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Effects of dog leash laws and habitat type on avian and small mammal communities in urban parks

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Abstract Remnant natural areas within urban settings can act as important refuges for wildlife, substantially increasing local biodiversity. However, habitat suitability for these species is potentially affected by human recreational activities including the presence of free-running dogs. To compare the diversity and abundance of songbird and small mammal communities between areas with bylaws that require, or do not require, dogs to be leashed, point counts and live-trapping surveys were conducted in three habitat types (deciduous, coniferous, and meadow) in the river valley parks of Edmonton, Alberta. Among birds, there was no difference between areas with different leashing bylaws in species diversity for any of the three habitat types. Similarly, there was no difference in bird diversity for a subset of species that were plausibly breeding at these sites. However, higher bird diversity was recorded in deciduous and coniferous sites than in meadow sites, regardless of leash designation, probably as a function of the horticultural practice of mowing meadows. Among both birds and small mammals, there was no difference in the abundance of individuals as a function of leashing bylaws. Our results suggest that off-leash dogs have no effect on the diversity or abundance of birds and small mammals in urban parks, but it is also possible that other factors, such as leash law compliance, reduced or obscured the effects of off-leash dogs in this study.

Keywords Urban parks · Dogs · Birds · Small mammals · Wildlife · Diversity · Leashing by-laws

Introduction

In developed countries of the world, 75% of humans already live in urban areas and the worldwide urban population is estimated to be increasing by 175 000 people each day (UN,

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2003). As urban areas expand to accommodate increases in both the human population and urbanization, remaining natural areas are giving way to further anthropogenic development (Searns, 1995). Increasing development in and surrounding cities heightens the value of remaining natural areas, which frequently occur in river valleys and ravines, and large areas of this sort may be capable of supporting several native wildlife species. In the city of Edmonton, Alberta, the North Saskatchewan River valley and several adjacent ravines comprise an enormous urban park system of 7400 ha, renowned as being the largest contiguous area of urban parkland in North America. Much of this area remains in a relatively natural state and appears to sustain a high diversity of wildlife (Mowat, 1993). In the past, city planners have developed park and trail systems within the river valley for a variety of human recreational uses. However, more recently and more generally, urban natural areas are recognised by both city planners and ecologists for their value in the conservation of biodiversity (Clergeau et al., 1998; Fernandez-Juricic and Jokimaki, 2001).

Protecting the biodiversity within urban parks requires that city planners carefully manage the variety of competing pressures on these areas. These pressures arise from high levels of human visitation associated with a number of recreational uses, the presence of both official and unofficial trail systems, and even such things as illegal garbage disposal (Tilghman, 1987). Dog-walking is one of the most common recreational activities in the Edmonton river valley and is conducted by about a quarter of park users (Edmonton Community Services, 2001). To accommodate dog-walkers, the City of Edmonton has designated certain parks and trails as 'off-leash' areas where dog owners are permitted to walk their dogs without a restraining leash. In total, there are 40 such areas in Edmonton, and 14 of these are within the North Saskatchewan River valley. Because the activity of domestic dogs may affect wildlife in urban areas, civic employees were interested in estimating diversity and abundance of small animals that might be most susceptible to dog disturbance in areas with and without leash laws.

A variety of negative effects on wildlife have been documented for domestic dogs elsewhere and these may plausibly apply to the Edmonton area. Most generally, wildlife may be chased or disturbed by dogs as a vestige of their natural hunting instincts (Sime, 1999). Flushing in response to the presence of dogs is a documented and conspicuous response shown by some city-dwelling passerines (e.g., Fernandez-Juricic and Telleria, 2000) and colonial shorebirds (e.g., Mitchell et al., 1988; Lafferty, 2001). Dogs can also cause physical injury (Doncaster, 1994; Shine and Koenig, 2001), nest disturbance (Govan, 1998), and even death (Fuller, 1990). Other effects may be more subtle and less easily observed. As examples, disturbance by dogs can cause energetic loss when it results in an evasive response, increased vigilance, or lost foraging opportunities (Burger, 1986; Fernandez-Juricic and Telleria, 2000). Domestic dogs also have the potential to introduce disease or parasites into urban wildlife populations (Sime, 1999). Finally, the presence of dogs may exert a cumulative effect with other disturbances to reduce habitat suitability (Fernandez-Juricic, 2002).

Because leashing of dogs may reduce some forms of disturbance (e.g., chasing) (Lafferty, 2001), we investigated the effect that dog leash laws have on the diversity and abundance of songbirds and small mammals. These groups are relatively unstudied in this context, yet appear to be both abundant and diverse (in the case of birds) in the Edmonton River Valley (Mowat, 1993). In general, urban bird communities appear to be more influenced by habitat features that occur at a local level than they are by large-scale landscape characteristics (Cleargeau et al., 1998, 2001) and this may be true of fragmented populations more generally (Mazerolle and Villard, 1999). Therefore, off-leash dogs in the Edmonton River Valley, which are officially restricted to designated sites, may affect wildlife on a very small spatial scale. Accordingly, we hypothesized that designated off-leash areas would represent comparatively

poor habitat and would negatively influence diversity and/or abundance of birds and small mammals relative to nearby similar habitat where dogs were required to be leashed within the same urban park system.

Methods

Study area

All census sites were located in the North Saskatchewan River valley and adjoining ravines within the city of Edmonton, Alberta (53° 33′ 00″ N–113° 28′ 00″ W). Within the 7400 hectares of parkland are 190 kilometers of multi-use trails and 22 different park areas. The presence of these amenities attracts an estimated 2 million users annually (Anonymous, 2002).

