a few were or might have been (e.g., nuthatch, Purple Finch (*Carpodacus purpureus)*). Also, Lepczyk *et al.* (2003) estimated that a minimum of about one bird/km/day (along a linear route) was killed by cats. Intuitively, one might suppose that juvenile birds are more susceptible to predation by cats that do venture into urban forests. However, the relative importance of juvenile birds to the overall population is much less, as mortality rates for young birds is known to be very high.

Outdoor cats generally range a maximum of 100 m to 200 m from their home base. Overall, although an abundant predator within cities, cats may not be a very important predator of urban forest birds. In his discussion paper, Shochat (2004) suggests that cats may not be a major nest predator, but that they may "represent a high risk to adult birds". He continues "…they may not affect the breeding bird population as much as the more naïve migratory birds passing through urban environments". In Ontario, it is likely that cats are not an important nest predator of raised nests, and may not even be major predators of other nests compared to other species such as Raccoons and Striped Skunks.

The role of rats in the urban environment is even less clear. There are many examples of the dramatic influence of rats on oceanic island bird communities. In a study of urban forest birds in Seattle, (Donnelly 2002), it was postulated that rats were the main cause of high predation rates of shrub-nesting birds.

2.12 Psychological and Social Behaviour

In a discussion of potential factors that led to a sharp decline in forest birds in plots that included residential dwellings, Friesen *et al*. (1995) noted the possibility that “A species psychological need for maintaining distance from houses (Whitcomb *et al.* 1981)…” may affect the presence of breeding birds. This was also postulated in a study of nesting worm-eating warblers in small woodlots, where the birds appeared to avoid buildings, although nesting success was not affected (Gale *et al*. 1997 *In* Mancke and Gavin 2000).

Morton (1992) also noted that there is evidence that neotropical migrants may be looking not just for habitat, but for a population with which to interact reproductively and that such social behaviour might require the presence of conspecifics.

Although these topics are among the most difficult to address and study, they could be a major driver in the settlement rules that forest birds employ. This potential effect is consistent with the relationship between regional forest cover and the presence or absence of area-sensitive forest birds.

Neotropical migrants: Songbirds that migrate between tropical and temperate ecosystems of North, Central and South America. (Riley and Mohr, 1994)

Clearly, psychological and social behaviour could be important to forest birds in the urban matrix and they require further research.

2.13 Removal of Top Predators

The “meso-predator release theory” postulates that when large predators such as the large canids and felines are extirpated from an environment, the populations of the meso-carnivores (such as Raccoon), are ‘released’. Two studies that examined the effects of the presence of Coyotes (*Canis latrans*) on nest survival of Song Sparrows (*Melospiza melodia*) in Michigan (Rogers and Caro 1998) and on chaparral bird species in urban California (Soule *et al.* 1988 *In* Diamond 1988) found that the *presence* (versus the absence) of Coyotes resulted in significant reduction in nest predation of important native species, and in the latter case, partly resulted in the presence of chaparral species.

In the GTA, whether in urban or rural areas, large predators are no longer present with the exception of the Coyote. Coyotes are common in rural Ontario, but are generally absent in urban areas except at the edges (although this pattern may be changing). This may in part explain the high abundance of urban Raccoons previously mentioned.

The loss of top predators may also allow increases in White-tailed Deer and subsequent increased browsing of the herb and shrub layers of forests, at least outside of higher density urban areas. deCalesta (1994) found a decline in songbird species richness and abundance in Pennsylvania forests that coincided with increased deer browse. Other studies have pointed to songbird decline in a forest or rural land-use matrix (Fuller 2001, Perrins and Overall 2001 both *in* Rooney and Waller 2003) or suburban matrix (Allombert *et al*. 2005). Yet, there are few, if any, studies of the effects of deer browse on forest birds pertaining to a predominantly urban matrix. Moreover, while deer are present across the GTA, they are generally absent from higher-density urban areas, and urban parklands that are not connected with ravine systems or other natural linkages, to a greater degree than meso-predators such as Raccoons.

2.14 Summary

Table 2 provides a concise summary of the findings of this report. It is important to recognize that many of these factors are interrelated and that the interaction of several stressors could be severely limiting even though any individual stressor might not be ranked very high. The "likely relative importance" is a widely-bracketed subjective analysis for effects in the urban environment based on the body of literature that was reviewed during the preparation of this report.

Table 2. Primary Stressors for Area-Sensitive Forest Breeding Birds in an Urban Environment

Stressor	Likely Relative Importance	Notes
Disruption of Ecosystem Process	High to Moderate	• Includes: disruption of nutrient and water cycles and productivity
Urban-sponsored Native Predators	High to Moderate	• Includes: Blue Jay, American Crow, Common Grackle, gray squirrel, red squirrel, eastern chipmunk, raccoon, striped skunk, red fox. • Bird feeders may be implicated
Noise	High to Moderate	• Increasing evidence that noise, especially traffic noise at high levels, can limit forest breeding birds
Barriers to Connectivity	Moderate to High	• Barriers may become more important when forest cover falls below 30 percent, actual effects of barriers poorly established for birds, effects difficult to isolate from other metrics (patch size, forest cover)
	Uncertain	• More uncertain how important barriers may be once forest cover exceeds 30 percent
	None	• Unlikely to be an effect where forest cover exceed 70 percent
Habitat Alteration	Moderate	• Includes: loss of vegetation (soil compaction, trampling, erosion, cutting, composting), non-native plants, loss of forest structure (e.g., closed canopy of urban forests)

