Landscape and Urban Planning 169 (2018) 269–275

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research paper

Habitat and nest use during natal dispersal of the urban red squirrel (*Sciurus vulgaris*)

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A R T I C L E I N F O

Keywords:
Urban ecology
habitat selection
habitat choice
radio tracking
animal movement

A B S T R A C T

As urban environments differ from the natural environment, the ability of a species to move in and use variable land composition types determines its fate in the urban environment. In many mammalian species, the selection of home ranges mainly occurs during natal dispersal. Thus, habitat selection of juvenile individuals greatly determines where animals are found in the city. Here, our goal is to understand how an originally forest-dwelling rodent selects components of an urban habitat. We used radio telemetry to record the habitat and nest use of Eurasian red squirrels (*Sciurus vulgaris*) in the city of Turku in southwestern Finland, with the main focus on habitat use during natal dispersal. We found that although the red squirrels preferred areas with more trees available than in the surrounding urban landscape they nevertheless often used sites with only a few trees. This result was highlighted by the analysis of the home range scale, as the area used did not differ greatly from the habitat composition of the available landscape. Juvenile red squirrels used the deciduous land cover type more often during movements in the natal area than during dispersal and explorative movements; however, they also settled in areas with less deciduous land cover type than in the natal area. Our results show that in urban areas movements of red squirrels are not restricted to their natural habitat type, which is a coniferous forest, but that they seem to be well adapted to urban areas, being able to utilize urban structures.

1. Introduction

Urban environments generally differ greatly from species natural environment. Urban landscapes consist of several land composition types and are extremely fragmented so that semi-natural areas are divided by roads and buildings. Roads can be an important cause of mortality in urban mammals (Lowry, Lill, & Wong, 2013, but see Fey, Hämäläinen, & Selonen, 2016) and natural nest sites are usually rare or entirely lacking for some species in urban landscapes (Rytwinski & Fahrig, 2012; Verbeylen, Bruyn, Adriaensen, & Matthysen, 2003). However, species often also benefit from urbanization through lack of natural predators and increased amounts of resources (Adams, 2016). Indeed some mammals may have even higher densities in urban areas than in their natural habitats (Bateman & Fleming, 2012). Mammals adapted to urban areas are usually generalists and used to human induced interference (McCleery, 2010).

In addition to direct effects through habitat loss and traffic mortality, human presence and infrastructure can also indirectly affect behavior and movement patterns of animals (Latham, Latham, Boyce, & Boutin, 2011). For example, individuals may show behavioral adjustments to urban environments and disturbance, such as spatial and temporal changes in feeding and movement patterns to avoid areas or periods of high human activity (Dowding, Harris, Poulton, & Baker, 2010; Lowry et al., 2013). In general, home range sizes are observed to be smaller in urban areas compared to their rural counterparts (Šálek et al., 2015). This is thought to arise from there being more stable food resources in an urban environment (Lowry et al., 2013), but may also be related to a decrease in movement ability in fragmented urban landscapes. Indeed, the ability of a species to move within a landscape and use its various features affects the species adaptability to urban environments. For example, although roads can act as barriers for Eurasian hedgehogs (Rondinini & Doncaster, 2002), they are not important barriers for dispersing Eurasian red squirrels (Fey et al., 2016). Thus, the occurrence of a species in fragmented urban landscapes is determined by its ability to move and the flexibility of its habitat use.

Movement ability and habitat selection are linked, since the selection of a future home range mainly occurs during dispersal; in mammals, this is usually during natal dispersal, when juvenile individuals move away from their mother's area to find their own home range (Clobert et al., 2001; Wolff, 1994). Habitat selection during natal dispersal therefore determines where animals are found in the city. Movement behavior during dispersal often differs from the movement

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http://dx.doi.org/10.1016/j.landurbplan.2017.09.011
Received 4 August 2016; Received in revised form 8 August 2017; Accepted 13 September 2017
0169-2046/

of individuals in their home range (Fey et al., 2016;Selonen & Hanski, 2006, 2010;van Dyck & Baguette, 2005), and there may also be individual differences in behavior during natal dispersal (Dingemanse, Both, van Noordwijk, Rutten, & Drent, 2003). In addition, habitat selection can be scale dependent as well (Ciarniello, Boyce, Seip, & Heard, 2007; Mateo Sánchez, Cushman, & Saura, 2014). For example, at the scale of nest sites certain elements of the habitat may be preferred, but at the level of the whole home range certain other habitat characteristics may be important. Although habitat use and dispersal have been studied to some extent, dispersal remains a process rarely studied in urban environments (but see Fey et al., 2016).

In this study, we investigated the habitat selection of small mammals in an urban environment, by using dispersing Eurasian red squirrels (*Sciurus vulgaris*), hereafter referred to as red squirrels, as a model species. The red squirrel is a diurnal arboreal rodent, which nests mostly in twig dreys, but also in cavities and nest boxes (Lurz, Gurnell, & Magris, 2005; Shuttleworth, 1999). It is widely distributed in the temperate and boreal forested areas of the whole of Eurasia, but has also become common in urban areas. Conifer seeds are the main food item of red squirrels (Andrén & Lemnell, 1992;Rajala & Lampio, 1962), but during the summer months red squirrels also feed on tree buds, the sap of broadleaf trees, berries, fruits, mushrooms, insects, bird eggs and nestlings (Lurz et al., 2005; Rajala & Lampio, 1962). The main dispersal period for the red squirrels is from summer to autumn, when juveniles born in the spring or early summer move to their own home range and settle there (Lurz et al., 2005; Wauters, Casale et al., 1994). In northern boreal forests, red squirrel densities are highest in mature spruce dominated forests (Andrén & Lemnell, 1992). The first records of red squirrels in the city centers of Finland are from the 1930s, and since then the number of red squirrels in urban areas has been gradually increasing (Haapanen, 1999).

