

**Impacts of Recreational Trails on Wildlife Species:  
Implications for Gatineau Park**

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## Abstract

Many protected areas operate with a dual mandate: to conserve the natural environment while simultaneously providing quality recreational opportunities. Although these two goals frequently enhance each other, they will also inevitably conflict. As such, an important question for protected area management and planning is: to what extent do recreational activities and recreational trail networks pose a threat to the wildlife species which occupy the park?

Outdoor recreational activities are often thought to be an environmentally benign activity, however more often than not, it has been reported that outdoor recreation can have negative consequences for wildlife. Having a robust understanding of the current empirical information on the impact of recreational activities on wildlife is required for park and protected area managers to make the most informed decisions. Thus, the purpose of this research project is to assess the impacts of recreational trails and associated trail use on wildlife species in general, with a specific focus on species of concern found within Gatineau Park, Québec.

Although the body of research concerning recreation and wildlife interactions is growing, sizeable knowledge gaps remain. Even for species with the greatest amount of research, the information is often inadequate to draw conclusions on whether recreational trail and trail use in protected areas pose a significant negative threat to the wildlife populations within. However, the effect of recreational trails and trail use on wildlife should not be deemed insignificant or non-existent without first conducting species specific monitoring in the field. Although recreational trails and trail use is unlikely to be the primary reason for the species' endangerment within Gatineau Park, it is a threat worth understanding and investigating further on a species-specific basis.

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Many protected areas operate with a dual mandate: to conserve natural ecosystems while simultaneously providing quality recreational opportunities. Although these two goals frequently enhance each other, they will also inevitably conflict (Knight & Cole, 1991). The challenge for land managers is to find a balance between enjoying nature and protecting it. Visits to terrestrial protected areas, ranging in scope from international ecotourism to local park visits, was recently estimated at 8 billion visits per year worldwide, with 3.3 billion visits occurring in North America (Balmford et al., 2015). Although the number of individuals visiting national parks in Canada decreased in the early 2000s, visitation has increased by 15% from 2011 to 2016 (Parks Canada, 2017). As recreational use of public lands increases, there is growing concern over the possible trade-offs that may exist between recreation and the protection of natural resources, such as wildlife.

Having access to natural areas tends to promote a greater level of awareness in the general public on issues related to the environment (Zaradic, Pergams, & Kareiva, 2009). This may result in the general impression that nonconsumptive outdoor recreation is an environmentally benign activity (Miller, 1998). In reality, recreational trail use has attracted concern from land managers and academics alike due to the potential relationships between visitor use and soil degradation (Ballantyne & Pickering, 2015; Cole, 1993), vegetation trampling (Havlick, Billmeyer, Huber, Vogt, & Rodman, 2016), and wildlife disturbances (Boyle & Samson, 1985; Miller, 1998; Rogala et al., 2011). More often than not, it has been reported that outdoor recreation has negative consequences for wildlife (Larson, Reed, Merenlender, & Crooks, 2016). Visitors to protected areas often underestimate their own impact on various fronts (Taylor & Knight, 2003) – from approaching wildlife far more closely than the species can tolerate, to encroaching into sensitive habitats, to reacting defensively to criticism, generally considering their own form of recreation relatively benign compared to negative impacts from other recreational groups. While there is wide recognition that high-impact recreation (e.g., off-road vehicles [ORV] and snowmobile use) can have negative repercussions on wildlife (Harris, Nielson, Rinaldi, & Lohuis, 2014; Spaul & Heath, 2016), there is also increasing evidence that seemingly nonconsumptive, low-impact activities such as hiking, cross-country skiing and bird watching along recreational trails can negatively affect wildlife at the individual, population, and community level (Boyle & Samson, 1985; Knight & Cole, 1991; Larson et al., 2016).

Parks and conservation areas apply a wide range of tools and techniques to manage recreational activities and minimize negative impacts on wildlife, including the development of official trail networks. Trails are an essential infrastructure component of protected areas – well-designed and well-managed trails aim to accommodate visitor use by providing hardened surfaces which can sustain substantial traffic, while also designed to minimize visitor impact by concentrating traffic onto reinforced surfaces (Wimpey & Marrion, 2011). Unfortunately, places that receive heavy recreational use often become crisscrossed by unofficial trail networks. Unofficial trails, also called informal or social trails, are pathways created by visitors outside of a park's formally managed trail system (Leung, Shaw, Johnson, & Duhaime, 2002). Perhaps due to a perception of limited trail access or simply a desire to reach a location not accessible by official trails, the proliferation of unofficial trails is now commonplace in many parks and conservation areas (Havlick et al., 2016; Manning, Jacobi, & Marion, 2006; Wimpey & Marion, 2011). As unofficial trails are not planned or formally established, common knowledge can assume that they are frequently poorly located with respect to resource protection needs and that off-trail users will not recognize or attempt to avoid sensitive flora and fauna (Wimpey & Marrion, 2011). For these reasons, managing the coexistence between wildlife and recreation requires a species-specific understanding of how wildlife responds to various forms of outdoor recreation, as well as the spatial context in which the activity occurs.

### **Gatineau Park**

Gatineau Park is a conservation and recreational area found in Canada's National Capital Region. In addition to being first and foremost a conservation park (the "Capital's Conservation Park" as of 2005), Gatineau Park is mandated to provide quality outdoor recreational experiences (NCC, 2005). A concern for many natural areas which are governed by a dual mandate of conservation and recreation is whether or not recreational activities are advancing or hindering the park's conservation targets.

Located in the Outaouais region of Québec, Gatineau Park covers an area of 361 square kilometres of land, located where the Canadian Shield meets the St. Lawrence Lowlands between the Ottawa and Gatineau Rivers. The park is the largest capital asset owned and managed by the National Capital Commission (NCC) under the National Capital Act, causing Gatineau Park to be markedly unique – it is the only federal park that is not operated by Parks

Canada or part of Canada's national parks system (NCC, 2005). Another distinguishing factor is how the southernmost portion of the park protrudes into Canada's National Capital Region, a metropolitan area which has a population of more than 1.3 million people as of 2016 (Statistics Canada, n.d.). According to the most recent estimates, Gatineau Park attracts approximately 2.7 million visitors a year, second only to Banff National Park among federally operated Canadian parks (NCC, 2017; Parks Canada, 2017).

Gatineau Park's location along the boundary of the Canadian Shield and the St. Lawrence Lowlands supports a range of natural habitats and rich biodiversity. The wealth of natural habitats within the park supports a broad diversity of wildlife including more than 50 mammal species and approximately 230 species of birds – over 61 of which are at risk (NCC, 2005). Gatineau Park's proximity to the cities of Ottawa and Gatineau make it very accessible to those seeking to escape the city. Visitors to Gatineau Park can participate in a wide variety of recreational activities, which are concentrated in the south of the park. Year-round visitors may enjoy over 170 kilometres of hiking trails, 98 kilometres of mountain biking trails, 200 kilometres of cross-country skiing trails, 25 kilometres of snowshoe trails, 10 kilometres of winter hiking trails, several self-guided interpretation trails and picnic areas, six public beaches, two campgrounds, a downhill ski complex, and a number of winter warming huts and canoe camping sites.

In addition to permitted activities in Gatineau Park, there has been an increase in informal recreational use which may conflict with authorized activities and have a significant impact on sensitive habitats within the park. Informal use of the park – defined as any type of activity not authorized by the NCC – was raised as a concern during the consultation period for the 2005 Gatineau Park Master Plan, and the discussions have continued into 2017. Informal trail usage in the park ranges from hiking in areas not supported by an established trail network to cutting down or trimming vegetation, often in order to create novel mountain bike trail networks (C. Verreault, personal communication, November 2016). As the volume of recreationists and types of recreational activities in the park diversify (e.g., mountain biking, fat biking, geocaching), careful consideration must be made to ensure that the activities are consistent with conservation initiatives within the park.

## **Purpose of Research**

The Gatineau Park Master Plan is a planning tool that sets out the park's long-term vision, as well as planning, land use and management objectives (NCC, 2005). In 2017, the NCC began the revision of the current Gatineau Park Master Plan (NCC, 2005). An important question for management and planning is: to what extent does the existing trail network pose a threat to the species which occupy the park, specifically species-at-risk? Having a robust understanding of the current empirical data on the impact of recreational activities on wildlife would be helpful to such a revision. The purpose of this research project is to assess the impacts of recreational trails and associated trail use on wildlife species in general, with a specific focus on species of concern found within Gatineau Park. A review of the existing research will provide guidance for future road and trail construction, removal or use. Understanding how animals use the landscape is critical in order to formulate strategies to conserve their habitats. Furthermore, determining which species in Gatineau Park may be most threatened by trails and trail use will be useful for the development of future species-specific conservation and mitigation strategies. Therefore, the proposed research questions are as follows:

### **Primary research question:**

What are the implications of existing research on recreational trail impacts on wildlife species for Gatineau Park management and planning?

### **Secondary research questions:**

1. For which species of concern in Gatineau Park is there existing empirical data suggesting that recreational trails and trail use poses a significant threat?
2. For these species, are there threshold trail densities or threshold fragmentation levels above which there is a threat to the species in question?
3. Provided that appropriate information is identified through answering (2), how does the current fragmentation in Gatineau Park compare to the thresholds?

## Methodological Approach

A review of empirical studies was conducted to document the effects of recreational trails and trail use on wildlife and to assess whether the current network of trails in Gatineau Park poses a significant threat to wildlife. The process consisted of searching for and identifying relevant empirical literature related to recreational trails and ensuing human disturbance on wildlife species generally, and more specifically on each of the 61 wildlife species of concern within the park (see Appendix A).

Searches for literature were made from April to July of 2017, using the Web of Science and Cab Direct databases, followed by the meta-search engine Google Scholar and generic internet searches in order to ensure that all relevant “grey” literature (including government documents and other non-peer reviewed content) was accounted for. Reference lists of relevant articles were searched for secondary articles to ensure all pertinent literature was captured. The search terms used for the preliminary research on the impact of recreational trails on wildlife species included (“recreation” OR “trail”) and (“wildlife”), in addition to species specific searches, such as (“recreation” OR “trail”) and (“cougar” or “*Puma concolor*”).

## Results

The purpose of this research paper was to evaluate impacts of recreational trails and trail use on wildlife species, with a particular focus on species of concern found within Gatineau Park. Throughout the literature, the distribution of articles was skewed in favour of vertebrates, mainly mammals and birds, which is commonplace in conservation research (Clark & May, 2002). Large mammals, particularly ungulates and large carnivores, were more frequently studied than small mammals, likely due to monitoring and tracking feasibility. Passerine birds, sometimes referred to as songbirds, and birds of prey were the most frequently studied groups of birds. For many less studied species, including particularly rare species at risk, information on recreational trails and trail use impacts was completely lacking. There were major gaps in knowledge of recreation and trail impacts for invertebrates, reptiles and amphibians, with no literature regarding the impacts of adjacent recreational trails on fish. Even for species with the greatest amount of information, data was often lacking in terms of specific thresholds of disturbance (intensity of use, distance thresholds, density of trail thresholds, etc.). The known

sensitivity of certain taxa to human disturbance (e.g., amphibians and reptiles, Marsh et al., 2017) highlights an urgent need to invest in more research on the impacts of recreational trails.

Throughout the literature, there were significantly more studies investigating the ecological effects of roads rather than developments such as recreational trails. This finding is not surprising as today roads are one of the leading causes of wildlife habitat degradation, fragmentation and loss, as well as a cause of direct mortality (Trombulak & Frissell, 2000). Although a specific literature search was not conducted for empirical studies pertaining to effects caused by roads, due to the nature of the search terms used, this type of literature was commonly recovered. Some studies which primarily investigated the ecological impacts of roads often investigated secondary, “low-use” roads and sometimes recreational trails. Roads can have a variety of ecological effects on wildlife including alteration of normal animal behaviour, barriers to movement, chemical, light and noise pollution, as well as direct mortality from vehicle collisions. In various regions, road-kill is a substantial source of mortality for large mammals (Ford & Fahrig, 2007), birds (Bishop & Brogan, 2013), amphibians (Ashley & Robinson, 1995), and reptiles (Ashley & Robinson, 1995). However, the ecological consequences of roads on invertebrates remains relatively unknown (Muñoz, Torres, & Megías, 2015; Riffell, 1999), save for a handful of studies focusing on well-known insect orders such as Odonata (dragonflies and damselflies, Soluk, Zercher, & Worthington, 2011), Lepidoptera (butterflies and moths, McKenna, McKenna, Malcom, & Berenbaum, 2011), and Coleoptera (beetles, Melis, Olsen, Hyllvang, Gobbi, Stokke, & Róskaft, 2010). Due to the major gaps in knowledge of recreation and trail impacts for invertebrates, reptiles and amphibians, when recreational trail research was lacking, relevant studies which investigated the ecological impacts of roads were discussed.

