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Using movement and habitat corridors to improve the connectivity for heathland carabid beetles

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ABSTRACT

Heathland areas in the Netherlands are declining in size and quality, and becoming more fragmented. The connectivity of the landscape for threatened insects might be improved by creating networks of corridors. We compared heathy roadside verges and linear forest clearings with heathland nature reserves and forests. The clearings were created in between the roadside verges and the nature reserves. In all four landscape types carabid beetles were inventoried with pitfall and window traps. Principal Component Analyses showed that the carabid species composition in roadside verges differed from that in nature reserves, both before and after the creation of the connecting forest clearings. However, an analysis of data on 31 target species (stenotopic species of drift sand, heathland and other nutrient-poor open habitats) selected from the pitfall trap catches revealed that 21 were present in the roadside verges. In addition, the occurrence of teneral individuals and flightless species indicate the verges provide valuable habitat where reproduction takes place. Forests themselves were barriers for almost all target carabids. In the forest clearings, similar amounts of target carabids were encountered in pitfall traps as in the nature reserves and roadside verges, but only teneral individuals of two species were found. In contrast, flying carabids were very abundant in the forest clearings: more than twice as many as in the nature reserves and the roadside verges. This indicates that dispersing carabids in particular make use of these linear forest clearings. We conclude that roadside verges can act as *habitat corridors* and that linear forest clearings are particularly used as *movement corridors*. Thus, both offer simple solutions for increasing the connectivity of fragmented landscapes for a threatened insect group.

Introduction

In the last 150 years, over 90% of the total area of heathland and drift sand in the Netherlands has been lost (Van Duuren et al. 2003). It has been replaced by agriculture or by forests (through forestation and vegetation succession). The remaining sites are losing quality through eutrophication and acidification caused by the atmospheric deposition of nitrogen and sulphur (Bobbink et al. 1998; Ketner-Oostra et al. 2006). Since nutrient-poor conditions are becoming increasingly rare in the Netherlands, remaining heathland and drift sand areas are very important habitats and refuges for certain species (Riksen et al. 2006). These habitats have also been designated European target ecosystems (European Community 1992). Not only does the reduction in their total area have severe implications; the resulting fragmentation and isolation also poses threats for the biodiversity (Hilty et al. 2006; Noss & Csuti 1997).

Carabid beetles (or ground beetles, Carabidae) form a highly diverse insect family, with approximately 370 species occurring in the Netherlands (Turin 2000). Many vegetation types have their own specialised carabids (Schaffers et al. 2008; Turin et al. 1991). Various studies have shown that habitat fragmentation is an important factor causing the decline of specialist carabid species (De Vries & Den Boer 1990; De Vries et al. 1996; Turin & Den Boer 1988). Species of heathland and drift sand are among the carabids most severely in decline in the Netherlands (Turin & Heijerman 1997) and other countries (Kotze et al. 2011). Although no official conservation policy – for example a Red List – exists for carabids in the Netherlands, in this paper we consider stentopic species of nutrient-poor open vegetations and other species of open areas which show a declining trend in our country as target species for conservation management of heathland and drift sand.

The construction of corridors is often proposed as a means to alleviate fragmentation effects on species (Beier & Noss 1998; Haddad & Baum 1999). In highly fragmented landscapes, such corridors could improve the exchange of individuals between remaining sites, thereby enabling colonisation of unoccupied sites or strengthening existing populations (Hanski & Pöyry 2007; Hilty et al. 2006). Different types of corridor can be distinguished: e.g. habitat corridors, which link discrete nature reserves by similar vegetation, thus increasing the habitat area and enhancing the opportunities

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for target species to live and reproduce; and movement corridors, which are primarily designed to facilitate movements of individuals of target species from one habitat patch to another (Anderson & Jenkins 2006). A corridor might be a movement corridor for one species and a habitat corridor for another species.

In this paper, we study the suitability of road verges and linear forest clearings for increasing the connectivity of nutrient-poor, open vegetation areas. First, we will examine to what extent roadside verges with high-quality nutrient-poor vegetation patches are suitable habitat for target carabids. This may provide insight into the potential corridor function of long stretches of suitable verge. However, the ecological conditions of verges might not be suitable for target species due to the negative effects of the linear outline and resulting ecotonial effects, the inferior quality of the vegetation, the small size and the disturbance, pollution and casualties caused by traffic (Angold 1997; Gish & Christensen 1973; Munguira & Thomas 1992; Spellerberg 2002).

Secondly, we examine ground-dwelling and flying carabids in linear forest clearings connecting two open areas. This gives insight into the potential corridor function of open linear structures through a forested landscape – for example recreational or forestry paths, fire lanes, or strips of tree-free vegetation under power lines. Such linear structures are expected to have a positive effect on dispersal (e.g. Haddad & Tewksbury 2005), though this is probably highly dependent on the quality and the width of the corridor. Due to the effects of the extensive 'edge habitat' in forest clearings, it seems likely that many target species will avoid these structures (Ewers & Didham 2008; Pryke & Samways 2001).

