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Road-kills affect avian population quality

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ABSTRACT

Owing to the extensive development of road networks, millions of animals are killed annually. This impact on the natural environment has been questioned: is there a selection of victims in the car collisions? and do road-kills, as do predators, influence a population by eliminating individuals in poor condition? We compared road-killed individuals to those killed by predators in SE Poland in three bird species: Yellowhammer *Emberiza citrinella*, Barn Swallow *Hirundo rustica*, and Chaffinch *Fringilla coelebs*. We applied ptilochronology, in which the width of feather growth bars represents an individual's relative nutritional condition. Our results show that the analyzed species were in significantly better body condition than those killed by raptors. Our study does not concur with previous studies which concluded that weaker individuals are more vulnerable on the road. Raptors select prey in poor condition, but road-killed individuals are in significantly better condition, so apparently road-kill results in the random elimination of healthy individuals. The conservation implications of this study are far-reaching; future road construction and safety regulations must take wildlife into consideration. If these human-created habitats are killing a significant proportion of the healthier part of natural populations in a non-selective manner, this could result in situations where fragmented populations could be driven to a critical stage, and/or the situation of declining or endangered populations worsened further.

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1. Introduction

Early in the process of the development of road networks arose a question as to its impact on the natural environment (Stoner, 1925). Several papers attempted to address the subject in order to highlight an indirect impact on wildlife. Parameters studied include traffic noise (Reijnen et al., 1995; Hoskin and Goosem, 2010), habitat fragmentation (Bélisle and Clair, 2001), reduction of habitat quality (Reijnen and Foppen, 1994; Grzybek et al., 2008; Laurence et al., 2009), roads as barriers (Develey and Stouffer, 2001; Laurence et al., 2009), reduction of population density (Reijnen et al., 1995; Kuitunen et al., 1998; Grzybek et al., 2008), mortality (Yosef, 1994, 2008; DeGeus, 1990; Russell et al., 2009; Barthelmess and Brooks, 2010), and road-effect zone (Forman and Alexander, 1998; Forman, 2001; Forman and Deblinger, 2001). However, the most obvious effect of vehicular traffic is the direct impact on animals following collisions (Pons, 2000; Erritzoe et al., 2003). Today, the greatest effect of road traffic is on the number of birds killed annually (Pons, 2000). The scale of this phenomenon is millions of individuals killed every year by car collisions (Forman and Alexander, 1998; Erritzoe et al., 2003).

With such great influence on animal mortality by a human-introduced parameter in the environment, one questions the role it plays on natural selection. In the natural environment, the main causes of bird mortality are diseases and inter-specific interaction – mainly predation (Newton, 1998). According to the optimal foraging theory, predators tend to select prey by choosing poorer individuals from the population (e.g., Temple, 1987; Abrams, 1990; Koivunen et al., 1996; Møller and Erritzoe, 2000; Pole et al., 2004; Penteriani et al., 2008). However, in the case of road-kills, despite many years of research the problem of selection remains unclear and is avoided by most authors (see Erritzoe et al., 2003).

Hence we premised that if road-kills are selective, they too should lead to the elimination of individuals which are in poor nutritional condition and hence more vulnerable to vehicular traffic. We assumed a similar effect on the prey population as there is with prey-selection by predators. The aim of this study was to compare the quality of prey selected by predators and those of road-kills from the same regional population and to compare them to individuals from free-living populations. We hypothesized that (1) the quality of individuals killed by cars does not differ from that of individuals selected by predators and (2) that both of mentioned above groups differed from free-living birds forming a local population. We predicted a tendency for car collision of poor individuals, i.e., a selection mechanism similar to that of prey-selection by predators, and thus both the groups (road-kills and preys) would differ from birds of the local wild population.

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2. Materials and methods

In order to compare between the two groups, we collected the rectrices of avian prey under the nests of six breeding pairs of Sparrowhawks *Accipiter nisus*, and from victims of road-kills during the same time period. We assume no difference in the selective effects of the six pairs of hawks or the different roads. Feather samples were collected from April to August, which corresponds with the Sparrowhawks' breeding season, during the years 2002–2009 in the Pogórze Przemyskie region, Western Carpathians, in southeast Poland.