The majority of articles accessed investigated summer terrestrial recreational activities; however winter terrestrial and winter aquatic activities were also encountered for certain species. A recent meta-analysis found that the effects of all types of winter recreation-related disturbances (e.g., ski runs and resort infrastructure) were more likely to be negative or have no effect, than be positive for wildlife (Sato, Wood, & Lindenmayer, 2013). This analysis was corroborated by Larson et al. (2016), whose meta-analysis revealed that winter terrestrial activities had greater evidence for negative effects on wildlife than summer terrestrial or aquatic activities, though the number of articles (and thus, number species sampled) was small. There are several possible explanations as to why winter recreation has greater evidence for negative

effects on wildlife. Larson et al. (2016) suggest that for many species, the winter months are characterized by scarce food supplies combined with energetically costly movement through heavy snow. Both of these factors may limit species' ability to relocate to avoid areas with human activity. Given the energetic and food constraints wildlife face during the winter, these results are likely to be area- and species-specific, as the total volume of recreationists using outdoor recreational areas may be lower in the winter, and recreationists may be less likely to venture off trail in certain areas in the winter simply due to difficulty of access.

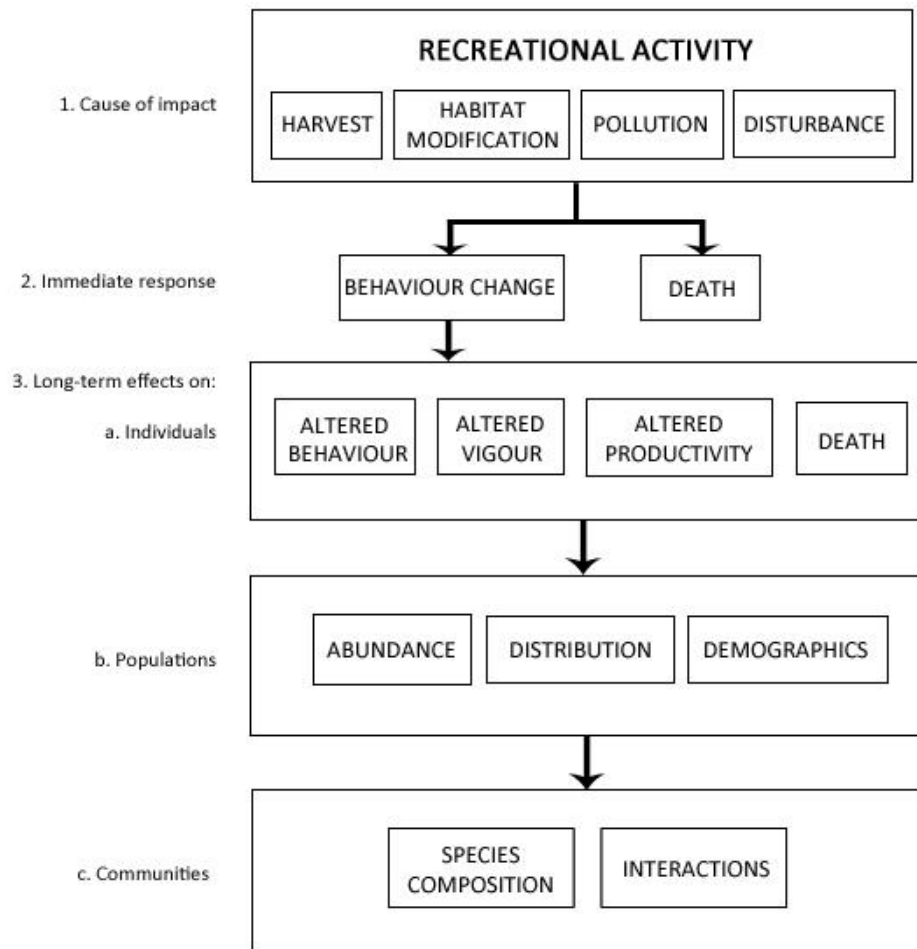
Recreational trails and trail use was found to cause a wide range of effects on wildlife, both positive and negative. In multiple instances, literature was gathered with evidence that a species was tolerant to recreational disturbances, whereas other accounts described the same species as being particularly sensitive. Furthermore, it is important to highlight that in the many cases where there was inconclusive or no information on a species, this does not imply that there is no effect of recreational trails and trail use. Although recreation and trail fragmentation effects are increasingly recognized as important factors affecting wildlife, more rigorous study is needed for all species to clarify wildlife responses to human recreation and recreational trails.

### **Overview of Trail and Recreational Impacts on Wildlife**

Wildlife can respond to recreational trails and trail use in different ways, and a wide variety of impacts from recreational trails and trail use on wildlife were identified in the empirical literature. Knight and Cole (1991) suggested that there are four general ways in which recreational activities can affect wildlife: harvesting, habitat modification, pollution and disturbance (see conceptual model in Figure 1).

Harvesting includes activities such as sport hunting, fishing and illegal poaching. As hunting wildlife characteristically results in death, the consequences of this type of recreational activity are immediate and permanent. If not managed properly, the consumptive take of wildlife can have disastrous effects on animal populations, especially if the activity leads to a disproportionate harvest of a particular sex or age group (Ginsberg & Milner-Gulland, 2005).

In contrast to consumptive activities, nonconsumptive forms of recreation can also have direct and indirect effects on wildlife. Broadly, wildlife can be impacted through direct habitat change as activities that modify a species' habitat will inevitably have an impact on wildlife behaviour, survival, reproduction and distribution. Numerous studies have documented that



**Figure 1:** A conceptual model of potential wildlife responses to recreational activities. Adapted from Knight and Cole (1991).

recreational activities can have adverse effects on soil – including erosion, compaction and reduced soil porosity (Wilson & Seney, 1994) – and also on vegetation, with the most obvious effects coming from the direct crushing and uprooting of plants (Havlick et al., 2016).

Furthermore, it is not uncommon for dead organic matter such as dead trees, fallen logs, brush piles and other natural litter to be cleared in recreational areas and on trails. The removal of any habitat constituents, including dead matter, may remove components of the ecosystem that provide shelter and food to many species of wildlife (Cole & Landres, 1995).

Recreationists can also adversely affect wildlife by leaving food or litter behind in recreational areas. It is a common phenomenon for wildlife behaviour to be positively reinforced when encountering human food sources (Knight & Cole, 1991). As such, improper disposal of food and garbage may increase populations of animals that seek human food sources as a

primary food supply (Cole, 1993), which increases the risk of injury to both recreationists and the wildlife. Frequent feeding on garbage and leftover human foods can cause wildlife to become habituated to this diet, which is a significant concern if it makes the animals dependent on artificial food sources, changes the quality of their diet, or changes intra- and interspecific interactions in the area. Furthermore, litter can cause direct mortality to animals. Animals have been documented mistaking trash for food, which has the potential to cause fatal stomach obstructions (Mrosovsky, Ryan, & James, 2009); while small mammals have been documented becoming trapped in discarded beverage bottles (Hamed & Laughlin, 2015).

Although all of the various ways that wildlife can be affected by recreationists warrant consideration, this analysis focused on the effects of disturbance (refer to Figure 1). Disturbance may result when recreationists come too close to wildlife, enter the animal's field of view, or cause noise in close proximity to the animal. Although the interaction is usually unintentional on behalf of the recreationist, it is probably the primary means by which recreational activities along trails affect wildlife (Cole, 1993). Frid and Dill (2002) proposed a theory that suggests human disturbance stimuli may be analogous to predation risk for some species. If so, human disturbance would then have direct impacts on individuals through altered habitat selection and vigilance, as well as indirect effects on populations and communities.

**Impacts of Recreational Trails and Trail use on Wildlife: Disturbance.** Non-consumptive activities such as hiking, biking and sightseeing on recreational trails have the ability to disturb a wide variety of species such as wolves (*Canis lupus*; Lesmerises, Dussault, & St-Laurent, 2012), cougars (*Puma concolor*; Sweanor et al., 2008), black bears (*Ursus americanus*; Mace, Waller, Manley, & Wittinger, 1999), moose (*Alces alces*; Yost & Wright, 2001), deer (family Cervidae; Richens & Lavigne, 1978), elk (*Cervus canadensis*; Rogala et al., 2011), small mammals (Hamed & Laughlin, 2015), various songbirds (Thompson, 2015), and birds of prey such as bald eagles (*Haliaeetus leucocephalus*; Stalmaster & Kaiser, 1998). Some species such as coyotes (*Canis latrans*) have adapted to the presence of humans and recreational activities (George & Crooks, 2006). For other species, recreational activities have been documented or suspected to have significant impacts on behaviour and survival.

Disturbances from recreational activities can have immediate and long-term impacts on wildlife species (Boyle & Samson, 1985; Knight & Cole, 1991; Taylor & Knight, 2003). Immediate responses to recreation include increased flight and vigilance (Campbell, 2011;

Naylor, Wisdom, & Anthony, 2009; Pittfield & Burger, 2017); interrupted foraging (Rogala et al., 2011); avoidance of otherwise suitable habitat (Dyer, O'Neil, Wasel, & Boutin, 2001; George & Crooks, 2006; Rogala et al., 2011); declines in abundance, occupancy, or density (Heil, Fernández-Juricic, Renison, Cingolani, & Blumstein, 2007; Reed & Merenlender, 2008), and physiological stress (Arlettaz et al., 2007). The immediate behavioural responses of wildlife to recreation (e.g., alert distance, flush distance, and distance moved) have conventionally been used to compare the degree of disturbance presented by different activities. Alert distance refers to the distance between the animal and the disturbance at the moment the animal first acknowledges the disturbance, while the flush distance (also termed flight distance in the literature) is the distance between the animal and the disturbance when the animal first flees or takes flight. Flush distance can be considered the inverse of tolerance: the closer the approach distance, the higher the tolerance. Finally, total distance moved is considered the distance traveled by the animals from their initial position until they have stopped fleeing.

Energetic losses from flight, decreased foraging time, or increased stress levels come at the cost of the energy resources needed for an individuals' survival, growth, and reproduction (Geist, 1978). For example, during exposure to four different types of recreational activities, elk were observed to increase their travel time, which reduced time spent feeding or resting (Naylor et al., 2009). The elk were the most disturbed by ATV exposure, followed by mountain biking and hiking. The elk were least disturbed, if affected at all, by horseback riding. In the long term, repeated short-term disturbances may accumulate into long-lasting changes that alter species richness and community composition (Kangas, Luoto, Ihantola, Tomppo, & Silkamaki, 2010) and affect individual fitness through effects on reproductive success and survival (Spaul & Heath, 2016). Such is the case in the aforementioned elk population – the shift away from areas with recreational disturbances to areas of potentially lesser quality forage could have a cumulative effect on the long-term condition of the elk, increasing the probability of an individual not surviving over the winter (Naylor et al., 2009). Wildlife displaced by human disturbance are less likely to survive and reproduce in unfamiliar or inferior habitats, however it is not uncommon for species to exhibit short-term effects through flush behaviour but suffer no long-term effects (Richens & Lavigne, 1978). It is important to note that just because an animal flees, this does not necessarily mean that the approach is causing the animal undue stress or that the approach is excessively costly (Gill, Norris, & Sutherland, 2001). Furthermore, there can be

physiological responses to approach, such as increased heart rate, even if the species does not flee (e.g., Steen et al., 1988). Nevertheless, more systematic research is needed on long-term effects of recreation to fill species-specific knowledge gaps (Knight & Cole, 1995).

Frequent human disturbance can also have long term impacts on predator-prey relationships, in turn affecting trophic-level interactions. Prey species such as elk can often escape predation from wolves by lingering near trails, as the two species have differential responses to human activity (Rogala et al., 2011). In some instances wildlife may become habituated to human disturbance when recreational use is frequent and spatially predictable (Kenny & Knight, 1992). Such is the case with cougars whose day-bed use has frequently been documented in areas near recreational trails (Sweanor, Logan, Bauer, Millsap, & Boyce, 2008). In other cases, wildlife may not habituate to human disturbance, such as the case with mountain sheep (*Ovis canadensis*) and white-tailed deer (*Odocoileus hemionus*), which did not habituate to pedestrians and snowmobiles over time, respectively (MacArthur, Geist, & Johnston, 1982; Moen, Whittemore, & Buxton, 1982).