A total of 56 separate sites were selected within the river valley with an equal number of sites located in areas designated as requiring dogs to be on-leash and off-leash. On-leash sites were defined as sites which either disallowed dogs or required that they be leashed. These areas were also believed by City officials to have high public compliance with leash laws (K. Moore, personal communication). Off-leash sites were in officially designated off-leash areas or, in two cases, were in areas that were designated as on-leash, but were known to experience frequent use by off-leash dogs and their owners (K. Moore, personal communication). Sites were further categorized into three habitat classifications according to the dominant vegetation type: deciduous-dominated, coniferous-dominated, and meadow. Aspen (*Populus tremuloides*), the dominant tree species in the North Saskatchewan River valley, was qualitatively the most common tree species in deciduous-dominated sites (Mowat, 1993) which also contained balsam poplar (*Populus balsamifera*). Coniferous sites were generally located on north-facing slopes or in steep-sided ravines, and were dominated by white spruce (*Picea glauca*). Within meadow sites, we used two habitat sub-types; those that consisted of natural unmowed vegetation (i.e. semi-natural sites) and grassy areas comprised partly or mainly by introduced grass species that are routinely mowed by the City (i.e. manicured sites). We anticipated that manicured sites may have different communities than natural ones, but too few natural sites of sufficient size were available to obtain similar numbers of sites within that habitat alone. The few natural sites that we did find were located in small patches of grassland on south-facing slopes and along the bottom of the river valley. Vegetation cover in the natural sites was comprised of several species of grass (e.g. *Bromus inermis*, *Agropyron* spp., *Festuca* spp.), thistle, and leguminous species (e.g. *Melalotus* spp.) (Mowat, 1993). The distribution of on-leash sites among habitat types was 11 deciduous, 10 coniferous, and seven meadow sites. Within off-leash areas, sampling occurred at 10 deciduous, 10 coniferous, and eight meadow sites. We used 1:10 000 locally-produced orienteering maps to place our sampling sites at the center of target habitat patches and then navigated to them using known reference points. The location of trails was not considered during site selection. The centers of the sites were placed at least 250 meters apart to minimize the possibility of double-counting individuals.

Bird surveys

We conducted bird surveys in all 56 sites a total of three times each between May and July 2002. Surveys were conducted between sunrise and 10 AM and only under calm weather

conditions (wind less than 5 on the Beaufort scale) without significant precipitation. Each site was sampled at a different time on each visit to control for temporal variation.

Each survey involved a 5-minute, 100 m, fixed-radius point count (Bibby et al., 1992) followed by a 5-minute playback (*sensu* Gunn et al. 2000 after Desrochers and Hannon, 1997) of a black-capped chickadee (*Poecile atricapillus*) mobbing call. The chickadee mobbing call is known to attract several bird species that occur within the study area (Hurd, 1996; Gunn et al., 2000) and we used it to increase detection of less vocal species (e.g., woodpeckers) and to provide opportunities for behavioural observations (below). A 5-minute post-playback point count concluded each survey. We recorded all birds that were seen or heard during the 15 min. Birds were only counted if they interacted with the habitat, meaning that birds observed flying over the study site were not recorded. Caution was taken to minimize the chance of double counting individual birds by carefully noting their direction and apparent movement during the census. When possible, we observed individual birds carefully to collect evidence of breeding activity (after Vickery et al., 1992) by taking advantage of the close approaches that typically followed use of the mobbing call (Gunn et al., 2000). Individual bird species were considered to be breeding at a site if we recorded one of the following criteria: (a) a male was singing on at least two of the three visits, or (b) an individual of either sex was seen exhibiting breeding behavior (i.e., traveling in a pair, carrying nesting material, food, or fecal sacs) on any visit (after Gunn et al., 2000).

Small mammal surveys

To accommodate the greater effort that it required, small mammals were live-trapped at a randomly selected subset of 32 of the original 56 sites between mid-July and mid-August, 2002. The distribution among habitat types of the 32 sites was 10 deciduous, 10 coniferous and 12 meadow sites. Twelve meadow sites were selected to allow for equal sampling effort among meadow sub-types (n = 6 of each) and among dog treatments (n = 3 within each meadow sub-type).

Each site was sampled using an array of 10 Victor Tin-Cat® live-, multiple-capture traps placed approximately 20 m apart. The arrangement of traps varied between sites to accommodate local physical features, but was generally comprised by two parallel lines of traps placed greater than 3 m away from either side of a trail. When possible, all traps were placed within the site's point count radius. When this was not possible, traps were placed as close as possible to the point count center and within the same habitat type.

Each site was pre-baited for five nights then trapped for two consecutive nights to permit mark-recapture population estimation (Sutherland, 1996). Three or four sites were trapped per night and these were spread among two or more of the treatment and habitat types to control for seasonal variation in small mammal numbers. Pre-baiting was conducted using pop cans with enlarged openings that were nailed in place and baited with sunflower seeds. To maximize trapping success, traps were placed along woody debris and in other areas likely to be used by small mammals. Traps were covered with plant material to conceal their presence from the public and to provide insulation from both heat and cold. Traps were set in the evenings, baited with a handful of sunflower seeds and dry cat food, and checked the following mornings. During the day between the first and second night of trapping, each trap was locked open and left in place. Traps that were placed in manicured meadow sites were covered with wooden boards for additional protection from the elements.

Following the first night of trapping, each trapped individual was identified to species, sexed, weighed, and marked with a permanent marker at the base of its tail and then released.

The average time it took to process each animal was approximately 1 min. After the second night of trapping the same procedure was followed but no animals were marked.

Statistical analysis

We calculated species diversity using the Shannon-Wiener diversity index (following Krebs, 1994). To examine differences in diversity and abundance among treatments and habitat types, we used parametric tests (ANOVA and *t*-tests) when the data satisfied the assumptions of normality and homogeneity of variance (Sokal and Rohlf, 1981). In some cases the data needed to be transformed to meet these assumptions so the square-root transformation ($\sqrt{Y} + \frac{1}{2}$) was applied (Sokal and Rohlf, 1981). We used Tukey's honestly-significant difference (HSD) statistic to conduct post-hoc, pair-wise tests among ANOVA means (Sokal and Rohlf, 1981). When the assumptions were not met and the data could not be transformed to meet them, we used the non-parametric analogue to a *t*-test, the Mann-Whitney U test.

Results

Birds

In total, 2 203 birds representing 61 species (including two unidentified *picidae* and *interidae* spp.) were counted during the bird censuses. The black-capped chickadee (see Table 1 for scientific names) was the most abundant species, accounting for 30% of all observations. Other common species, each accounting for at least 5% of all observations, were the least flycatcher, red-eyed vireo, red-breasted nuthatch, and yellow warbler.