Stressor	Likely Relative Importance	Notes
Direct Disturbance	Moderate	• Walkers and mechanical disturbance (e.g. mountain bikes) impede the breeding of sensitive birds, heavy-use trails may displace more birds.
Nest Parasitism	Moderate	• Studies show nest parasites contribute to lower productivity, but are not primary constraints on productivity, parasites can be enhanced by the urban matrix
Urban-sponsored Non-native Predators	Moderate to Low	• Outdoor cats which mostly prey on small mammals, may affect some species
Psychological and Social Behaviour	Uncertain/ High?	• Breeding birds may need to maintain a distance from urban infrastructure or may need the presence of members of the same species
Food Supply Changes	Uncertain/ Moderate?	• Evidence that forest birds relate to invertebrate food supply and that invertebrates are reduced in urban forests
Light	Uncertain/ Low?	• Little empirical evidence is available
Removal of Top Predators	Uncertain/ Low?	• May help explain large numbers of certain urban-sponsored predators
Contaminants	Uncertain	• Empirical data lacking, probably more effect on food supply; ecological risk assessment relatively new

3. Forest Habitat Guidelines

In addition to the stressors on forest breeding birds discussed in the preceding chapter, it is important to consider how the overall arrangement of habitat influences the breeding bird community. Clearly, the result (i.e., the presence or absence of productive, breeding area-sensitive forest birds) is the sum of all of these (and other) influences. There are likely yet-to-be-described interdependencies and complementary effects. Key habitat criteria are discussed separately from potential stressors, although the habitat criteria may be the underlying cause of most if not all of the stressors.

A review of recent literature associated with various forest-habitat metrics was undertaken for the Second Edition of *A Framework for Guiding Rehabilitation in Great Lakes Areas of Concern* (Environment Canada 2004). The *Framework* noted:

> *Recent literature indicates that a complex relationship exists between the relative importance of overall forest cover versus forest-patch size and the ultimate response of individual wildlife species (Lee* et al. *2002). On balance, the axiom "the larger the better" appears to be being replaced by "the greater amount of habitat within the landscape mosaic, the better" (see for examples Austen* et al*. 2001; Golet* et al*. 2001; Fahrig 2002; Friesen* et al*. 1998; Friesen* et al*. 1999). These studies and reviews have shown or suggested that forest-patch size and shape may play a lesser role in maintaining biodiversity than the total amount of forest cover, although the three metrics are to some extent interrelated.*

Evidence from empirical studies that have examined the independent effects of habitat loss *versus* habitat fragmentation suggest that habitat loss has a much larger effect than habitat fragmentation on the distribution and abundance of birds (Fahrig 2002).

Extensive forested areas and areas with high forest cover, are more likely to incorporate a wide variety of microhabitat conditions (often referred to as characteristics of quality). This includes old-growth conditions, forest-understorey type, serial stages, community types and types of adjacent habitats. For example, any amount of ravine-forest habitat in Toronto is unlikely to ever support the additional variety of habitat conditions that could be found in tableland forests.

It is likely that each species or guild of species responds to these metrics, and urban-associated stressors, differently, and this is borne out by the empirical data that are available. Since the various habitat metrics and urban stressors are intertwined and in many cases interrelated, it is very difficult, and may be impossible, to determine with confidence their relative importance to each species, especially when one considers productivity rather than merely presence or absence on the landscape.

Determining the relative importance of the four *Framework* criteria for forest habitat (i.e., forest cover, quality, patch size and connectivity) is a useful step towards determining what might be required to maintain area-sensitive forest birds within an urban matrix. The following table provides a subjective assessment of the relative importance of the underlying criteria used in forming the guidelines, based on the literature reviewed during development of the 2004 2nd edition of the *Framework*.

Table 3. Key Forest Habitat Criteria

General category	Likely Relative Importance	Comments
Percent Forest Cover	Very High	• Threshold may be around 30 percent for forest birds, below which area-sensitive forest breeding birds decline and other habitat metrics start to play a greater role (e.g., patch size, connectivity)
Habitat Quality	High	• A general concept that incorporates a range of factors such as: shape, interior, age, composition, structure invasive species.
Patch Size	Less than 30 percent forest cover: High	• In fragmented landscapes with less than 30 percent forest cover this metric may play a greater role. There is little guidance in the literature on the upper level of patch size effect on forest birds, likely to be landscape/species dependent and in the 1,000s of ha.
	More than 30 percent forest cover: Moderate	• In landscapes with more than 30 percent forest cover patch size appears to be less critical, but it is difficult to isolate the effect of patch size from other key factors.
	More than 70 percent: None	• In landscapes with more than 70 percent forest cover, patch size may not be important
Connectivity	Moderate	• Few empirical studies demonstrating the importance of connectivity for forest birds, so it has been difficult to tease apart the relative importance of forest cover and connectivity; ecological mechanisms and effects of fragmentation are poorly understood. It is likely to be more important once forest cover is less than 30 percent, and less important over 70 percent.

Clearly, in an urban context, two of the three most important criteria, adequate total forest cover and patch size, are unlikely to be attained through restoration efforts nor perhaps even maintained by good management practices. The least important criterion, connectivity, is the only one which is often maintained to some extent in urban systems. This raises doubts about the ability of urban systems to support some area-sensitive forest-bird species and points towards long-term approaches that maintain areas with substantial forest cover and 'big woods'.

