Connecting Populations of Greater horseshoe bat (*Rhinolophus ferrumequinum*) at the Northern Border of their Distribution – a Modelling Approach

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1. Introduction

Greater horseshoe bat (*Rhinolophus ferrumequinum Schreber, 1774*) population has undergone serious decline during the last decades in Western and Central Europe due to the loss of summer and winter roosts, poisoning, habitat alteration and fragmentation (Jones et al. 1995, Bontadina et al. 2000). Luxembourg shelters one of the last most Northern situated vital maternity colonies in the Upper Moselle valley counting 150 reproductive females (Fig. 1; Fig. 2).

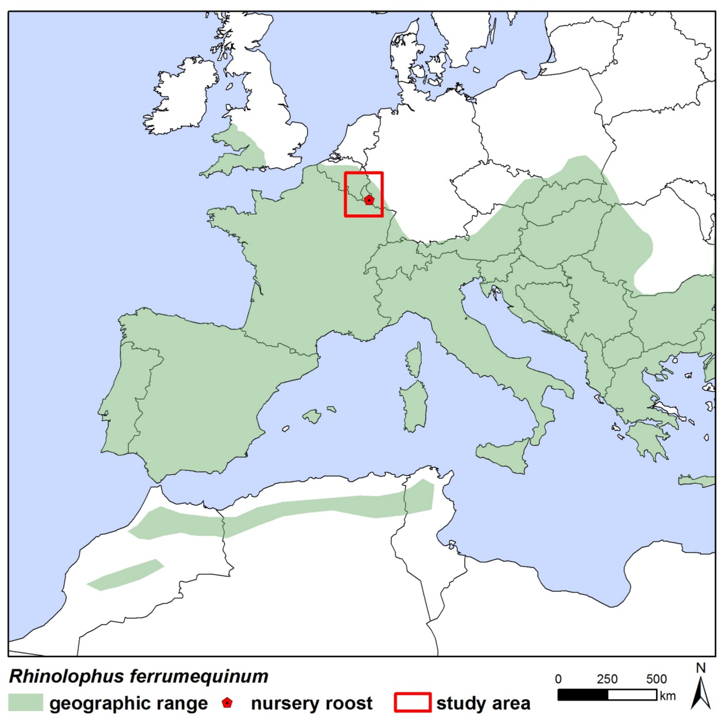

Fig. 1: *Luxembourg shelters a vital maternity colony of the critically endangered greater horseshoe bat (R. ferrumequinum) at the north-western distribution range of this species. (Geographic range: map IUCN Red List of Threatened Species).*

As the building with the colony could be secured in 2011, a species action plan is being implemented to protect and restore foraging habitats and commuting flight paths in order to increase the carrying capacity of the landscape for this species.

In order to the fact that habitat fragmentation contributes to population decline, we aim to increase habitat connectivity with still existing maternity colonies and hibernation sites in northern France, western parts of Germany and eastern regions of Belgium. Furthermore we started to identify, protect and prepare dispersal paths, allowing the species to recover and spread to former repartition areas in Western and Central Europe.

Fig. 2: Roost site with R. ferrumequinum (and Myotis emarginatus) and landscape in the Moselle valley.

2. Methods

We assessed the impact of habitat fragmentation and the functional connectivity of the landscape by using ESRI ArcGIS "low cost-distance" analyse and calculating cost-paths between known greater horseshoe bat populations. The study area covered Luxembourg (2.586 km^2) and adjacent parts of western Germany (Rhineland-Palatinate, Saarland), northern France (Lorraine) and Belgium (Wallonie). This lead to a research area of 19.300 km^2 in the dimensions of 113 km east-west and 171 km north-south direction. Available landscape data of Luxembourg (OBS - *Occupation Biophysique des Sols*) as well as CORINE Land Cover data (2006) were used for the adjacent areas of Germany, France and Belgium.
The data of 3.559 fixes from 26 radio-tracked individuals of *R. ferrumequinum*, were used to assess habitat preferences (Dietz et al. 2013) and to retain 6 relevant land use classes (Tab. 1) at a raster with 4 x 4m spatial resolution.

Tab. 1: *Six different land use classes as used for landscape modelling identified relevant for R. ferrumequinum.*

land use class	*habitats*
open land	*grass land, meadows, pastures, arable land, ...*
tree / scrub	*orchards, vineyards, hedges, solitary trees, tree alleys, ...*
forest	*deciduous, mixed and coniferous forests, forest edges, ...*
water	*water bodies, riparian vegetation, reed, ...*
vegetation in urban areas	*grass verges, parkland, gardens, ...*
urban areas	*settlements, industry, roads, parking, sealed areas, ...*

For calculating landscape paths, every land use class was attributed to a different migration resistance index for the bats extrapolated from own radio-tracking data and reclined to the study of Tournant et al. 2013 (Tab. 1). High cost values represent high migration resistance.
Then all faunistic data (n = 205; Fig. 3) of *R. ferrumequinum* within the research area were compiled for Luxembourg (Pir 1994, Harbusch et al. 2002, own unpubl. data), France (CPESCP 2009), Belgium (EUROBATS 2006) and Germany (Backes 2013, Harbusch 2008, 2010, unpubl. data).
Overall 26 starting points involving maternity colonies, major transit and hibernation sites were chosen to calculate cost-paths in between an to all 205 records.