We examined bird diversity as a function of habitat type and leashing bylaw designation in two ways; by including all birds that were detected and with only those birds that exhibited evidence of breeding. Across all species, bird community diversity differed as a function of habitat (Fig. 1(A); $F = 100.0, df = 2{,}50, P \leq 0.001$), but not as a function of dog leashing bylaws ($F = 1.5, df = 1{,}50, P = 0.23$) or the interaction between leashing bylaws and habitat ($F = 0.6, df = 2{,}50, P = 0.53$). Posthoc tests revealed that bird diversity did not differ between the deciduous-dominated and coniferous habitats (Tukey's HSD $P = 0.85$), but both of these were significantly more diverse than the meadow areas (Fig. 1(A); Tukey's HSD $P \leq 0.001$ for each). These results were qualitatively identical for birds that exhibited evidence of breeding (Fig 1(B)). Again, diversity differed as a function of habitat (Fig. 1(B); $F = 78.9, df = 2{,}50, P \leq 0.001$), but not bylaw designation (Fig. 1(B).; $F = 0.003$, $df = 1{,}50, P = 0.87$) or the interaction between bylaw designation and habitat ($F = 0.06$, $df = 2{,}50, P = (0.60)$. Pair-wise differences between habitats were also similar; breeding bird diversity did not differ between deciduous-dominated and coniferous habitats (Fig. 1(B). Tukey's HSD $P = 0.21$), but both of these habitat types had significantly greater diversity than meadow areas (Fig. 1(B); Tukey's HSD $P \leq 0.001$ for each).

To assess differences in the abundance of birds as a function of leash designation, we compared the maximum number of individuals of all species detected at each site. The average of these abundances differed between habitat types (Fig. 2; $F = 106.2, df = 2{,}50$, $P \leq 0.001$), but not between on-leash and off-leash sites (Fig. 2; $F = 0.004, df = 1{,}50$, $P = 0.95$) or as a function of the interaction between leashing bylaw designation and habitat type ($F = 1.1, df = 2{,}50, P = 0.34$). The effect of habitat resulted in similar differences as before, and meadow sites had approximately 80% fewer birds than deciduous and coniferous-dominated sites.

Table 1 Summary of the number and species of birds detected during censusues

Common name	Latin name	Number of detections during surveys (% of these detections made in OFF leash sites)	
ring-billed gull	*Larus delawarensis*	8 (63)	
ring-necked pheasant	*Phasianus colchicus*	2 (100)	
sharp-shinned hawk	*Accipiter striatus*	3 (33)	
Cooper's hawk	*Accipiter cooperii*	4 (50)	
pileated woodpecker	*Dryocopus pileatus*	8 (50)	
downy woodpecker	*Picoides pubescens*	44 (50)	a
hairy woodpecker	*Picoides villosus*	3 (33)	
unidentified woodpecker	*Picidea*	6 (33)	a
northern flicker	*Colaptes auratus*	1 (0)	
yellow-bellied sapsucker	*Sphyrapicus varius*	2 (50)	
western wood-pewee	*Contopus sordidulus*	2 (50)	
eastern phoebe	*Sayornis phoebe*	5 (40)	
alder flycatcher	*Empidonax alnorum*	3 (33)	
least flycatcher	*Empidonax minimus*	114 (56)	a
American crow	*Corvus brachyrhynchos*	53 (66)	
common raven	*Corvus corax*	2 (0)	
blue jay	*Cyanocitta cristata*	14 (50)	
black-billed magpie	*Pica pica*	56 (43)	
black-capped chickadee	*Poecile atricapillus*	670 (51)	a
boreal chickadee	*Poecile hudsonicus*	2 (0)	
white-breasted nuthatch	*Sitta carolinensis*	47 (45)	a
red-breasted nuthatch	*Sitta canadensis*	148 (45)	a
house wren	*Troglodytes aedon*	12 (33)	a
ruby-crowned kinglet	*Regulus calendula*	13 (46)	a
golden-crowned kinglet	*Regulus satrapa*	8 (38)	a
American robin	*Turdus migratorius*	68 (53)	a
Swainson's thrush	*Catharus ustulatus*	7 (57)	b
hermit thrush	*Catharus guttatus*	1 (0)	b
cedar waxwing	*Bombycilla cedrorum*	10 (70)	a
blue-headed vireo	*Vireo solitarius*	27 (30)	a
red-eyed vireo	*Vireo olivaceus*	141 (57)	a
warbling vireo	*Vireo gilvus*	4 (50)	
black-and-white warbler	*Mniotilta varia*	1 (100)	
Tennessee warbler	*Vermivora peregrina*	11 (36)	b
orange-crowned warbler	*Vermivora celata*	3 (33)	
yellow warbler	*Dendroica petechia*	194 (51)	a
Magnolia warbler	*Dendroica magnolia*	1 (0)	
yellow-rumped warbler	*Dendroica coronata*	31 (19)	a
blackpoll warbler	*Dendroica striata*	7 (71)	
ovenbird	*Seiurus aurocapillus*	13 (38)	a,b
Canada warbler	*Wilsonia canadensis*	2 (100)	
American redstart	*Setophaga ruticilla*	3 (0)	
red-winged blackbird	*Agelaius phoeniceus*	1 (0)	
unidentified blackbird	*Icteridae*	9 (11)	a
northern oriole	*Icterus galbula*	7 (57)	a
western tanager	*Piranga ludoviciana*	31 (48)	a
rose-breasted grosbeak	*Pheuticus ludovicianus*	6 (50)	
purple finch	*Carpodacus purpureus*	5 (40)	a

(*Continued on Next Page*)

Table 1 (*Continued*)

Common Name	Latin Name	Number of detections during surveys (% of these detections made in OFF leash sites)	
pine siskin	*Carduelis pinus*	56 (34)	
red crossbill	*Loxia curvirostra*	6 (100)	
white-winged crossbill	*Loxia leucoptera*	7 (100)	
savannah sparrow	*Passerculus sandwichensis*	54 (52)	a,b
le Conte's sparrow	*Ammodramus leconteii*	8 (63)	a,b
vesper sparrow	*Pooecetes gramineus*	2 (100)	a,b
dark-eyed junco	*Junco hyemalis*	39 (54)	a,b
chipping sparrow	*Spizella passerina*	69 (42)	a
clay-colored sparrow	*Spizella pallida*	63 (43)	a,b
white-throated sparrow	*Zonotrichia albicollis*	60 (55)	a,b
Lincoln's sparrow	*Melospiza lincolnii*	1 (0)	
song sparrow	*Melospiza melodia*	21 (62)	a,b
house sparrow	*Passer domesticus*	4 (50)	
Total detections		2203 (49)	

