# "Footprints" in parks: using GIS to measure human impact in two of Ontario's national parks

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## Abstract

*High visitor use is generally considered to compromise the ecological integrity of parks, but the degree to which specific features (roads and related infrastructure) affect parks overall is seldom clear. Using Geographic Information Systems (GIS), the human "footprint" in and around park boundaries can be quantified based on the documented effects of various types of roads and other human-built features. The landscapes in and around two national parks in Ontario are contrasted as illustrative of how variation in this "footprint", together with other landscape and human-use attributes, is correlated with the disappearance of disturbance-sensitive mammals. From these results, one can infer what actions may be taken to manage development and visitor use in and around parks to best maintain disturbance-sensitive mammals.*

## Introduction

The need to maintain Canada's national parks in perpetuity beyond their aesthetic and recreational values is reflected in recent amendments to the National Parks Act, which emphasize the importance of maintaining ecological integrity in all aspects of park management (National Parks Act, 2000, Section 8(2)). The recent Panel on the Ecological Integrity of the national parks defined an ecosystem as having ecological integrity "when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes" (Parks Canada Agency, 2000: 1–15). Reports, such as the Banff-Bow Valley report (Banff-Bow Valley Task Force, 1996) and the 1997 State of the Parks Report (Canadian Heritage, 1998) have identified the degree to which some of the parks – particularly the smaller parks in highly developed landscapes, and parks with high levels of visitation – currently have a degraded state of ecological integrity.

For example, research on mammal assemblages (Glenn and Nudds, 1989; Gurd and Nudds, 1999) has shown that some national and provincial parks in Ontario have undergone faunal relaxation, that is, they do not contain their historic complement of mammal species. Thus, they lack ecological integrity by definition. To reduce the risk of concluding faunal relaxation had not occurred when in fact, faunal turnover had occurred (and thereby committing a Type II error), both Glenn and Nudds (1989) and Gurd and Nudds (1999) separated mammals into disturbance-tolerant ('d') and disturbance-intolerant ('u') species. Gurd and Nudds (1999) improved upon the sampling methods of Glenn and Nudds (1989) and used Geographic Information Systems (GIS) to randomly sample historic range maps of both 'd' and 'u' species and found that in twenty of the seventy-two cases, parks had fewer species than were present historically (Gurd and Nudds, 1999). Fifteen of these cases were in the Eastern Canadian and the highly altered Alleghenian-Illinoian mammal provinces (Table 1).

Table 1. National and provincial parks in the Alleghenian-Illinoian and Eastern Canadian Mammal provinces and the net loss of disturbance-intolerant ('u') and disturbance-tolerant ('d') species. The net loss reported here is based on rounded off values from Gurd and Nudds (1999). National parks are underlined, and parks in Ontario are marked with an asterisk (*). "n.s." indicates "no significant difference between present and historic richness" according to Gurd and Nudds (1999). The number of 'u' and 'd' species lost according to Wiersma and Nudds (2001) for the national parks common to both studies is included for comparison. The two parks presented in this study are shaded in.

| | **Gurd and Nudds (1999)** | | **Wiersma and Nudds (2001)** | |
|---|---|---|---|---|
| **Park** | **'u' species** | **'d' species** | **'u' species** | **'d' species** |
| *Alleghenian-Illinoian mammal province* | | | | |
| Algonquin * | n.s. | n.s. | | |
| Cape Breton Highlands | 6 | 6 | 3 | 1 |
| Forillon | 10 | 10 | 7 | 4 |
| Gaspésie | 5 | 7 | | |
| Kouchibouguac | 9 | n.s. | 5 | 0 |
| Point Pelee * | 16 | n.s. | 9 | 7 |
| Prince Edward Island | 13 | 8 | 5 | 1 |
| Quetico * | n.s. | n.s. | | |
| Riding Mountain | n.s. | n.s. | 3 | 1 |
| Turtle Mountain | 11 | n.s. | | |
| *Eastern Canadian mammal province* | | | | |
| Chapleau | n.s. | n.s. | | |
| Grand-Jardins | 13 | 10 | | |
| Jacques-Cartier | 12 | n.s. | | |
| Killarney * | n.s. | n.s. | | |
| Lake Superior * | n.s. | n.s. | | |
| Mont Tremblant | 12 | n.s. | | |
| Pukaskwa * | n.s. | n.s. | 1 | 0 |

