Biological Conservation 164 (2013) 39–49

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Evaluating the effect of habitat connectivity on the distribution of lesser horseshoe bat maternity roosts using landscape graphs

Pierline Tournant [a,b,*], Eve Afonso [b], Sébastien Roué [c], Patrick Giraudoux [b,d], Jean-Christophe Foltête [a]

[a] ThéMA UMR 6049 CNRS, University of Franche-Comté, 32, rue Mégevand, F-25030 Besançon, France
[b] Chrono-Environnement, UMR 6249 CNRS, University of Franche-Comté, Place Leclerc, F-25030 Besançon, France
[c] Commission de protection des eaux de Franche-Comté, 3 rue Beauregard, F-25000 Besançon, France
[d] Institut Universitaire de France, Paris, France

ARTICLE INFO

Article history:
Received 8 November 2012
Received in revised form 9 April 2013
Accepted 15 April 2013
Available online 3 June 2013

Keywords:
Distribution model
Fragmentation
Habitat patches
Least-cost distance
Conservation
Landscape graph

ABSTRACT

The destruction and fragmentation of habitats due to anthropogenic land use changes have led to the decline of numerous species by reducing the size and the connectivity of the remaining local populations and so contributing to their isolation. The impact of habitat fragmentation can be modeled using landscape graphs, which have become a popular tool. Habitat reduction and fragmentation has been suggested as one hypothesis for the decline of the lesser horseshoe bat *Rhinolophus hipposideros* in most of western and central Europe. Consequently, we expected habitat connectivity to influence the spatial distribution of the species, particularly through the presence of maternity roosts, which are essential for the persistence of the species. We designed this study to evaluate the impact of landscape connectivity on the distribution of the lesser horseshoe bat by comparing the predictive power of landscape composition alone with a model including both landscape composition and connectivity. We assessed the impact of landscape composition on maternity roost presence for different distances covered daily by bats (600, 2500 and 5000 m). We then applied a landscape graph-based approach to the roosting habitat of the lesser horseshoe bat to extract several patch-level metrics representing the functional connectivity of the landscape at different spatial scales. The results from those approaches show that the bats' presence in the Franche-Comté region depends on the availability of wooded elements near small built areas and, at a broader scale, on the spatial integration of maternity roosts into a connected network allowing exchanges of individuals among roosts. This approach is a promising way to establish whether the presence probability of a given species depends on the potential connectivity between habitat patches quantified at different spatial scales. We expect that this method can be applied to taxa for which habitat fragmentation is one of the causes of population decline. We anticipate that using a graph-based species distribution model as a tool to predict species presence may focus conservation efforts on areas where habitat potential connectivity and landscape composition together should be taken into account, e.g. where anthropogenic landscape modifications are the main drivers of habitat connectivity.

1. Introduction

Among the different processes contributing to the loss of biodiversity, habitat fragmentation is considered to be one of the major causes of decline or extinction of species as a result of human pressure (Fahrig, 1997; Lindenmayer and Fischer, 2006). A major effect of such fragmentation is the loss of connectivity between habitat patches used by species to obtain their basic resources for survival. As a consequence, species have to live in local populations whose conservation depends on the spread of genes by exchange of individuals and on their integration within a connectivity network (Tischendorf and Fahrig, 2000). Populations located in small isolated habitat patches therefore face a high risk of extinction (Fahrig, 2003). Such populations are particularly sensitive to modifications of their habitat by the development of linear infrastructures, for example, which may put an end to connectivity between several sub-populations (Forman and Alexander, 1998). Species habitat fragmentation has thus become a major issue in conservation biology leading researchers to create new tools with which to assess, model, and predict the impact of human activities on species distribution and population dynamics.

Powerful GIS tools can be used to model species habitat relationships from biological data at different scales (Calabrese and Fagan, 2004; Franklin and Miller, 2009). Spatial multivariate approaches have been recognized to be a significant component

* Corresponding author at: ThéMA UMR 6049, CNRS, University of Franche-Comté, 32 rue Mégevand, F-25030 Besançon, France. Tel.: +33 8 166 5403; fax: +33 8 166 5355.

E-mail address: pierline.tournant@univ-fcomte.fr (P. Tournant).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.04.013

of conservation planning since they produce quantitative predictive models of species distribution (Austin, 2002). These models are widely applied in ecology and conservation biology (for a review, see Austin, 2007; Guisan and Thuiller, 2005) including for the assessment of the impact of climate, land use, and other environmental changes on species distributions. Nevertheless, species distribution models (SDMs) still have their limitations, mainly in theoretical applications (Guisan and Thuiller, 2005). Although they are based on empirical data such as field observations, they often ignore ecological principles such as population dynamics (Richard and Armstrong, 2010). Besides including the potential quality of the habitat when modeling the distribution of a species, it may also be important to take into account as a landscape variable individuals' functional use of that habitat. Guisan and Zimmermann (2000) show that SDMs can be improved by adding information about ecological processes, for instance habitat connectivity.