Behavioural changes can take different forms, such as shifting an animals' home range or altering the time of day that an animals is active. Wolves (Hebblewhite & Merrill, 2008), bobcats (*Lynx rufus*; George & Crooks, 2006) and grizzly bears (*Ursus arctos*; Gibeau, Clevenger, Herrero, & Wierzchowski, 2002) altered their movement in time and space in response to human recreation. Bobcats observed by George and Crooks (2006) were not only less likely to be detected less along recreational trails, but also shifted their daily activity pattern to become more nocturnal in high humane use areas. While behavioural changes are not always detrimental to individuals directly, seemingly harmless changes in behaviour can indirectly compromise the health of wildlife populations. For example, deer vigilance has been observed to be lower in areas with high levels of human recreation, suggesting that some deer become habituated to the presence of humans, which could in turn result in the animals being more susceptible to predation (Schuttler et al., 2017). Ungulate responses to human recreation range from increased general alertness, to retreating slowly, to outright flight, depending on the ungulate species and the type of disturbance (Stankowich, 2008). Stankowich (2008) generalized behavioural responses of ungulates to human disturbance, though he noted a high degree of heterogeneity in responses across and within species.

There is a growing body of empirical literature on the effects of recreation on various wildlife species. A recent global review of published empirical literature found that human recreational activities in protected areas are impacting wildlife more often than not, in negative ways (Larson et al., 2016). The authors reviewed 274 scientific articles published between 1981 and 2015 on the effects of recreation on a variety of animal species across all geographic areas and recreational activities. More than 93% of the articles reviewed indicated at least one impact of recreation on animals, the majority of which (59%) were negative. The results of the recent review (Larson et al., 2016) along with other reviews (see for example, Boyle & Samson, 1985; Burgin & Hardiman, 2015; Duffus & Dearden, 1990; Sato et al., 2013) present an opportunity for an open discussion on how to balance protected area visitors with the well-being of wildlife.

**Impacts of Unofficial Trails on Wildlife.** Areas that receive heavy recreational use often become crisscrossed by unofficial trails when visitors venture “off-trail” to reach locations that cannot be reached by following the formal trail network. Through the same mechanisms as official trails, unofficial trails can also affect local and regional ecology through negatively impacting soil (Wilson & Seney, 1994), vegetation (Havlick et al., 2016) and moving or removing habitat constituents such as dead logs, leaf litter or rocks. Moreover, unofficial trail proliferation in conservation areas is problematic as it has been documented that unofficial trail use can have a greater negative impact on wildlife species when compared to official trail use (Miller, Knight, & Miller, 2001; Taylor & Knight, 2003).

Predictability in the location and frequency of recreational activities is an important factor in the type and intensity of response that a species will have to human disturbances in the wild. Many studies have indicated that wildlife species have more intense reactions to spatially unpredictable activities, such as unofficial trail use (Hamr, 1988; MacArthur et al., 1982; Miller et al., 2001; Schultz & Bailey, 1978; Taylor & Knight, 2003). Wildlife may perceive activities taking place on official trails as more spatially predictable and nonthreatening, thus allowing wildlife to habituate to this type of activity (Knight & Cole, 1995; Miller et al., 2001; Yarmoloy, Bayer, & Geist, 1988). For example, approaching wildlife from a parking lot (an area with frequent human use) elicited less of a response from mountain sheep than when hikers approached the sheep from over a ridge, where human use was sporadic (MacArthur et al., 1982). Accordingly, when human activity occurs in an unfamiliar manner, many species are unable to adjust to the disturbance (Miller et al., 2001), with the greater impact reflected by

larger alert and flushing distances and further distances fled (Miller et al., 2001; Taylor & Knight 2003; Thiel, Ménoni, Brenot, & Jenni, 2007).

Taylor and Knight (2003) observed that mule deer (*Odocoileus hemionus*) had greater responses to off-trail hiking and mountain biking when compared to the same on-trail activities. The distance between the recreationists and the deer when the deer first became visibly aware of the disturbance was significantly higher when recreationists moved along randomly chosen unofficial trails (alert distance: 228 meters) when compared to official recreational trails (alert distance: 190 meters). When approached within 100 meters on an unofficial trail, 96% of mule deer fled. On average, mule deer fled more than 60 metres farther from their initial position from off-trail recreationists compared to on-trail approaches, likely because the recreationists' movements were more varied and less predictable. Similar results were obtained by Miller et al. (2001), who identified that the alert distance, flush distance and distance moved were all greater for four species – mule deer, vesper sparrows (*Pooecetes gramineus*), western meadowlarks (*Sturnella neglecta*), and American robins (*Turdus migratorius*) – when recreational activities occurred on unofficial trails compared to official recreational trails. Finally, as long as recreationists' movements remained spatially and temporally predictable, chamois (*Oreamnos americanus*, a close relative of mountain goats) were able to habituate to recreational activities within its range. However, once recreationists left official trails or travelled in groups of three or more, flushing distance significantly increased (Hamr, 1988).

Most of the research into the effects of recreationists on unofficial trails has focused on various ungulate and bird species. It is well known that ungulates may habituate to highway traffic and vehicle noise when they learn over time that the disturbance is not a dangerous predator (Yarmoloy et al., 1988). Although roads may have negative impacts on wildlife species, the movement on roads is predictable in space and time, and therefore presents the opportunity for habituation. It is also common that birds habituate to routine sounds (i.e., traffic on roads, recreationists on designated trails), while unexpected sounds (e.g., gun shots) cause them to flee. Consequently, humans who leave official roads and trails are perceived as spatially unpredictable and as higher risk than recreationists who tend to make more predictable movements on official trail networks. Importantly, because wildlife often reacts strongest to recreationists who venture off trails, visitors should stay on designated trails to minimize detrimental disturbance to wildlife.

## Impacts on Species of Concern in Gatineau Park

This section contains a detailed discussion of impacts of recreational trails and trail use on the species at risk identified in Gatineau Park, organized by species group and by species.

**Large mammals.** The impact of recreational trails and trail use was investigated for three large mammal species of concern found within Gatineau Park (see Table 1). The three species include cougars, eastern wolves (*Canis lupus lycaon*), and the wolverine (*Gulo gulo*). Although the basic ecology and habitat requirements of cougars and wolves are relatively well known, even basic knowledge for species such as the wolverine is limited.

**Table 1:** Information on potential impacts by recreational trails and trail use for large mammals, with information pertaining to roads when relevant.

Common name	Scientific name	Impact
1. Cougar	<i>Puma concolor</i>	Human-altered landscapes may represent modified, but not necessarily unsuitable cougar habitats. Cougars frequently use trails and dirt roads as travel corridors and for access to prey. High-density residential developments and roads may act as barriers to cougar movement.
2. Eastern wolf	<i>Canis lupus lycaon</i>	The literature varies as to whether wolves are drawn to, or avoid roads, trails, and other human developments. Some wolves will exploit such features through access to human food sources, greater traveling efficiency, and increased access to prey.
3. Wolverine	<i>Gulo gulo</i>	Winter recreation (helicopter skiing, backcountry skiing and snowmobiling) and the presence of roads reduced habitat use. Habitat avoidance resulting from human activities may impact behaviour patterns such as denning, kit rearing, travel and foraging.

**Cougar.** The cougar is a highly adaptable carnivore that occupies a wide variety of habitat types throughout North America (Kertson, Spencer, Marzluff, Hepinstall-Cymerman, & Grue, 2011). Once perceived as a wilderness species, the cougar's ability to travel long distances occasionally brings the species into seemingly inappropriate habitat – cougars now frequent areas of human development, and interactions with people are becoming increasingly more common (Burdett et al., 2010; Kertson et al., 2011). Although information on the effect of recreational trails and trail use on cougars is mainly descriptive in scope; there is evidence that cougars reduce their use of areas with high human activity (Beier, 1993; Burdett et al., 2010;

Morrison, Boyce, Nielsen, & Bacon, 2014), but they are generally tolerant of human infrastructure in their home ranges (Kertson et al., 2011; Sweanor et al., 2008).

Human-altered landscapes may represent modified, but not necessarily unsuitable cougar habitats. Cougar movement on trails and dirt roads has been well-documented, which suggests that these corridors do not inhibit movement, but they may even facilitate cougar movement (Sweanor et al., 2008). Beier (1995) found that cougars favored dirt roads and hiking trails as routes through dense chaparral, which was corroborated by Dickson, Jenness, and Beier (2005) and Kertson et al. (2011) who both documented that cougars use unpaved, low-speed forest roads and trails as travel corridors. In addition to providing pathways through dense forest, trails and dirt roads may facilitate access to prey (Kertson et al., 2011). However, cougars are not impervious to all disturbances. Morrison et al. (2014) observed that cougars selected areas farther from trails during the summer and closer to trails in the winter, coinciding with the seasonal fluctuation of human activity in Cypress Hills Interprovincial Park, located on the borders of Alberta and Saskatchewan. Cougars can also be expected to be closer to trails during the evening, a time of low visitor use (Morrison et al., 2014). Various studies document that cougars show an active aversion to roads and high-density residential developments, both which may act as effective barriers to cougar movement (Dickson et al., 2005; Kertson et al., 2011; Markovchick-Nicholls et al., 2008).

***Eastern wolf.*** Grey wolves (*Canis lupus*) and one of their many subspecies, eastern wolves (*Canis lupus lyacon*), are both reasonably well studied in terms of human impacts. Once widespread across Canada, centuries of hunting and eradication efforts combined with habitat loss and low reproductive rates have reduced the wolves range to predominately remote northern areas and various protected areas (CPAWS, 2008). Wolves are resilient and adaptable animals, but they show a wide range of sensitivity to human presence. Much of the literature on human disturbance of wolves is based on road access and road density. For example, road densities greater than 0.6 kilometres/square kilometres are considered too high for the long-term persistence of wolves in the Great Lakes region (Mladenoff, Sickley, Haight, & Wydeven, 1995). Although information on the effect of recreational trails and trail use on wolves is mainly descriptive in scope; there is evidence that avoidance of trails and roads causes indirect habitat loss for wolves (Hebblewhite & Merrill, 2008; Theuerkauf et al., 2003; Whittington, St. Clair, &

Mercer, 2004), consistent with this species treating human disturbance as a predation risk (Frid & Dill, 2002).

Frame, Cluff and Hik (2007) reported that human activity such as hiking near wolf dens or rendezvous sites could induce unfavourable behaviour changes, as wolves tend to relocate pups after den disturbance. However, the most recent COSEWIC assessment and status report on eastern wolves argues that the effect of recreational activities on wolves is likely negligible, as human contact with critical wolf habitat would be limited because the core of the population occurs in protected areas where human activities are regulated (COSEWIC, 2015a).

Whittington et al. (2004) found that both roads and recreational trails alter wolf movement across their territories. Wolves avoided high-use roads more than low-use trails, though trails appeared to affect movement behaviour of wolves as much, if not more than roads. Whittington, St. Clair, and Mercer (2005) observed that wolves in the town of Jasper, Alberta showed a stronger aversion to roads than trails, likely due to the high traffic volumes. In Banff, Kootenay, and Yoho National Parks, human activity on trails led to complete avoidance of the area within 50 meters by both wolves and elk (Rogala et al., 2011). Areas 50-400 meters from trails with human activity led to differential responses; wolves avoided these areas, whereas elk appeared to use these areas as predation refugia. Alternatively, in many regions, wolves selected areas near roads, trails and pipelines because these features increased speed and ease of travel through their territory (Callaghan, 2002; James & Stuart-Smith, 2000; Thurber, Peterson, Drummer, & Thomasma, 1994).

Although the literature varies as to whether wolves are drawn to, or avoid roads, trails, and other human developments, it has been reported that some wolves will exploit such features through access to human food sources, greater traveling efficiency (Callaghan, 2002; James & Stuart-Smith, 2000; Thurber et al., 1994; Whittington et al., 2005), and increased access to prey (James & Stuart-Smith, 2000). Individual wolves and wolf packs have inherent behavioural variability and may react differently to human activity depending both on the timing of the interaction and its location (Mladenoff et al., 1995). For example, Hebblewhite and Merrill (2008) showed that wolf response to human activity varied with the time of day, such that individuals in areas of high human activity moved closer to high-use areas at night but avoided these areas during the day. This was corroborated by Benson, Mahoney, and Patterson (2015), who found that individual wolves who exhibited greater variation between day and night in their

selection of roads at higher road densities were more likely to survive. This pattern was even more evident during the winter when the trade-off between fitness costs (e.g., road mortality) and benefits (e.g., ease of travel, access to prey) associated with roads was likely to be more pronounced (Benson et al., 2015).

