# Early Impacts of Residential Development on Wood Thrushes in an Urbanizing Forest[1]

**L. E. Friesen[2], E. D. Cheskey[3], M. D. Cadman[4], V. E. Martin[5], and R. J. MacKay[6]**

## Abstract

Environmental protection policies sometimes protect forests along an advancing suburban front although many of the forests may be brought into close proximity to residential housing. Research suggests that even when forests are physically preserved, their bird communities are simplified as the surroundings become urbanized. However, little is known of the time required for these changes to appear or of the mechanisms that drive them. We obtained population measures on the Wood Thrush (*Hylocichla mustelina*), an urban-sensitive woodland species in at least portions of its breeding range, before, during, and after development occurred alongside a large (140 ha) upland deciduous forest in Waterloo, Ontario, and compared these measures with those from rural control sites. From 1998 to 2001, the number of houses within 500 m of the urbanizing forest increased from 24 to 470. We detected no significant differences between the relative abundance of Wood Thrushes in the urbanizing and rural control sites, nor was there any significant difference in levels of nesting success, productivity, and brood parasitism. We did not detect any significant changes in successive nest locations of individual banded birds in response to encroaching development. These results suggest that the anticipated impacts of development on Wood Thrushes, and perhaps other forest birds, in adjacent woodlands may not be immediate but, rather, they may require a number of years to manifest. The high return rate (59 percent) of adult females on the urbanizing site in 2001 suggests pronounced site tenacity that may offset any aversion to nesting near houses.

*Key words*: housing, Neotropical migrants, residential development, urbanization, Wood Thrush.

## Introduction

Deciduous forests in eastern North America have undergone a considerable resurgence since the 1930s, mainly because of the abandonment and regeneration of marginal farmland (Martin 1988, McKibbon 1995). But now there are growing concerns that the pace of urban growth is beginning to outstrip that of forest regrowth. In many regions, sprawling land development accounts for the greatest amount of land use change and threatens forests, wetlands, and croplands on an accelerating scale (Mitchell 2001).

The result of urban sprawl can be the loss of older, established forests, as in York Region in the Greater Toronto Area, Canada, where upland deciduous forest cover dropped from 18 percent in 1991 to 14 percent in 2000 (L. Munt, pers. comm.). Or forests may be preserved along an advancing suburban front although their condition is altered. For example, forest cover in the Halton area along Ontario's Niagara Escarpment increased slightly, from 43 to 44 percent, from 1976 to 1995 (Braid and Ramsay 2000). At the same time, the forests became more fragmented, in part because of a proliferating intrusion of rural residences into the forests (Braid and Ramsay 2000).

A growing body of research across eastern North America suggests that even when forests are retained, their bird communities change as the matrix becomes more urbanized. Habitat specialists, many of them Neotropical migrant species, usually decrease or disappear in the presence of nearby housing. Supporting evidence comes from studies that have focused on the following:

1. A single site through time as the surrounding area became more urbanized (Holt 2000)

2. A number of sites in a single landscape having differing intensities of adjacent residential development (Dowd 1992, Friesen et al. 1995, Mancke and Gavin 2000, Dawson et al. 2001)

---

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

[2]Canadian Wildlife Service, Room 211, Blackwood Hall, University of Guelph, Guelph, Ontario, N1G 2W1, Canada
[3]29 Park Street, Eden Mills, Ontario N0B 1P0, Canada
[4]Canadian Wildlife Service, Room 211, Blackwood Hall, University of Guelph, Guelph, Ontario N1G 2W1, Canada
[5]Planning, Housing and Community Services Department, Regional Municipality of Waterloo, 150 Frederick St., Kitchener, Ontario, N2G 4J3, Canada
[6]Department of Statistics and Actuarial Science, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

3. Sites in two or more landscape types having different housing densities (Nilon et al. 1995, Kluza et al. 2000)

Results from Ontario are illustrative of the emerging pattern, if not the details, documented by these studies; there, 4-ha woodlots without adjacent development contained a higher abundance and diversity of Neotropical migrants than 25-ha urban woodlots (Friesen et al. 1995). Of the nine most common Neotropical species recorded in this study, the Wood Thrush showed the most dramatic response to development: while common in rural forests, it practically disappeared in urban forests of similar size (Friesen et al. 1995).

The ecological impacts of land use adjacent to forests evidently add to the effects of fragmentation per se (Saunders et al. 1991) and contribute to profound changes within the Neotropical forest bird community. However, little is known of how much time is required for these changes to appear after the advent of development: Are they immediate, gradual, or do they occur suddenly after a certain interval of time? Similarly, little is known of the mechanisms that drive and shape the changes: Are they linked to poor nesting success resulting from a higher abundance of urban-adapted predators and/or Brown-headed Cowbirds (*Molothrus ater*)? Low adult return rates?