Methods

Study area

The study areas were located on the Veluwe (Fig. 1; all locations between 52°00′–52°30′N and 5°30′–6°15′E), an area in the centre of the Netherlands, with Pleistocene, sandy and acidic soils on which pine and oak forests, heath and drift sand typically occur (Weeda et al. 2002). Here, from the end of the 15th century until around 1900, the landscape was dominated by heathland and drift sand. Between around 1900 and 1970 many of these areas were afforested with conifers, leaving only small and fragmented areas with low-productive vegetation (Fig. 1), which are currently under threat from eutrophication and encroachment by trees.

The highway verges in this region were constructed in the period 1953–1977 using the local sandy soil. They have often been colonised by nutrient-poor plant communities such as dry inland heath (*Genisto-Callunetum*), nutrient-poor heathy grassland (*Thero-Airion*) and pioneer drift sand vegetation (*Spergulo-Corynephoretum*). Particularly in the first few decades after their construction, these verges contained relatively large patches of habitat suitable for species typical of nutrient-poor habitats. The vegetation in these verges was not usually managed, as this seemed unnecessary, given to the nutrient-poor conditions. Currently, however, the interesting plant communities are slowly disappearing, due to succession of the vegetation towards communities dominated by grasses, shrubs and pine trees (Noordijk et al. 2008b; Sýkora et al. 2002), with the result that nowadays the remaining nutrient-poor vegetation patches in the verges are small and isolated from similar sites.

General setup

We selected three heathland nature reserves – Caitwickerzand, De Haere and Hulshorsterzand – all along highways. At each location we studied carabids in four landscape elements: the heathland; a nearby roadside verge; a forest clearing; and the undisturbed forest adjacent to the forest clearing. First of all, we examined to what extent roadside verges are suitable habitat for target carabids (study 1). In a second study, we also examined linear forest clearings, created in the winter of 2004/2005, connecting the open area of the verge and the nature reserve, as well as the adjacent undisturbed forest (Table 1). This gives insight into the potential corridor function of open linear structures through a forested landscape (study 2).

The roadside verges we monitored were selected on the basis of their vegetation quality; we chose patches of well developed *Genisto-Callunetum* and *Spergulo-Corynephoretum* vegetation. These patches were isolated from other similar patches, both in nature reserves and in the verges, by vegetation types with higher standing biomass. Such patches can function as reference habitats, indicating the potential insect diversity in roadside verges in the Veluwe region. At the beginning of the fieldwork, these road verges were all isolated from nearby nature reserves by Scots pine (*Pinus sylvestris*) forest. After sampling the road verges and nature reserves for two years, at each location a strip of forest was removed between the reserve and the verge. These linear forest clearings differed in size, orientation, and type of soil cover (Table 1). At two locations, the topsoil was also removed, to expose bare sand. At one location an existing patch of nutrient-poor grassland was enlarged and connected to both nature reserve and roadside verge by removing trees.

Carabid sampling was done with pitfall and window traps. The pitfall traps to capture ground-dwelling individuals were placed

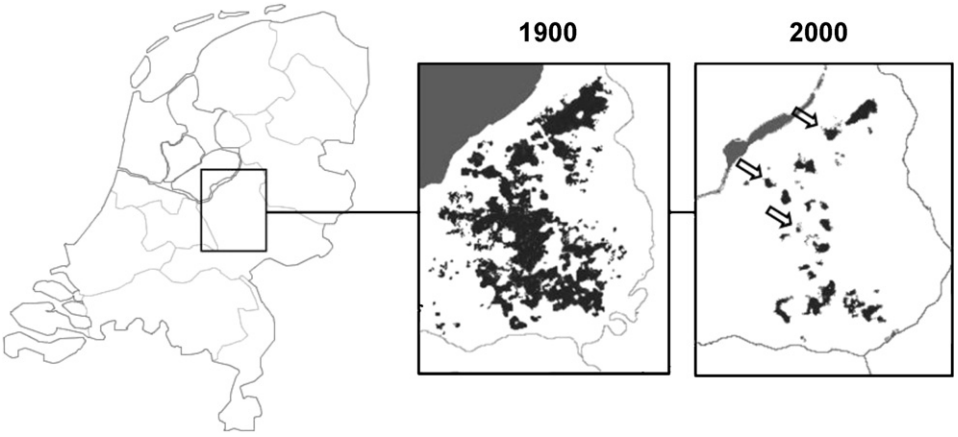

Fig. 1. Distribution of heathland and drift sand in the Veluwe region in the central part of the Netherlands in 1900 and 2000. The arrows indicate the study locations alongside highways.