Throughout the literature, broad, landscape-scale studies conducted on wolves responses to roads, trails and human activity typically find avoidance tendencies, while studies conducted at finer scales have found tendencies for attraction (Whittington et al., 2005). Although it is important to understand wolf behaviour at broad spatial scales, understanding how individual wolf behaviour changes in response to human activity may be more important, because it is often at this scale that management decisions can be made and enforced. According to Whittington et al. (2005), the disparity in behaviour at different spatial scales is due to density of people. Most landscape studies (in which wolves avoided roads) occurred in populated areas, while finer scale studies (where wolves showed attraction to roads and trails) were in more remote areas. In studying a populated area at a fine scale (Jasper, Alberta), Whittington et al. (2005) found wolves selected low-use roads and trails as travel routes more often than high-use roads and trails. Observing wolf behaviour at a fine scale suggests that wolves, in general, may select roads, trails and other linear features for travel corridors and increased hunting efficiency (Callaghan, 2002; James & Stuart-Smith, 2000; Lesmerises et al., 2012; Musiani, Okarma, & Jedrzejewski 1998; Thurber et al., 1994).

***Wolverine.*** Elusive and secretive, the wolverine is often characterized as a wilderness species who operates at broad spatial scales and whose persistence is related to the presence of large areas of low human population densities (Heim, 2015; Krebs, Lofroth, & Parfitt, 2007; Weaver, Paquet, & Ruggiero, 1996). Wolverines are thought to prefer rugged and remote habitat, areas that were historically largely undisturbed and inaccessible to humans. Studies in North America (Carroll, Noss, & Paquet, 2001; Heim, 2015; Krebs et al., 2007; Rowland et al., 2003; Weaver et al., 1996) and Europe (May, Landa, van Dijk, Linnell, & Andersen, 2006) have suggested that wolverines actively avoid areas of human activity. However, the growing popularity of winter backcountry recreation (Shaw, 2017) suggests that these previously undisturbed areas are no longer truly remote. The potential effects of winter recreation on wolverine reproduction, behaviour, habitat use and populations are largely unknown, but of growing concern (Carroll et al., 2001; Copeland et al., 2007, Heinemeyer & Squires, 2015; May

et al., 2006; Krebs et al., 2007). Due to wolverine's secretive nature, wide-ranging dispersal and low-density, empirical studies on the species are largely based on relatively simple assessments such as presence or absence data.

Krebs et al. (2007) identified that human activity in the Omineca and Columbia Mountains in British Columbia significantly reduced habitat value for wolverines resulting in functional habitat loss. In the winter, helicopter skiing and backcountry skiing in western Canada were negatively associated with habitat use by female wolverines, and in the summer, females were positively associated with roadless areas and negatively associated with recently clearcut areas (Krebs et al., 2007). Taken together, these results suggest that wolverines, particularly females, respond negatively to a variety of human activities within their home ranges. Avoidance of winter recreational activities was also found to influence den location selection for individual wolverines in Norway (May et al., 2012).

A study conducted in central Idaho found that wolverines showed no attraction to or avoidance of trails during the summer, although they avoided roads in their winter range (Copeland et al., 2007). It was unclear whether the apparent indifference to trails was due to the low frequency of trail use by recreationists, or whether wolverines were insensitive to human presence. Several empirical studies have similarly reported that wolverines avoid roads and other human infrastructure, attributed to perceived predation risk (Carroll et al., 2001; May et al., 2006; Rowland et al., 2003) however a recent study presents evidence that there are instances where wolverines may be attracted to industrial infrastructure, which may be related to foraging opportunities (Scrafford, Avgar, Abercrombie, Tinger, & Boyce, 2017). Rowland et al. (2003) found that low road density and low human population density were better predictors of wolverine counts than habitat type or amount, while Carroll et al. (2001) predicted that the probability of wolverine occurrences would be rare when road densities exceed 1.7 kilometres/square kilometres.

It is still unclear if the association of wolverines with roadless, isolated areas is truly a cause-effect relationship or whether the association is simply due to the species' preference for areas that are generally inhospitable to human development, such as high elevation habitats (Copeland et al., 2007). Various studies point to some form of response by wolverines to human recreational activities, but information is lacking on short- and long-term implications of recreational activities on the behaviour of individuals and populations. The wolverine's use of

rugged habitats and secretive nature make the species one of the least studied mid-sized carnivores (Weaver et al., 1996), which presents challenges for conservation and management of this poorly understood species (Rowland et al., 2003).

An extensive research project titled the “Wolverine – Winter Recreation Study” was launched in 2009 in order to map the presence of wolverines compared to motorized and non-motorized winter recreation in central Idaho, Montana and Wyoming. The research, conducted over six winters, aimed to identify and evaluate wolverine responses to winter recreation. Led by the USFS Rocky Mountain Research Station and Round River Conservation Studies, the most recent report (Heinemeyer & Squires, 2015) summarized the data collection efforts from the final field season (2015). The analysis and reporting was expected to be completed by the end of 2016, and the published results should be of great interest to those managing wolverine habitat ranges. Until further studies clarify the impacts of human recreation on wolverines, caution should be used in recreation management throughout wolverine habitat.

**Small mammals.** Within Gatineau Park, there are ten small mammal species of concern (see Table 2). Seven of the ten small mammal species are bats. The other three small mammal species of concern include two rodents (southern bog lemming, *Synaptomys cooperi*; and southern flying squirrel, *Glaucomys volans*) and one carnivore (least weasel, *Mustela nivalis*).

**Table 2:** Information on potential impacts by recreational trails and trail use for small mammals, with information pertaining to roads when relevant.

Common name	Scientific name	Impact
1. Eastern pipistrelle / tri-colored bat	<i>Perimyotis subflavus</i>	No information.
2. Eastern small-footed bat	<i>Myotis leibii</i>	No information.
3. Hoary bat	<i>Lasiurus cinereus</i>	A barrier effect caused by roads was found. Bat activity doubled 300 m away from roads.
4. Least weasel	<i>Mustela nivalis</i>	No information.
5. Little brown bat / Little brown myotis	<i>Myotis lucifugus</i>	Observed using trails as travel corridors. Frequently found foraging in open habitats, such as roads and open canopy forests.
6. Northern long-eared bat / Northern myotis	<i>Myotis septentrionalis</i>	Select roads and open corridors for foraging habitat.

**Table 2:** Continued.

7. Red bat	<i>Lasiurus borealis</i>	Red bats use habitats such as forest edges, fields, roadways, and trails for foraging. Red bats may also select roosting sites near recreational trails roosts. Roads and trails provide important travel corridors through forested landscapes.
8. Silver-haired bat	<i>Lasionycteris noctivagans</i>	A barrier effect caused by roads was found. Bat activity tripled 300 m away from roads.
9. Southern bog lemming	<i>Synaptomys cooperi</i>	Southern bog lemming abundance was observed to be greater at sites surrounded by higher trail densities. However, the species may be vulnerable to becoming trapped in discarded open containers left behind by recreationists.
10. Southern flying squirrel	<i>Glaucomys Volans</i>	Roads may isolate flying squirrel populations.

**Bats – general.** Numerous bat species are listed as threatened or endangered across the world. Some species of cave-roosting bats are extremely vulnerable to disturbance during hibernation and the birthing season (Thomas, 1995). A study of the effect of cave tours on a maternity colony of cave myotis (*Myotis velifer*) found the bats to be negatively impacted by light and noise caused by recreationists (Mann, Steidl, & Dalton, 2002). Additionally, several bat species have been identified in roadkill surveys, and based on a recent meta-analysis there is evidence to suggest that roads pose a threat to bats (Fensome & Mathews, 2016). Bats have been recorded turning back along their commuting routes in response to an approaching motor vehicle (Zurcher, Sparks, & Bennett, 2010), and thus road traffic may serve as a barrier during commuting and foraging (Bennett & Zurcher, 2013). However the severity of the roadkill issue is not well known, and there is also contrasting evidence which suggests that bats may tolerate roads and indirectly benefit from using roads as travel corridors.

**Hoary bat.** A review of the scientific literature did not reveal any studies of the effects of recreational trails on hoary bat movement or behaviour, however hoary bat activity was observed to be reduced near three large highways in California. Hoary bat activity was lowest at zero metres from the road, and was approximately twice as high at 300 metres from the road (Kitzes & Merenlender, 2014).

**Little brown bat.** It is not uncommon to find little brown bats foraging in open habitats, such as ponds, roads and open canopy forests (Segers & Broders, 2014). In White Mountain

National Forest, in New Hampshire and Maine, little brown bat activity was concentrated at trail and water body edges (Krusic, Yamasaki, Neefus, & Penkins, 1996). Although little brown bats likely feed along such open habitat edges, it is thought that trails and other linear features are predominately used as travel corridors.

***Northern long-eared bat.*** A review of the scientific literature did not reveal any studies of the effects of recreational trails on northern long-eared bat movement or behaviour, however there is evidence that northern long-eared bats selected roads and open corridors for foraging habitat (Owen et al., 2003).

***Red bat.*** There is evidence that red bats forage and roost along the edge of forested areas, including along the edges of agricultural fields, roadways, and trails (Salcedo, Fenton, Hickey, & Blake, 1995; Saugey, Crump, & Vaughn, 1998). Foraging habitat use in Missouri was observed to be greatest in forest patches with relatively high road density, but away from urban areas (Amelon, Thompson & Millspaugh, 2014). In a study conducted in Pocomoke State Forest, Maryland, recreational trails were the most prevalent anthropogenic linear feature found near red bat roosts. Roosts were found closer to unpaved (1.8-3.1 metres wide) and paved (4.6-6.1 metres wide) trails when compared to distances to natural linear features such as streams throughout the forest (Limpert, Birch, Scott, Andre, & Gillam, 2007). It is suspected that roads and trails provide the species with corridors that are used for efficient commuting within a forested landscape.

***Silver-haired bat.*** A review of the scientific literature did not reveal any empirical studies of the effects of recreational trails on silver-haired bat movement or behaviour, however, silver-haired bat activity was observed to be reduced near three large highways in California. Silver-haired bat activity was lowest directly adjacent to the road, and was approximately three times as high at 300 metres from the road (Kitzes & Merenlender, 2014).

***Southern bog lemming.*** Information on the effect of recreational trails and trail use on southern bog lemmings was scarce, however one study conducted in West Virginia and Maryland found that the capture of southern bog lemmings was greater at sites surrounded by higher trail densities (Francl, Castleberry, & Ford, 2004). Furthermore, Hamed and Laughlin (2015) observed an unintended effect of recreation on small mammals on remote gravel roads

within the Cherokee National Forest. Small mammals are vulnerable to becoming trapped in discarded open containers, which could be discarded by recreationists along roads and trails. The authors observed that 3.6% of all containers found (107 of 2,297 containers) contained the remains of 202 small mammals, including the first record of container-caused mortality of a southern bog lemming. As southern bog lemming abundance may be higher near recreational trails as reported by Francel et al. (2004), pollution-caused mortality of southern bog lemming and other small mammals warrants future research.

***Southern flying squirrel.*** A review of the scientific literature did not reveal any empirical studies of the effects of roads or recreational trails on southern flying squirrel movement or behaviour. The most relevant studies deal with flying squirrel movement between fragments of habitat separated by roads, agricultural fields and clearcuts. Flying squirrels are most likely to occur in large, well-connected patches and least likely to occur in small, unconnected patches (Walpole & Bowman, 2011).

For gliding mammals such as southern flying squirrels, roads can isolate populations by presenting a barrier due to a lack of traversable canopy cover (Asari, Johnson, Parsons, & Larson, 2010). Vernes (2001) observed average glide angles and ratios (horizontal distance over vertical drop) of northern flying squirrels (*Glaucomys sabrinus*) and concluded that, in order to successfully traverse habitat gaps, the height of a flying squirrels' launch point should be at least half of the horizontal distance that must be travelled. The maximum estimated glide of a southern flying squirrel is 75 metres (Bendel & Gates, 1987), and thus treeless gaps between patches larger than 75 metres will physically limit the gliding capabilities of southern flying squirrels (Bendel & Gates, 1987; van der Ree, Cesarini, Sunnucks, Moore, & Taylor, 2010). If road or trail development must take place in proximity to flying squirrels, it has been suggested that in order to avoid creating isolated populations, crossing poles can be installed to restore a degree of habitat connectivity (Kelly, Diggins, & Lawrence, 2013).

