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A comparison of grey squirrel (*Sciurus carolinensis*) densities between an urban park and semi-rural woodland in Glasgow

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ABSTRACT
This study compared the grey squirrel (*Sciurus carolinensis*) population of a city-centre park with a semi-rural woodland in the City of Glasgow to assess whether grey squirrels were naturally more opportunistic and would therefore exist in higher numbers where human numbers were greater. The study found that grey squirrels were more abundant in the semi-rural woodland where human numbers were lower but there was evidence that the foraging behavior of grey squirrels was influenced by human presence in the city centre park.

INTRODUCTION
There is much debate surrounding the relationship between the grey squirrel (*Sciurus carolinensis*) and the native red squirrel (*Sciurus vulgaris*). The first record of a grey squirrel in Scotland is 1892 (Bryce, *et al*., 2002) and 1911 in Ireland (Lawton, 2003), introduced from North America. The decline of the red squirrel over the last 70 years is observed to coincide with the expansion of the grey squirrels through mainland Britain (Rushton *et al*., 1997) - a similar decline and expansion has been observed more recently in Italy (Bruemmer *et al.*, 1999), and yet there is only speculative evidence to suggest that grey squirrels are responsible for the red squirrel decline (The Mammal Society, 2007). In a study by Bryce, *et al*., (2002) it was shown that the two species even coexist and have done for several years.

Grey squirrels are larger (Kenward *et al*., 1998), appear to have a more variable diet (Lawton, 2003), are opportunists (Gurnell, 1996) and live in more varied habitats than red squirrels (Bryce *et al*., 2002). They also possess immunity to, and can be passive carriers of, the parapoxvirus which afflicts red squirrels (Rushton, 2000). For these reasons grey squirrels may be more successful than red squirrels at the present time. Grey squirrels are becoming more and more numerous in urban areas, much like the red fox (Harris, 1986). It is possible that the grey squirrels have also proliferated as they are better adapted for living in urban areas.

The aim of this study was to investigate grey squirrel abundance in two locations of varying human activity. Based on a pilot study two locations in and near the City of Glasgow were chosen. The hypothesis was that the squirrel abundance would be higher in the city centre park as bird feeders and human activity would provide the animals with easy and stable access to food. This was in contrast to the rural park where the animals would use natural sources of food.

METHODS
Fieldwork was undertaken at Kelvingrove Park (NS 572 664) and Garscube Estate (NS 551 703). The two sites were chosen for their location with respect to the city centre. Kelvingrove (34 ha) is near the city centre and is surrounded almost entirely by tenements, apartment blocks and high rise flats. Garscube Estate (37.2 ha) is on the outskirts of the city, and the surrounding buildings are more predominantly bungalows with accompanying gardens. On one side of the estate there is dense woodland. As a result, the two locations are quite different from one another in terms of visitor numbers. For this reason they were selected as the comparable sites in this study - a busy urban park and quiet semi-rural woodland.

Visual counts along transect lines was chosen as the suitable method for this study (Gurnell *et al*., 2004a). Two transects were selected for each site to provide even coverage of the area and to sample two different habitat types. The total length of the two transects was 1410m and 1350m for Kelvingrove and Garscube, respectively. The transect lines were walked with a set limit of 25m on either side of the line for observation. The total area observed when walking the transect represented approximately 21% of Kelvingrove Park and 18% of Garscube Estate, respectively.

A total of 40 surveys were undertaken between the months of November 2004 and February 2005. Ten surveys were made both during morning and afternoon at both locations. Counts of people were only made on 29 surveys. Transects were not walked in harsh weather conditions, (e.g heavy rainfall, snow) so as to remove weather as a confounding factor. Squirrel behaviour is suppressed somewhat in these unfavourable conditions (Shorten, 1954; personal observations). The morning surveys were undertaken between 9am and 11am, and the afternoon transects between 2pm and 3:30pm.

Squirrels were counted directly from a continual walk along the transect lines, and care was taken not to

count the same squirrel twice. In addition to the squirrel counts a drey count was performed during one of the surveys. Dreys are similar to bird nests but are generally spherical, composed of closely-packed leaves and twigs (Fig. 1). Their location and height in the tree was recorded, using a clinometer (Invicta, IP250, Leicester) as was the total height of the tree and the tree category (see below).

Fig. 1. Squirrel drey in tree, Kelvingrove Park.

The numbers of trees of each type were counted along the transects at both locations. Two types of tree were recorded: deciduous, and evergreen - which included holly (*Ilex acquifolium*) or *Rhodedendron sp*. and coniferous trees. From the observed counts the number of trees per hectare were determined.

RESULTS

Habitat analysis

There was an obvious dominance of deciduous trees in Kelvingrove (second transect) and so this was termed "Deciduous woodland". Similarly the second transect in Garscube showed deciduous dominance. Where the numbers of deciduous were similar to the numbers of evergreen, the habitat was labelled "Mixed woodland" (Table 1).