4. Setting Area-Sensitive Forest Breeding Bird Expectations for Urban Forest Reserves

In tackling the question *How Much Habitat is Enough?* for area-sensitive forest breeding birds it is necessary to understand the current community of area-sensitive forest breeding birds within urban areas. In the following chapter a selection of this evidence is presented.

4.1 Profiles of Area-Sensitive Forest Breeding Birds in Urban and Suburban Forests

To see what empirical evidence there is for area-sensitive forest breeding birds in forests within the urban matrix, a number of recent studies of forests within the urban matrix of the Greater Toronto Area were examined. Summaries of these are presented in the following sections.

4.1.1 Altona Forest, City of Pickering

Detailed territory mapping of breeding birds has been conducted in this forest for 1949/50, 1994/95, 1997 and 2000/01 (Henshaw 2001). The forest area is presently about 45 ha; it was somewhat larger prior to 1994, when portions of it were developed. Forest cover in the City of Pickering is approximately 18 per cent, most of which is located north of Altona Forest.

After normalizing data for area surveyed (now about a 9.9 ha core portion of the forest), the species residing in the area (including forest associated) have remained relatively constant over the period of record. This was in sharp contrast to a 70 per cent decline in the number of territories of neotropical forest-associated migrants. The number of neotropical bird species also declined from between seven and nine in 1949/50 to three to four in 2000/01. With only one exception (the Red-eyed Vireo (*Vireo olivaceous*)), species recorded were below the lowest densities generally reported in the literature. It is thought that if conditions do not change the only two neotropical migrants to persist in Altona Forest in the future would be the Red-eyed Vireo and the Great Crested Flycatcher (*Myiarchus crinitus)*.

The following area-sensitive forest birds are likely to persist at Altona Forest:

- Red-breasted Nuthatch (*Sitta canadensis)* (one pair)
- White-breasted Nuthatch (*Sitta carolinensis)* (one to three pairs)
- Wood Thrush (one to two pairs)

Resident forest-associated breeding species that dominated the avifauna of the forest were: Blue Jay, American Robin, Black-capped Chickadee (*Poecile atricapillus*), American Crow, Downy Woodpecker (*Picoides pubecens*) and Northern Cardinal (*Cardinalis cardinalis*).

4.1.2 High Park, City of Toronto

High Park is approximately 150 ha of which, approximately 47 ha is forested (one 30 ha block, one 13 ha block and smaller blocks throughout). Large mature deciduous trees (largely oak) are also present in many areas around the park. A review of current and historical breeding birds was undertaken in 2001 (Gartner Lee Limited 2001). Although treed canopy cover in the City may reach 20 per cent (when well-treed residential areas are included), actual forest habitat cover is much less and is likely less than 5 per cent (it is approximately 3 per cent in nearby Mississauga). In addition, the quality of many forest patches is low, with many linear valley features dominated by non-native species.

The current and historical breeding birds are known for the Park, although formal survey data and information on numbers are lacking. Approximately seven to nine neotropical migrant species currently nest annually, and most of these are represented by only one or two pairs (e.g., Wood Thrush, Great Crested Flycatcher, Eastern Wood Pewee (*Contopus virens)* and Orchard Oriole (*Icterus spurius)*). There are no area-sensitive forest warblers or tanagers, and very few flycatchers or thrushes. Other forest-associated breeding birds number some 14 to 16 species. Likely dominant are: Blue Jay, Black-capped Chickadee, Downy Woodpecker, American Robin, European Starling and Common Grackle.

Of the area-sensitive forest birds, the following are usually breeding at High Park:

- Hairy Woodpecker (*Picoides villosus)* (one to two pairs)
- White-breasted Nuthatch (several pairs)
- Blue-gray Gnatcatcher (*Polioptila caerulea)* (several pairs)
- Wood Thrush (one to two pairs)

4.1.3 Block 12 Forest, Vaughan

This 70 ha mature deciduous and mixed forest is located in a rapidly urbanizing area. There are existing buildings located immediately adjacent to and within the forest. Urban development is planned to occur over the next few years in adjacent lands, which are currently agricultural. A busy road (Dufferin Street) runs north-south alongside the western edge of the Block 12 forest. An extensive forested area is located immediately to the other side (west) of Dufferin Street. Pre-construction monitoring recently examined breeding birds over a three-year period (Gartner Lee Limited 2003). The monitoring used repeated fixed transects and walk-abouts; approximately seven surveys per year were made.

In each year between 11 and 19 territories of area-sensitive forest birds were noted among eight to 14 species. Of these species, between four and ten were represented by single pairs or in the case of an Acadian Flycatcher, by an unmated male. Only two species, the White-breasted Nuthatch and the Wood Thrush were consistently represented by multiple pairs.