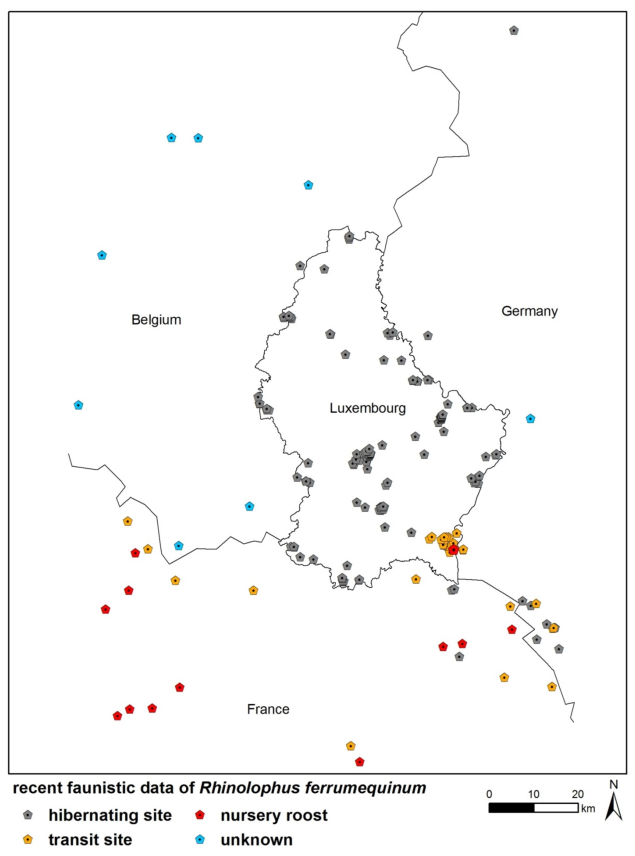

Fig. 3: *Compiled map with current data of R. ferrumequinum and land use cover of Luxembourg and adjacent regions of Belgium, Germany and France.*

3. Results

Analysis of cost-distances and the calculation of cost-paths between the Luxemburgish *R. ferrumequinum* colony and adjacent populations show that the bats depend on the availability of traditional landscape elements like orchards and hedgerows adjacent to human settlings and from woodland areas in open landscape. We identified potential flight pathways (Fig. 4) as scientific authoritative predictions of connectivity and habitat fragmentation between existing maternity colonies, colonies and their foraging areas and between colonies and hibernating sites.