We attempted to answer these questions by obtaining population measures on the Wood Thrush, an urban-sensitive woodland species in at least parts of its breeding range (Friesen et al. 1995, Kluza et al. 2000, but see Mancke and Gavin 2000). Long-term demographic studies of sensitive species have been identified as one of the highest avian research priorities in urbanizing areas, particularly as they help to identify source/sink populations (Marzluff et al. 2001a). Our research was conducted before, during, and several years after development occurred alongside a large upland deciduous forest in the City of Waterloo, Ontario, Canada (*fig. 1*). The population measures from the urbanizing forest were compared with those from rural control sites to distinguish between local and regional effects.

## Study Area and Methods

The Regional Municipality of Waterloo in southern Ontario, Canada is a fragmented urban/agricultural landscape with 14 percent forest cover that varies locally from 10 to 25 percent (see Friesen et al. 1999 for a general description of the landscape). Forested Hills (140 ha), an urbanizing forest, is an Environmentally Sensitive Policy Area, a designation that effectively precludes development within its borders (Regional Municipality of Waterloo 1995). The forest is situated on the western edge of the City of Waterloo, which had a population of 102,300 in 2001, representing a 3.5 percent increase over the previous year (Regional Municipality of Waterloo 2002). Rapid growth is expected to continue, especially in this neighborhood, with Forested Hills becoming completely encircled by housing between 2007 and 2012.

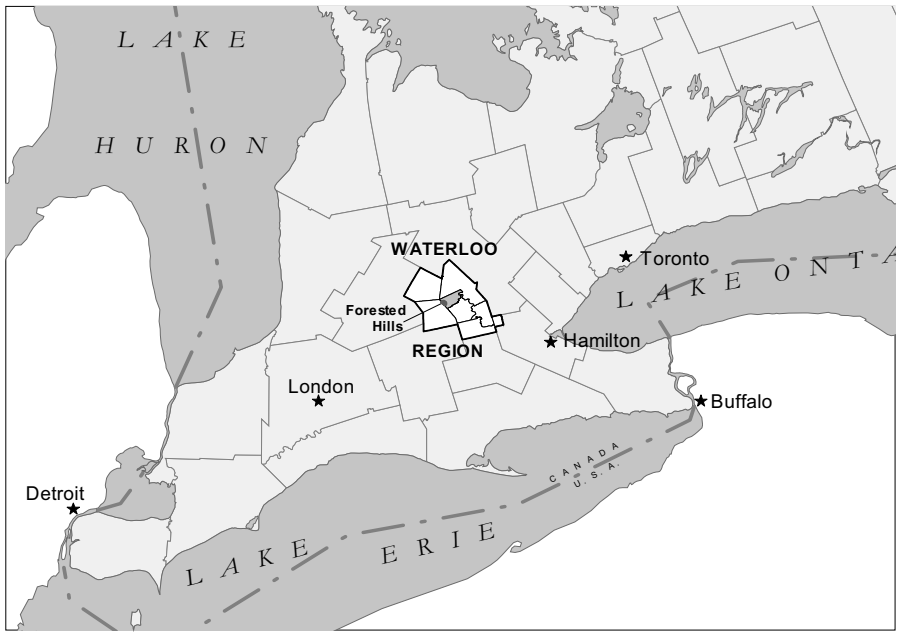


**Figure 1—** Location of study area in southern Ontario, Canada.

## Point Counts

In a separate study to monitor avian population changes in response to increased housing density, point counts were established within Forested Hills and neighboring rural forests. Data for Wood Thrushes were summarized from 18 point-count stations within Forested Hills and nine point-count stations in four control forests located within 1 km of Forested Hills but lying outside of the designated development zone. The purpose of the controls was to deal with year-to-year variation within the Wood Thrush population due to causes other than development pressure. There was no matching of control and Forested Hill stations for vegetative or spatial features. All 27 stations were monitored from 1998 to 2001 by the same observer, using, two or three 10-minute point counts. To account for the varying number of visits (2 vs. 3), the average abundance of Wood Thrushes per station was calculated over visits in a given year.

## Demographic Study

Field research on Wood Thrushes' demography was conducted from 1997 to 2001 in Forested Hills on six rural woodlots, sized 3 to 24 ha (*fig. 2;* see Friesen et al. 2000 for more details of these study sites). Note that these sites were different than the control sites used in the point-count study. One of the six rural sites was situated 1 km from Forested Hills; the other five were 10 to 20 km from Forested Hills. All six control woodlots were in rural landscapes where agriculture, primarily corn and soybean production, was the predominant land-use. Primary habitat at all study sites was upland deciduous forest dominated by sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), and white ash (*Fraxinus americana*).

At the outset of the study, the land surrounding Forested Hills consisted of fields that were either actively cropped or were lying fallow awaiting development. We used property assessment and building permit data from the Regional Municipality of Waterloo to determine the extent of development before and during our study.

We located Wood Thrush nests and monitored them every 2 or 3 days using a mirror attached to a telescoping pole (see Friesen et al. 1999 for details). Nesting success was estimated using the Mayfield (1975) method, based on a 25-day nesting cycle. A nest was considered successful if host or cowbird fledglings survived to at least 10 days of age, when fledging is known to occur (Roth et al. 1996). Parasitism rates were calculated as the proportion of nests found during the incubation stage that contained cowbird eggs. We mist-netted and banded adults at their nests throughout the breeding season to determine incidences of double-brooding and renesting among females (see Friesen et al. 2000 for details); this information is needed to accurately assess productivity and population viability. Adult annual return rates were calculated as the proportion of birds captured and banded in one year and recaptured and/or resighted the following year.

