Biological Conservation 187 (2015) 154–163

Contents lists available at ScienceDirect

Biological Conservation

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

Biodiversity collision blackspots in Poland: Separation causality from stochasticity in roadkills of butterflies

Piotr Skórka [a,*], Magdalena Lenda [a], Dawid Moroń [b], Rafał Martyka [a], Piotr Tryjanowski [c], William J. Sutherland [d]

[a] Institute of Nature Conservation, Polish Academy of Sciences, Mickiewicza 33, 31-120 Kraków, Poland
[b] Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Sławkowska 17, 31-016 Kraków, Poland
[c] Institute of Zoology, Poznan University of Life Sciences, Wojska Polskiego 71 C, 60-625 Poznań, Poland
[d] Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, United Kingdom

ARTICLE INFO

Article history:
Received 18 November 2014
Received in revised form 16 March 2015
Accepted 16 April 2015

Keywords:
Conservation
Decision making
Interpolation
Invertebrates
Road ecology
Roadkills
Spatial clusters

ABSTRACT

Collisions with cars are an important mortality factor for many wild animals. Measures to mitigate road mortality are costly so should be implemented using cost-effective measures in locations where the road mortality is consistently highest and non-random in different species. It is thus important to identify what features causes these biodiversity collision blackspots. Almost all of the data and literature on collisions refer to vertebrates with little known about invertebrates. We used data on butterfly roadkills in three large landscape plots in Poland to identify sites where the collision rate seems to be routinely high. Biodiversity collision blackspots were identified from occurrence in successive years using spatial hierarchical clustering. Biodiversity collision blackspots comprised just 4% of the total road length, but included 49% of all road-killed butterflies. Habitats within 500 m of each blackspot was compared to random non-blackspot sites using generalized linear mixed models. The occurrence of blackspots was linked with high traffic volume, but only when cover of grassland in a landscape was high and verges had low plant species richness. Similarly, blackspots occurred with high probability when traffic volume was high but especially if grassland cover in the landscape and verge mowing frequency were also high. These blackspots had higher species richness and abundance of butterflies in the surrounding landscape than in random sites. Biodiversity collision blackspots analysis identified road sections of high road mortality for different butterfly species. Moreover, blackspots were also indication of species rich areas of conservation concern that were intersected by roads. Thus, conservation practitioners may direct mitigation measures, such as less frequent mowing and speed limit, in a cost-efficient manner in these spatially-limited locations.

1. Introduction

The increasing and more affluent human population linked to the development of the automotive industry has resulted in both more and wider roads (Selva et al., 2011), while technological change has resulted in faster traffic. Roads are known to be a cause of disturbance for some natural populations. Roads also lead to habitat fragmentation by dividing continuous habitat into separate blocks and impeding both the movement of individuals and gene flow (Forman and Alexander, 1998; Trombulak and Frissell, 2000; Forman et al., 2003; Tanner and Perry, 2007; Jackson and Fahrig, 2011). The presence of roads can change the soil, microclimatic conditions, and pollutant levels (Forman et al., 2003; Moroń et al., 2012). For example, increased nitrate levels may affect both plant and animal populations (Port and Thompson, 1980). The most obvious and direct impacts of roads is probably through mortality linked with vehicle collisions (Malo et al., 2004; Seiler, 2005; Rytwinski and Fahrig, 2012; Cosentino et al., 2014).

Road mortality may be considered as an example of a point process, which is a type of random incident for which any one realisation takes a set of isolated points either in time or geographical area (Diggle, 2003; McDonald, 2013). However, individual incidents may generate a non random spatial pattern of incident densities when these incidents result from some, say environmental, factors (Diggle, 2003; Daley and Vere-Jones, 2008). Road mortality is known to have a considerable impact on the local population viability of many vertebrates, especially amphibians and mammals (Hels and Buchwald, 2001; Falcucci et al., 2009; Rytwinski and Fahrig, 2012; Silva et al., 2012; Teixeira et al., 2013). Little is known

* Corresponding author.
E-mail addresses: pskorka@iop.krakow.pl, skorasp@gmail.com (P. Skórka).

http://dx.doi.org/10.1016/j.biocon.2015.04.017
0006-3207/

about its cause, pattern or impacts in insects, despite the fact that insects are among the most commonly recorded roadkills (Rao and Girish, 2007; Ranea et al., 2008; Soluk et al., 2011).

Several measures for alleviating road mortality of other taxa have been proposed, and have been implemented at local or landscape scales, including fencing, speed limits, tunnels, road signs, bridges and carrying individuals across the road (Van Langevelde et al., 2009; Ascensão et al., 2013; Smith and Sutherland, 2014). Road verges have become an important surrogate of semi-natural habitat in modified landscapes (Ruiz-Capillas et al., 2013). In butterflies or bumblebees, road mortality may be mitigated by widening road verges, sowing some flowering plants, less frequent mowing and retaining more grassland in the landscape (Munguira and Thomas, 1992; Ries et al., 2001; Skórka et al., 2013). However, such mitigation actions may be costly and too expensive to implement along all road sections (Beaudry et al., 2008; Litvaitis and Tash, 2008; Polak et al., 2014).