In 1999, the City of Hamilton, Ontario was in the construction phase of a four- to six-lane expressway through the Red Hill Creek Valley. In response to concerns raised by the public, the city commissioned an investigation into the status of the southern flying squirrel population in the valley, and made predictions on the potential impacts of the proposed expressway. The studies, conducted by Bednarczuk and Judge (2003), utilized mark-recapture techniques, radio-telemetry and trapping surveys to quantify potential impacts of the expressway on southern

flying squirrels. The trapping survey confirmed the presence of flying squirrels in the Red Hill Creek Valley and along the Niagara Escarpment. Only one individual flying squirrel crossed a “wide” road, and three individuals crossed a “narrow” road. However, these results were deemed insufficient to quantify the effects that a major six-lane expressway could have on the flying squirrel populations.

**Birds.** A fair amount of research has been directed toward assessing the impacts of human disturbance along recreational trails on bird behaviour, density and diversity of birds. Research has shown that trails can negatively affect birds in many ways, including: altering foraging patterns and efficiency (Knight, Anderson, & Marr, 1991, Skagen, Knight, & Orians, 1991); altering distribution and habitat use (McGarigal, Anthony, & Isaacs, 1991; Stalmaster & Newman, 1978; Knight et al., 1991); lowering reproductive success (McIntyre & Schmidt, 2012), increasing energy expenditures (Stalmaster & Kaiser, 1998) and increasing stress (Spaul & Health, 2016).

Birds that forage or nest on the ground as well as more conspicuous species have been reported to have the greatest response to the presence of recreationists, when compared to birds foraging or nesting higher in the canopy (Fernández-Juricic, Vaca, & Schroeder, 2004; Fernández-Juricic, Venier, Renison, & Blumstein, 2005; Kangas et al., 2010; Thompson, 2015). Additionally, birds may be particularly sensitive to habitat edges created by recreational trails and other linear features. Negative effects of habitat edges have been reported for forest nesting birds for over 30 years (Gates & Gysel, 1978). The risks of nesting near edges include increased predation rates and increased rates of brood parasitism by brown-headed cowbirds (*Molothrus ater*), for both forest and grassland nesting species (Herkert, 1994). However, certain bird species are positively associated with forest edges, and prefer to nest along roads and trails (Wolf, Hagenloh, & Croft, 2013).

Although a good deal of research exists on the effects of recreational trails and trail use on birds, many of the bird species of concern within Gatineau Park would benefit from more rigorous study. Within Gatineau Park there are 25 bird species of concern (see Table 3). Three of these species are classified as raptors, ten as forest species, seven as grassland species, four as wetland species, and one urban species, which commonly nests and breeds in urban and suburban habitats (the chimney swift, *Chaetura pelagica*). The overall impact of recreational

trails and trail use is inconclusive for many species, and information pertaining to recreational trails is completely lacking for others.

**Table 3:** Information on potential impacts by recreational trails and trail use for birds, with information pertaining to roads when relevant.

Common name	Scientific name	Impact
<b>Raptors</b>		
1. Bald eagle	<i>Haliaeetus leucocephalus</i>	Recreational activities can interfere with a wide variety of behaviours such as foraging, nesting, and the survival of young. Flush distances from recreational activities range from 25 to 991 m.
2. Golden eagle	<i>Aquila chrysaetos</i>	Egg-laying is negatively associated with recreational trail use.
3. Peregrine falcon anatum	<i>Falco peregrinus anatum</i>	Peregrine falcons may be disturbed by recreationists on cliff ledges above nests – particularly rock climbers. Peregrine falcons were found to be both negatively and positively affected by roads.
<b>Forest species</b>		
4. Canada warbler	<i>Cardellina Canadensis</i>	Fragmented forest may not have direct negative effects on abundance. Require habitat sizes of 400 ha.
5. Cerulean warbler	<i>Setophaga cerulean</i>	No information
6. Eastern wood-pewee	<i>Contopus virens</i>	Area of trail-free habitat has a significant positive influence on total bird density.
7. Golden-winged warbler	<i>Vermivora chrysoptera</i>	May be tolerant to human disturbance.
8. Loggerhead shrike	<i>Lanius ludovicianus migrans</i>	May tolerate roads as the species has frequently been observed foraging in roadside ditches.
9. Olive-sided flycatcher	<i>Contopus cooperi</i>	No information
10. Red-headed woodpecker	<i>Melanerpes erythrocephalus</i>	Red-headed woodpeckers respond positively to highly modified landscapes such as golf courses, which could have similarities to recreational areas.
11. Rusty blackbird	<i>Euphagus carolinus</i>	Nest survival may increase with increasing distance from roads.
12. Whip-poor-will	<i>Caprimulgus vociferous</i>	May be tolerant of recreational trails as the species is positively associated with young clear-cut forests and are most likely to be detected along forest edges
13. Wood thrush	<i>Hylocichla mustelina</i>	Minimum patch size for breeding is 1.0 ha. May be tolerant of recreational trails as the species is considered relatively tolerant of forest management activities on small spatial scales.
<b>Grassland species</b>		
14. Bank swallow	<i>Riparia riparia</i>	No information
15. Barn swallow	<i>Hirundo rustica</i>	No information

**Table 3:** Continued.

16. Bobolink	<i>Dolichonyx oryzivorus</i>	When approached by pedestrians, the species flushed at a distance of 22 m, moving an average distance of 34 m. Buffer zones around habitat should be 28-59 m.
17. Common nighthawk	<i>Chordeiles minor</i>	No information
18. Eastern meadowlark	<i>Sturnella magna</i>	No information
19. Grasshopper sparrow	<i>Ammodramus savannarum</i>	Actively selects for habitat where no trails exist. More likely to be found in large patches.
20. Short-eared owl	<i>Asio flammeus</i>	Human disturbance may reduce nesting success although the overall relationship is poorly understood.
<b>Wetland species</b>		
21. Least bittern	<i>Ixobrychus exilis</i>	May tolerate roads and even habituate to short-term recreational disturbances such as the occasional passage of small boats.
22. Louisiana waterthrush	<i>Seiurus motacilla</i>	A buffer of at least 100 metres wide from the shoreline is recommended to protect sensitive habitat from human activities.
23. Sedge wren	<i>Cistothorus platensis</i>	No information
24. Yellow rail	<i>Coturnicops noveboracensis</i>	No information
<b>Urban species</b>		
25. Chimney swift	<i>Chaetura pelagica</i>	No information

**Bald eagle.** There are various experimental studies which have shown that bald eagle distribution and behaviour can be negatively affected by recreational activities such as hiking (Brown & Stevens, 1997; Fraser, Frenzel, & Mathisen, 1985; Grubb, Bowerman, Giesy, & Dawson, 1992; Stalmaster & Kaiser, 1998; Watson, 2004), fishing (Stalmaster & Kaiser, 1998), and boating (McGarigal et al., 1991; Stalmaster & Kaiser, 1998; Steidl & Anthony, 1996). Recreational activities interfere with a wide variety of eagle behaviours, for example foraging (McGarigal et al., 1991; Stalmaster & Kaiser, 1998), nesting (Steidl & Anthony, 2000; Watson, 2004) and potentially the survival of young (Steidl & Anthony, 2000). Disturbance to eagles does not only depend on the presence of an eagle nearby or the type of recreational activity, but it also involves the timing and location of the encounter, and also the eagle's physical and behavioural state. Furthermore, there is evidence that the presence of recreational trail infrastructure alone influences bald eagle habitat preferences, with eagles actively seeking areas of trail-free habitat (Fletcher, McKinney, & Bock, 1999).

Reported bald eagle flush distances differ within and among studies, as the results were obtained under varying conditions and represent the range of responses by individual eagles. In

response to recreational activities, bald eagle flush distances range from 25 to 991 metres (see Table 4). Eagles were found to consistently flush at greater distances in areas that had little human use than in areas frequently used by people, which may be evidence that eagles in high human use areas become habituated to the presence of recreationists (Buehler, Mersmann, Fraser & Seegar, 1991; Stalmaster & Newman, 1978; Steidl & Anthony, 1996)

Compared to other recreational activities, Stalmaster and Kaiser (1998) suggest that foot traffic may be the most disturbing human activity to eagles. After being disturbed by pedestrians, eagles required nearly four hours to resume normal behaviours compared to 36 minutes after being disturbed by a boat. Similarly, Grubb and King (1991) found that pedestrians made up the most disturbing group of 13 different categories of human activity which included pedestrians, boats, ORVs, gunshots, and aircraft. Fraser et al. (1985) found a similar relationship between terrestrial and aerial disturbance, but did not test aquatic activity. Eagles were largely unaffected by fast moving boats and land-based vehicles, but became increasingly agitated and flushed more often as vehicles approached slowly, suggesting that comparatively slow, prolonged disturbances are the most disturbing to eagles (Grubb & King, 1991; McGarigal et al., 1991; Stalmaster & Kaiser, 1998). Holmes, Knight, Stegall and Craig (1993) report that in general, raptors are more sensitive to humans approaching on foot than to humans approaching in vehicles.

**Table 4:** Bald eagle flush distances in response to various human activities.

Activity	Average distance (m)	Range (m)	Suggested buffer around habitat / nests	Source
<b>Pedestrian</b>				
Pedestrian	72	/	120 m	Watson (2004)
Pedestrian	185		500-600 m	Grubb et al. (1992)
Pedestrian	188	/	/	Stalmaster & Kaiser (1998)
Pedestrian	196	25-300	250 m	Stalmaster & Newman (1978)
Pedestrian	476	57-991	500 m	Fraser et al. (1985)
<b>Boating</b>				
Boating	100	/	500-600 m	Grubb et al. (1992)
Boating	87.5 (breeding)	/	200-220 m	Steidl & Anthony (1996)
Boating	101 (non-breeding)	/	200-220 m	Steidl & Anthony (1996)
Boating	126	/	restrict boat activity 400 m from shoreline	Stalmaster & Kaiser (1998)
Boating	197	50-468	400-800 m	McGarigal et al. (1991)

Throughout the Skagit River Bald Eagle Natural Area in Washington, the number of bald eagles was negatively correlated with recreational boating and pedestrian events. Adult eagle feeding activity declined exponentially with increased recreational activity (Stalmaster & Kaiser, 1998). During high levels of disturbance on the weekend (an average of 53 recreational disturbances per day, with a maximum of 115 events in one day), eagles would eventually avoid foraging and feeding altogether. Eagle feeding activity on weekends was predicted to be reduced by 90%. McGarigal et al. (1991) also found that boating significantly altered foraging behaviour of nesting bald eagles on the Columbia River. When humans camped near nesting eagles in Alaska, it was found that the amount of prey adult eagles consumed decreased by 29% and the number of times an adult fed its nestlings decreased by 23% when compared to control nests (Steidl & Anthony, 2000). Because of the nestlings' dependence on adults for food, nestlings probably suffer high energetic costs with such a reduction in food. Consequently, nestling bald eagles are more likely to be adversely impacted by human disturbances which could in turn negatively affect population persistence.

Although there does not appear to be evidence that recreation is negatively affecting bald eagle survival directly, there is evidence that the normal activities of eagles can be disrupted by recreational trails and trail use. Frequent disturbances could increase total energy needs of eagles due to increased fleeing while also interfering with food acquisition (Stalmaster & Kaiser, 1998). The responses of bald eagles to recreational activities are variable, and depend on the type of human disturbance and the eagle's physiographical and behavioural state (e.g., nesting versus foraging). Implementing spatial restrictions on recreational activities has been suggested by various authors as a way to reduce conflicts between humans and bald eagle populations (Table 4). These buffer zones range from 120 metres away from eagle habitat for pedestrians, to 400-800 metres away from the shore for boating activities. Temporal restrictions of human recreation have been suggested less frequently in the literature, but when used in conjunction with spatial restrictions they have the potential to maintain undisturbed habitat resources for eagles during important times of the year. For example, Isaacs, Anthony, and Anderson (1983) suggest using spatial buffer zones from February 1 to August 31 to protect breeding pairs. The type of recreational activity should be considered when implementing restrictions, as different effects can occur from different types of recreational activity.

**Golden eagle.** Information on the effect of recreational trails and trail use on golden eagles was scarce; however one recent study reported that golden eagle territory occupancy, egg-laying, and nest survival are negatively associated with recreational trail use (Spaul & Heath, 2016). Many golden eagle studies focus on the negative effects of recreational trails which permit ORV use, with consistent negative impacts on territory occupancy and nest survival (Spaul & Heath, 2016; Steenhof, Brown, & Kochert, 2014).

According to Spaul and Heath (2016), pedestrians who access golden eagle habitat during the early breeding season negatively influenced the likelihood of golden eagles laying eggs, supporting the hypothesis that large raptors are particularly vulnerable to disturbance during the early breeding season (Watson, 2010). It is suggested that the presence of humans during a critical time such as breeding and egg-laying, may result in a stress response that reduces the likelihood of eagles laying eggs (Spaul & Heath, 2016). In order to increase the number of golden eagles who lay eggs, Spaul & Heath (2016) suggest a temporal restriction – closing trails near nesting golden eagles to pedestrians and other nonmotorized activities during the early breeding season.