The following area-sensitive forest birds are usually present in multiple pairs at the Block 12 forest:

- Hairy Woodpecker (one to two pairs)
- White-breasted Nuthatch (several pairs)
- Brown Creeper (*Certhia americana)* (one to two pairs)
- Wood Thrush (several pairs)
- Black-throated Green Warbler (*Dendroica virens)* (not present to two pairs)
- Black-and-white Warbler (*Mniotilta varia)* (not present to two pairs)

4.1.4 TRCA Breeding Bird Data for the City of Toronto

The Toronto and Region Conservation Authority (TRCA) has been undertaking breeding bird surveys over the past few years in many urban forests within their jurisdiction. These multi-year data (generally 2000, 2001, 2004) are available in a GIS format and were shared for analysis in this project. A detailed analysis of birds by individual woodlots has not been undertaken and therefore some breeding locations or individual pairs are likely to be represented by multiple records. Breeding records considered "possible" have been included in this analysis. All of the data for a large portion of the urbanized City of Toronto (i.e., from Lakeshore Drive to Steeles Avenue, and from Hwy. 27 to Markham Road) are included in this brief analysis. All points mapped in the TRCA database are identifiable as "possible", "probable" or "confirmed" and further analysis could be undertaken on these data.

Approximately 20 of an unknown number of surveyed locations of widely varying woodlot size contained at least one area-sensitive forest bird on the potential list (palette) of area-sensitive forest birds for the Toronto area. Of the area-sensitive forest birds, the following are usually present; the numbers given are numbers known to TRCA across the entire area described (*not* numbers per woodland):

- Cooper's Hawk (one pair, once only)
- Hairy Woodpecker (17 records, some duplication possible, over two years)
- Pileated Woodpecker (*Dryocopus pileatus)* (six records, over two years)
- Least Flycatcher (*Empidonax minimus)* (four pairs, over two years)
- Red-breasted Nuthatch (eight records, over two years)
- White-breasted Nuthatch (18 pairs over five years)
- Blue-grey Gnatcatcher (*Polioptila caerulea)* (five to six pairs over two years)
- Wood Thrush (14 records over three years)
- Pine Warbler (*Dendroica pinus)* (one pair, once only)
- American Redstart (*Setophaga ruticilla)* (three pairs, two were immature males)
- Scarlet Tanager (two territories in 2004).

Considering the multi-year data set and the duplication of records, this is a very small number of records for the area examined and is consistent with other sources that were examined for this document. These TRCA data, if examined further, would be a valuable contribution to understanding breeding bird distribution in an urban environment of southern Ontario.

Another study examined the species richness of forest breeding birds within TRCA jurisdiction using presence-absence data (Zajc and Murphy 2005). Only 12 area-sensitive forest species were found in the entire data set and among 485 forest patches that were identified, 80 per cent had no area-sensitive species. That study found that both patch and landscape variables may influence certain bird species and that urbanization was an important variable. However, the definition of urbanization and the scale of investigations (i.e., 800 m around patches defined "landscape area") may have influenced the outcome.

4.2 Potential and Actual Area-Sensitive Breeding Birds in the City of Toronto

Using the breeding bird data in the preceding subchapters, other published data on breeding birds in the GTA, monthly newsletters from the Toronto Ornithological Club and comments from Paul Prior of the Toronto and Region Conservation Authority, a palette of area-sensitive forest breeding birds for the Toronto area was prepared (Table 4). The purpose of this palette is to provide additional empirical evidence on which area-sensitive forest species can be expected to occur in forests within the urban matrix.

Only species that currently nest in south-central Ontario were included as potential area-sensitive forest breeding birds. Species were determined to be area-sensitive if they have been designated by the Ontario Ministry of Natural Resources in the *Significant Wildlife Habitat Technical Guide* (2000). To this group, a number of additional species were added. These were either thought to be area-sensitive in this region by Henshaw (pers. obs.) (i.e., Ruffed Grouse [*Bonasa umbellus*], Golden-crowned Kinglet [*Regulus satrapa*], White-throated Sparrow [*Zonotrichia albicollis*] and Purple Finch); and/or were so designated by other sources such as Freemark and Collins (1992) (Red-bellied Woodpecker [*Melanerpes carolinus*], Wood Thrush, Chestnut-sided Warbler [*Dendroica pensylvanica*], Northern Waterthrush [*Seiurus noveboracensis*], Louisiana Waterthrush [*Seiurus motacilla*], Mourning Warbler [*Oporornis philadelphia*] and Hooded Warbler).

Table 4. Potential GTA Area-sensitive Forest Breeding Birds and their Current Breeding Status in the City of Toronto *(and contiguous urban areas)*

Common Name	Scientific Name	Current Breeding Status in the City of Toronto
Sharp-shinned Hawk	*Accipiter striatus*	✓, irregular, rare
Cooper's Hawk	*Accipiter cooperi*	✓, irregular, rare
Northern Goshawk	*Accipiter gentilis*	**X**, generally absent
Red-shouldered Hawk	*Buteo lineatus*	**X**, generally absent
Broad-winged Hawk	*Buteo platypterus*	**X**, generally absent
Ruffed Grouse	*Bonasa umbellus*	**X**, generally absent
Barred Owl	*Strix varia*	**X**, generally absent
Yellow-bellied Sapsucker	*Sphyrapicus varius*	**X**, generally absent (occasionally on territory)