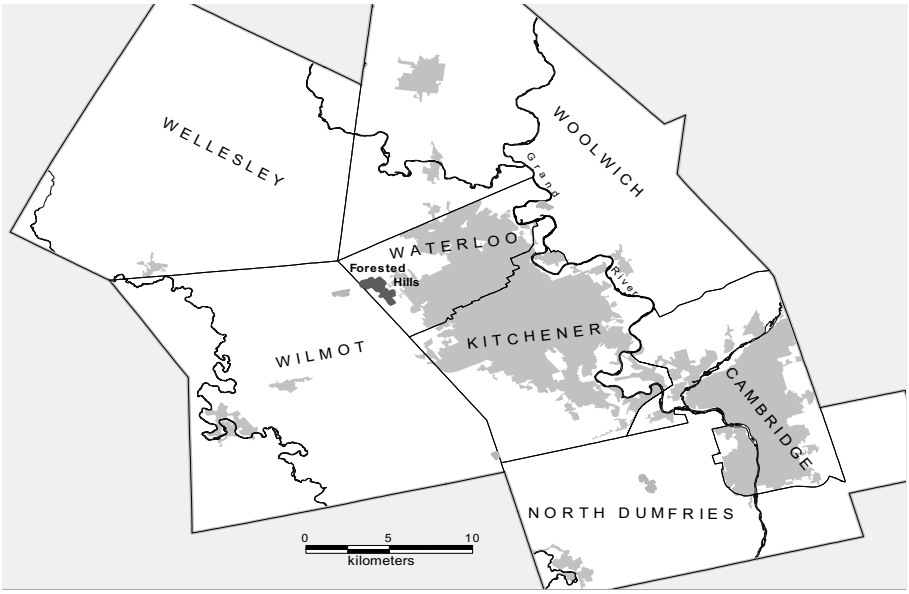


**Figure 2—** Location of Forested Hills and rural control sites in the Regional Municipality of Waterloo, Ontario, Canada.

We adopted "conservative" and "optimistic" survival rates for adult and juvenile Wood Thrushes to estimate whether the production of young Wood Thrushes was sufficient to support a self-sustaining population. Published estimates of annual adult survival of Wood Thrushes range from 0.58 to 0.70 (Roth et al. 1996); juvenile survival rates range from 0.29 to 0.35 (Trine 1998). We determined that 0.86 female young per pair were required annually to maintain a viable population if the highest estimated adult and juvenile survival rates were used; 1.45 female young were needed if the lowest estimated survival rates were used. Our fecundity model (see Donovan et al. 1995 for details) incorporated nesting values derived from our study population, i.e., Wood Thrushes were double-brooded (Friesen et al. 2000) and 15 percent attempted three nests in a season (L. Friesen, unpubl. data).

### Mapping and Spatial Analysis

A GPS unit was used to gather positional data on each nest in the study, to an estimated accuracy of +/- 5 m. GPS coordinates were brought into MapInfo® (GIS software from MapInfo Corporation) for mapping and analysis. Points representing the nests were created and overlaid on digital imagery to verify the accuracy of the nest locations.

Various comparative measures of the location of successive nests were possible. Our primary interest was in detecting responses to urbanization pressures, and our focus, therefore, was on the measurement of a hypothesized drift in nest locations relative to the source of those pressures. We speculated that individual Wood Thrushes might respond to encroaching development by moving successive nests away (i.e., in a westerly direction) from the source of the disturbance, which was concentrated along the eastern side of the forest. We, therefore, measured changes in successive nest locations of individual banded birds to determine whether there was a shift in location away from the residential development. This was done by calculating the net change in x (easting) coordinates for successive nests. The control group consisted of all successive nests from the control sites, plus 1998 and 1999 nests from Forested Hills. The latter were included with the control group because in those years development remained well removed from the study site (the closest encroachment to any nest at that time was approximately 250 m).

### Statistical Analyses

An analysis of variance (Sokal and Rohlf 1981) was used to test the hypothesis of a difference in population trend over years between Forested Hills and the control sites; the average number of Wood Thrushes detected per year at each station was used as the response. The multiple comparison method (Sauer and Williams 1989) was used to test whether the Mayfield estimates of daily survival of Wood Thrushes differed among years and woodlot size classes. Standard chi-squared procedures (Sokal and Rohlf 1981) were used to examine differences in parasitism rates among the woodlot size classes and between years. We pooled data across years, unless noted otherwise, and considered results significant if $P \leq 0.05$. For purposes of analysis of the movement of nests, the nests were divided into a control group and a study group, and we hypothesized that the means from each group were equal against a two-sided alternative (two sample t-test).

## Results

In 1997, 24 houses were located within 500 m of Forested Hills (*fig. 3*). Residential construction associated with the new development began in 1998. By 2001, the number of houses within 500 m of the eastern edge of the forest had increased to 470 (*figs. 4-6*). The number of houses within 50 m of the forest increased from 5 in 1997 to 55 in 2001.