**Peregrine falcon.** A review of the scientific literature did not reveal any empirical studies of the effects of recreational trails on peregrine falcon (subspecies *anatum*) movement or behaviour. An observational study conducted by Herbert and Herbert (1965) reported that nesting peregrine falcons did not appear to be disturbed by recreationists at the base of their nesting cliffs, but any approach from above triggered an intense reaction. According to Environment Canada (2015), peregrine falcons may be particularly vulnerable to activities such as rock climbing, and to a lesser degree, bird watching, hiking and ORV use as the falcon generally nests on cliff ledges or crevices.

A recent meta-analysis on the effects of recreational activities and the distribution, nest-occupancy, and reproductive success of breeding raptors could not discern whether or not peregrine falcons were impacted by recreational activities, and also presented mixed results on the impacts of roads on the species. Depending on the location and context, peregrine falcons were both negatively and positively affected by roads (Martínez-Abraín, Oro, Jiménez, Stewart, & Pullin, 2008). The fact that studies presented conflicting evidence suggests that sensitivity to roads is, to some extent, a population-specific trait, rather than a species-specific trait.

Guidelines set by the Ontario Ministry of Natural Resources (1987) suggest spatial and temporal restrictions to restrict access to peregrine falcon nest sites, as the peregrine falcon, like other large raptors, is particularly vulnerable to disturbance during the breeding season (Watson, 2010). To protect important falcon habitat, management plans should prohibit recreational activities, such as hiking, picnicking, camping, hunting and wildlife viewing within 0.6 to 0.8 kilometres of the nest site during the breeding season, March 15 to August 31. The suggested buffer zones for rock climbing, mountain biking and ATV use should be wider than pedestrian activities, suggested at 0.9 to 1.2 kilometres.

**Canada warbler.** A review of the scientific literature did not reveal any empirical studies relating trails and trail use to the Canada warbler. However, there is evidence that Canada warblers are relatively tolerant to local-scale habitat fragmentation caused by timber harvesting (Schmiegelow, Machtans, & Hannon 1997; Schmiegelow & Monkkonen, 2002) and fragmentation caused by linear features, such as human development (Machtans, 2006). On the other hand, there are studies which suggest that the Canada warbler is sensitive to fragmentation (Robbins, Dawson, & Dowell, 1989; Hobson & Bayne, 2000) and also sensitive to roads, although the mechanism causing this relationship to roads is unknown (Miller, 1999).

Robbins et al. (1989) calculated the minimum breeding area requirements based on the incidence of individual bird species in forest patches of varying size. They concluded that Canada Warblers require at least 400 hectares of habitat for successful breeding. However, this does not necessarily imply 400 hectares of continuous, unfragmented habitat. A recent study in Alberta reported that fragmentation within Canada warbler habitat does not appear to have direct negative effects on abundance, as long as a deciduous forest matrix is retained (Ball et al., 2016).

**Eastern wood-pewee.** The threats affecting eastern wood-pewees (*Contopus virens*) have not been clearly identified and are poorly understood, largely due to a lack of research. Possible threats may include loss or degradation of breeding habitat and wintering grounds, changes in flying-insect prey availability, high rates of nest predation or changes in forest structure (COSEWIC, 2012a). A study by Thompson (2015) examined the impacts of recreational trails on forest-dwelling bird communities in eastern North America within 24 publically owned natural areas. The study did not investigate effects on individual species specifically, but eastern wood-pewees were frequently reported in these natural areas and the study found a significant positive

influence of the area of trail-free habitat on total bird density. Additional studies are needed to confirm if the area of trail-free habitat specifically influences eastern wood-pewee density.

***Golden-winged warbler.*** No empirical literature relating trails or trail use to golden-winged warblers could be found, however, the prevalence of golden-winged warblers utilizing early-successional forests after clear-cutting occurs is well documented (Roth & Lutz, 2004). Golden-winged warblers are known to inhabit a variety of early-successional or disturbance ecosystems (Bakermans, Ziegler, & Larkin, 2015), however no information on the species tolerance to immediate human disturbance could be found. Disturbed sites such as abandoned farmland, clear-cuts and fire managed forest stands result in a heterogeneous mix of shrubs, saplings and residual trees – all which provide important nesting locations for golden-winged warblers (Roth & Lutz, 2004).

***Loggerhead shrike.*** No specific literature relating trails and trail use to loggerhead shrikes (subspecies *migrans*), could be found, but studies have reported on the potential relationship between loggerhead shrikes and roads. Almost half of all the loggerhead shrikes observed in a study in Alberta were detected less than 200 metres from roads (52.2%), while 6.2% were detected between 200 and 400 metres and 41.6% were detected more than 400 metres from roads (Bjorge & Prescott, 1996). The species has frequently been observed foraging in roadside ditches, which may increase their susceptibility to mortality from vehicle collisions (COSEWIC, 2014b).

Although detecting loggerhead shrikes near roads may be commonplace, the distance between roads and nesting locations shows great variability. Loggerhead shrikes nesting in Smiths Falls, Ontario, nested on average 127 metres from roads (Chabot, Titman, & Bird, 2001), while loggerhead shrikes in Grassland National Park, Saskatchewan nested at sites significantly further away from roads (over 2,000 metres) and at higher elevations than control sites (Shen, He & Guo, 2013).

***Red-headed woodpecker.*** Red-headed woodpeckers occur in open deciduous woodlands, forest edges, parks, open agricultural areas with tree rows and residential areas (Smith, Withgott, & Rodewald, 2000). Although no specific literature relating trails and trail use to red-headed woodpeckers was found, one study by Rodewald, Santiago and Rodewald (2005) explored the

possibility that highly modified landscapes such as golf courses may provide suitable habitat for this species.

Due to the structural similarities between golf courses and natural habitats used by red-headed woodpeckers (large open space, interspersed trees), Rodewald et al. (2005) expected that golf courses would support red-headed woodpecker breeding habitat. The authors detected 158 red-headed woodpeckers and 16 nests on 26 of the 100 golf courses studied. The woodpeckers that bred on the golf course experienced a high rate of nest success – 75% of nests produced one or more chicks. These findings suggest that red-headed woodpeckers may respond positively to highly modified landscapes, and that such landscapes may have a role in the conservation of other declining wildlife species that breed or nest in disturbed ecosystems.

***Rusty blackbird.*** Although no specific literature relating trails and trail use to rusty blackbirds was found, a recent study in Maine, USA, suggested that rusty blackbird nest survival increased with increasing distance from roads (Luepold, Hodgman, McNulty, Cohen, & Foss, 2015). The authors suggest that open habitat created by roads may increase the incidence of nest predators, such as the red squirrel (*Tamiasciurus hudsonicus*). However, this result did not hold constant across multiple years. Red squirrels tend to avoid open areas such as clearings and roads in the first place, and this may cause the negative relationship between roads and nest survival to vary over time.

***Eastern whip-poor-will.*** Eastern whip-poor-will behaviour varies in response to human modified landscapes. Whip-poor-wills are positively associated with young clear-cut forests and are most likely to be detected along forest edges (Wilson & Watts, 2008). A recent study found that the occurrence of eastern whip-poor-wills increased by 3.3 times where young clear-cuts were present compared to when they were absent (Tozer et al., 2014). This finding is supported by others, who have found that the occurrence of the species increases with clear-cut forested habitat (Hunt, 2013; Wilson & Watts, 2008). In addition, the infrastructure such as roads may attract eastern whip-poor-wills (English, Nocera, Pond, & Green, 2017). It has been observed that the species commonly sits on gravel roads or road shoulders at night, likely hunting insects, making them particularly vulnerable to automobile collisions (Jackson, 2003).

Eastern whip-poor-wills may benefit from an active forest management strategy which emulates natural disturbances and maintains habitat openings through clear-cutting. No specific

literature relating trails and trail use to eastern whip-poor-wills could be found, however future studies should explore whether trail infrastructure elicits a response similar to that of clear-cutting.

**Wood thrush.** In general, wood thrush is considered relatively tolerant of forest fragmentation and forest management activities on small spatial scales (i.e., partial timber harvesting, selective removal of mature trees; Gram, Porneluzi, Clawson, Faaborg, & Richter, 2003). Campbell (2011) observed how a variety of forest birds – including wood thrushes – responded to approaching pedestrians in public natural areas in Peterborough, Ontario. All species had greater alert distances when approaching pedestrians walked directly at the species, rather than approaching from the side, and also recorded longer alert distances when pedestrians had wide arm movements (swinging arms 90°) compared to walking with no arm movement. On average, wood thrushes had an alert distance of 17 metres and a flush distance of 15 metres.

According to Robbins et al. (1989), the suggested minimum patch size for a breeding wood thrush is 1.0 hectares. However, fragmentation dynamics cannot be considered in the context of patch size alone. Although the suggested minimum area for breeding may persist under ideal conditions, the matrix surrounding the ecosystem may negatively affect the species within the patch – such as the interactions which take place along the interface of urban and suburban and forest boundaries. This effect is apparent in a study conducted in Waterloo, Ontario, where wood thrushes practically disappeared as housing development encroached into previously rural areas (Friesen, Eagles, & Mackay, 1995).

**Bobolink.** Bobolinks have consistently reported to be sensitive to the size of their home range (Buxton & Benson, 2016; Herkert, 1994; Bollinger & Gavin, 2004), while also avoiding the edges of forests (Bollinger & Gavin, 2004; Fletcher & Koford, 2003), roads (Fletcher & Koford, 2003) and suburban development (Bock et al., 1999). As a grassland species, it is not surprising that bobolinks avoid forested habitat, but interestingly, bobolinks appear to avoid forest edges more than any other edge habitat (Bollinger & Gavin, 2004). Compared to forest edges, density of bobolinks was two times greater near agricultural edges and 1.5 times greater near road edges (Fletcher & Koford, 2003).

Throughout the literature, one study was found which explored the behavioural response of bobolinks to approaching pedestrians. When approached in a straight line, on average

bobolinks took flight at a distance of  $21.8 \pm 9.6$  metres from the pedestrian, moving away from the approacher an average distance of  $33.5 \pm 17.6$  metres (Keyel, Peck, & Reed, 2012). The appropriate size of “buffer zones” which aim to dilute the effects of human disturbance on the species were recommended to be 28 metres to prevent 75% of bobolinks from flushing, 40 metres to prevent 95% of bobolinks from flushing and 59 metres to prevent 99% of bobolinks from flushing.

***Grasshopper sparrow.*** A study was conducted investigating the influence of recreational trails on bird communities in mixed-grass prairie ecosystems in Boulder, Colorado. Within this natural area, grasshopper sparrows were never detected directly adjacent to trails (0 metres from the trail), and were shown to be significantly more abundant along control transects where no trails existed than along established trails (Miller, Knight, & Miller, 1998). These results demonstrate that recreational trails through grassland ecosystems affect the distribution and abundance of grasshopper sparrows.

Johnson and Temple (1990) found that grasshopper sparrow nests were more likely to be found on large (130–486 ha) than small (16–32 ha) tallgrass prairie patches, which is supported by Vos and Ribic (2013) and Buxton and Benson (2016) who report that nest density and abundance of grasshopper sparrow increased with increasing patch size. These results suggest that the grasshopper sparrow is an area-sensitive species, which calls for thoughtful trail planning and management of recreation in natural areas to ensure that habitat requirements are satisfied.

***Short-eared owl.*** Human disturbance may reduce short-eared owl nesting success (Reid, Doyle, Kenney, & Krebs, 2011), although the overall relationship between human disturbance and short-eared owls is poorly understood (Booms et al., 2014). As the owl is nomadic in nature, it is inherently difficult to monitor and therefore the species is not well sampled. No reliable patterns can be discerned from banding data, and seasonal movements of the species are variable (Reid et al., 2011). No empirical literature relating trails and trail use to short-eared owls could be found.

***Least bittern.*** No empirical literature relating trails and trail use to least bitterns could be found; however the species may tolerate and even habituate to short-term recreational disturbances such as the occasional passage of small boats (Kushlan & Hancock, 2005; Poole, Lowther, Gibbs, Reid, & Melvin, 2009). It is noted, however, that frequent disturbances of least

bittern nesting sites can cause nest abandonment (Kushlan & Hancock, 2005). Ideal nesting and foraging habitat for the species is located away from areas frequently disturbed by humans (Jobin, Fradette, & Labreque, 2011).