Common Name	Scientific Name	Current Breeding Status in the City of Toronto
Red-bellied Woodpecker	*Melanerpes carolinus*	✓, irregular, rare
Hairy Woodpecker	*Picoides villosus*	✓, regular, uncommon
Pileated Woodpecker	*Dryocopus pileatus*	✓, regular but rare
Acadian Flycatcher	*Empidonax virescens*	**X**, generally absent
Least Flycatcher	*Empidonax minimus*	✓, regular, scarce
Red-breasted Nuthatch	*Sitta canadensis*	✓, regular, uncommon
White-breasted Nuthatch	*Sitta carolinensis*	✓, regular, fairly common
Tufted Titmouse	*Baeolophus bicolor*	**X**, generally absent (occasionally on territory)
Brown Creeper	*Certhia americana*	**X**, generally absent
Winter Wren	*Troglodytes troglodytes*	**X**, generally absent
Golden-crowned Kinglet	*Regulus satrapa*	**X**, generally absent
Blue-gray Gnatcatcher	*Polioptila caerulea*	✓, regular, uncommon
Veery	*Catharus fuscescens*	**X**, generally absent (occasionally on territory)
Hermit Thrush	*Catharus guttatus*	**X**, generally absent
Wood Thrush	*Hylocichla mustelina*	✓, regular, fairly common
Yellow-throated Vireo	*Vireo flavifrons*	**X**, generally absent
Blue-headed Vireo	*Vireo solitarius*	**X**, generally absent
Prothonotary Warbler	*Protonotaria citrea*	**X**, generally absent
Chestnut-sided Warbler	*Dendroica pensylvanica*	**X**, generally absent (occasionally on territory)
Black-throated Blue Warbler	*Dendroica caerulescens*	**X**, generally absent
Black-throated Green Warbler	*Dendroica virens*	**X**, generally absent
Blackburnian Warbler	*Dendroica fusca*	**X**, generally absent
Pine Warbler	*Dendroica pinus*	✓, regular but scarce
Cerulean Warbler	*Dendroica cerulea*	**X**, generally absent
Black-and-white Warbler	*Mniotilta varia*	**X**, generally absent
American Redstart	*Setophaga ruticilla*	✓, regular, scarce, may be mostly 2nd-year males
Ovenbird	*Seiurus aurocapillus*	**X**, occasional singing males probably does not breed
Northern Waterthrush	*Seiurus noveboracensis*	**X**, generally absent
Louisiana Waterthrush	*Seiurus motacilla*	**X**, generally absent
Mourning Warbler	*Oporornis philadelphia*	✓, irregular, rare
Canada Warbler	*Wilsonia canadensis*	**X**, generally absent
Hooded Warbler	*Wilsonia citrina*	**X**, generally absent
Scarlet Tanager	*Piranga olivacea*	✓, irregular, rare, may be mostly non-breeders
White-throated Sparrow	*Zonotrichia albicollis*	**X**, generally absent
Purple Finch	*Carpodacus purpureus*	**X**, generally absent

Note: ✓ recorded as recently breeding, **X** *not recorded as recently breeding. Regular implies annual nesting. Fairly common implies low densities, often present in suitable habitat. Uncommon implies very low densities, but usually can be located in suitable habitat. Rare implies one to several pairs across the entire City. Irregular implies infrequent low density nesting, sometimes none known in any particular year Scarce implies very low densities, difficult to encounter.*

Of the 43 potential area-sensitive forest breeding birds only 14 occur as breeding birds with any regularity in the urban environment, and 29 species have been lost or have not expanded into the urban forests. Of the 14, nine are regular breeders, and five are considered to be “uncommon” or “fairly common”.

By way of example, a smaller less-urbanized area (about 2,000 ha) that is forested on the Oak Ridges Moraine (also within the GTA), supports about 33 species from this list, 30 of which are regular breeders, and about 24 of which are at least “fairly common” in abundance (not including the low density raptors) (B. Henshaw, unpub. data).

5. Maintaining Area-sensitive Forest Breeding Birds in the Urban Matrix – Is it Possible?

This report is primarily concerned with the maintenance of area-sensitive forest breeding bird populations. The *Framework* has presented an argument for maintaining at least 30 per cent of a landscape in forest cover. This was determined to be the minimum functional level at which many of the area-sensitive forest breeding birds (and by association many other wildlife species) might be retained on the landscape.

The difficulty of conserving or restoring 30 per cent forest cover in urban areas, combined with the uncertainties regarding the viability of some ecological functions in an urban matrix, requires the separate evaluation of urban forests as area-sensitive forest breeding bird habitat.

This document assesses the literature regarding urban effects on area-sensitive forest breeding birds; examines various data sets and recent breeding bird studies from the GTA; and compares empirical data to a palette of breeding species that are potentially within this range. This last stage is particularly useful in that it tends to bridge the 'generation stagger'; there is often a tendency to compare today's biological conditions with that of only a few decades ago, rather than that of previous human generations. At the time of European settlement the dominant breeding birds in the lands now occupied by the City of Toronto were warblers, vireos and flycatchers rather than starlings, sparrows and pigeons.

The summary of 13 primary stressors on area-sensitive forest breeding birds presented in Table 2 provides ample evidence of effects, that even without interactions among them, might be sufficiently limiting for sensitive species. Add to this uncertainty around some of those effects, and the results from published studies, and it is very unlikely that urban areas will provide viable breeding habitat for area-sensitive forest birds.

Study after study supports the notion that urban forest fragments are not friendly towards area-sensitive forest breeding birds. Donnelly (2002) reported that species generally disappeared above 52 per cent urban land-cover, but that the most sensitive species may not be conserved even when disturbance is minimal.