### Point Count Data

There was no evidence of a difference ($P = 0.60$) or a trend ($P = 0.75$) on the relative abundance of Wood Thrushes between Forested Hills and the control sites (*fig. 7*).

### Nesting Success, Productivity, Population Viability, and Adult Return Rates

Two hundred and thirty-nine Wood Thrush nests were monitored across the study sites from 1997-2001 (*table 1*). There was no significant difference ($\chi^2 = 0.268$, df = 1, $P = 0.604$) in nesting success between Forested Hills (51 percent, N = 102) and the control sites (47 percent, N = 137). Similarly, there was no significant difference ($\chi^2 = 2.83$, df = 1, $P > 0.701$) in parasitism rates between Forested Hills (34 percent) and the control sites (46 percent) for all five years combined.

Productivity at all of our study sites surpassed the source-sink threshold if we assumed optimistic survival rates for adults and juveniles (70 percent and 35 percent respectively; *fig. 8*). When we assumed conservative survival rates for adults and juveniles (58 percent and 29 percent respectively), Forested Hills but not the control sites surpassed the source-sink threshold. In either case, we detected no significant difference in fecundity levels between Forested Hills and the control sites.

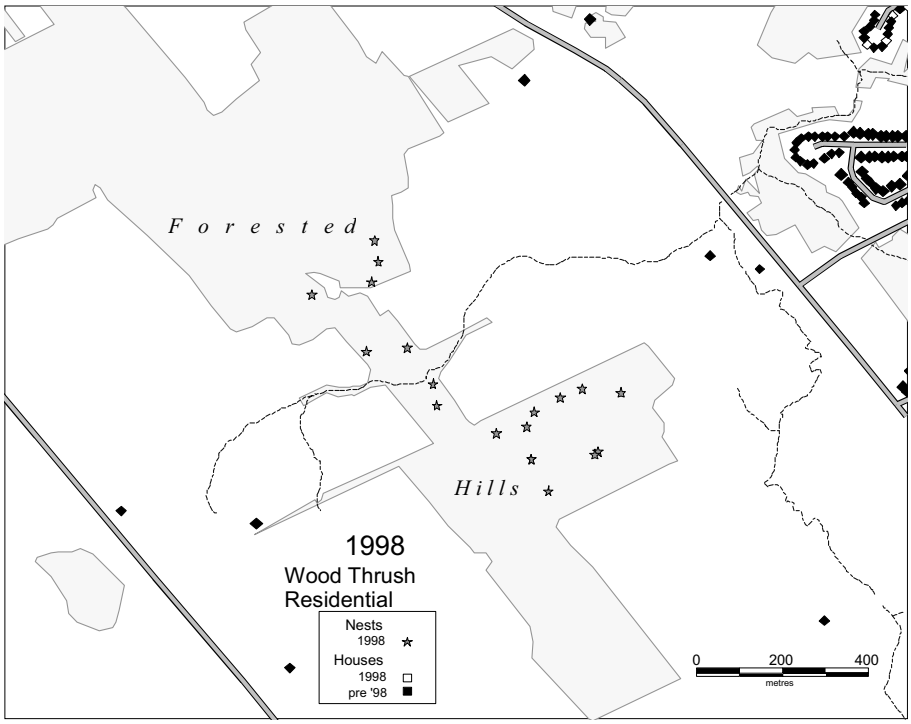


**Figure 3—** Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

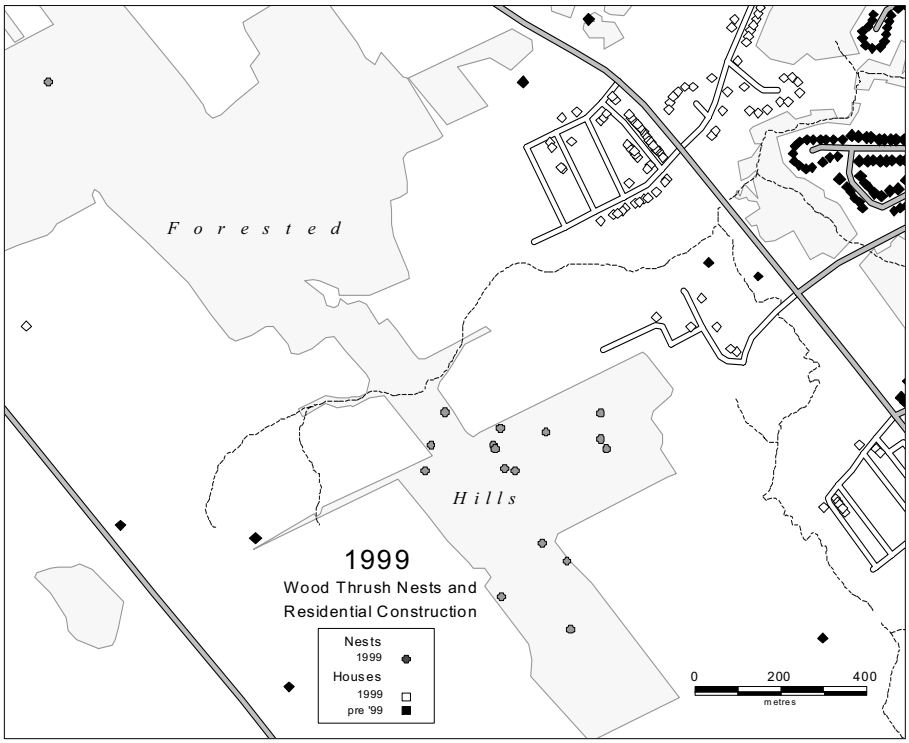


**Figure 4—** Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

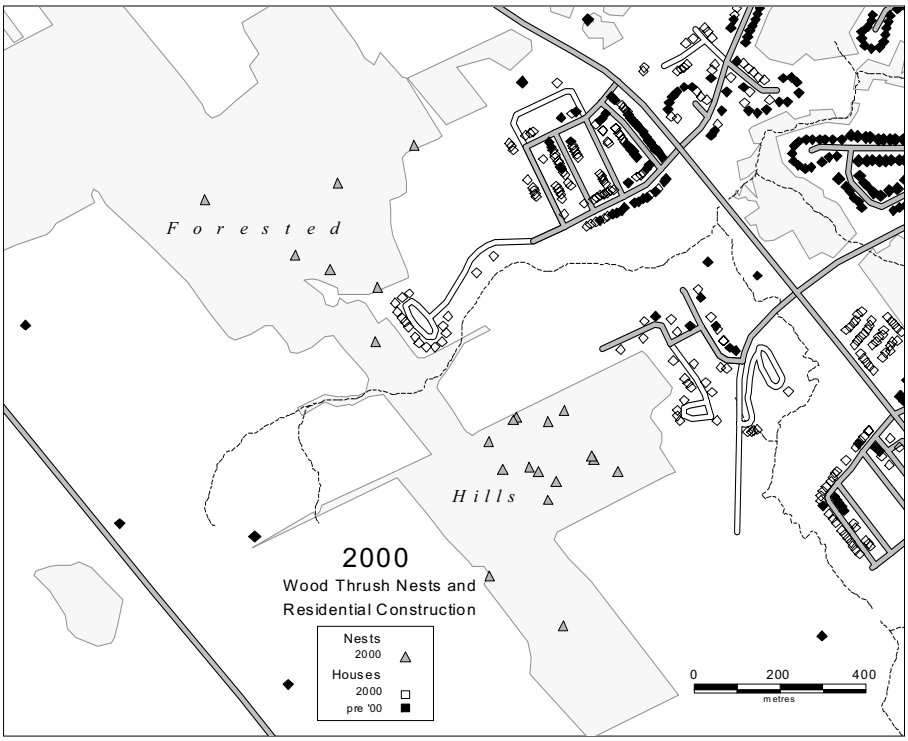


**Figure 5—** Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

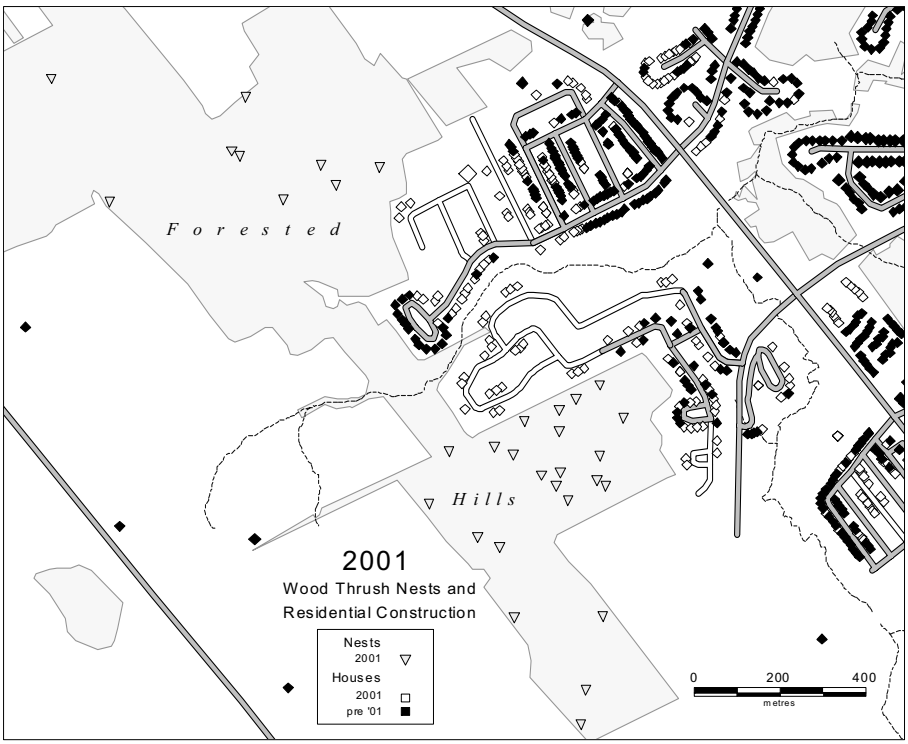


**Figure 6—** Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

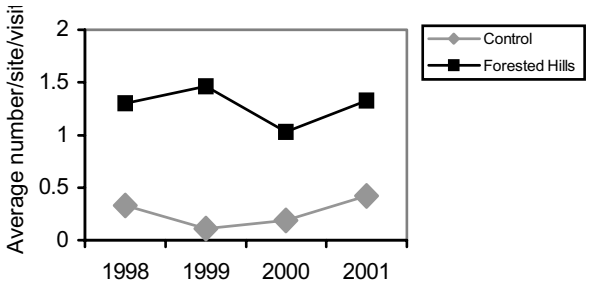