However, Gurd and Nudds (1999) simply compared present day mammal richness to historic richness. Without knowing the historic species composition, there still existed a risk of not identifying species turnover *within* either of these two broad categories, i.e. loss of one 'u' species balanced by immigration of another 'u' species. Thus, such tests for faunal relaxation might still be too conservative. Wiersma and Nudds (2001) used new GIS data, for the national parks only, to directly sample historic range maps in areas that are presently parks to estimate historic mammal richness and composition. When losses were calculated in the same manner as Gurd and Nudds (1999), that is, by subtracting present-day from historic richness, only 12/24 (50%) of the parks common to both studies had experienced a net loss in 'u' species. However, by comparing the historic composition of mammals in parks to present day composition, Wiersma and Nudds (2001) found that 23/24 (96%) of parks had experienced losses of 'u' species. Further, Gurd and Nudds (1999) found a strong correlation between losses of 'u' species and the size (area) of parks in the highly altered Alleghenian-Illinoian mammal region ($r^2 = 0.83$, $p = 0.0001$). However, Wiersma and Nudds (2001) observed a much weaker relationship ($r^2 = 0.15$, $p = 0.30$) when actual 'u' species losses (again, based on comparisons of historic and present-day mammal composition) were regressed against park size, suggesting that factors other than, or in addition to, the size of the parks may contribute to faunal relaxation.

Rivard *et al.* (2000) conducted a nation-wide study and found that mammal extirpations and alterations in species composition were correlated with human-built features inside and outside of the national parks, such as infrastructure and roads, as well as features outside of parks, such as road density, the amount of natural cover and the number of towns and cities. However, they measured changes in species composition since the time of park establishment. Because landscape changes may have already been well underway in many cases when most parks were established, some species that were historically present in areas that are now parks may have already been missing at the time of park establishment, and therefore this may not be the appropriate historical reference point.

As part of a nation-wide analysis using mammal composition prior to widespread European settlement as the historical reference point, Wiersma (2001) measured the amount of human development and habitat change in and around parks to see whether these correlated with losses of disturbance-sensitive mammals. Here, we describe methods to calculate the impact of human-built features in and around two national parks in Ontario; Point Pelee and Pukaskwa (Figure 1) and we illustrate the correlation between these attributes and the degree of faunal relaxation by mammals in these two parks.

## Effects of Human Development

In national parks, visitor use, and the associated human-built infrastructure, is thought to be detrimental to the preservation of species. All five of the national parks in Ontario reported that human-built features had caused significant ecological effects (Table 2, Canadian Heritage, 1998), but specific effects were neither defined nor tested. Among the various types of human-built infrastructure found in and around parks, roads are believed to have significant ecological effects that range further than the physical space they occupy (USDA, 2000). Roads fragment habitat and increase 'edge' habitat (Jalkotzy *et al.* 1997; Foreman and Alexander, 1998; Trombulak and Frissell, 2000; USDA, 2000), which may contribute to the loss of species that require large amounts of undisturbed habitat.