Some species-specific work on the Scarlet Tanager (Rosenberg *et al.* 1999) has established a sliding scale whereby tanagers show almost no area-sensitivity at all at 70 per cent forest cover, but would not be expected to occur where forest cover falls much below 20 to 30 per cent. Project Tanager also applied these data to calculate a sliding scale for isolation effects. It is sobering to consider that the *lower* limit for tanager occurrence was 20 to 30 per cent forest cover. The tanagers clearly prospered at forest levels greater than 70 percent and the effective minimum forest cover for that species in southern Ontario (off the Canadian Shield) may be somewhere between 40 and 50 per cent.

Crooks *et al.* (2004) noted urbanization causes biotic homogenization, and may actually increase local diversity, but decrease overall regional diversity. Neotropical migrants were consistently negatively associated with street density while non-native species and cowbirds were consistently negatively associated with forest cover (Hennings and Edge 2003). To these studies can be added other familiar citations such as Friesen *et al.* (1995) and studies from non-forest habitats; coastal scrub communities in California range from high species richness and low abundances at one extreme (core areas) to high abundance of few species, including non-natives at the other extreme (urban matrix) (Crooks *et al.* 2004).

In GTA urban environments, the data presented in this document, from several relatively well-studied forest fragments, clearly indicate a paucity of area-sensitive forest birds. TRCA-wide data supported this pattern. The species that are occurring are in low densities, with the results of presence/absence surveys likely overrepresenting the actual productivity that may be occurring within the urban matrix.

Much of the evidence presented, along with the review of potential stressors, leads one to the conclusion that area-sensitive forest birds and urbanization are not compatible (this document has not attempted to define suburban/urban).

There remains the question -- how large would a forest patch (i.e., the “big woods”) need to be to support such species? At some stage, a huge continuous forest would be of sufficient size. There are some real difficulties in answering this question. Firstly, precious few data are available on the individual fitness of birds in urban-forest fragments. Secondly, estimates made to date are from a variety of landscapes in a variety of locations, and results are not always transferable. For example, Burke and Nol (2000) recommend preservation of tracts at least 500 ha in extent to guard against local population declines. Their recommendations are based on work undertaken in largely non-urban environments, where pressures on area-sensitive forest breeding birds were likely less limiting; the minimum area would likely be greater in the urban matrix. In Maryland, U.S.A., guidelines suggest that blocks of 3,000 ha of mature forest should be preserved (Maryland Partners in Flight 1997).

It is worth considering the study and discussion by Mancke and Gavin (2000) that urge the importance of the “big woods” (>5,000 ha) although their study was not designed to establish the size of the “big woods”. In fact, they note that forest fragment extent may be an inadequate tool for landscape analysis, preferring the metric “distance to big woods” or more accurately “distance to a place that produces dispersing birds”. Distance to edge is also more helpful than woodlot area as woodlot area cannot account for edge effects (after all birds have no concept of patch size in a forest that is 500 m wide by 50 km long).

Finally, Mancke and Gavin (2000) also note that “some species will not coexist with buildings (or the negative biotic interaction caused by buildings)”. This is also consistent with the findings of other studies.

Even if it were possible to determine a forest area that might preserve viable populations of these birds in the urban matrix, it would still be necessary to manage some of the stressors that a large human population will inevitably bring to bear on an attractive natural area. One has only to visit the popular Rouge River Park in Scarborough, or various conservation areas within the GTA to realize that human disturbance could be a very real factor in areas close to or within large populated areas.

Rather than trying to establish, whether a 1,000 ha forest or a 3,000 ha forest might be sufficiently robust using species-specific habitat quantity and quality thresholds, it is worth considering that forest areas of this size are not going to be realistically restorable within the existing urban matrix.

Based on this review an alternative approach that seeks to identify and protect existing forest cover well above the minimum 30 per cent threshold, before significant pressures of urbanization arrive, is the most practical and appropriate means to provide habitat for area-sensitive forest birds. To this objective could be added other forest cover metrics such as the big woods and aggregation of forest (clumping); native forest species, particularly long-distance migrants, were present and more abundant where forest was aggregated greater than 64 per cent (Donnelly 2002). This does not completely preclude restoring and enhancing existing urban forest patches to maintain other forest-associated bird species that are urban-tolerant or restoring urban forests for other ecological services they provide.

There is a tendency to rate woodlands in areas with the lowest forest cover as the most significant, over those in areas where forest cover is still at relatively high levels. In terms of area-sensitive forest birds at least, the opposite appears to be true. High forest cover and the big woods are likely to be more important for the conservation of forest birds in southern Ontario, not connected fragments.

In recent years, there has been a movement to use legislative tools (e.g., the *Oak Ridges Moraine Conservation Act*) to endeavour to protect natural areas/countryside from conversion to urban-land uses. This has led to increased planning controls over large areas of the Oak Ridges Moraine, and in 2005, to a *Green Belt Protection Act* and a larger growth plan for the greater Golden Horseshoe that extends beyond the Moraine. While there is very limited scope within existing built-up urban areas to provide viable habitat for area-sensitive forest birds, there is still opportunity to do so within the undeveloped portions of many ‘urban’ watersheds (i.e., outside of the existing urban limits). In many cases there are sufficient non-urban lands in the undeveloped portions of these watersheds that the 30 per cent threshold would be attainable. These areas could, in some way, help to begin to compensate for the lack of such habitat within the urban portion of the watershed; forest habitat could be maintained or restored to partially offset permanent loss in urban areas.