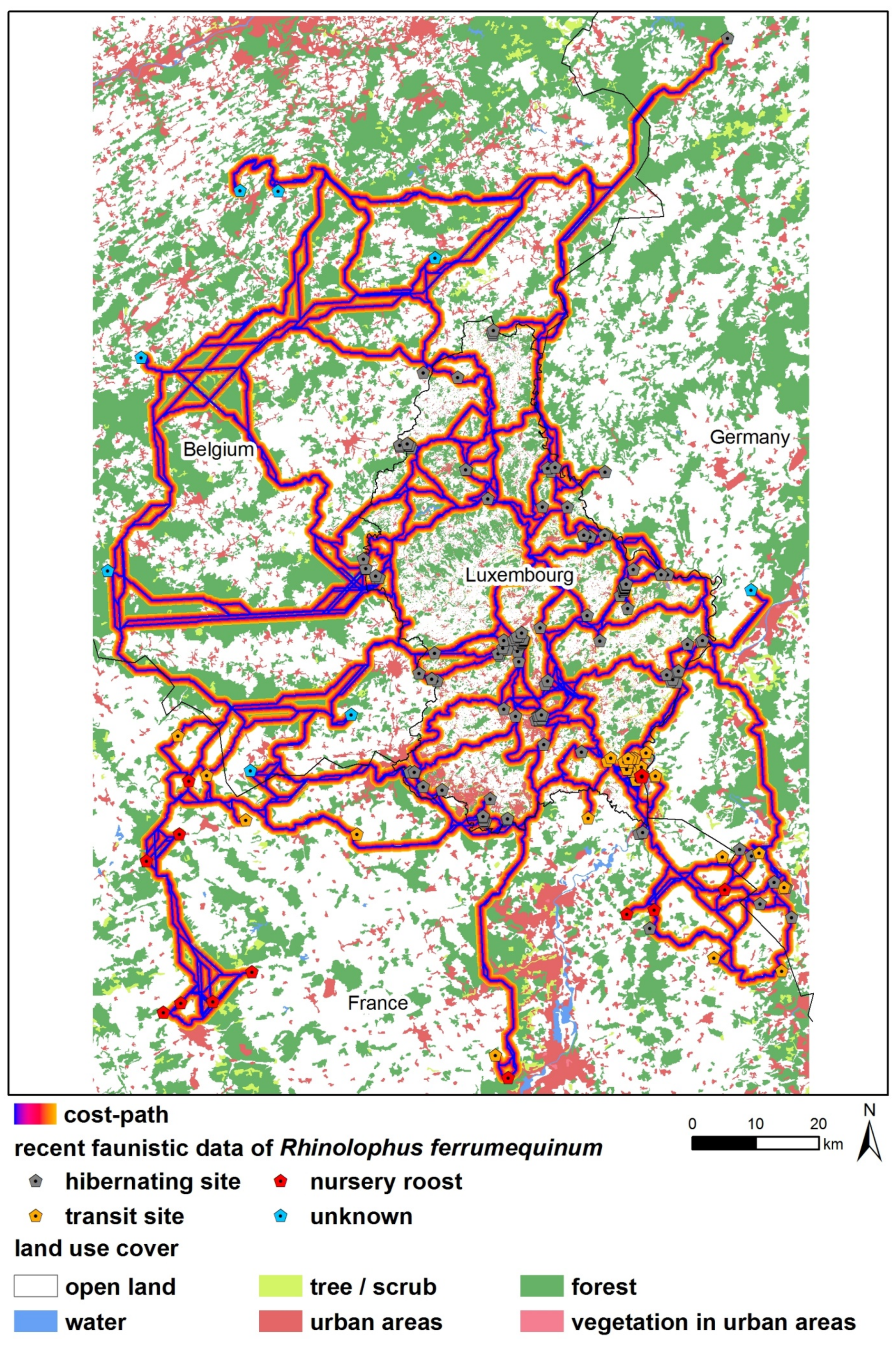

Fig. 4: *Map of cost-pathways of greater horseshoe bat for Luxembourg and adjacent regions at its northern distribution area as calculated by cost-distance analyses.*

As this grid of low-cost pathways helps to identify connectivity corridors between greater horseshoe populations on a transboundary level, a superior resolution (Fig. 5) leads to the identification of important linear key landscape structures on a regional and even municipality scale.

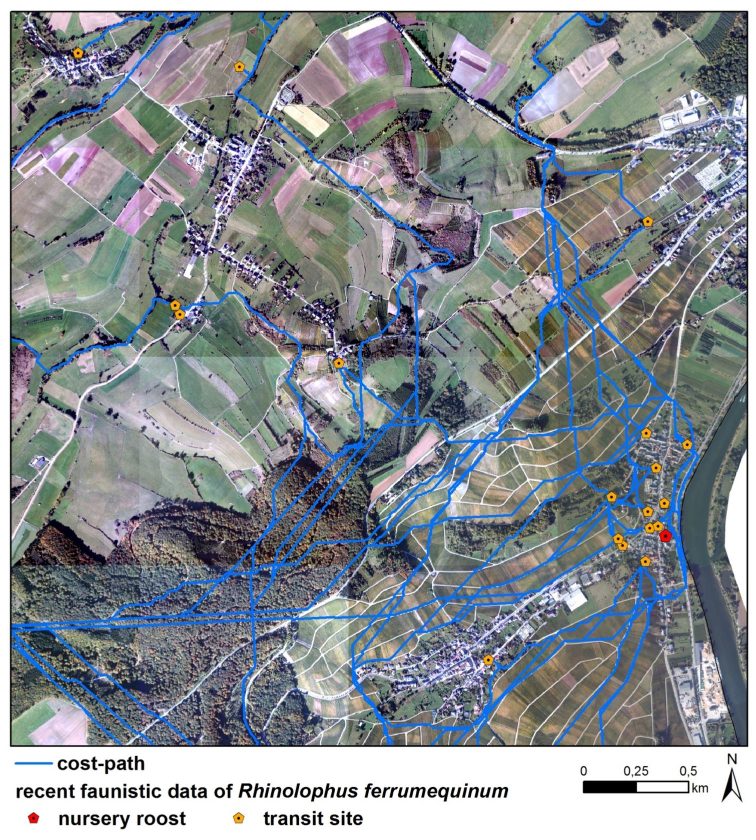

Fig. 5: *Map of cost-pathways identifying important connectivity corridors around the last reproduction colony of greater horseshoe bat in the Upper Moselle valley.*

4. Perspectives

Modelling potential flight paths for the highly endangered greater horseshoe bat is a scientific instrument in species conservation policy. It is appropriate to identify and to protect subsequently landscape structures and assure the connectivity between populations. Modelling also displays evident deficiency zones with gaps in natural landscape structures between different bat roosts and also between roosts and feeding grounds as well as fatal points where traffic infrastructures as roads and motorways are crossing migration and flight paths of (greater horseshoe) bats.

The identified corridors of an important indicator species should be integrated in local development schemes, overall plans, forest management plans and biodiversity and species protection programmes even for the conservation of other threatened animals like e.g. the european wildcat (*Felis s. silvestris;* Pir et al. 2012).

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