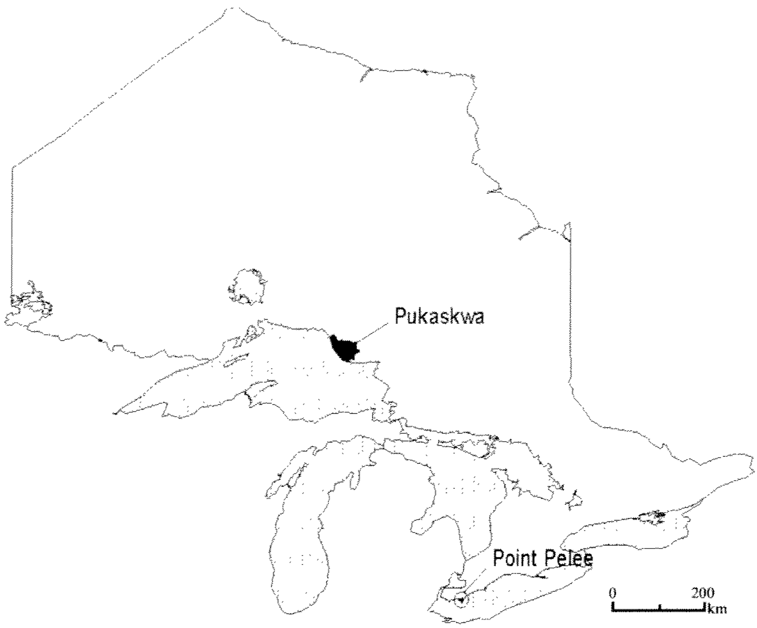


Figure 1. Pukaskwa National Park and Point Pelee National Park.

Wolves (*Canis lupus*, which have been extirpated from Point Pelee) and caribou (*Rangifer tarandus*, which are present as an extremely small and potentially threatened population in Pukaskwa) avoid roads (Foreman and Alexander, 1998; Trombulak and Frissell, 2000; USDA, 2000), thus road density (km of road per square km of habitat) may be a critical factor for the persistence of such large ranging species (Jalkotzy *et al.* 1997; Foreman and Alexander, 1998; Findlay and Zheng, 1999; USDA, 2000).

Although roads are the most intrusive type of infrastructure in parks, and the most widely studied, townsites and campgrounds are the place in the parks where visitor density is often highest. Canada's national parks experience 14.5 million person-visits per year (Canadian Heritage, 1998) and visitor densities in small parks such as Point Pelee were approximately 28, 000 visitors per square kilometer in 1996 (Canadian Heritage, 1998). Several studies have been conducted on the effects of campsites (Cole and Fichtler, 1983; Cole, 1992, 1995; Leung and Marion, 1999) in parks, and have found that the effects of camping activities extend beyond the boundaries of the sites (Cole and Fichtler, 1983; Leung and Marion, 1999), and that even backcountry sites that are infrequently visited can experience significant effects of human use (Cole 1987, 1995).

## Methods

The amount of human disturbance within parks, and in a 50-km zone extending out from each park boundary was analyzed using National Topographic Series

Table 2. Stressors reported causing significant ecological impacts (taken from Canadian Heritage 1998) for the five national parks located in Ontario.

| Park | Human disturbance | Park Infrastructure | Urbanization | Utility Corridors | Visitor/tourism facilities |
|---|---|---|---|---|---|
| Bruce Peninsula | | • | | • | • |
| Georgian Bay Islands | | • | • | • | • |
| Point Pelee | | | • | • | • |
| Pukaskwa | | | • | • | • |
| St. Lawrence Islands | • | • | • | • | • |

Table 3. Human-built features and buffer widths used to determine the "footprint" size in and around Canadian National Parks. Buffer width data are based on road avoidance distances (Jalkotzy et al. 1997) for species that have been observed to be missing from parks (Wiersma and Nudds 2001).

| polygon features | linear features | buffer width (m) |
|---|---|---|
| built-up areas (townsites) | trails | 25 |
| campgrounds | limited use roads | 50 |
| golf courses | roads | 100 |
| mine areas | railways | 100 |
| | highways | 200 |

Table 4. Park attributes for landscape and human use features inside parks and within a zone 50 km outside of park boundaries for two national parks in Ontario. Effective area is defined as the area not impacted by human-built infrastructure. Habitat area is defined as the area not covered by unsuitable habitat types (e.g. bare rock, agricultural land).

| | in park | | | | 50 km zone outside park | | | |
|---|---|---|---|---|---|---|---|---|
| Park | size (km$^2$) | effective area (km$^2$) | habitat area (km$^2$) | visitor density (# visitors/km$^2$) | size (km$^2$) | effective area (km$^2$) | habitat area (km$^2$) | population density (pop'n/km$^2$) |
| Point Pelee | 16.0 | 13.24 | 16.0 | 28,660.7 | 2900.75 | 571.8 | 44.58 | 50.55 |
| Pukaskwa | 1878.0 | 1847.9 | 1878.0 | 9.05 | 10,362.0 | 10,040.8 | 10,362.0 | 0.56 |