[a]Species considered to be breeding, within at least one study site (see methods for definition)
[b]Species that nest on the ground or in low shrubs which were thus considered to have potentially greater vulnerability to the effects of urban dogs

We considered the 11 species that nest on the ground or in low shrubs to have potentially greater vulnerability to the effects of urban dogs. Thus, we compared the abundance of these species individually as a function of dog designation and grouped birds by habitat to increase the power of the test (*sensu* Cohen, 1988). Eight species displayed clearly non-significant differences in abundance between on-leash and off-leash sites (Mann-Whitney $U \leq 92.0$, $df = 1$ to 29, $P \geq 0.16$ for each species). The ninth species, the song sparrow, was only marginally non-significant ($U = 9.0$, $df = 7$, $P = 0.08$), but in the unpredicted direction; almost twice as many sparrows were counted in off-leash sites as were in on-leash areas. When subjected to a Bonferroni adjustment to account for the multiple comparisons, all species-specific differences were highly non-significant (adjusted P required for significance (0.0056). There were insufficient data to analyze the two other ground-nesting species (vesper sparrow and hermit thrush) that were counted during the surveys.

In addition to these ground-nesting birds, we also examined differences in the abundance of the five most common forest species encountered during the survey period for which differences may have been more apparent owing to larger values and lower variance (again, *sensu* Cohen, 1988); black-capped chickadee, least flycatcher, red-breasted nuthatch, red-eyed vireo, and yellow warbler). Four species showed non-significant differences in abundance between on-leash and off-leash sites (Mann-Whitney $U \leq 237.5$, $df = 26$ to 42, $P \geq 0.33$). Comparable to song sparrows, red-eyed vireos were 33% more abundant in the off-leash sites than they were in on-leash sites (Mann-Whitney $U = 116.0$, $df = 38$, $P = 0.03$). However, after subjecting the data to a Bonferroni adjustment to account for the multiple comparisons made between species this difference was not significant (adjusted P required for significance (0.01).

Small mammals

Three species were detected in the small mammal census. In order of decreasing abundance these species were the deer mouse (*Peromyscus maniculatus*), red-backed vole (*Clethri-*

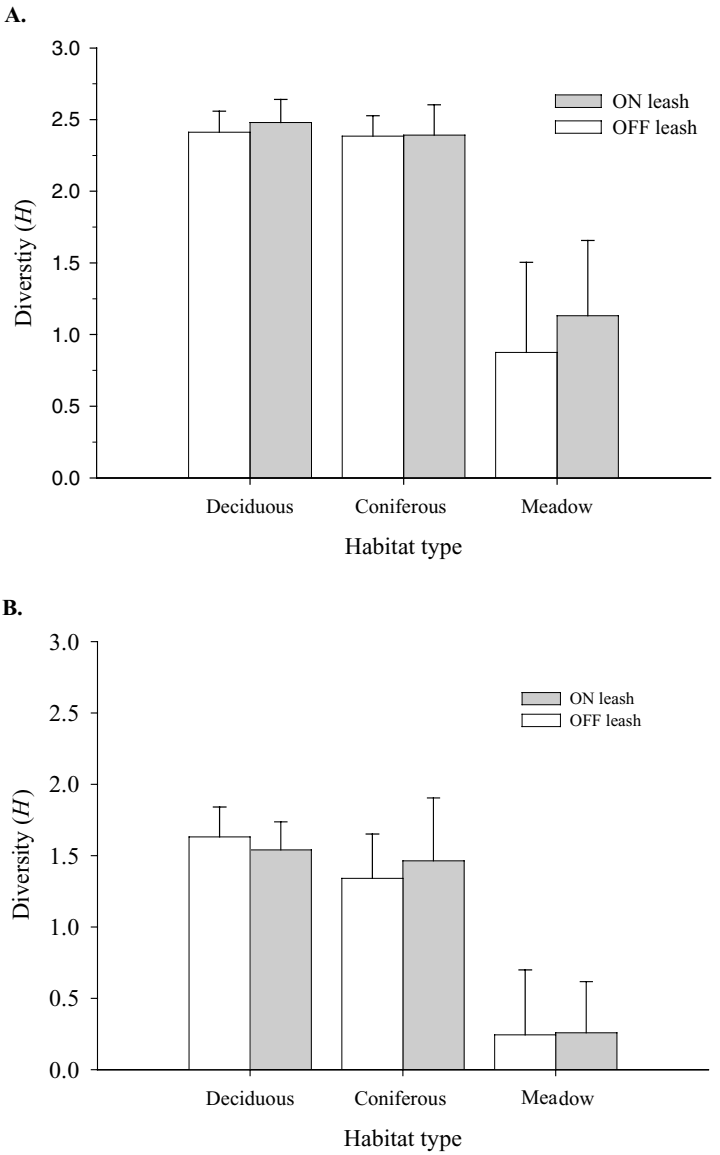

Fig. 1 Shannon-Wiener indices of bird diversity (mean ± SD) across dog treatment and habitat types observed in the Edmonton river valley parks for (A) all bird species recorded during survey period and (B) only those bird species considered to be breeding at a site

onomys gapperi), and meadow vole (*Microtus pennsylvanicus*), comprising a total of 287 individuals. Sixty-one individuals were recaptured on the second night of trapping, bringing the total number of captures to 348.

Abundance was compared using two sources of data; the highest counts per site based on the greatest number of individuals trapped in one night and population estimates derived for each site using the Petersen mark-recapture technique (as described by Sutherland, 1996).