Human impact

At Kelvingrove 8.3 ± 0.98 people (mean ± SE) were observed in the morning. In the afternoon 9.5 ± 0.97. This compared 2.7 ± 0.49 and 3.4 ± 0.68 people at Garscube in the morning and afternoon, respectively. A two-factor GLM was performed and a significant difference was found between the two sites ($F_{1,116}$ = 52.81, p <0.0001). It is clear that Kelvingrove sees more human visitors at both times of day than Garscube Estate.

Squirrel numbers

The numbers of squirrels observed at both times of day and at both locations were converted to densities using the areas of the transects. In Kelvingrove the mean squirrel density of the area observed was 1.49 ± 0.21 and 1.7 ± 0.24 squirrels/ha in the morning and afternoon, respectively. In Garscube the mean squirrel density of the area was 2.7 ± 0.29 and 1.5 ± 0.25 squirrels/ha in the morning and afternoon, respectively. A three-factor GLM showed that there were significant differences in squirreldensity between locations ($F_{1,72}$ = 5.38, p = 0.023), time of day ($F_{1,72}$ = 5.22, p = 0.025) and habitat type ($F_{1,72}$ = 5.49, p = 0.022), and there was no interaction between these factors ($F_{1,72}$ = 0.33, p = 0.569), (Fig. 2). Overall, Garscube Estate had a significantly higher density of grey squirrels than in Kelvingrove Park with mean densities of 2.7 and 1.7 squirrels/ha, respectively. In Garscube a significantly higher number of squirrels were observed in the morning than the afternoon, and significantly more squirrels were observed in deciduous woodland.

Drey counts

A total of 28 dreys were located (14 in Kelvingrove, 14 in Garscube). This represented 1.99 and 2.22 dreys/ha in Kelvingrove and Garscube, respectively. For Kelvingrove, the mean height of trees supporting dreys was 8.16 ± 0.77 and 9.75m ± 1.27 in Garscube. There was no significant difference in height of dreys above the ground (two-sample t-test = 1.07, p = 0.295) with a mean height of 4.86 ± 0.39 and 5.47 ± 0.45 m, respectively. Dreys were located at similar positions within trees at 63 ± 4.6 and 64 ± 5.9% from the base of the tree in Kelvingrove and Garscube, respectively. Squirrels did not appear to have any preference for deciduous or evergreen trees for drey construction with 46% and 54% found in deciduous and evergreen trees, respectively.

DISCUSSION

Human impact

Approximately three times more people were observed using Kelvingrove Park compared to those recorded at Garscube. Kelvingrove Park is a centrally located urban park surrounded by housing. It is an area of green trees, grass, wildlife and open spaces in a busy industrial city. Garscube Estate is far more rural, attracting mainly dog-walkers and joggers. The surrounding houses each have their own gardens. The trees are more abundant and the paths less managed than the city park, adding to the rustic attraction of the site.

Squirrel numbers

There are several indirect methods for determining squirrel numbers but where individuals are not counted directly estimates are uncertain. Numbers are either over- or under-estimated (Don, 1985). The difference in squirrel numbers between the two habitat types in Garscube indicates that grey aquirrels have a preference for deciduous trees. Grey squirrels prefer broadleaved woodland (Kenward *et al*., 1998; Rushton, *et al*., 2000), although various studies have made differing conclusions (Bryce *et al*., 2001). Rushton *et al*., (1997) suggest "grey squirrels prefer broadleaved, but may occur in conifers, depending on the availability of broadleaved woodland nearby". It would have been advantageous to compare squirrel numbers in well defined habitat types, but the nature of Kelvingrove and Garscube did not allow this.

Location		Length of transect (m)	No. of deciduous trees	No. of evergreen trees	Habitat type
Kelvingrove	Transect 1	420	106	107	Mixed woodland
Kelvingrove	Transect 2	990	97	76	Deciduous
Garscube	Transect 1	530	201	178	Mixed woodland
Garscube	Transect 2	820	58	27	Deciduous

Table 1. Length of transect (m) and tree counts at each site used to determine woodland type.