**Figure 7—** Average abundance of Wood Thrushes per point count station in Forested Hills and surrounding control sites in the Regional Municipality of Waterloo, Ontario, Canada.

Fifty-nine percent (N = 10) of the females and 31 percent (N = 5) of the males that were banded at Forested Hills in 2000 returned to that site in 2001. By comparison, 22 percent (N = 4) of the females and 35 percent (N = 6) of the males that were banded in the control sites in 2000 were recaptured or resighted in 2001.

### *Nest location*

Eighty-two nests were available for spatial analysis; 27 were from Forested Hills and 55 made up a control group composed of the rural control sites as well as the first two years (predevelopment) of data from Forested Hills. Our analysis of the nest-to-nest movement of banded individuals did not detect any significant shift of nests away from the encroaching development ($t = 0.914$, $p = 0.360$).

## Discussion

Considerable evidence exists to suggest that housing developments can have a profound ecological effect on adjacent forests. These effects include changes in vegetation structure (Matlack 1993) and bird composition (reviewed in Marzluff et al. 2001a). However, our results suggest that the anticipated impacts of development on the abundance of Wood Thrushes, and perhaps other Neotropical migrant species in adjacent woodlands, may not be an immediate effect but instead require years to manifest themselves.

Sometimes, when habitat is fragmented or the surrounding matrix is altered, there is a time lag during which populations initially show few, if any, ill effects but then decline, either in a sudden drop or gradually over a period of many years (Knick and Rotenberry 2000). Red-shouldered Hawks (*Buteo lineatus*), for example, were the most common Buteo species in Waterloo Region in the 1920s (Soper 1923), remained common in the 1940s (Knechetel 1945). They declined steadily thereafter (Weir 1987) and by the 1970s persisted only in small numbers although they still nested at that time in several urbanizing forests