Among a set of different methods, graph theory is now used in landscape ecology as an effective framework within which to model and analyze landscape connectivity (Urban et al., 2009). Landscape graphs have been successfully used to describe habitat networks for conservation purposes (Andersson and Bodin, 2009; Saura and Pascual-Hortal, 2007) and also to assess habitat connectivity for focal species (Morzillo et al., 2011; O'Brien et al., 2006; Pereira et al., 2011). In such approaches, initially based on the concept of metapopulation, the landscape is considered to be a network made up of nodes and links. Habitat patches that are thought to be optimal for the focal species are represented as the nodes of the network, and the connections between nodes are determined on the basis of ecological assumptions about the movements of the species within the landscape. The graph resulting from these connections is used to quantify the potential landscape connectivity by means of different connectivity metrics (Rayfield et al., 2011). These landscape connectivity metrics may be integrated into a spatially explicit model in order to associate spatial landscape structure with animal movements. This means that hypotheses about population distribution can be proposed. Foltête et al. (2012a) already applied this method for an amphibian species, the European tree frog (*Hyla arborea*), by including altitude and two landscape connectivity metrics from landscape graph as predictors.

We concentrate on the lesser horseshoe bat (*Rhinolophus hipposideros*). This species used to be common throughout northwestern Europe, but it has declined dramatically since the 1960s across most of its distribution range (Kokurewicz, 1990; Motte and Libois, 2002). Several hypotheses have been proposed for this decline, such as contamination by pesticides, habitat destruction, climate change, or competition for prey with pipistrelle bat populations (Arlettaz et al., 2000; Bontadina et al., 2001; Motte and Libois, 2002). The main assumption is a reduction in its foraging habitats and a loss of connectivity among its maternity roosts because of habitat fragmentation (Bontadina et al., 2001). By analyzing the roosting spatial network of two bat species, Fortuna et al. (2009) and Rhodes et al. (2006) demonstrated that the use of roosting sites is decisive for the structural organization of bat populations. Moreover, the importance of maternity roosts in the reproductive phase of the lesser horseshoe bat (females gather to give birth and raise their single young in those places) means that roost availability and distribution appear to be significant determinants of population dynamics and therefore of the conservation of this species. Recent studies have stressed the importance of linear wooded elements such as tree lines, woodland edges, and well-structured hedgerows in the movement of bats (Bontadina et al., 2002; Motte and Libois, 2002; Ramovš et al., 2010; Schofield, 1996; Zahn et al., 2008). By contrast, the species totally avoids open land, possibly due to intense predation by owls. Landscape connectivity is therefore assumed to be a key-factor for the population sustainability of this species (Bontadina et al., 2002; Schofield, 1996). Although several studies reported that the landscape surrounding maternity roosts is becoming homogeneous and made general recommendations for future conservation planning (Bontadina et al., 2001; Schofield, 1996), none quantify the potential impact of connectivity loss on this bat species.

In this paper we propose to evaluate the effect of landscape connectivity on the presence of maternity roosts of the lesser horseshoe bat in Franche-Comté (Eastern France). We argue that both the landscape composition and connectivity, measured respectively by overall land cover frequencies and by graph-based connectivity metrics, are essential in assessing whether a landscape is suitable for the lesser horseshoe bat. We hypothesize that the total area of woodland elements considered as the foraging area and also the spatial distribution of potential maternity roosts are crucial for this species. We compare the predictive power of landscape composition alone as to the presence of maternity roosts against a model that integrates both composition and connectivity.

2. Materials and methods

2.1. Study area and maternity roosts

The study area (11,780 km^2) covered much of the Franche-Comté region (16,200 km^2; Eastern France; Fig. 1). Non-built areas are mainly covered by forests (42%: deciduous, coniferous, and mixed) and farmland (46%: pastures, meadows, and arable land). A conservation association (CPEPESC Franche-Comté) supplied data on the location of maternity roosts and the abundance of lesser horseshoe bats. The association exhaustively prospected

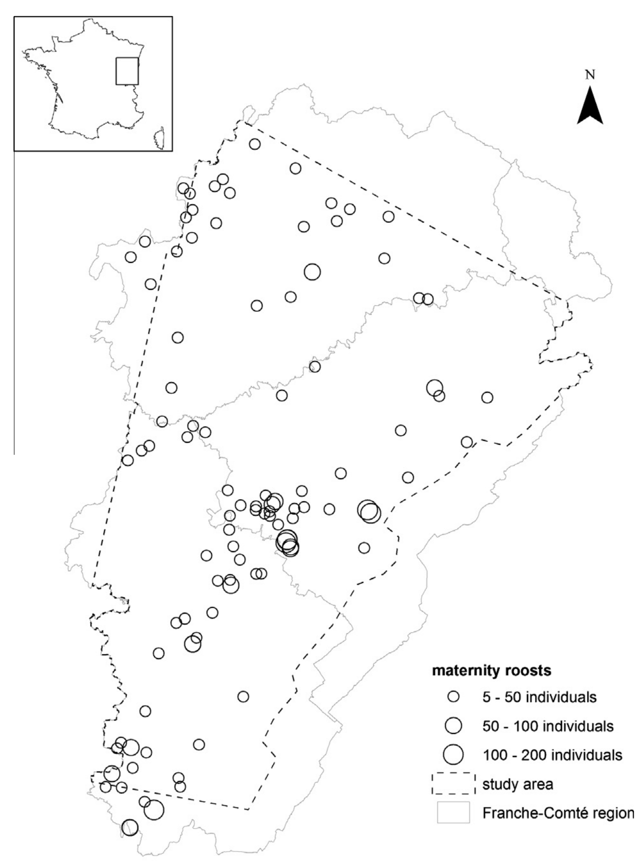

Fig. 1. Location of lesser horseshoe bat maternity roosts with abundance of individuals in the Franche-Comté region, Eastern France.