6. Restoring and Enhancing Urban Forests

It is very important to note that the provision of forest within the urban matrix produces a wide range of benefits for many, non-forest birds, migrant birds, some forest-associated breeding birds, a host of ecological and environmental services and many social benefits to the urban human population. However, within this list of benefits breeding habitat for area-sensitive forest birds cannot be reliably included. Perhaps more accurately the term urban-sensitive birds should be used, as there are likely birds beyond the scope of this study (i.e., forest birds that are not area-sensitive) that also do not prosper in forests embedded within the urban matrix.

Yet, efforts to improve habitat for other forest breeding birds can improve wildlife habitat for a variety of native forest species within the urban matrix, including migrating area-sensitive forest breeding birds. Local-scale activities such as shrub and tree planting and increasing vegetation diversity (e.g., creating light gaps in closed canopy forests) can improve bird diversity in urban areas (Clergeau *et al.* 2001). Indeed, some forest associated (non-area-sensitive) species do well in intermediate cover levels (e.g., Black-capped Chickadee, flickers and Red-breasted Nuthatch) (Rohila 2002 *In* Donnelly 2002) and increasing urban canopy cover may help some native forest birds (Hennings and Edge 2003). Some desirable wildlife species may thrive in well-managed urban woodlots.

Although small urban reserves may have no value as breeding habitat for some native area-sensitive forest breeding bird species (Donnelly and Marzluff 2004), it is worth mentioning that small reserves (less than 40 ha) can continue to fill a worthy niche in conservation strategies for preserving biological diversity, educational opportunities and their scientific role (Shafer 1995). In southern Ontario they may be particularly useful for migrant birds in spring and fall.

Many authors of related studies provide specific recommendations based on the results of their work. However, these are often quite specific to the circumstances of their study and a synthesis of the literature is required. Marzluff and Ewing (2001) provide an excellent discussion and suggestions for the restoration of ecological function in urban landscapes. They concentrate their comments on restoring the individual fitness of forest birds, which, they argue, is the ultimate determinant of community composition. Their comments are directly aimed at forest fragments and their surrounding urban areas.

The following discussion is based primarily on Marzluff and Ewing (2001), but has been adapted for southern Ontario, and it incorporates some additional material based on the preceding chapters of this document.

Increase Vegetation Layers

The maintenance or restoration of native vegetation layers (ground cover, shrub, understorey and canopy) and structural diversity, especially lower levels, is important for many area-sensitive forest birds. Some structural aspects may be selected for preferential management (e.g., logging) to attract certain species of management concern. Structural diversity may also be a useful criterion for prioritizing land acquisition programs.

Maintain Native Vegetation and Deadwood

Invasive vegetation has been related to declines in native forest birds. Deadwood is a critical habitat component for many species of wildlife. Where appropriate, forest management should allow for an increase in deadwood and concentrate on planting and encouraging native species.

Provide Adequate Critical Function Zones (CFZ)

These areas (see discussion in the Environment Canada *Framework* document) extend beyond the physical limits into the surrounding urban matrix. Often, the CFZ for forest fragments is relatively narrow (encompassing critical root zones for example).

Provide Adequate Protection Zones (PZ)

Protection Zones are located outside of the CFZ to manage the intrusion of effects emanating from the urban matrix, into the forest habitat. They need to be designed to ensure that edge effects are managed. This may require alternative approaches to avoid attracting large numbers of edge-specialists, such as dense plantings of simple-structured forest. Fences and other barriers can be also used to limit the effects of people, noise, light, urban runoff and even some pets.

Recognize That Human Intrusion May Not Be Compatible with Interior Conditions

Human use of natural areas, even passive activities such as walking on nature trails, has an effect on wildlife (see Disturbance to Vegetation, and Physical Disturbance). This is especially evident in urban areas where use may be relatively intense. Human intrusion is usually incompatible with maximum use of forest by wildlife where wildlife use is a management priority, such as core forest areas. Careful trail design, the use of techniques to focus pedestrian flow and the identification of, and fencing for, exclusion areas can all be considered in mitigating human use.

Make the Urban Matrix More Like the Forest Fragments

Greening the urban environment may make the gaps between the fragments less critical. Forest canopy in urban areas has been shown to increase at least some forest birds within adjacent forested areas (Hennings and Edge 2003).

Discourage Open Lawns

Lawns cover vast areas in southern Ontario and could provide many benefits if converted to wildlife friendly habitats. This could include planting of native species, introducing vertical structure (vegetation storeys), and reducing or eliminating the area of manicured turf.

Realize that Habitat Fragments May Not Support All Target Species

Many urban forest fragments will not support area-sensitive forest birds. Forest birds that can survive in urban areas, including non-area-sensitive species (e.g., Great Crested Flycatcher, Eastern Wood Pewee) should be encouraged; especially as some of these species are also of conservation concern. Some researchers have even suggested that managers in chronically fragmented landscapes focus on shrubland and grassland birds as forest birds are unlikely to be maintained.

Develop Monitoring Programs and Research Programs that Address Fitness

Monitoring programs in southern Ontario that address key questions focussing on reproduction, survival and dispersal are required to properly manage natural areas. Those studies will then hopefully provide important information about the long-term sustainability of forest breeding birds within an urban matrix. Furthermore, species-specific information on population demographics and habitat requirements in an urban matrix will potentially allow the development of critical population and habitat threshold models. This, then, can focus restoration efforts in areas of greatest ecological significance and provide guidance to adaptively manage remaining habitat in order to maintain or increase forest bird diversity. Presence-absence studies alone may not indicate trends in populations prior to critical population thresholds.