The cost and inconvenience of implementing measures to reduce road mortality implies that they should be positioned at high concentrations of incidents of different species within a limited geographical area, referred to as road mortality blackspot or hot spots (Gomes et al., 2008; Litvaitis and Tash, 2008; Cureton and Deaton, 2012; Iosif, 2012); here we use the term "biodiversity collision blackspots", focusing on multispecies collision incidents. Identifying biodiversity collision blackspots and subsequent comparison of these blackspots with non-blackspot sites is an important exercise since it allows the separation of areas where mortality is linked with specific features of a road or/and landscape (causality) from the areas where mortality is simply accidental with clusters due to stochastic processes during the sampling period. Implementing mitigation measures in the latter areas may be a waste of resources, but most of studies do not recognize this dual nature of road mortality.

Identifying biodiversity collision blackspots requires knowledge of the number and spatial locations of roadkills; identifying these sites is usually based on arbitrary criteria, and is often synonymous with the sites where collision occurred (Litvaitis and Tash, 2008), or it is made by personal judgement, which is likely to be highly subjective. Several statistical methods allow the identification of blackspots basing on objective, statistical criteria (Anderson, 2009). One such method is nearest neighbour spatial hierarchical clustering (Anderson, 2009), which compares spatial location of incidents with a random distribution of points across a landscape. Moreover, there are several interpolation methods (Gattrell et al., 1996; Gomes et al., 2008) that may improve discrimination between biodiversity collision blackspots and areas with low rate of road mortality. However, they are rarely used in published studies on road mortality of animals (Ramp et al., 2006; Gomes et al., 2008).

Having identified the location and number of biodiversity collision blackspots, one may predict sites where number of roadkills of different species would be the largest by comparing local and landscape features of biodiversity collision blackspots and random sites with average or low rate of road mortality. The high road mortality may results from (1) high population sizes of different species living in the vicinity of roads and at road verges, (2) the specific structure of a road and traffic, (3) the landscape composition around the road and (4) interactions between these factors. However, it is unknown how biodiversity collision blackspots differ from road sections with average or low mortality rate in insects.

In this study, we used data on butterfly roadkills in three large agricultural landscapes to predict the number and spatial locations of biodiversity collision blackspots by using the nearest-neighbour hierarchical clustering and spatial interpolation methods (Johnson, 1967; King, 1967; Everitt, 1974). Then, we compared species richness and abundance of butterflies as well as traffic volume, road features and landscape composition between biodiversity collision blackspots and randomly chosen sites along roads. We validated our findings by comparing the number of mortality incidents in blackspots and randomly chosen sites with independent counting of dead butterflies in a different year. We also investigated factors affecting number of roadkills in biodiversity collision blackspots and randomly chosen sites.

2. Methods

2.1. Study area

We conducted our study in three landscape plots in southern Poland (Fig. 1, Table 1, .kmz files in Supplementary Material). The plots represented three distinct agricultural landscapes; their characteristics are given in Table 1. Plot Krakow, was an agricultural landscape near large town, plot Proszowice was located in intensive farmland and plot Tarnow was located in less intensive farmland (with small fields and numerous abandoned fields). The

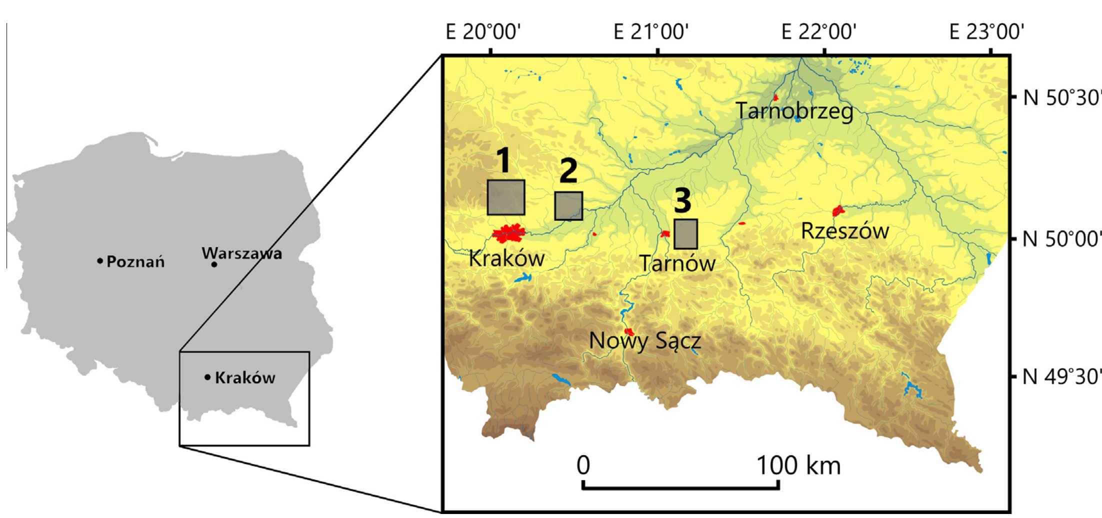

Fig. 1. Map of Poland and localization of the studied landscape plots. Explanations: 1 – plot Kraków, 2 – plot Proszowice, 3 – plot Tarnów. Colors in right panel represent altitude above sea level, from low (green) to high (brown) Larger towns are red patches, rivers and waterbodies are in blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)