in the City of Waterloo (Craig Campbell, pers. comm.). By 1991, the hawk had disappeared from the region (Cheskey 1991). The relationship between bird species' presence and the age of urban habitat fragments has been noted for other habitat types. Soulè et al. (1988) observed that in chaparral habitat in southern California, species' loss was, in part, a function of fragment age; the longer a patch was isolated by urban development, the greater the species' loss until a new equilibrium was reached.

**Table 1—** *Nesting success and parasitism of Wood Thrushes in the Regional Municipality of Waterloo, Ontario, Canada*

| Site | Year | Number of nests | Nesting success (%)[a] | Wood Thrush young[b] | Nest parasitism (%) |
|---|---|---|---|---|---|
| **Forested Hills** | 1997 | 13 | 32 | 2.4 | 46 |
| | 1998 | 19 | 63 | 2.4 | 32 |
| | 1999 | 17 | 60 | 3.1 | 24 |
| | 2000 | 21 | 53 | 2.8 | 14 |
| | 2001 | 32 | 44 | 2.1 | 50 |
| | All years | 102 | 51 | 2.5 | 34 |
| **Control sites** | 1997 | 30 | 53 | 2.1 | 50 |
| | 1998 | 25 | 46 | 1.9 | 76 |
| | 1999 | 26 | 44 | 2.4 | 50 |
| | 2000 | 32 | 38 | 2.8 | 22 |
| | 2001 | 24 | 55 | 2.4 | 38 |
| | All years | 137 | 47 | 2.3 | 46 |

[a] Proportion of nests expected to fledge young based on the Mayfield (1975) estimate.
[b] Average number of Wood Thrush nestlings fledged from nests that produced at least one Wood Thrush and/or Brown-headed Cowbird.

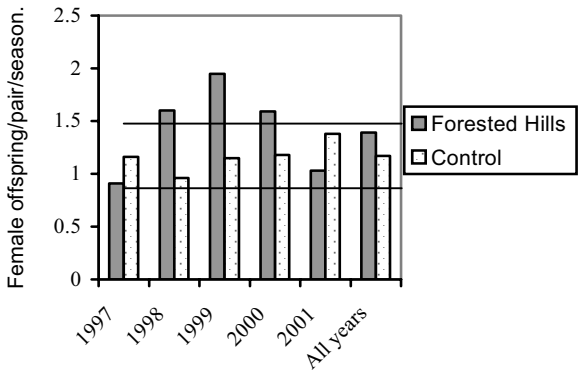


**Figure 8—** Annual female fledgling productivity of Wood Thrush pairs in Forested Hills and the control sites. Upper solid line is the level of productivity needed for a sustainable population, using the lowest estimated survival rates of adults and juveniles (58% and 29% respectively). Lower solid line is the level of productivity needed for a sustainable population using the highest estimated survival rates of adults and juveniles (70% and 35% respectively).