7. Applicability of the *How Much Habitat is Enough?* Forest Guidelines in Urban Areas

How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (2nd edition) (Environment Canada 2004) provides forest guidelines designed with Areas of Concern as the primary target, although the principles within them are applicable to many parts of Ontario. The forest guidelines are presented in Table 5.

Table 5. Summary of Forest-Habitat Guidelines from Environment Canada (2004)

Parameter	Guideline
Per cent forest cover	• At least 30 per cent of the AOC watershed should be in forest cover.
Size of largest forest patch	• A watershed or other land unit should have at least one 200 ha forest patch which is a minimum 500 m in width.
Per cent of watershed that is forest cover 100 m and 200 m from forest edge	• The proportion of the watershed that is forest cover 100 m or further from the forest edge should be greater than 10 per cent. • The proportion of the watershed that is forest cover 200 m or further from the forest edge should be greater than five per cent.
Forest shape	• To be of maximum use to species such as forest breeding birds that are intolerant of edge habitat, forest patches should be circular or square in shape.
Proximity to other forested patches	• To be of maximum use to species such as forest-interior birds, forest patches should be within two km of one another or other supporting habitat features.
Fragmented landscapes and the role of corridors	• Connectivity width will vary depending on the objectives of the project and the attributes of the nodes that will be connected. Corridors designed to facilitate species movement should be a minimum of 50 m to 100 m in width. Corridors designed to accommodate breeding habitat for specialist species need to be designed to meet the habitat requirements of those target species.
Forest quality — species composition and age structure	• Watershed forest cover should be representative of the full diversity of forest types found at that latitude.

To maintain scientific currency and reflect the recent advances in the understanding of landscape dynamics and ecological systems the *Framework* may be periodically updated (as it was in 2004).

Although the *Framework* is meant to guide restoration activities, and not to prescribe them, certain habitat objectives are necessary if certain levels of ecological function are desired. It is clear that some of the criteria will not be attainable within the urban matrix. For example, urban areas in the GTA often have forest cover of 3 per cent to 7 per cent; and the 30 per cent guideline will be unattainable, at least within the urbanized portion of the watershed.

While some of the criteria may be unattainable, other *Framework* criteria can be fully or partially met. Some may attain greater importance. And the relative importance of the individual criteria will change as landscape composition changes. Indeed, the current *Framework* does not directly address the relative importance of per cent forest cover versus, for example, the role of corridors. In this instance guidelines pertaining to forest configuration and linkages, will assume greater importance when other conditions, such as total forest cover, decline. In particular, stressing the importance of percent forest cover will make the *Framework* more applicable in guiding restoration and conservation of forest habitat.

On a watershed basis, most *Framework* forest guidelines can currently still be met in the remaining non-urbanized portions of AOC watersheds through forest habitat protection and restoration. However, this opportunity will very likely be lost with continued conversion of watersheds to urban land use. Enhanced protection and restoration efforts in the non-urbanized portions of watersheds may even serve to mitigate and compensate for the loss of forest-bird habitat in urban portions of the watershed, although such efforts will not fully represent the range of bioregions within a watershed (e.g. the Carolinian life zone within the Toronto AOC).

In terms of urban forests directly, their inadequacy to support the original palette of area-sensitive forest birds, even after on-site mitigation and restoration, does not preclude their importance for other ecological values and functions. As noted in the *Framework*: "*new baselines for habitat and ecosystem functions may have to be established, and innovative systems devised to compensate for the effects of lost habitat and to mitigate the impact of urban centres on the surrounding landscape".* Urban forests must be assessed in terms of realistic expectations and ecological goals within the context of urban 'ecosystems'.

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10. Appendix 1: Suggested Research Questions

During the preparation of this report several key questions were recurrent themes either in the literature (e.g., Marzluff and Ewing 2001), or because of a lack of available information. Answers to the following suggested questions may benefit the study and conservation of forest breeding birds in the urban matrix.

Corridors

- How important are corridors to forest birds at different levels of forest cover levels; what is the use of corridors by detrimental fauna and flora; and what is the net benefit to breeding birds?

Predators

- Which are the key predators of nests in urban forests; are the predation rates elevated; and how are they supported in the urban matrix? What is the role of bird feeders or other supplemental food sources in this regard?
- Are Brown-headed Cowbirds more abundant in urban settings; if so, why? Do they impact forest birds in a significant way?
- Are urban forests ‘sinks’ for forest birds due to elevated predation rates?

Food Resources

- What is the effect of urban environment on insect assemblages in urban woodlots?
- To what extent are urban contaminants (including airborne contaminants) directly or indirectly limiting the productivity of forest birds?
- What is the effect of invasive plant species on forest habitats and breeding bird fecundity?

Ecological Planning

- What is the effect of increased ‘urban greening’ (i.e., more urban trees, natural areas within the urban matrix) on forest birds in southern Ontario?
- What is the difference in forest-bird viability in fragments adjacent to dispersed housing *versus* higher density subdivisions?
- Among forest birds, why are neotropical migrants particularly sensitive to residential housing? What is the role of psychological and/or social behaviour?
- What design guidelines can be applied to Protection Zones around forest fragments to maximize bird fitness without hindering inter-patch movements?
- Does urban light pollution negatively impact forest breeding birds?
- What are the effects of traffic noise of differing intensities on breeding birds in southern Ontario landscapes?