Urban Forestry & Urban Greening 27 (2017) 100–108

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

The role of urban habitats in the abundance of red squirrels (*Sciurus vulgaris*, L.) in Finland

Jukka Jokimäki[a,*], Vesa Selonen[b], Aleksi Lehikoinen[c], Marja-Liisa Kaisanlahti-Jokimäki[a]

[a] Arctic Centre, University of Lapland, P.O. Box 122, 96101-FI Rovaniemi, Finland
[b] Department of Biology, 200014-FI, University of Turku, Finland
[c] Finnish Museum of Natural History, P.O. Box 17, 00014-FI, University of Helsinki, Finland

ARTICLE INFO

Keywords:
Winter feeding
Mammals
Monitoring
Predation
Urbanization
Citizen science

ABSTRACT

Because the amount of urban areas has increased, it is important to investigate the abundance of wildlife species in relation to urban environments. Analyzing the impact of urbanization on the presence of forest-dwelling mammals is of interest due to the possible effects of urbanization on human-wildlife relationships and urban biodiversity. The Eurasian red squirrel (*Sciurus vulgaris*) is a declining forest species, and its occurrence in urban environments has been inadequately studied. The loss and fragmentation of forests due to urbanization may be detrimental for squirrels, whereas the abundant and predictable food resources and the low number of natural predators in urban areas may encourage squirrels to invade towns. We used large-scale data collected by volunteer bird watchers along a 950 km south-north gradient to study whether the winter abundance of squirrels in Finland is dependent on urbanization, while controlling for effects of habitat type, food abundance (spruce cone crop; number of winter feeding sites), predator abundance (northern goshawk, *Accipiter gentilis*; feral cat *Felis catus*), season and latitude. We found that squirrel abundance increased with human population density, number of feeding sites and spruce cone crop and decreased with latitude and season. Feral cats showed weak negative connection with squirrel numbers, but there were no effect of goshawks. Relative squirrel abundance was approximately twice as high in urban habitats than in forests. Artificial feeding rather than a low number of predators may attract squirrels in urban environments. Planting spruce trees in urban environments will also benefit squirrels. Our results indicate that urban areas are an important habitat for the red squirrel even along the northern edge of their distribution range, where natural forest areas are still widespread. We conclude also that a citizen science −based bird survey protocol associated with mammal surveys seems to be a good large-scale monitoring method to study the urbanization of squirrels.

1. Introduction

Globally, more people now live in urban than in rural areas, and at the same time, urbanized areas are increasing at an even higher rate than the urban population (UN, 2014). According to Seto et al. (2011), global urban land cover will increase approximately 30-fold by 2030. Therefore, understanding the impact of urban development on animal populations is important due to the possible effects on biodiversity and human-wildlife relationships (Baker and Harris, 2007; Bateman and Fleming, 2012). Urbanization is one of the most extreme forms of land-use alteration, and only remnants of the original habitats persist in towns. At the same time, urban areas are characterized by high levels of predictable anthropogenic food resources and human-caused disturbances (e.g., traffic), milder microclimates, and an altered abundance of predators (e.g., Rebele, 1994; Shochat et al., 2006; Gilbert, 2012; Francis and Chadwick, 2013; Tryjanowski et al., 2015).

Urbanization is globally recognized as one of the main threats to biodiversity (Wilcox and Murphy, 1985). An important challenge for urban ecology is to conserve species that live in urban environments. In addition, most of the contacts between people and nature occur in urban environments, and citizen views related to conservation are formed in urban environments (Lepczyk and Warren, 2012; Shanahan et al., 2014). Urban mammals have been used by urban inhabitants for aesthetic, biological and recreational purposes (Adams, 2016). Unfortunately, mammalian diversity generally decreases with urbanization (McCleerly, 2010). However, the behavioral flexibility of individuals and increased human tolerance might favor the urbanization of some species (Baker and Harris, 2007; McCleerly, 2010; Lowry et al., 2012).