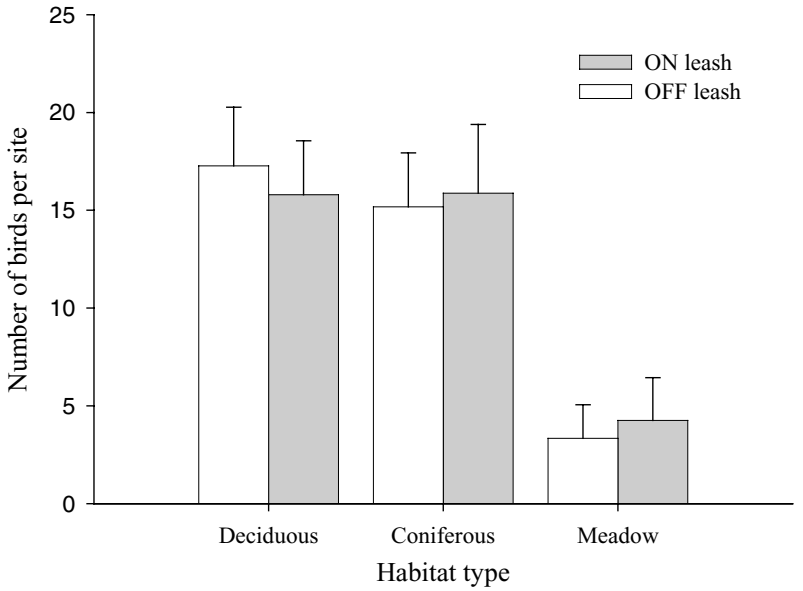

Fig. 2 Average number of birds detected per site (mean ± SD) across all species, treatment, and habitat types in the Edmonton River valley parks

Square-root transformation population estimates of each species were analyzed separately via two-way ANOVA (for deer mice and red-backed voles which occurred in both forested habitat types) and t-test (for meadow voles which occurred only in meadow habitat). For deer mice and red-backed voles, population estimates did not differ as a function of habitat (Figs. 3(A) and (B), $F = 0.003$ and 1.02 respectively, $df = 2{,}9$ and 2,7, $P = 0.96$ and 0.33), leash designation ($F = 0.04$ and 0.64, $df = 1{,}9$ and 1,7, $P = 0.85$ and 0.43) or the interaction between dog treatment and habitat type ($F = 0.63$ and 2.23, $df = 2{,}9$ and 2,7, $P = 0.44$ and 0.16). Meadow voles also displayed a clearly non-significant difference between on-leash and off-leash sites (Fig. 3(C), $t = -0.12$, $df = 2{,}3$, $P = 0.92$). Across all three species, these results were qualitatively unchanged when we made similar comparisons using the maximum one-night capture rate for each site as a measure of abundance.

Manicured vs. semi-natural comparisons

Because the apparent bird and small mammal diversity of meadow habitat differed so strikingly in the field as a function of horticultural practice, we examined these differences with an *a posteriori* analysis. Bird diversity was significantly greater in semi-natural sites than it was in manicured sites ($t = 2.42$, $df = 8{,}4$, $P = 0.04$). However, overall, bird abundance did not differ as a function of horticultural practice ($t = 1.20$, $df = 10{,}9$, $P = 0.26$), presumably because of changes in the composition of the bird community. Predictably, more typically-urban species (i.e. black-billed magpie, American crow, ring-billed gull, American robin, and house sparrow) were found in manicured sites compared to a more native composition of the bird community within semi-natural sites (i.e. savannah sparrow, Le Contes sparrow, vesper sparrow and clay-colored sparrow).

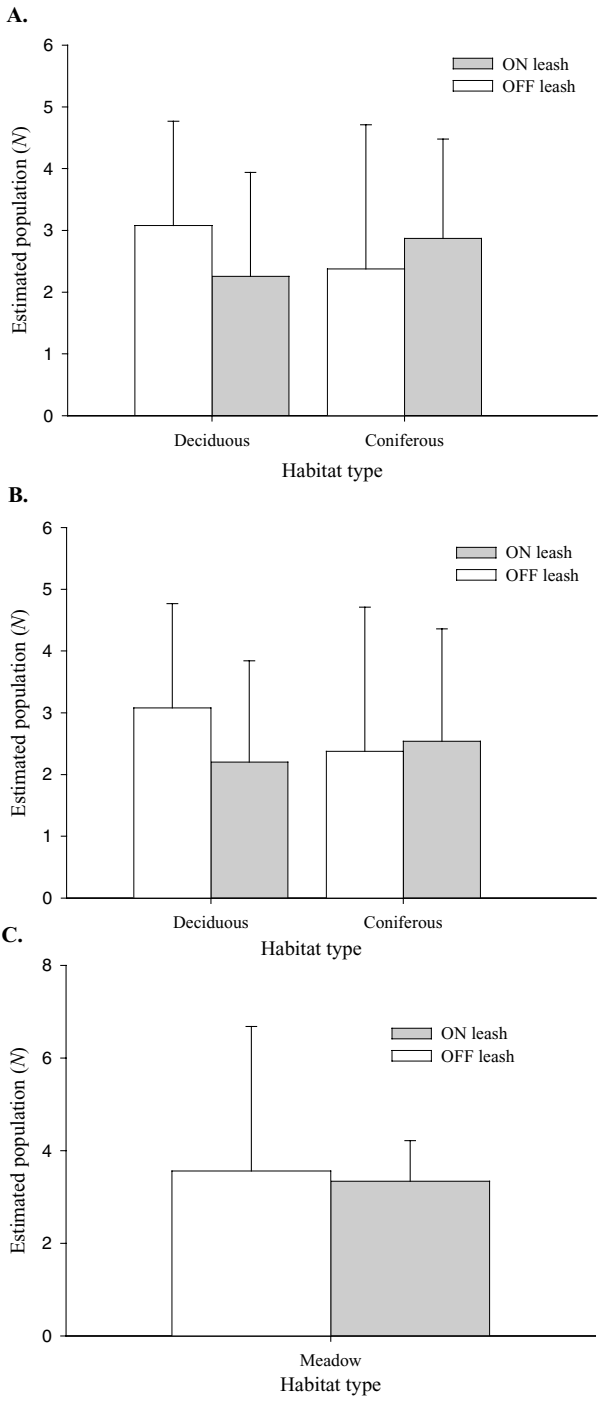

Fig. 3 Estimates of small mammal population sizes (mean ± SD) across treatment and habitat types observed in the Edmonton river valley parks for (A) deer mice and (B) red-backed voles and (C) meadow voles. Estimates were calculated with square root transformed data using the Petersen method of mark-recapture

Small mammal abundance was also higher in semi-natural sites. As many as 11 meadow voles were caught during one night in a single semi-natural meadow site, and the average one-night maximum capture rate was six (only meadow voles were trapped in meadow sites). This average value corresponds to an approximate and average population estimate of 11 individuals per semi-natural meadow site. In contrast, not one individual of any species was caught among all manicured sites during the entire survey period. The lack of variance in this category precludes statistical analysis.