There are 142 wetlands in Québec with confirmed least bittern occurrences. According to Jobin et al. (2011), the wetlands where least bitterns could be found ranged from 0.5 hectares to 983 hectares in size, and road density was higher around wetlands occupied by least bitterns than in the regional landscape. However, this result was likely due to a sampling bias due to wetland accessibility rather than selection for wetlands near roads. Like various other species, infrequent and unpredictable disturbance into wetland habitat is likely disruptive to the least bittern, and therefore protective measures should be put in place for remaining small and large wetlands to reduce wetland isolation and augment wetland connectivity.

**Louisiana waterthrush.** The Louisiana waterthrush (*Parkesia motacilla*, formerly *Seiurus motacilla*) is described as an area-sensitive forest interior bird that is associated with riparian zones in mature forests and prefers non-fragmented forests (Prosser & Brooks, 1998). The only confirmed nesting site in Québec is a site in Gatineau Park on the Eardley Escarpment. Through targeted surveys of known nesting sites and suitable habitat sites, the species has been observed intermittently in the park since 1974 – however in 2008, no birds were found at this site (Savignac, 2008).

The use of off-road vehicles along riparian zones and streams is currently recognized as one of the major threats to the Louisiana waterthrush (COSEWIC, 2006). Although no empirical literature relating trails and trail use to Louisiana waterthrushes could be found, the most recent COSEWIC report notes that trampling of nesting areas adjacent to streams caused by hiking, dog-walking and fishing is occurring in Gatineau Park (COSEWIC, 2015b). A high proportion of nests would be exposed to this type of activity in the park, and therefore a riparian buffer of at least 100 metres wide is recommended to protect sensitive Louisiana waterthrush breeding habitat (Ontario Partners in Flight, 2008).

**Reptiles.** Despite the wealth of information available for mammals and birds, comparatively little is known regarding the consequences of human recreation and landscape modifications on reptiles. A potential reason for this knowledge gap is that reptiles are often secretive and evasive of humans, who they may regard as predators (Frid & Dill, 2002). There

are eight reptile species of concern found within Gatineau Park (see Table 5). Four of the species are turtles and the other four species are snakes. Only three of the eight reptile species had empirical literature relating recreational trails, trail use and roads to the species behaviour. All three of these species were turtles – Blanding’s turtles, common map turtles and wood turtles. Although the other species were periodically mentioned in studies investigating roadkill casualties (e.g., Ashley & Robinson, 1996; Haxton, 2000), no specific empirical literature for milksnakes, northern water snakes, ringneck snakes, smooth green snakes or snapping turtles could be found.

**Table 5:** Information on potential impacts by recreational trails and trail use for reptiles, with information pertaining to roads when relevant.

Common name	Scientific name	Impact
1. Blanding's turtle	<i>Emys blandingii</i>	No significant barrier effect from roads, however roads may be a significant ecological trap for the species.
2. Common map turtle	<i>Graptemys geographica</i>	Boating causes disturbances to basking as well as injuries and casualties.
3. Milksnake	<i>Lampropeltis triangulum</i>	Negligible impact by recreational areas (COSEWIC, 2014a).
4. Northern water snake	<i>Nerodia sipedon</i>	No information
5. Ringneck snake	<i>Diadophis punctatus</i>	No information
6. Smooth green snake	<i>Opheodrys vernalis</i> [previously <i>Liochlorophis vernalis</i> ]	No information
7. Snapping turtle	<i>Chelydra serpentina</i>	No information
8. Wood turtle	<i>Glyptemys insculpta</i>	Hiking and other human disturbance may lead to local extirpation.

**Blanding’s turtle.** Blanding’s turtles may show an aversion to crossing roads (Proulx, Fortin, & Blouin-Demers, 2014). Along the Ottawa River ranging from Gatineau Park to Clarendon, QC, Blanding’s turtles crossed roads significantly less than expected if the turtles were moving randomly in relation to roads, regardless if the road was paved or unpaved. Refsnider and Linck (2012) reported that Blanding’s turtles in their study made numerous road crossings and most turtles (59%) crossed a paved road at least once, however roads were not found to cause a significant barrier effect.

Blanding’s turtles are frequently reported using anthropogenically disturbed sites for nesting, sometimes more often than natural nest sites (Beaudry, DeMaynaider, & Hunter, 2010). During the three years which Beaudry et al. (2010) observed 19 Blanding’s turtles, nest sites

were 84% anthropogenic in origin, and 58% of the sites were created in the last five years or less. These results are supported by a study conducted by Refsnider and Linck (2012), who observed Blanding's turtles using anthropogenic nesting sites 69% of the time. Notable nest sites from both studies include backyard lawns, young clear-cuts and shoulders of roads. The high use of road shoulder sites for nesting, despite low hatching success and increased vulnerability of nesting females to road mortality (Refsnider & Linck, 2012), suggests that roads may represent an ecological trap to Blanding's turtles. Future studies should investigate whether Blanding's turtles are using recreational trails as nesting sites, as trails with high disturbance from pedestrians with dogs, hikers and mountain biking could similarly become an ecological trap for this species.

***Common map turtle.*** There is strong evidence that recreational boat use in common map turtle habitat is a major source of disturbance, injury and mortality (Bulté, Carrière, & Blouin-Demers, 2010; COSEWIC, 2012b). Turtles are easily startled into the water by motorboats, often interrupting basking behaviour (as observed in yellow-blotched map turtle [*Graptemys flavimaculata*] behaviour; Moore & Seigel, 2006). Frequent interruptions to basking behaviour have been reported to have energetic consequences in common map turtles, including decreased mean daily body temperatures and a decreased metabolic rate (Jain-Schlaepfer, Blouin-Demers, Cooke, & Bulté, 2017). Additionally, turtles often abandon their attempts to nest upon approach of a boat (Moore & Seigel, 2006). Such abandonment of basking and reproductive behaviours could translate into adverse effects such as reduced reproductive output and overall population decline.

Research has demonstrated that female common map turtles are two to nine times more likely than males to sustain injuries from propellers, perhaps partly due to their larger body size when compared to males (Bulté et al., 2010). The number of turtle mortalities each year is virtually impossible to quantify, however, if such sex-skewed prevalence of traumatic injuries is indicative of the number of female mortalities, then motorboat-turtle collisions may have the capacity to compromise the persistence of local common map turtle populations. Although there was no particular literature on the impacts of recreational trails on common map turtles, human interference and recreation along shorelines may prevent individuals from using suitable habitat (COSEWIC, 2012b; Ryan, Conner, Bouthitt, Sterrett, & Salsbury, 2008). Common map turtles show a preference for habitats with natural shorelines (Carrière & Blouin-Demers, 2010), and the

abundance of the turtles has been observed to decline in areas with urban development and human activity (Rizkalla & Swihart 2006; Ryan et al., 2008). As such, construction of trails directly along the water's edge should be avoided, however additional research on common map turtles is needed to identify the minimum distance that infrastructure should be located to prevent disturbance.

**Wood turtle.** Garber and Burger (1995) present evidence through a long-term ecological study that the opening a wilderness area to pedestrians led to the extirpation of the local wood turtle population. Before the area was open to the public, the authors determined that the wood turtle population levels were stable – the mean age of juvenile and adult wood turtles remained constant and the overall number of juvenile and adult turtles was not declining. In 1982, the year before the area was opened to recreation, 106 wood turtles were counted in the area. After the forest was opened to pedestrians, there was a rapid decline in wood turtle populations: nine years after the area was open to recreationists (1991), only 14 individuals could be found, and after 1991, not one individual could be found. Ruling out increased nest predation, water quality, and the population of surrounding communities as the cause, the decline of the wood turtle populations was attributed to several mechanisms related to recreationists such as turtle removal, handling by recreationists, and roadkill.

**Amphibians.** While certain human activities, such as habitat fragmentation, have been shown to have negative consequences on amphibian populations (Fahrig, 2002), information specifically on the effect of recreational trails and trail use on amphibians is scarce. It is well known that amphibians are sensitive to environmental changes associated with habitat loss and fragmentation, and may be significantly more vulnerable to road mortality than other species (Fahrig, Pedlar, Pope, Taylor, & Wegner, 1995; Hels & Buchwald, 2001). Contrastingly, von May and Donnelly (2009) observed significantly more frogs and lizards on trails rather than off trails, and others suggest that trail infrastructure may benefit certain species through producing microhabitats (Davis, 2007). Besides this small body of conflicting evidence, relatively little is known about the relationship between amphibians and recreational trails and trail use. No specific empirical literature for the three amphibian species of concern within Gatineau Park could be found – the four-toed salamander, pickerel frog and western chorus frog (see Table 6).

**Table 6:** Information on potential impacts by recreational trails and trail use for amphibians, with information pertaining to roads when relevant.

Common name	Scientific name	Impact
1. Four-toed salamander	<i>Hemidactylium scutatum</i>	No species specific information, but abundance may increase near trails if organic debris are left adjacent to trails.
2. Pickerel frog	<i>Lithobates palustris</i>	No information
3. Western chorus frog	<i>Pseudacris triseriata</i>	Roads effect dispersal. No information on recreational trails and trail use.

**Four-toed salamander.** Terrestrial salamanders increase in density with an increase in woody debris, logs and stones (Grover, 1998). It is therefore not surprising that an increase in availability of woody debris near recreational trails resulted in more salamanders being found adjacent to trails (Davis, 2007). Recreational trails through forested areas are frequently cleared of debris, such as fallen trees. Often, this debris is deposited along the edges of trails. These results, although not negative in nature, suggest that recreational trails can cause alterations in the normal distribution or behaviour of terrestrial salamanders. Although no specific literature could be found on the four-toed salamander, the effect in the aforementioned study by Davis (2007) may have similar repercussions on the salamanders found within the park.

**Insects.** There are six insect species of concern found within Gatineau Park (see Table 7). Four of the species belong to the order Odonata, which contains the dragonflies and damselflies. Three are dragonflies (Cyrano darner, *Naiaschna pentacantha*; eastern pondhawk, *Erythemis simplicicollis*; and extra-striped snaktetail, *Ophiogomphus anomalus*) and one is a damselfly (little glassywing, *Pompeius verna*). The remaining two species belong to the order Lepidoptera, which contains butterflies, moths and ants. Both Lepidopterans are butterflies (monarch, *Danaus plexippus*; and swamp spreadwing, *Lestes vigilax*). Invertebrates were the only group reviewed for which no trace of empirical literature on recreational trail or trail use could be found. This section aims to provide an overview of the magnitude of invertebrates which may face road and vehicle related mortality.

**Table 7:** Information on potential impacts by roads for invertebrates.

Common name	Scientific name	Order	Impact
1. Cyrano darner	<i>Naiaeschna pentacantha</i>	Odonata	No information
2. Eastern pondhawk	<i>Erythemis simplicicollis</i>	Odonata	Reported in the study area of Soluk et al. (2011) but not analyzed. No evidence that roads act as behavioural barriers.
3. Extra-striped snaketail	<i>Ophiogomphus anomalus</i>	Odonata	No information
4. Swamp spreadwing	<i>Pompeius verna</i>	Odonata	No information
5. Little glassywing	<i>Lestes vigilax</i>	Lepidoptera	No information
6. Monarch	<i>Danaus plexippus</i>	Lepidoptera	Throughout the entire state of Illinois during one week, more than 500,000 individuals may be killed on roads.

**Odonata.** Few studies directly investigate dragonfly and damselfly behaviour near roadways, and instead most measure total roadway fatalities. A study in India (Rao & Girish, 2007) collected insect casualties over busy roadways. Of the 1,269 individual insects collected, 61% were various species of dragonflies. At a Lake Huron coastal wetland in Michigan, Riffell (1999) investigated road mortality in a population of dragonflies crossing a highway which separates the necessary wetland habitat from the terrestrial habitat. It was reported that the average daily mortality rate was 87 dragonflies per kilometre per day, with a maximum of 256 casualties documented in a single day.

Soluk et al. (2011) were the first to examine dragonfly mortality and behaviour associated with roadways for a number of species. The eastern pondhawk (*Erythemis simplicicollis*; a species of concern within Gatineau Park) was observed in the study area (Des Plaines River Valley, Illinois), but due to trouble distinguishing between this species and *Pachydiplax longipennis*, the species was not analyzed specifically but rather treated as aggregate data for both species. For all species observed, 58% of individuals in flight were observed over the road and 47% crossed the road to the other side. The estimated mean number of casualties ranged from 2 to 35 dragonflies per kilometres per day. There was no evidence in this study to suggest that roadways act as strong behavioural barriers to dragonflies, as significantly fewer dragonflies would be expected near the roadways (rather than 58%) if roads act as a barrier.