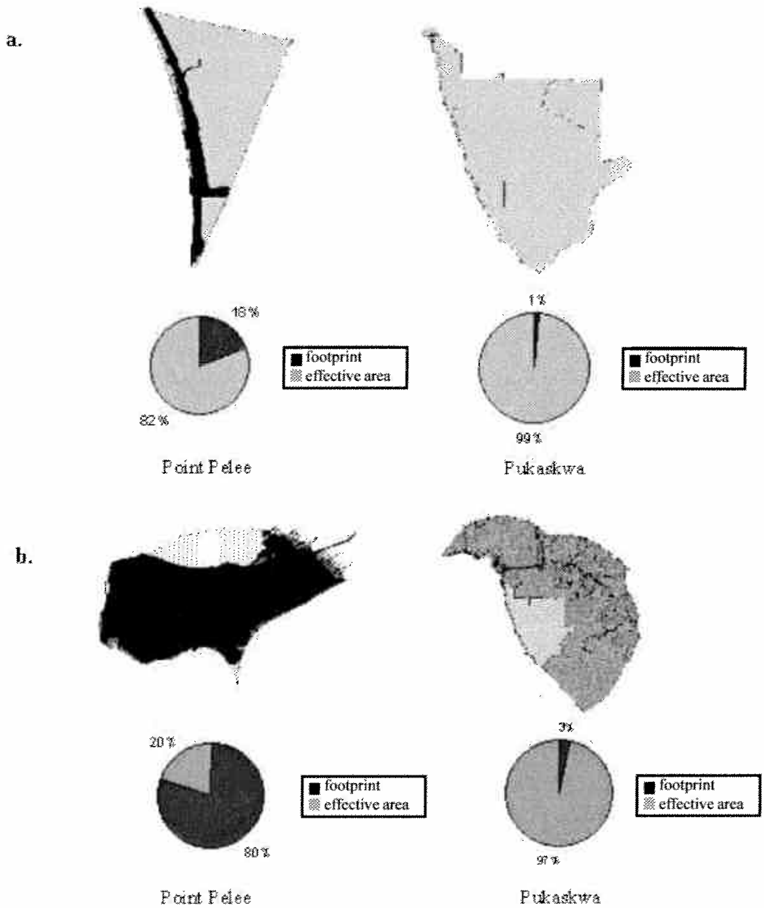


Figure 2. Point Pelee National Park and Pukaskwa National Park Comparison

a. Point Pelee National Park (16 $km^2$) and Pukaskwa National Park (1878 $km^2$) showing the "footprint" and "effective area". For comparison, the "effective area" of each park expressed as a percentage of the total is given by the pie charts.

b. Area outside of Point Pelee and Pukaskwa National Parks extending 50 km from park boundaries (excluding Lake Erie and Lake Superior, respectively), showing the "footprint" and "effective area". For comparison, the "effective area" outside each park expressed as a percentage of the total is given by the pie charts.

(NTS) digital maps (scale 1:250 000) in ArcView™ (Environmental Systems Research Institutes (ESRI) version 3.2) and ArcInfo™ (ESRI, version 8.1). Human disturbance was quantified by calculating the "footprint" of human-built features within and outside each park. First, linear features such as roads, railways and trails were transformed into area (polygon) features through a buffering process. Buffer widths represent the impact of roads beyond their physical space, and were determined using the "avoidance distances" by various animals from Jalkotzy *et al.* (1997). Jalkotzy *et al.* (1997) presented road avoidance distance values for a wide range of species, but we selected only those values for species that have been observed to be missing from parks, based on historic mammal composition (Wiersma and Nudds, 2001). The values used for the buffer distance in the ArcInfo™ analysis are presented in Table 3.