Discussion

Designation of sites for dogs to be on- or off-leash had no measurable effect on the diversity or abundance of birds and small mammals within the sites that we surveyed in the Edmonton River valley. There was a similar lack of difference in bird abundance when we restricted analyses to only those species that appeared to be breeding, only those species that nest on the ground or in low shrubs, and only the most abundant species. These results contrast with some other studies, which reported that many species of wildlife are affected by free-running dogs (Sime, 1999; Lafferty, 2001). We expected that an effect on diversity of leash designation would be apparent at the scale of our censuses because comparable local scales appear more generally to influence the composition of urban bird communities (Clergeau et al., 1998, 2001; Melles et al., 2003). Given that our results did not support our hypothesis that leashing bylaws affect the diversity or abundance of birds and small mammals, there are two types of interpretations for them. In the first category, several factors make it is plausible that free-running dogs do not affect urban birds or wildlife, or not by the measures we employed (diversity and abundance). In a second category, our design may have precluded identifying effects of dogs that really exist.

Consistent with the first interpretation, free-running dogs may not affect birds and small mammals in the vicinity of human use trails because dog activity is restricted to such small temporal and spatial scales that its effects are negligible. Behavioral data suggests that off-leash dogs generally do not travel far off trail, and that when they do it is only for brief periods (Bekoff and Meaney, 1997). By our subjective and anecdotal assessment, dogs in our study area travelled off trail very little, especially in wooded sites, and only slightly more in semi-natural meadow sites. However, dogs did typically stray widely within the manicured meadow sites (AF, personal observation), but in those areas low habitat quality likely overwhelmed our ability to detect differences in diversity or abundance owing to dog activity.

A second biological reason that there was no apparent effect of leashing bylaws is that wildlife, particularly birds, in suburban and urban areas exist there because they are fairly tolerant of moderate levels of human activity (Cooke, 1980), including accompanying dogs. Fernandez-Juricic et al. (2001) have shown that birds can even become habituated to dogs in highly used urban parks. Bird tolerance appears to be highest once territories are established and nesting has begun (Tilghman, 1987) and this corresponds with the timing of our censuses. In fact, moderately perturbed habitats often have greater species richness than do the most natural habitats (Blair, 1996; Tilghman, 1987), perhaps as a function of greater habitat diversity. Thus, the tendency for song sparrows and red-eyed vireos to be more abundant in areas with off-leash dogs may mean that this disturbance somehow improves habitat quality for these species. This supports Mortberg's (2001) assertion that the effect of disturbance from recreation on densities of breeding birds is species-specific.

A third reason that leash designation may not affect birds and small mammals in Edmonton is because these communities may already have responded to the presence of wild coyotes (*Canis latrans*), which are abundant in Edmonton's North Saskatchewan River Valley (Mowat, 1993; Patriquin, 1992). Coyotes are a natural predator of both birds and small mammals (Pattie and Fisher, 1999) and historically occurred in the aspen parkland ecoregion that surrounds Edmonton. The presence of coyotes may reduce the novelty, and hence reaction to, free-running dogs and they may also enhance bird and small mammal communities by reducing the occurrence in ravine parks of domestic cats (Crooks and Soule, 1999).

A second category of explanation for our results is that free-running dogs had negative biological effects on wildlife in our study area, but we were not able to detect them. There are three main ways that this may have come about. The first is that the effect of leash laws was swamped by variation in one or more habitat or site characteristics that exerted greater influences on wildlife diversity or abundance. Among these potential characteristics are landscape structure adjacent to woodlands (Jokimaki, 1999; Melles et al., 2003), habitat structural complexity (e.g., Scott et al., 2003), distance to the nearest trail (Tilghman, 1987; Miller et al., 1998), distance to water (e.g., Tilghman, 1987), level of human activity (Fernandez-Juricic and Jokimaki, 2001), average canopy height (Tilghman, 1987), and the size of censused patches (Crooks et al., 2004). Trail proximity may have particular importance because trails can alter species composition in forest ecosystems (Miller et al., 1998) and both official and unofficial trails are ubiquitous in the Edmonton River Valley. Other studies have shown that bird diversity decreases along a gradient of increasing urbanization (Blair, 1996; Clergeau et al., 1998; Reynaud and Thioulouse, 2000), and such effects could obscure or contradict the potential negative effect of off-leash dogs. During site selection, we did not attempt to measure trail density, proximity to city center, patch size or any of the other habitat characteristics named above, and these may also be profitable subjects of further investigation.

A second reason that we may not have detected existing differences in the diversity or abundance of birds and small mammals is that this effect was confounded by variation in habitat quality between the two leashing designations. In contrast to the majority of the urban parks, it was our subjective impression that the designated off-leash areas within Edmonton were less developed. Parks personnel confirmed that off-leash areas are generally designated in areas where conflicts with a majority of other user types can be avoided (K. Moore and D. Frost, personal communications). Development levels may have an influence on wildlife because of its implications in both biotic and abiotic components of habitat quality. Biologically, less developed parks have increased amounts of vegetative cover (Jokimaki, 1999), and decreased occurrences of exotic species (Blair, 1996). Greater vegetation cover in particular is known to affect both birds (Jokimaki, 1999) and small mammals (Dickman, 1986). More specifically, increased cover can cause birds to show more tolerance towards human-related disturbances (Knight and Temple, 1995). Off-leash areas may also have occurred in areas with greater food availability, particularly for insectivorous species, which may generally be more sensitive to the effects of urbanization (Parsons et al., 2003; Lim and Sodhi, 2004). It would be worthwhile to subject this hypothesis, that off-leash areas occur in areas of higher habitat quality, to further investigation.

A final reason why we failed to detect an impact of leash designation within the urban parks of Edmonton may be that no difference existed in dog behaviour as a function of leashing bylaws. Via personal observation throughout the summer, and through personal communication with City of Edmonton Park Rangers, there is evidence that some people do not comply with leashing bylaws in city parks. Non-compliance may be a widespread problem as Lafferty (2001) also noted low levels of compliance with leash laws by dog

owners on a southern California beach. It is possible that the rate of non-compliance was high enough to nullify functional differences in our leash designation treatments and, consequently, differences in our response variables.