A higher abundance of potential nest predators in urban woodlots might explain why some bird species disappear or have lower densities near buildings (Kluza et al. 2000). Populations of raccoons (*Procyon lotor*), jays, crows, grackles, and squirrels can be substantially higher in suburban/urban areas than in rural areas (Riley et al. 1998; Haskell et al. 2001, Marzluff et al. 2001b). If predator abundance had increased in Forested Hills along with development, one might expect Wood Thrush nesting success to be lower there than in the rural control sites. However, nesting success was not significantly different in the urbanizing forest than at the other study sites, suggesting that the predator community, or at least its effect, was similar in all the areas.

The identity of these predators in our study area remains unknown, for despite regular nest monitoring, no act of nest predation has ever been witnessed. Raccoons, however, are frequently observed and were the only predator recorded at every site in an artificial nest/camera study conducted in 2001 (L. Friesen, unpubl. data). Few domestic cats have been sighted at any of our study sites. Cats have been identified as a predator whose effects are most pronounced in urban/suburban areas (Barratt 1998). Cats could directly influence Wood Thrush nesting success by killing adult birds during the breeding season (probably not a common occurrence in our study, given the low incidence of nest abandonment) and they would have difficulty accessing the nests themselves, which often are located in thin-stemmed saplings. Cats may become a more prominent presence at Forested Hills as housing density increases and if homeowners permit their pets to roam freely. At this point, raccoons and Blue Jays (*Cyanocitta cristata*) likely pose a far greater threat to Wood Thrush nests than cats owing to their higher abundance in the forest and their ability to access almost any nest they find.

Residential development around Forested Hills is still in its early stages and further monitoring is needed to better assess the impact of predators that exploit urban and suburban habitats. It may be that the availability of human refuse (i.e., compost heaps, garbage cans) and food from bird feeders subsidizes a suite of urban predators including raccoons, crows, grackles, and squirrels that in turn may increase pressures on nesting birds in nearby forests. On the other hand, it may be that potential nest predators alter their behavior in urban environments to the benefit of nesting birds, e.g., scavenging at compost heaps might draw potential predators, such as raccoons, away from songbird nests (Haskell et al. 2001). Ecologists have only recently begun to examine the relationship between potential urban predators and songbird nesting success (e.g., Mazluff et al. 2001b). What they have learned so far suggests that the relationship is complex and resistant to easy generalizations.

Contrary to our hypothesis, the mapped locations of nests at Forested Hills (*figs. 3 to 6*) suggested no obvious movement of nests away from the intensifying development over years. Any movement to this effect, if present, was too subtle for us to detect at this juncture.

Many of the banded birds in our study revealed high site tenacity between years, as evidenced by the 59 percent return rate for females at Forested Hills in 2001. Older birds may be compelled by habit and/or instinct to return to previous nesting sites, regardless of changes to the surrounding landscape. Potential immigrants, especially young birds, are not bound by such commitment and might reject a site such as Forested Hills for a less urbanized forest. If this were the case, then changes to the Wood Thrush community would become evident only after the original population disappeared through natural attrition, a process requiring 5 to 10 years. Once gone, new recruits might not replace the original population.

## Acknowledgments

This project was generously supported by the Canadian Wildlife Service, Environment Canada, Ontario Region; the City of Waterloo, Ontario; the Environmental Conservation Branch, Environment Canada, Ontario Region; the Federation of Ontario Naturalists; Human Resources Development Canada, Ontario Region; the Science Horizons Youth Internship Program, Environment Canada, Ontario Region; and the Regional

Municipality of Waterloo. We are grateful to the landowners who permitted access to their lands and indebted to the many field assistants who participated in the project over the years. Special thanks to L. Campbell for help with preparation of this document, L. Munt for information on forest cover loss in York Region, and Craig Campbell for information on birds in Waterloo Region. We thank T. Rich, C. Hunter, D. Demarest, and an anonymous reviewer for their perceptive and constructive comments on the manuscript.

## Literature Cited

Barrat, D .G. 1998. **Predation by house cats, *Felis catus* (L.), in Canberra, Australia. 11. Factors affecting the amount of prey caught and estimates of the impact on wildlife.** Wildlife Research: 475-487.

Braid, A. M., and D. Ramsay. 2000. **Niagara escarpment biosphere reserve landscape change study**. In: Landscape changes at Canada's biosphere reserves. Toronto, ON: Canada MAB, Environment Canada; 21-28.

Cheskey, E. D. 1991. **Planning for the birds: An approach to ecologically based strategic planning in the Grand River forests.** Waterloo: Heritage Resource Centre, University of Waterloo.

Dawson, D. K., C. S. Robbins, and L. J. Darr. 2001. **Effects of urbanization on the distribution of area-sensitive forest birds in Prince George's County, Maryland**. In: G. D. Therres, editor. Conservation of biological diversity: a key to the restoration of the Chesapeake Bay and beyond: conference proceedings. Annapolis, MD: Maryland Department of Natural Resources; 207-213.