Overall, few studies have observed patterns of dragonfly behaviour in response to roads. Studies that are published have generally collected dead specimens after the collision had taken

place. Nonetheless, such high rates of mortality (e.g., Rao & Girish, 2007; Riffell, 1999) suggest that a better understanding of the behavioural responses of dragonflies to roadways is needed, in addition to an analysis of the factors that contribute to their vulnerability. When considering the construction of a road, placement of roads in critical habitats (i.e., wetlands) or separating habitats (i.e., between a forest and wetland) should be avoided if alternative options exist (Riffell, 1999). For small, isolated or endangered populations of dragonflies, such high losses from road mortality are significant, as small populations are particularly susceptible to extinction.

*Lepidoptera.* No studies were found that directly investigated butterfly behaviour near roadways. However, according to various studies which explored overall roadway casualties, the reported level of road mortality of Lepidopterans is considered low to moderate (Muñoz et al., 2015). Over two active seasons (May-August of 2012/13), insect casualties on a two kilometre stretch of the Trans-Canada Highway included 15 different orders, predominantly pollinators (96%) such as bees, wasps, butterfly, moths and flies (Baxter-Gilbert, Riley, Neufeld, Litzguis, & Lesbarrères, 2015). It was estimated that Lepidopterans are struck and killed at a rate of 10.1 individuals per kilometres per day. The same rate was reported by Yamada, Sasaki, and Harauchi (2010) in northern Japan (~ 10/kilometres/day), whereas the mortality rate was much higher than those seen in southern India (0.5-3/kilometres/day; Rao & Girish, 2007) and much lower than mortality rates reported in Spain (80/kilometres/day; De la Puente, Ochoa, & Viejo, 2008) and southern Poland (47/kilometres/day; Skórka, Lenda, Moroń, Kalarus, & Tryjanowski, 2013).

Extrapolating expected levels of road mortality across a number of landscape scales, Gilbert et al. (2015) estimated that total Lepidopteran road mortality per summer ranged from nearly 500,000 on the two kilometre stretch of the Trans-Canada Highway, 50 million individuals across southern Ontario, nearly 300 million individuals across the Boreal Shield region and over nine billion individuals when extrapolated across the entire North American road network. A similar study estimated that along roadways for the entire state of Illinois, the total number of monarch butterflies killed could exceed 500,000 individuals in one week (McKenna et al., 2001).

Overall, without background population densities and behavioural research, it is not easy to draw conclusions on whether or not road mortalities have a severe negative effect on Lepidoptera populations. Studies that are published have generally collected dead specimens

after the collision had taken place. It is clear, however, that a substantial amount of butterflies will be victims of vehicle collisions, and that the numbers of casualties are potentially staggering (e.g., Baxter-Gilbert et al., 2015; McKenna et al., 2001). It would be necessary to undertake long-term, population level studies to assess the impact of roads on insect populations.

### **Conclusions and Management Implications**

This research paper has evaluated the impacts of recreational trails and trail use on a wide range of taxa and found a similarly wide range of direct and indirect effects, both positive and negative, on the 61 species of concern within Gatineau Park. Although the body of research concerning recreation and wildlife interactions is growing, sizeable knowledge gaps remain. Much of the research on recreational trails has been focused on wide-ranging carnivores and ungulates. However, even for species with the greatest amount of research, the information is inadequate to confidently confirm whether networks of recreational trails in protected areas pose a significant threat to the wildlife populations within. For example, the literature varies as to whether species such as wolves are drawn to, or avoid roads, trails, and other human developments. On one side, there is research suggesting that a wolf population cannot persist in areas with road densities higher than 0.6 kilometres/square kilometres (Mladenoff et al., 1995). Contrastingly, wolves commonly exploit such areas for easy access to human food sources, greater traveling efficiency, and increased access to prey (James & Stuart-Smith, 2000).

Such seemingly contradictory information was not unique to wolves, but was also found for species across a wide range of taxa such as cougars, southern bog lemmings, Blanding's turtles, Canada warblers and a variety of other songbirds. It can be concluded that wildlife reactions to recreational activities and trails are strongly species-specific and context dependent. Factors such as current animal behaviour (e.g., nesting vs. feeding), environmental context (e.g., open vs. forested habitat), recreationist group size, season, and animal age can all make a significant difference in how various animals respond to recreational disturbances, which results in the many cases of contradictory evidence for even relatively well-studied species. Other lesser known, rare, and endangered species would also benefit from additional research on the effects of recreational trails, especially for less mobile species, species with short dispersal distances, short life cycles, or low productivity, as trails may inhibit movement or cause specialized habitat loss. Gathering reliable data in this field can be time consuming and costly, mainly due to the

difficulty of controlling the wide variety of variables that can influence how wildlife react to humans in the wild.

The information gathered in this research paper on 61 species of concern within Gatineau Park will help accomplish two objectives: (1) improve the knowledge base that can be used to evaluate and make informed decisions on trail management and planning initiatives in Gatineau Park, and (2) identify major knowledge gaps and species for which no empirical information related to recreational trails and trail use exists. The information recovered can be used to develop and apply mitigation strategies to address the interactions that have been described for each described wildlife species or species group. In order to make informed decisions on future recreational trail construction, maintenance, or removal, it is suggested that individual species of concern are monitored within the park to explore their unique interactions with recreationists under a variety of differing circumstances (e.g., investigating effects of recreationist group size, activity type, movement speed, and seasonality on wildlife behaviour). Routine monitoring has been identified as an integral part of an adaptive management approach to protected area management. However, monitoring species interactions with recreationists is only a mechanism through which threats can be identified (Theberge, Theberge, & Dearden, 2016), and appropriate measures must be taken to translate these observations into remedial actions.

Once species interactions with recreationists and recreational trails are understood from monitoring programs, various strategies can be developed to mitigate negative impacts of recreational activities. The most common strategy presented in the literature involves spatial separation of recreational activities and sensitive wildlife habitat. New and existing trails should follow existing habitat edges and avoid riparian and forage resources, known nesting and bedding sites, and known wildlife travel corridors. Buffer zones are a tool used to maintain spatial separation between recreational trails and sensitive wildlife habitat. Buffer zones are often based on species-specific flush distances. The flush distances for a variety of species was discovered in the literature; however this information was not available for all species of concern found within Gatineau Park. An additional priority following the spatial restriction of recreational trails and trail use should be to maintain areas that preserve connectivity between the remaining large blocks of habitat that are required for long-distance migrants and species that need undisturbed habitat.

A second strategy involves the temporal separation of recreationists and wildlife at critical time periods. Temporal restrictions of human recreation have been suggested less frequently in the literature when compared to spatial separation, but when used in conjunction with spatial restrictions they have the potential to maintain undisturbed habitat resources for wildlife during important times of the year (e.g., important mating periods or critical winter months). Temporary closures or other visitor restrictions may be necessary at some locations during particularly vulnerable times for some species. There is also strong evidence that predictability in the location and frequency of recreational activities is an important factor in the type and intensity of response that a species will have to human disturbances in the wild, although this area of study could use much more rigorous research. As wildlife often reacts strongest to recreationists who venture off trails, visitors should stay on designated trails to minimize detrimental disturbance to wildlife. This research supports the ongoing efforts to keep visitors to Gatineau Park on the established trail network and off of the proliferating unofficial trail network.

Finally, informational and educational programs can be used to educate the public on the potential negative impacts of recreational activities on wildlife. With an adequate understanding of the potential negative impacts of recreational activities both on and off recreational trails, visitors are more likely to comply with policies and regulations designed to protect species and their habitat (Taylor & Knight, 2003). Thus, education can provide an important role in encouraging appropriate behaviours on trails, increasing the likelihood that visitors will respect spatial and temporal restrictions, while also encouraging visitors to remain on the established trail networks.

Although the interactions between recreational trails and trail use and wildlife species of concern within Gatineau Park appears complex and contradictory in some cases, based on the current body of literature, the effect of recreational trails and trail use on wildlife should not be deemed insignificant or non-existent. The most commonly reported response in the literature of wildlife to recreational trails included displacement and avoidance. However, both short- and long-term impacts of such responses on individuals, populations and communities are not well understood and warrant future research in the field. Although recreational trails and trail use is unlikely to be the primary reason for the species' endangerment within Gatineau Park, it is a

threat worth understanding and investigating on a species-specific basis, as disturbance is taking place in the very protected areas designated to provide protection for these species.

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## Appendix A

### Species of concern within Gatineau Park

#### Mammals [13]

Common name	Scientific name
Cougar	<i>Puma concolor cougar</i>
Eastern pipistrelle	<i>Perimyotis subflavus</i>
Eastern small-footed bat	<i>Myotis leibii</i>
Eastern wolf	<i>Canis lupus lycaon</i>
Hoary bat	<i>Lasiurus cinereus</i>
Least weasel	<i>Mustela nivalis</i>
Little brown myotis	<i>Myotis lucifugus</i>
Northern long-eared bat	<i>Myotis septentrionalis</i>
Red bat	<i>Lasiurus borealis</i>
Silver-haired bat	<i>Lasionycteris noctivagans</i>
Southern bog lemming	<i>Synaptomys cooperi</i>
Southern flying squirrel	<i>Glaucomys volans</i>
Wolverine	<i>Gulo gulo</i>

#### Birds [25]

Common name	Scientific name
Bald eagle	<i>Haliaeetus leucocephalus</i>
Bank swallow	<i>Riparia riparia</i>
Barn swallow	<i>Hirundo rustica</i>
Bobolink	<i>Dolichonyx oryzivorus</i>
Canada warbler	<i>Cardellina canadensis</i>
Cerulean warbler	<i>Setophaga cerulea</i>
Chimney swift	<i>Chaetura pelagica</i>
Common nighthawk	<i>Chordeiles minor</i>
Eastern meadowlark	<i>Sturnella magna</i>
Eastern wood-pewee	<i>Contopus virens</i>
Golden eagle	<i>Aquila chrysaetos</i>
Golden-winged warbler	<i>Vermivora chrysoptera</i>
Grasshopper sparrow	<i>Ammodramus savannarum</i>
Least bittern	<i>Ixobrychus exilis</i>
Loggerhead shrike migrans subspecies	<i>Lanius ludovicianus migrans</i>
Louisiana waterthrush	<i>Seiurus motacilla</i>
Olive-sided flycatcher	<i>Contopus cooperi</i>
Peregrine falcon anatum	<i>Falco peregrinus anatum</i>

**Birds continued**

Red-headed woodpecker	<i>Melanerpes erythrocephalus</i>
Rusty blackbird	<i>Euphagus carolinus</i>
Sedge wren	<i>Cistothorus platensis</i>
Short-eared owl	<i>Asio flammeus</i>
Whip-poor-will	<i>Caprimulgus vociferus</i>
Wood thrush	<i>Hylocichla mustelina</i>
Yellow rail	<i>Coturnicops noveboracensis</i>

**Fish [6]**

<b>Common name</b>	<b>Scientific name</b>
Brassy minnow	<i>Hybognathus hankinsoni</i>
Bridle shiner	<i>Notropis bifrenatus</i>
Margined madtom	<i>Noturus insignis</i>
Rosyface shiner	<i>Notropis rubellus</i>
Stonecat	<i>Noturus flavus</i>
Yellow bullhead	<i>Ameiurus natalis</i>

**Reptiles [8]**

<b>Common name</b>	<b>Scientific name</b>
Blanding's turtle	<i>Emys blandingii</i>
Common map turtle [Northern map turtle]	<i>Graptemys geographica</i>
Milksnake	<i>Lampropeltis triangulum</i>
Northern water snake	<i>Nerodia sipedon</i>
Ringneck snake	<i>Diadophis punctatus</i>
Smooth green snake	<i>Liochlorophis vernalis</i>
Snapping turtle	<i>Chelydra serpentina</i>
Wood turtle	<i>Glyptemys insculpta</i>

**Amphibians [3]**

<b>Common name</b>	<b>Scientific name</b>
Four-toed salamander	<i>Hemidactylium scutatum</i>
Pickerel frog	<i>Lithobates palustris</i>
Western chorus frog	<i>Pseudacris triseriata</i>

**Insects [6]**

<b>Common name</b>	<b>Scientific name</b>
Cyrano darner	<i>Naiaeschna pentacantha</i>
Eastern pondhawk	<i>Erythemis simplicicollis</i>
Extra-striped snaketail	<i>Ophiogomphus anomalus</i>
Little glassywing	<i>Pompeius verna</i>
Monarch	<i>Danaus plexippus</i>
Swamp spreadwing	<i>Lestes vigilax</i>