Whether or not there exist effects of off leash dogs on the diversity and abundance of birds and small mammals, dog activity may disrupt several more subtle aspects of wildlife communities that we did not measure. Most importantly, dogs may reduce nesting success (e.g., Gutzwiller et al., 1998), but not species abundance or the frequency of nesting attempts in habitats that ultimately function as sinks for regional populations (*sensu* Pulliam, 1988). For this reason, animal density and abundance may not be reliable indicators of habitat quality as we have implicitly assumed (Van Horne, 1983). In addition, domestic dogs have the potential to impose stress-related physiological effects on wildlife and may introduce diseases and parasites into populations of urban wildlife (Simes, 1999). Finally, dogs may exert greater effects on larger mammals that provide more visible targets for chase (e.g., white-tailed deer [Fuller, 1990; Ballard , 1999], red squirrel, snowshoe hare) that we did not census.

Manicured versus semi-natural meadow sites

Because our sample of meadow habitat included both manicured and semi-natural sites, we were able to show that meadow sites with manicured grass had significantly lower levels of avian diversity and small mammal abundance than did semi-natural sites with non-manicured grass. The abundance of birds at manicured sites also tended to be lower than it was at semi-natural sites, but not significantly so with our conservative multiple-comparison procedure. The lower diversity of birds in manicured sites is probably a function of their decreased habitat suitability as nesting or foraging sites. Because most birds do not forage far from vegetative cover, which they perceive as protection from predators (Giesbrecht and Ankney, 1998; Rodriguez et al., 2001), the lack of vegetative cover in these areas probably compromised both habitat quality and resource availability (Scheiman et al., 2003). Similar limitations of short grass would have afflicted the small mammal community (Jensen and Honess, 1995), explaining the complete lack of mammal detections in this area. Most of the native songbirds in the study area, which are insectivorous, granivorous, or fruitivorous, probably also lacked appropriate forage in the manicured sites. Instead, these sites would have contained the kind of human refuse (i.e. because they are the site of picnics, festivals, and organized sport) that is favoured by the scavenging and urbanized species we found there (e.g., ring-billed gulls, black-billed magpies, American crows, house sparrows and American robins; see also Fernandez-Juricic et al., 2002; Parsons et al., 2003). Our findings support a general expectation that more heavily modified areas are typically dominated by a few species that occur at high densities (Tilghman, 1987; Edgar and Kershaw, 1994; Melles *et al.*, 2003; Fraterrigo and Wiens, 2005), and also suggest that these practices exert far greater effects than the presence of off-leash dogs.

Conclusions

Although this study found no impact of dog leashing by-laws on the diversity and abundance of both birds and small mammals, it would be imprudent to conclude that dogs have no effect on wildlife for the several reasons described above. Among the results of this study, perhaps the most pertinent finding that relates directly to the management of urban parks that are assumed to have much value to resident wildlife (Fernandez-Juricic and Jokimaki, 2001) is

the issue of leash law compliance. The suspected lack of compliance indicates the need for investigation into the reasons why people ignore leashing bylaws so that steps can be taken to improve the situation. The striking effect of horticultural practices on the diversity (birds) and abundance (mammals) suggests an inexpensive solution for increasing biodiversity in urban areas. It is likely that cities could substantially increase biodiversity simply by letting existing green spaces revert to a more natural state (Crooks et al., 2004).

If future research finds that dogs do adversely affect wildlife, there are several measures that might reduce this impact. Increased enforcement and higher fines may increase the effect of leashing laws. Better visual delineation of sensitive areas might be effective to further restrict the spatial impact of dog activity. Finally, city planners might try to identify key habitat features that are elsewhere correlated with wildlife diversity (e.g., structural diversity: Linehan et al., 1967; Tilghman, 1987) and then assess and limit the impact of dogs and other recreational activity on these attributes.

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References

Anonymous (2002) Edmonton smart: Sports and Recreation, http://www.smartcity. edmonton.ab.ca(smart_s&r.html. Accessed June 16, 2003

Ballard WB, Whitlaw HA, Young SJ, Jenkins RA, Forbes GJ (1999) Predation and survival of white-tailed deer fawns in northcentral New Brunswick. J Wildl Manage 63:574–579

Bekoff M, Meaney CA (1997) Interactions among dogs, people, and the environment in Boulder, Colorado: A case study. Anthrozoos 10:23–31

Bibby CJ, Burgess ND, Hill DA (1992) Bird census techniques. Academic Press, London

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

Burger J (1986) The effect of human activity on shorebirds in two coastal bays in the northeastern United States. Environ Conserv 13:123–130

Cleargeau P, Savard JL, Mennechez G, Falardeau G (1998) Bird abundance and diversity along an urban-rural gradient: A comparative study between two cities on different continents. Condor 100:413–425

Clergeau P, Jokimaki J, Savard JL (2001) Are urban bird communities influenced by the bird diversity of adjacent landscapes? J Appl Ecol 38:1122–1134

Cohen J (1988) Statistical power analysis for the behavioural sciences, 2nd edn. Hillsdale, Lawrence Erlbaum Associates, Inc., New Jersey

Cooke AS (1980) Observations on how close certain passerine species will tolerate an approaching human in rural and suburban areas. Biological Conserv 18:85–88

Crooks KR, Soule ME (1999) Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400(6744):563–566

Crooks KR, Suarez AV, Bolger DT (2004) Avian assemblages along a gradient of urbanization in a highly fragmented landscape. Biological Conserv 115:451–462

Desrochers A, Hannon S (1997) Gap crossing decisions by forest songbirds during the post-fledging period. Conserv Biol 11:1204–1210

Dickman CR (1986) Habitat utilization and diet of the harvest mouse *Micromys minutus* in an urban environment. Acta Theriologica 13:249–256

Doncaster CP (1994) Factors regulating local variations in abundance: Field tests on hedgehogs, *Erinaceus europaeus*. Oikos 69:182–192

Edgar DR, Kershaw GP (1994) The density and diversity of the bird populations in three residential communities in Edmonton, Alberta. Canadian Field-Naturalist 108:156–161

Edmonton Community Services (2001) River valley parks and trails summer 2001 user survey

Fernandez-Juricic E (2002) Can human disturbance promote nestedness? A case study with breeding birds in urban habitat fragments. Oecologia 131:269–278