Natural environments that are modified by human activities possess

* Corresponding author.
E-mail address: jukka.jokimaki@ulapland.fi (J. Jokimäki).

http://dx.doi.org/10.1016/j.ufug.2017.06.021
Received 16 December 2016; Received in revised form 28 June 2017; Accepted 29 June 2017
Available online 30 June 2017
1618-8667/

challenges to native animals. During recent decades, many new mammalian species, such as the European red fox (*Vulpes vulpes*, L.; Francis and Chadwick, 2012), raccoon (*Procyon lotor*, L.; Adams, 2016), and Eurasian badger (*Meles meles*, L.; Harris, 1984) have colonized urban areas. Some of them (e.g., the red fox) currently have even higher densities in urban areas than in their natural habitats (Bateman and Fleming, 2012). However, only a few mammal species, such as the brown rat (*Rattus norvegicus*, Berkenhaut) and the house mouse (*Mus musculus*, L.), are abundant in town centers (Gilbert, 2012).

Urban areas have some features, such as stable and abundant food resources and low numbers of natural predators that may attract wildlife and promote, for example, the urbanization of squirrels (Francis and Chadwick, 2013; Adams, 2016). Artificial feeding stations and waste offer easily available food resources, especially to species feeding on seeds or having a generalist diet (Adams, 2016). Although feeders in gardens are primarily designed to feed birds, they also attract squirrels in urban areas, especially during the winter when food resources may become scarce in forest habitats. In general, urban areas contain a lower number of larger natural predators than do rural areas (Bateman and Fleming, 2012), but the abundance of medium-sized carnivores might be even higher in urban environments than in more natural environments (Nilon and Pais, 1997; Baker and Harris, 2007; Bateman and Fleming, 2012). However, at the same time, urban squirrels may be more vulnerable to predation by domestic cats than are squirrels living in rural and forest areas (Wauters et al., 1997; Shuttleworth, 2001; Magris and Gurnell, 2002). It is likely that there is an optimal level of human influence at which the living requirements for a species are best met or limit the level of urbanization that a species can tolerate (Francis and Chadwick, 2013; Adams, 2016). However, the roles of artificial food and the number of predators promoting the urbanization of squirrels are still not well known.

Arboreal squirrels (*Sciurus* spp.) are strictly dependent on forests. Therefore, they might be sensitive to the forest loss caused by urbanization. However, urban areas also contain different types of green spaces, such as remnant habitat patches, cemeteries, public parks and the gardens of residential areas, which may be suitable living environments for many forest species (Adams, 2016). For example, squirrels can also inhabit fragments of forests within the urban matrix (Verboom and van Apeldoorn, 1990; Baker and Harris, 2007; Babińska-Werka and Żółw, 2008; Parker and Nilon, 2012; Mäkeläinen et al., 2015; Fey et al., 2016). The red squirrel (*Sciurus vulgaris*, L.) is a native forest specialist species in most European countries, and although the species still is common throughout most of its range (Gurnell and Wauters, 1999), its current population is declining in many parts of Europe (Gurnell and Pepper, 1993; ÓTeangana et al., 2000; Bertolino and Genovesi, 2003; Shar et al., 2008; Selonen et al., 2010). Most previous red squirrel studies were conducted within forest or agricultural areas and considered the effects of fragmentation on the red squirrel at a relatively small local scale. These studies indicated that red squirrel occurrence and abundance increase with woodland size (Celada et al., 1994; Verbeylen et al., 2003) and the area of woodland covered by coniferous trees (Verboom and van Apeldoorn, 1990) but decrease with the distance from the nearest source area (Verboom and van Apeldoorn, 1990; Celada et al., 1994; Verbeylen et al., 2003).