Donovan, T. M., F. R. Thompson, J. Faaborg, and J. R. Probst. 1995**. Reproductive success of migratory birds in habitat sources and sinks**. Conservation Biology 9: 1380-1395.

Dowd, C. 1992. **Effect of development on bird species composition of two urban forested wetlands in Staten Island, New York.** Journal of Field Ornithology 63: 455-461.

Friesen, L. E., M .D. Cadman, and R .J. MacKay. 1999. **Nesting success of Neotropical migrant songbirds in a highly fragmented landscape.** Conservation Biology 13: 338-346.

Friesen, L. E., P. F. J. Eagles, and R. J. MacKay. 1995. **Effects of residential development on forest-dwelling Neotropical migrant songbirds.** Conservation Biology 9: 1408-1414.

Friesen, L. E., V. E. Wyatt, M. D. Cadman, R. J. MacKay, E. D. Cheskey, M. Allen, and D. Ramsay. 2000. **Extent of double-brooding and seasonal movement of nesting females in a northern population of Wood Thrushes**. Wilson Bulletin 112: 505-509.

Haskell, D. G., A. M. Knupp, and M. C. Schneider. 2001. **Nest predator abundance and urbanization.** In: J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Boston, MA: Kluwer Academic Publishers; 243-258.

Holt, J. P. 2000**. Changes in bird populations on the Highlands Plateau, North Carolina (USA), 1946-1995, with emphasis on Neotropical migrants**. Natural Areas Journal 20(2): 119-125.

Knick, S. T., and J. T. Rotenberry. 2000. **Ghosts of habitats past: Contribution of landscape change to current habitats used by shrubland birds.** Ecology 81: 220-227.

Kluza, D. A., C. R. Griffin, and R. M. DeGraaf. 2000. **Housing developments in rural New England: Effects on forest birds.** Animal Conservation 3: 15-26.

Knechtel, G. 1945. **Birds of Waterloo County.** Unpublished manuscript in the collection of Craig Campbell, Waterloo, ON.

Mancke, R. G., and T. A. Gavin. 2000. **Breeding bird density in woodlots: Effects of depth and buildings at the edges.** Ecological Applications 10: 598-611.

Martin, V. 1988. **Changing landscapes of southern Ontario.** Erin, ON: Boston Mills Press.

Marzluff, J. M, R. Bowman, and R. Donnelly. 2001a. **A historical perspective on urban bird research: Trends, terms, and approaches.** In: J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Boston, MA: Kluwer Academic Publishers; 1-17.

Marzluff, J. M., K. J. McGowan, R. Donnelly, and R .L. Knight. 2001b. **Causes and consequences of expanding American Crow populations.** In: J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Boston: Kluwer Academic Publishers; 331-364.

Matlack, G. R. 1993. **Sociological edge effects: spatial distribution of human impact in suburban forest fragments**. Environmental Management 17: 829-835.

Mayfield, H. 1975. **Suggestions for calculating nest success.** Wilson Bulletin 87: 456-466.

McKibben, B. 1995. **An explosion of green**. Atlantic Monthly 275(4): 61-83.

Mitchell, J. G. 2001. **Urban sprawl**. National Geographic 200(1): 48-71.

Nilon, C. H., C. N. Long, and W. C. Zipperer. 1995. **Effects of wildland development on forest bird communities.** Landscape and Urban Planning 32: 81-92.

Price, J., S. Droege, and A. Price. **The summer atlas of North American birds.** San Diego, CA: Academic Press.

Regional Municipality of Waterloo. 1995. **Regional official policies plan.** Kitchener, ON.

Regional Municipality of Waterloo. 2002. **Population and households annual bulletin: Year-end population and household estimates.** Planning and Works Communication. Report # 02-017, Kitchener, ON.

Riley, S., J. Hadidain, and D. A. Manski. 1998. **Population density, survival, and rabies in raccoons in an urban national park**. Canadian Journal of Zoology 76: 1153-1164.

Roth, R. R., M. S. Johnson, and T. J. Underwood. 1996. **Wood Thrush (*Hylocichla mustelina*).** In: A. Poole and F. Gill, editors. The birds of North America, no. 246. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Sauer, J. R., and B. K. Williams. 1989. **Generalized procedures for testing hypotheses about survival or recovery rates.** Journal of Wildlife Management 53: 137-142.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. **Biological consequences of ecosystem fragmentation: A review.** Conservation Biology 5: 18-32.

Sokal, R. R., and J. J. Rohlf. 1981. **Biometry.** 2nd edition. New York: W. H. Freeman and Company

Trine, C. L. 1998. **Wood Thrush population sinks and implications for the scale of regional conservation strategies.** Conservation Biology 12: 576-585.

Weir, R. D. 1987. **Red-shouldered Hawk.** In: M. D. Cadman, P. F. J. Eagles, and F. M. Helleiner, editors. Atlas of the breeding birds of Ontario. Waterloo: University of Waterloo Press; 120-121.