Fernandez-Juricic E, Jokimaki J (2001) A habitat island approach to conserving birds in urban landscapes: Case studies from southern and northern Europe Biodiver Conserv 10:2023–2043.
Fernandez-Juricic E, Telleria JL (2000) Effects of human disturbance on spatial and temporal feeding patterns of blackbird *Turdus merula* in urban parks in Madrid, Spain. Bird Study 47:13–21
Fernandez-Juricic E, Jimenez MD, Lucas E (2001) Bird tolerance to human disturbance in urban parks of Madrid (Spain): Management Implications. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world, Kluwer Academic, Norwell, MA, pp 259–273
Fernandez-Juricic E, Jimenez MD, Lucas E (2002) Factors affecting intra- and inter-specific variations in the difference between alert distances and flight distances for birds in forested habitats. Can J Zool 80:1212–1220
Fuller TK (1990) Dynamics of a declining white-tailed deer population in north central Minnesota. Wildlife Monographs 110, pp 37
Fraterrigo JM, Wiens JA (2005) Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. Landscape and Urban Planning 71:263–275
Giesbrecht DS, Ankney CD (1998) Predation risk and foraging behaviour: An experimental study of birds at feeders. Canadian Field-Naturalist 112:668–675
Govan H (1998) Community turtle conservation at Rio Oro on the Pacific Coast of Costa Rica. Marine Turtle Newsletter 80:10–11
Gunn JS, Desrochers A, Villard M, Bourque J, Ibarzabal J (2000) Playbacks of mobbing calls of black-capped chickadee as a method to estimate reproductive activity of forest birds. J Field Ornithology 71:472–483
Gutzwiller KJ, Marcum HA, Harvey HB (1998) Bird tolerance to human intrusion in Wyoming montane forests. Condor 100:519–527
Hurd CR (1996) Interspecific attraction to the mobbing calls of black capped chickadees (*Parus atricapillus*). Behav Ecol Sociobiol 38:287–292
Jensen SP, Honess P (1995) The influence of moonlight on vegetation height preference and trappability of small mammals. Mammalia 59:35–42
Jokimaki J (1999) Occurrence of breeding bird species in urban parks: Effects of park structure and broad-scale variables. Urban Ecosys 3:21–34
Knight RL, Temple SA (1995) Wildlife and recreationists: Coexistence through management. In: Knight RL, Gutzwiller KJ (eds) Wildlife and recreationists: Coexistence through management and research, Island Press, Washington, DC, pp 327–333
Krebs CJ (1994) Ecology: The experimental analysis of distribution and abundance. 4th edn. HarperCollins College Publishers, New York
Lafferty KD (2001) Birds at a southern California beach: Seasonality, habitat use and disturbance by human activity. Biodiver Conserv 10:1949–1962
Lim HC, Sodhi NS (2004) Responses of avian guilds to urbanisation in a tropical city. Landscape and Urban Planning 66:99–215
Linehan JT, Jones RE, Longcore JR (1967) Breeding-bird populations in Delaware's urban woodlots. Audobon Field Notes 21:641–646
Mazerolle MJ, Villard M-A (1999) Patch characteristics and landscape context as predictors of species presence and abundance: A review. Ecosci 6:117–124
Melles S, Glenn S, Martin K (2003) Urban bird diversity and landscape complexity: Species—environment associations along a multiscale habitat gradient. Conservation Ecology 7:5. [online] URL: http://www.consecol.org/vol7/iss1/art5
Miller CK, Knight RL, Miller CK (1998) Influence of recreational trails on breeding bird communities. Ecological Appl 8:162–169
Mitchell JR, Moser ME, Kirby JS (1988) Declines in midwinter counts of waders roosting on the Dee estuary. Bird Study 35:191–198
Mortberg UM (2001) Resident bird species in urban forest fragments; landscape and habitat perspectives. Landscape Ecol 16:193–203
Mowat C (1993) A natural history inventory of the North Saskatchewan River Valley, North Bank, Groat to Quesnell Bridges. Draft Report, pp. 119
Parsons H, French K, Major RE (2003) The influence of remnant bushland on the composition of suburban bird assemblages in Australia. Landscape and Urban Planning 66:43–56
Patriquin D (1992) The summer and winter biological inventory of Whitemud Ravine Park 1990–91. For: City Wide Programs, Edmonton Parks and Recreation, City of Edmonton, pp. 119
Pattie D, Fisher C (1999) Mammals of Alberta. Lone Pine Publishing, Edmonton, AB, pp. 118–119
Pulliam HR (1988) Sources, sinks, and population regulation. American Naturalist 132:652–661
Reynaud P, Thioulouse JF (2000) Identification of birds as biological markers along a neotropical urban-rural gradient (Cayenne, French Guiana) using co-inertia analysis. J Environ Manage 59:121–140

Rodriguez A, Andren H, Janson G (2001) Habitat-mediated predation risk and decision making of small birds at forest edges. Oikos 95:383–396
Scheiman DM, Bollinger EK, Johnson DH (2003) Effects of leafy spurge infestation on grassland birds. J Wildl Manage 67:115–121
Scott ML, Skagen SK, Merigliano MF (2003) Relating geomorphic change and grazing to avian communities in riparian forests. Conserv Biol 17:282–296
Searns RM (1995) The evolution of Greenways as an adaptive urban landscape form. Landscape and Urban Planning 33:65–80
Shine R, Koenig J (2001) Snakes in the garden: An analysis of reptiles 'rescued' by community-based wildlife careers. Biological Conserv 102:71–283
Sime CA (1999) Domestic dogs in wildlife habitats. In: Joslin G, Youmans H (coordinators) Effects of recreation on Rocky Mountain wildlife: A review for Montana committee on effects of recreation on wildlife, Montana Chapter of the Wildlife Society, pp. 8.1–8.17
Sokal RR, Rohlf FJ (1981) Biometry. W. H. Freeman and Company, New York, pp. 859
Sutherland WJ (1996) Ecological census techniques. Cambridge University Press, Cambridge, pp. 336
Tilghman NG (1987) Characteristics of urban woodlands affecting breeding bird diversity and abundance. Landscape and Urban Planning 14:481–495
United Nations (UN) (2003) Urban and Rural Areas. http://www.un.org/esa/population/publications/wup 2003/2003urban_rural.htm. Accessed November 24, 2004
Van Horne B (1983) Density as a misleading indicator of habitat quality. J Wildlife Manag 47:893–901
Vickery PD, Hunter ML, Wells JV (1992) Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697–705