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Original article

Effects of roads on fruit crop and removal rate from rowanberry trees (*Sorbus aucuparia*) by birds in urban areas of Finland

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ABSTRACT

Roads destroy natural habitats. To reduce erosion, support wildlife and decorate surroundings, ornamental trees are planted near the roadside. However, it is inadequately understood how roads influence fruit production of trees and birds that consume their fruits, within urban landscapes. During the autumn and winter of 2012–2013, we studied the extent to which birds used the fruit from rowanberry trees (*Sorbus aucuparia*), in two cities along a 700 km latitudinal gradient in Finland. In matched pair design (total of 35 pairs), we compared roadside trees (approximately 8 m from main roads) with trees grown away from roads (control trees; approximately > 80 m from the roads). During the autumn, each rowanberry tree pair was photographed, and frugivorous birds were surveyed twice per month until all of the rowanberry fruit-crop was consumed. There was no difference in fruit crop size between roadside trees and control trees. A total of eight frugivorous bird species and 960 individuals were observed foraging in roadside trees. The three most abundant species were Bohemian waxwing (*Bombycilla garrulus,* 56.4%), Pine Grosbeak (*Pinicola enucleator,* 28.9%) and Fieldfare (*Turdus pilaris,* 10.5%). Total abundance and species richness of frugivorous birds were lower around roadside trees than control trees during most of the study period. Fruits were consumed later from roadside trees than from control trees, probably due to human-caused disturbance. Therefore, roadside rowanberry trees extended the period when frugivorous birds stayed in urban habitats. Later consumption of fruits in northern areas than in southern areas was related to earlier peak abundance of frugivorous birds in south than in north. Our results indicated that rowanberry is a suitable ornamental tree for urban and roadside landscaping and may additionally benefit birds and other frugivorous wildlife.

1. Introduction

One of the most common types of human induced changes in the landscape is road building (Adams, 2016; Forman and Alexander, 1998; Forman et al., 2003; Spellerberg, 1998). For example, almost 25% of all land areas in Europe are currently located within 500 m of a road (Torres et al., 2016). Transportation systems have many effects on landscapes as well as wildlife (Coffin, 2007; Fahring and Rytwinski, 2009; Forman and Alexander, 1998; Forman et al., 2003; Riley et al., 2014). Road networks destroy natural habitats, increase habitat fragmentation and form dispersal barriers for animals. Moreover, roads increase animal collisions and chemical pollution caused by traffic (Adams, 2016; Benítez-López et al., 2010; Francis and Chadwick, 2013). In addition, roads can change animals' behavior by causing changes in their habitat use (Trombulak and Frissell, 2000). Despite that, there is still a lack of data on foraging behaviors and movement patterns of birds around urban roads. In addition, little attention has been given to road-related disturbances to wildlife when road corridors with trees are planned within urban landscapes (Reijnen et al., 1997).

Previous studies indicated that the richness of species and the density of many animal groups decreased near roads, while road casualties increased near roads (Benítez-López et al., 2010; Berthinussen and Altringham, 2012; Fahrig and Rytwinski, 2009; McClure et al., 2013). However, roads may also have positive effects on wildlife (Morelli et al., 2014). Roadside trees might offer nesting and foraging sites for birds, and they might facilitate movement of arboreal animals (Adams, 2016; Francis and Chadwick, 2013; Morelli et al., 2014; Mullaney et al., 2015; Murgui, 2007). Therefore, it is essential to consider the importance of trees for wildlife during road construction planning and design (Adams, 2016; Aslan and Rejmánek, 2010; Francis

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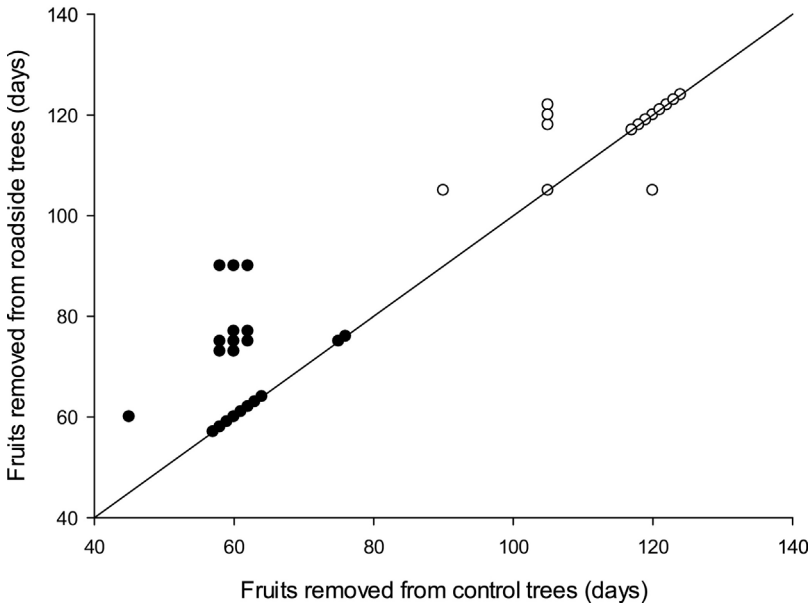

Fig. 1. The estimated time (days, day 1 was September 1, 2012) for the removal of all of the fruit crop from near roadside rowanberry trees and control trees. The continuous line indicates that the rowanberry fruits were removed at the same time. If there is a dot above the continuous line, then fruit was removed later from the near roadside trees than control trees and *vice versa*. Open dots indicate the northern area (Rovaniemi) and filled dots indicate the southern area (Turku) in Finland. Note that the some data points were shifted to reduce overlap on the graph. The time period begins at 15 September 2012.

and Chadwick, 2013).