Our goal is to understand how an originally forest-dwelling rodent chooses habitats and is able to move in an urban landscape. We have therefore: I) determined the habitat use of dispersing juvenile red squirrels in an urban built environment at a scale of a) squirrel locations and b) home ranges; II) establish whether habitat use differs between movements before dispersal in the natal home range, movements during exploration and dispersal, and movements within the settlement home range; III) examined what kind of nests the red squirrels (juveniles and adult females) use, as well as what kind of landscape features are selected for around nest sites in the urban landscape, where natural nest sites might be limited.

2. Materials and methods

2.1. Study area and data collection

We studied movements of Eurasian red squirrels in the inner city areas of Turku (180 000 inhabitants), in Southern Finland (60°27′05″N, 022°16′00″E). The landscape consists of heavily built grid plan areas (buildings form ‘blocks'), public gardens, and fragmented park areas. Most of the park areas consist of deciduous trees; Scots elm (*Ulmus* glabra) and lime tree (*Tilia* sp.) being the dominant species. Coniferous trees of the area are mostly Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*).

During the period 2012–2014, we collared and monitored 38 red squirrels, 32 of which were juveniles. We captured juvenile red squirrels at an approximate age of 1.5 to 2 months (178 ± 48 g). We trapped red squirrels on the ground by using live traps, or from their nest box or cavity by using nets, and equipped them with radio collars designed for small mammals (Biotrack, UK). The collars weighed approximately 5 or 8 g, depending on the weight of the squirrel, so that the weight of the collar was a maximum of 7% of the squirrels' body weight. Kenward (1982) has shown that collars with 4–7% of body weight do not have an effect on Eastern gray squirrels (*Sciurus carolinensis*). After collaring, we immediately released the squirrels at the place of their capture.

We followed the red squirrels with portable receivers (Biotrack sika) and 3-element Yagi antennas approximately five times a week from early June to late September (resulting in an average of 62.6 ± 6.9 locations per individual). During active dispersal movements, the red squirrel locations were recorded more frequently (at least daily, but often several times a day; however, within one day only one location was recorded, unless the individual performed potential dispersal movement). We continued radio tracking throughout the following winter with tracking intervals of one to two weeks. Red squirrel locations were obtained during the daytime, while nest sites were located mainly after dusk. Each individual location was determined by walking under a single tree or a group of trees where the animal was located. We recorded the location of an individual by using either a portable GPS device or a map, e.g. if the squirrel was in the middle of buildings or in a private yard. Radio tracking was continued until the transmitter battery failed or the death of the animal. From 32 juvenile individuals tracked, 23 survived until the end of the dispersal, and of these we were able to recapture 12 to remove the collar. As regards the remaining individuals, the battery of the radio collar ran out and we were unable to locate the individuals.

2.2. Data acquisition and spatial analyses

In order to calculate land cover classes, we created a land composition map by placing the red squirrel location points on a map with an aerial orthophotograph (National Land Survey of Finland, 2008, ETRS-TM35FIN, terrain resolution: 0.5 m) of the study area using ArcGis 10.1 (ESRI 1999–2012, Redlands, CA). The land cover map was constructed by manually digitizing different land cover areas from the aerial photograph onto a map with a scale of 1:800 and a minimum mapping unit of 1 m. We divided the landscape into six different land cover classes: deciduous trees, coniferous trees, shrub or grass, waterway, building, and asphalt or gravel/sand (hereafter referred to as “asphalt”).

First, we studied the habitat use by red squirrels at the scale of the squirrel locations (third order selection sensu Johnson, 1980) with 10 meter radius buffers around each squirrel location. Within these buffers, the proportion and area of every land cover category was calculated using Python script for ArcGis and FRAGSTATS v4. We compared the land cover around each red squirrel location to the land cover in the available locations, which were defined for each squirrel tracking location. The available locations were 100 random 10 m radius buffers placed within a circle with radius of 100 m around each squirrel location. We selected the size of the available area based on the average daily movement distance of the red squirrels (being approximately 100 m in our data). The average area and proportion of each land cover class were calculated from the 100 random buffers and this was repeated for all squirrel locations.

After investigating habitat selection at a local scale, we examined red squirrel habitat selection at the scale of home ranges (second order selection sensu Johnson, 1980). We compared the habitat within the natal and settlement area to the habitat available within our study area. To define the available area, we calculated 400 m radius buffers around each red squirrel location and then merged all the buffers into one polygon. A 400 m radius was selected to describe the average dispersal distance of the study squirrels. We calculated the available land cover by creating 1000 random points with 110 m radius buffers within this available area. A 110 m radius buffer formed an area equivalent to the average size of red squirrels' natal and settlement areas (being 3.9 ha). For juvenile red squirrels, we calculated the natal and settlement areas separately by using 100% minimum convex polygon (MCP) for observations of that phase. Only settlement areas of juvenile red squirrels that survived long enough to clearly settle were included in the analysis, thus the 10 dispersed individuals, the 13 philopatric individuals and the 9 individuals that did not survive at the end of the dispersal period, lead, in total, to 32 natal areas and 10 settlement areas. In five