Once linear features were buffered, they were combined with area features such as built-up areas, campgrounds and golf courses. The cumulative "footprint" was then subtracted from the total area of the park to determine the "effective area" of the park. Similarly "footprints" of features outside the park were created and subtracted from the total land area within 50 km of the park boundary. In addition to "effective area" of parks, AVHRR satellite data from Natural Resources Canada (www.nrcan.gc.ca) was used to calculate how much of the "effective area" in and around parks was also viable habitat (i.e. land not covered by bare rock or agricultural development). Data on visitor densities from Parks Canada (Canadian Heritage, 1998) was also incorporated into the analysis. Cities, towns and villages in the 50-km zone outside the parks were identified using hard copy NTS maps and the population for these communities was taken from the most recent census data (1995) from the Statistics Canada Community Profiles database (www.statcan.ca).

## Results

Pukaskwa (1878 $km^2$) is a much larger park than Point Pelee (16 $km^2$), but it has a smaller "footprint", relative to its size than Point Pelee (Table 4, Figure 2). In addition, Pukaskwa is surrounded by suitable habitat, while Point Pelee is effectively insularized from the surrounding habitat matrix. Pukaskwa also only lost one 'u' species, while Point Pelee has nine fewer 'u' species than were present historically (Table 1). Pukaskwa has much lower visitor densities (9.05 visitors/$km^2$) than Point Pelee (28,660.67 visitors/$km^2$) (Canadian Heritage 1998). Human population density in the 50-km zone outside Point Pelee is nearly one hundred times higher (50.55 persons/$km^2$) than outside Pukaskwa (0.56 persons/$km^2$) (www.statcan.ca).

## Discussion

Wiersma and Nudds (2001) only found that 15% of the variation in the number of disturbance-sensitive mammals lost from parks in the Alleghenian-Illinoian mammal province was explained by park size alone and hypothesized that "effective area", amount of habitat and visitor/population density might also be significantly correlated with species loss. The sample size of national parks in Ontario is too small for statistical analysis, however, the data presented here are consistent with conclusions made elsewhere, that is, larger parks tend to lose fewer species.

In a similar study applied to national parks across the country, Wiersma (2001) found that the landscape and human use factors measured here, in combination with park size, explained 37% of the variation in 'u' species loss. In Ontario, Vasarhelyi et al. (in review, *this* volume) examined national and provincial parks to determine which might be large enough to sustain minimum viable populations (MVP) of black bears (*Ursus americanus*) and wolves (*Canis lupus*). They concluded that Pukaskwa National Park was the only national park which might sustain bears and wolves, given optimistic estimates of MVP. Finally, in the Alleghenian-Illinoian mammal province (which covers much of southern Ontario), Gurd *et al.* (2001) used historic mammal richness to estimate the minimum size of an area that would contain the same number of disturbance-sensitive species of mammals as it did historically. They estimated this to be ~5000 km$^2$, which is larger than any of the national parks in Ontario. Thus, it appears that large parks, with large amounts of habitat and minimal human disturbance in and around their park boundaries, appear to be necessary to minimize losses of disturbance-intolerant mammals and so comply with Parks Canada's legislated mandate to promote the ecological integrity of parks.

Parks that have lost species can attempt to safeguard against further losses by increasing the effective area of parks by reducing the amount of human development within park boundaries. Point Pelee National Park has already moved in this direction by removing buildings and reducing vehicular traffic in the park (Parks Canada Agency 2000). Doing so may also create conditions favourable for successful re-introductions of species that have gone missing, as is being done with the Southern flying squirrel (*Glaucomys volans*) in Point Pelee National Park. A further management strategy suggested here is the need to increase habitat area inside and outside of the park. This will require park managers to co-operate with local landowners, First Nations, and provincial and municipal governments. Georgian Bay Islands National Park has already taken steps towards regional management with the Greater Georgian Bay Cores and Corridors Project (Tegler *et al.* 1999; Zorn and Quirouette, 1999; Wiersma, in press). Because large protected areas are required (but not always possible), park management within the entire landscape will be necessary if the ecological integrity of the national parks is not to be further compromised.

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