In particular, ornamental trees with fruits, such as native rowanberry (*Sorbus aucuparia*), were reported to be important food resources for many migrating and overwintering frugivorous birds in urban environments (Tyrväinen, 1975; Kolunen and Vikberg, 1978; Jokimäki and Kaisanlahti-Jokimäki, 2012; Lehikoinen et al., 2010; Suhonen and Jokimäki, 2015; Suhonen and Jokimäki 2015). Via this mutual interaction, birds get food resources and trees get dispersers for their seeds. Therefore, the relationship between birds and rowanberry trees should also be taken into account in urban forestry and greening. While roadside ornamental trees may provide food for birds, at the same time birds are exposed to human-caused disturbances associated with roads (Fernández-Juricic, 2000a, 2000b; Suhonen and Jokimäki, 2015). In our previous study, we showed that rowanberry tree crop size was larger in urban than rural landscapes, but birds consumed fruits later in urban habitats than in rural habitats, possibly due to human-caused disturbances in urban areas (Suhonen and Jokimäki, 2015). However, fruit crop size, abundance of frugivorous birds and fruit consumption may also vary within urban landscapes. For example, it is not well-known, how urban roads influence the fruit production of trees. Human-caused disturbances associated with roads can be an important factor in explaining the interaction between roadside ornamental trees and frugivorous bird species. The presence of a road may modify an animal's behavior through altered movement patterns and escape responses (Trombulak and Frissell, 2000). However, it is not known how roadside trees within an urban environment affect the foraging behavior of birds.

In this paper, we studied the autumn-winter season fruit crop size and removal from the rowanberry trees located near (approximately 8 m from the main road, hereafter roadside trees) and further away from roads (approximately 80 m from the main road; hereafter control trees) by frugivorous birds in two urban areas (Turku and Rovaniemi) in Finland. In this study, we had four main research questions related to the rowanberry crop size, the abundance of frugivorous birds, and the removal rate of the fruit crop. First, do rowanberry crop sizes differ between the roadside trees and the control trees? We predicted that because of road-related factors, such as pollution, crop-size would be lower in roadside trees than in control trees. Second, which bird species use roadside trees as foraging habitat within an urban landscape? According to our best knowledge, this study is the first to explore which bird species are able to use roadside trees as a foraging habitat within an urban environment. Third, do rowanberry fruit removal rates differ between the roadside trees and the control trees? We predicted that because of road-related disturbances (e.g., vehicles and traffic noise) frugivorous birds would avoid roadside trees as primary foraging sites. Fourth, does the rowanberry fruit removal rate differ between southern and northern areas? As migratory birds move southward during the autumn migration, we predicted that fruits would be consumed earlier in the north than in the south.

2. Materials and methods

2.1. Study areas

The study was conducted during autumn-early winter period of 2012–2013 in the following two urban areas in Finland: Turku area, which includes the towns of Turku and Raisio (60° 15′ N, 22° 0′ E; approximately 200,000 inhabitants), and Rovaniemi area (66° 30′ N, 25° 42′ E; approximately 61,000 inhabitants). Distance between Turku and Rovaniemi areas is approximately 700 km. Our study roads and trees were located in the urban parts in both study areas (residential human density > 10 inhabitants per hectare; percent built > 50%; Marzluff et al., 2001).

In the Turku area, mean monthly temperatures varied from 15.3 °C in August (long-term average 1981–2010: 15.8 °C) to −6.5 °C in December (long-term average 1981–2010: −2.6 °C; Ilmatieteenlaitos, 2012). In the Rovaniemi area, the mean monthly temperatures varied from 12.9 °C in August (long-term average 1981–2010: 12.5 °C) to −13.1 °C in December (long-term average 1981–2010: −9.4 °C). In the Turku area, there was snow cover only during December (snow depth: 26 cm; long-term average 1981–2010: 0 cm). Whereas in the Rovaniemi area, there was snow cover in November (21 cm; long-term average 1981–2010: 13 cm), December (19 cm; long-term average 1981–2010: 26 cm) and January (40 cm; long-term average 1981–2010: 48 cm; Ilmatieteenlaitos, 2012).

2.2. Study species

Deciduous and fruit-producing rowanberry is a common native tree species that grows widely in most parts of Europe (Räty et al., 2016). Rowanberry is also popular as a planted tree in many cities and gardens (Räty et al., 2016), and it is one of the most common ornamental tree species on roadsides of northern Europe (Sjöman et al., 2012). Rowanberry is also one of the most common tree species used in roadside