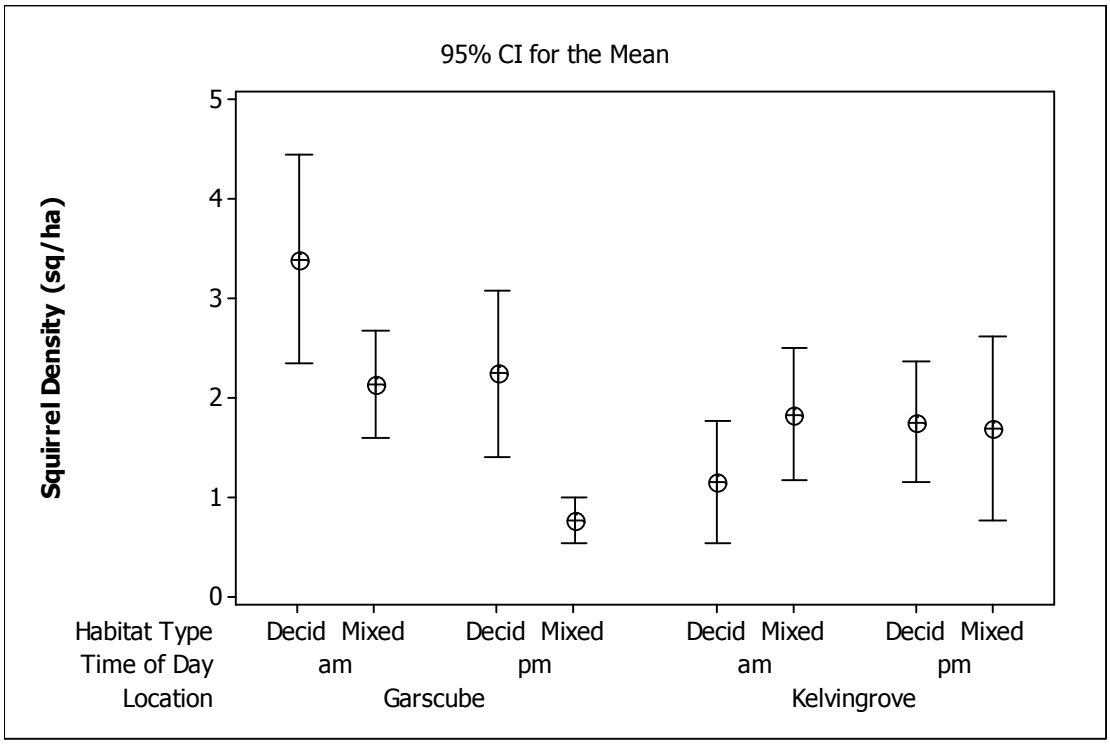

Fig. 2. Interval plot comparison of squirrel densities between sites, times of day and habitat types.

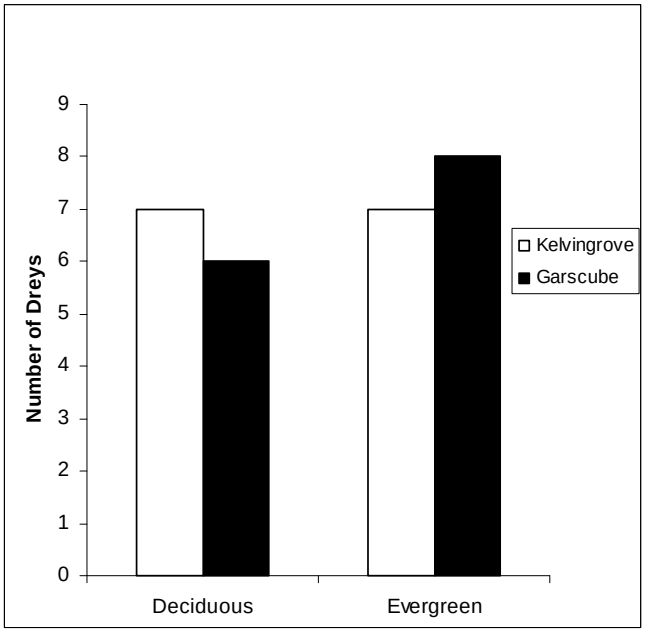

Fig. 3. Frequency of dreys in the different tree types at Kelvingrove Park and Garscube Estate.

It would appear that the Garscube squirrel population is not divided between habitat types and occurs readily in both, although, population estimates are dependant on time of day. In the afternoon there were fewer in the mixed woodland than in the deciduous woodland, although in the morning the numbers were relatively similar.

Overall in Garscube more squirrels were observed in the morning than in the afternoon, although in Kelvingrove the density is similar at both times of day. This may be reflective of increased human activity in the afternoon at Garscube.

Shorten (1954) suggested that squirrels are attracted to quieter areas when foraging. This is supported by this study as there was a significantly higher density of squirrels in Garscube compared to Kelvingrove Park. However, it was observed that the behaviour of the squirrels differed in the two locations. In Kelvingrove Park squirrels were seen to approach humans and took food from their hands, whereas in Garscube Estate their behaviour was the complete opposite. They actively moved away from humans and took refuge in high branches until they could continue foraging undisturbed (personal observation).

Drey counts are another frequently used method for estimating squirrel abundance (Gurnell, et al, 2004), although Shorten, (1954) considers that "drey counts would be a misleading index of squirrel abundance". It is unsurprising that the total number of dreys observed in this study does not differ between the two sites as visual counts were reasonably similar.

No significant difference was found between the height of the trees chosen in Kelvingrove and Garscube. The proportional height of the drey in the tree was deemed a more useful variable to analyse, as it took tree-height away as a confounding factor. There was no preference for height, and it is more likely that deciding factors for drey-construction include availability of materials and tree structure itself as dreys require a sturdy fork in a branch for stability.

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