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Factors affecting road mortality and the suitability of road verges for butterflies

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ABSTRACT

Little is known of the impact of roads on insect mortality. This is a significant gap, because road verges are regarded as an important tool for insect conservation. In this study, we investigated which factors affect the number of roadkills in grassland butterflies and, simultaneously, the species composition and abundance on road verges. We established sixty transects, two hundred metres long, on roads in farmland areas and with differing traffic volume. Each transect consisted of two parallel lines, one on either side of the road. Ordination methods showed that the species composition of the butterflies killed on the roads was primarily explained by the species composition of those living on the road verges. At least 6.8% of the butterflies were estimated to end up roadkilled. Also, the number of species and abundance of butterflies killed on the roads were positively dependent on both the abundance of butterflies on the road verges and on the traffic volume, but negatively correlated with the richness of plant species on the road verges. However, the proportion of individuals killed was negatively linked with the abundance of butterflies on the road verges, the richness of the plant species and the share of grassland in the landscape. There was a statistically significant tendency for small-bodied species to be overrepresented in the roadkill samples. Our results indicate that the verges which were of high conservation value for butterflies suffered the least from road mortality. The sowing of plant species, less frequent mowing and maintaining a high grassland cover in the vicinity of roads are recommended conservation actions for the improved conservation value of road verges for butterflies.

1. Introduction

The development of road networks and increased traffic volume is one the most significant causes of habitat fragmentation (Forman and Alexander, 1998; Trombulak and Frissell, 2000; Forman et al., 2003; Fahrig and Rytwinski, 2009; Selva et al., 2011) that has lead to decreased populations of many animal species (Warren et al., 2001; Fahrig, 2003; Forman et al., 2003; Thomas et al., 2004; Biesmeijer et al., 2006; Silva et al., 2012). Several studies, mostly carried out on mammals, amphibians and some insects, indicate that roads dividing habitat fragments may be an obstacle to the movements of individuals and, therefore, to the gene flow between the fragments (Bhattacharya et al., 2003; Shepard et al., 2008; Smith-Patten and Patten, 2008; Jackson and Fahrig, 2011; Soluk et al., 2011; Neumann et al., 2012). On the other hand, many studies indicate that the negative effects of roads may be mitigated by the high conservation value of road verges (a strip of grass or other vegetation beside a road) or other habitats associated with roads (Ries et al., 2001; Saarinen et al., 2005; Valtonen et al., 2006, 2007). Road verges may serve as dispersal corridors and be a suitable habitat for many insects (Forman and Alexander, 1998; Trombulak and Frissell, 2000; Wynhoff et al., 2011). They are considered as being especially favorable for both common and endangered butterflies (Munguira and Thomas, 1992; Ries et al., 2001; Saarinen et al., 2005).

However, if the road mortality is high, then the conservation value of the respective road verges would be diminished. Road networks and traffic volumes are increasing across the globe (Forman and Alexander, 1998; Selva et al., 2011) and thus the estimation of road mortality and establishment of which factors affect the number of roadkills is an essential issue as regards the conservation of insects living on road verges and in semi-natural habitats in the vicinity of roads. Surprisingly, there are only a few estimations of the number of roadkills and the factors determining them (Munguira and Thomas, 1992; Ries et al., 2001). On a larger spatial scale, it has been shown that butterflies are one of the most common insect groups being killed on roads (Mckenna et al., 2001; Rao and Girish, 2007).

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One might predict that the number of road kills may be affected by five major factors: (1) traffic volume; (2) the population size of insects living on road verges; (3) the properties of the road and verge; (4) the landscape composition in the vicinity of roads; and (5) species traits. The greater the volume of traffic, the greater the probability of collision with a car and thus the number of roadkills should be higher for roads with a higher traffic value. Insects usually have low or moderate dispersal abilities; hence most roadkills should be individuals living on road verges or in the proximity of roads. The higher the population density, the higher the chance that the individual will try to emigrate (Nowicki and Vrabec, 2011) and cross the road, exposing itself to the possibility of being hit by a vehicle. Obviously, various verge properties may either cause individuals to remain or induce them to cross the road and migrate. One may also predict that wider verges and verges with a larger supply of resources will provide a habitat sufficient to sustain, and thus retain, individuals (Munguira and Thomas, 1992; Saarinen et al., 2005). However, when the habitat area is restricted and the quality of the resources low, this may prompt dispersal and individuals may be willing to cross the road in order to seek another, more suitable site. Many road verges are regularly mown and this kind of activity may force individuals to search for other, more suitable sites (Valtonen et al., 2006), as has been shown for managed grassland patches (Dover et al., 2010). It may thus be expected that, in rarely mown, wide road verges, with a larger number of nectar and host plant species the chance that individuals will try to emigrate and, in consequence, the number of roadkills, should be lower. Landscape structure may also influence the number of roadkills, as well as the number of species and individuals in habitat patches (Munguira and Thomas, 1992; Saarinen et al., 2005; Öckinger and Smith, 2007; Berg et al., 2011; Vergnes et al., 2012). However, it is difficult, *a priori*, to put forward precise predictions. One may hypothesize that, the larger the cover of semi-natural habitats in the vicinity of roads, the higher the influx of individuals should be, increasing population size on road verges and thus, as stated above, escalating the number of roadkills. However, the opposite effect may also be expected. Road verges are supplementary habitats for most insects and thus, when the share of semi-natural habitats in the vicinity of roads is large, then individuals may be willing to emigrate to those patches, leading to a lower population density on road verges and, in effect, to the probability of a lower road mortality.