Only a few red squirrel studies have been conducted within urban areas despite the fact that the species is currently quite common in urban habitats in Europe (Luniak, 2004; Babińska-Werka and Żółw, 2008). One local study conducted in Brussels indicated that patch size and patch quality have positive effects and that isolation has a negative effect on red squirrel patch occurrence in urban areas (Verbylen et al., 2003). A study in Warsaw parks also indicated that park size positively affects red squirrel abundance (Babinska-Werka and Zolow, 2008). However, large-scale studies with multiple study sites and covering different habitats are needed to better understand the urbanization process of red squirrel. In addition, as squirrels are important dispersal agents of seeds (Steele, 2008), they may also impact on distribution of urban trees. Therefore, it is important to know how urbanization influence squirrel abundance.

The main aim of this study was to analyze how human density affects the winter abundance of red squirrels throughout Finland. The analysis included also habitat type, natural (size of the Norway spruce cone crop) or artificial (number of feeding sites) food abundance, and natural (northern goshawk, *Accipiter gentilis,* L.) or human-associated (feral cats, *Felis domesticus*, L.) predator abundance. In addition, we also studied whether latitude and the time of the winter season affect the squirrel abundance. We conducted our study during the winter season because winter is a critical period for the survival of squirrels in the northern latitudes (Selonen et al., 2015), and because due to the lack of leaves in the broad-leaved trees, the detectability of squirrels is high during winter (Hernández, 2014). We predicted that if squirrels somehow benefit from humans, then their abundance should increase with human density and should be higher within urban than other habitat types. If food resources, either artificial or natural, have an effect then squirrel abundance should increase with the number of feeding sites or with the size of the Norway spruce cone crop. If squirrel winter abundance is dependent on predators, then their abundance should change with predator abundance. Because the severity of winter increases toward the north, we predicted that red squirrel abundance would decrease from the south to the north. Due to winter mortality, we predicted that squirrel abundance would decrease during the winter. However, the squirrel abundance could also increase towards to the spring, because the visibility of squirrels increases due their early-starting mating season.

2. Methods

2.1. Study area

The study was conducted in Finland along an approximately 950 km south-north gradient (Fig. A1 in Appendix A; between 59°50′ and 68°40′ N and 19°40′ and 30°20′ E). The human population of Finland was 5.5 million in 2014 with a mean population density of 18/km^2 (Statistics Finland, 2015). The majority of the human population is concentrated in the southern part of the country (approximately 170 inhabitants/km^2), whereas the population density is the lowest in the north (approximately 0.2 inhabitants/km^2; Statistic Finland, 2015). Approximately 78% of the total area of Finland (390,906 km^2) is land covered (Statistics Finland, 2015), and approximately 77% of this is forests, 9% is agricultural areas and only 4% is built-up areas. Almost the entire country belongs to the boreal taiga forest terrestrial biome, where forests are dominated by coniferous trees. The study area lies within the cool boreal climate zone.

The study was conducted during the winter season. The average monthly temperature during mid-winter in December 2014 (study year) was −1.3 °C (1981–2010 long-term average −3.2 °C) in southern Finland (Helsinki) and −8.4 °C (−11.7 °C) in northern Finland (Sodankylä; Finnish Meteorological Insitute, 2014). The corresponding amounts of snow cover on the 15th of December were 4 cm (1981–2010 long-term average 6 cm) in Helsinki and 32 cm (1981–2010 long-term average 36 cm) in Sodankylä. The coniferous tree cone crop, the primary food of the squirrels, was moderate during the studied winter (Finnish Museum of Natural History, hereafter FMNH).

2.2. Study species

The red squirrel occupies the boreal and temperate areas of Eurasia and is mainly a coniferous forest specialist (Shar et al., 2008). Individuals live in the same home ranges throughout the year, although they may move between habitats depending on the food situation (Wauters and Dhondt, 1992). In Finland, urban squirrels were first observed in the southern part of the country in the cities of Helsinki and Turku in the early 1930s (Haapanen, 1999).