As a result of evolutionary history and the interaction of a species with its environment and other species, mortality rate is often species-specific. Species, of course, differ between one another; however, this obvious fact has important consequences for our understanding of car-induced mortality. The traits of some species may mean that they are exposed to a higher risk of collision with cars than occurs for other species. In animals like butterflies, body size may be predictor of road mortality, because this trait influences flying speed (Wickman, 1992; Kingsolver and Srygley, 2000) and thus the probability of collision with a vehicle.

However, one of the greatest problems in understanding animal road mortality is the fact that factors which increase mortality may also have a positive impact on abundance and species richness on road verges, which leads to a conservation dilemma. Therefore, in order to understand effects on mortality and evaluate the value of road verges, the ways in which the factors that have an impact on the number of roadkills would affect the abundance and species richness of butterflies at road verges must be tested simultaneously.

To the best of our knowledge, the foregoing hypotheses have not been investigated in a composite study. An understanding of the factors affecting both the number of roadkills and butterfly population sizes on road verges would be essential to both undertaking appropriate mitigation actions steering them toward the alteration of traffic volume, the properties of road verges, and the surrounding landscape, or, indeed, to all of these factors. The aim of this study was therefore to test the aforementioned predictions on grassland butterflies, which frequently inhabit road verges and are considered to be the flagship of insect conservation, with many of them being commonly known to the general public.

2. Methods

2.1. Study area

We conducted our study in Southern Poland, on roads in an agricultural landscape in the environs of the cities of Kraków, Tarnów and Rzeszów (Fig. 1; Supplementary material). This is a landscape dominated by cereal crops, which cover 40% of the study area; root crops, primarily potatoes, cabbage and beet, cover 14%; grasslands cover 10%; fallow covers 10%; forests cover 14%; and human settlements cover 10%. Other habitats cover 2% of the study area. The average density of the human population is 140 people $\times$ km^{-2}. The climate of the studied area is transitional from oceanic to continental (Wiszniewski, 1973) mean yearly temperature is 8.2 °C (in July: 18.5 °C, in January: −3.0 °C), annual rain-fall is 645 mm and mean snow cover thickness is 8 cm (Lorenc, 2005). The snow cover lies on average from the third week of December to the middle of March (Lorenc, 2005).

2.2. Selection of transects

The butterflies killed by cars were collected on 60 transects, each of them 200 m long. They were selected from a larger sample of randomly chosen sites; however, it was necessary that they met certain criteria. Each transect consisted of two parallel lines, one on either side of the road. Thus the sampling unit used in our analyses were data from these two lines on either side of the road. The

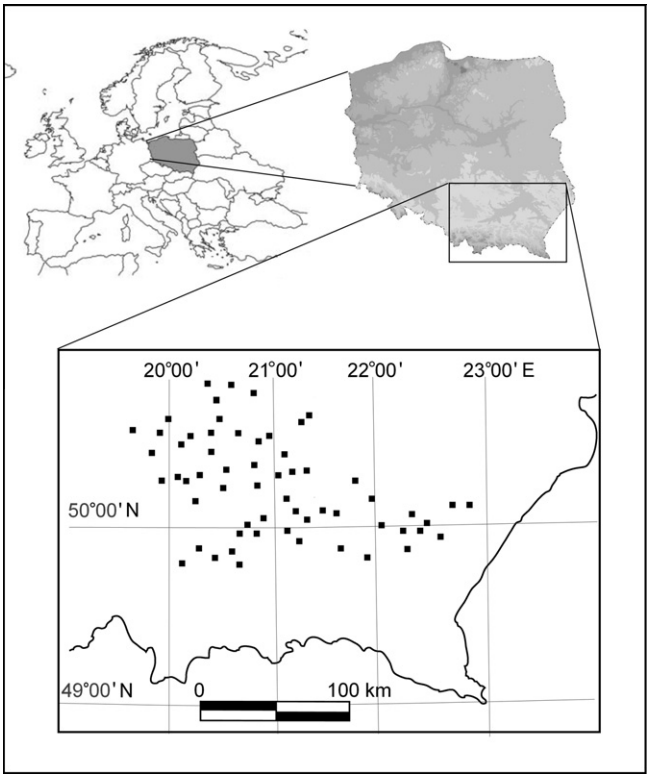

Fig. 1. Map of Poland and location of the region where the roadkills and butterflies on road verges were studied. Black dots indicate the location of transects in this study.