In order to compare nutritional condition of road-kills and prey taken by Sparrowhawk and birds from general population we collected rectrices of free living Chaffinches. Birds were mist-netted during breeding season in the Sparrowhawk territories in 2008 and 2009.

Ptilochronology (Grubb, 1989) was used to determine the relative nutritional condition of the prey. This technique is based on the evaluation of the width of feather growth bars during each 24-h period at the time of moult and depends on the amount of energy and nutrients invested by an individual into the regeneration process, which at the same time depends on the nutritional condition and quality of an individual (Grubb, 1989, 2006).

Growth bar width indicates an individual's relative nutritional condition. Other indices of nutritional condition, such as total body mass or fat percentages, are more commonly applied (Grubb, 1989, 2006). However, the interpretation of these traditional indices is often questioned. In certain circumstances, the highest body mass or fat percent does not correspond with the highest nutritional condition of an individual (Grubb, 1995).

Feather growth as an index of nutritional condition is based on natural selection, which forces birds to regenerate lost feathers as rapidly as possible. Therefore, birds in better nutritional condition regenerate feathers much faster than individuals in poor condition (Grubb et al., 1991; Grubb, 2006). Thus, feather quality is a relatively accurate indicator of an individual's quality.

On each feather, 10 growth bars centered on the point two-thirds of the distance toward the tip of the feather were measured by RY, who served as a blind test. A total of 129 (27 road-kill vs. 102 Sparrowhawk prey) feather samples were collected from three species: Yellowhammer *Emberiza citrinella* (10 vs. 23), Barn Swallow *Hirundo rustica* (7 vs. 16), and Chaffinch *Fringilla coelebs* (10 vs. 63). Feather length of 22 free living Chaffinches, mist-netted from the general population, were measured. We found no differences in rectrices between those Chaffinches predated by Sparrowhawks and birds from the free-living population ($t = 0.28$, $df = 25$, $p = 0.775$). Hence, all comparisons were restricted to differences in feather growth bars.

Statistical procedures were performed using Statistica 8.0 software (StatSoft Inc., 2008) according to Zar (1999). We analyzed the normality of distribution by the Shapiro–Wilk W test and then applied Student *t*-test and one-way ANOVA to compare the independent groups. Distribution of data within each of the analyzed groups did not differ significantly from normality ($p > 0.05$).

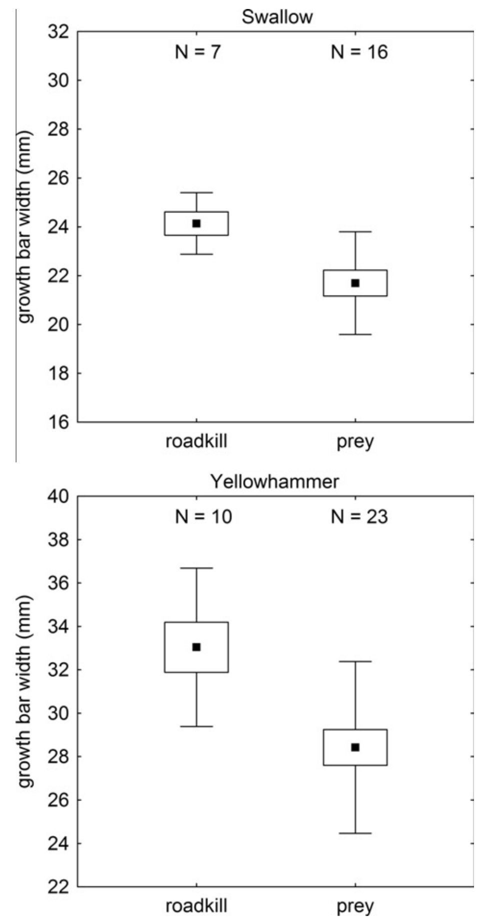

Fig. 1. A comparison of the growth bar width on rectrices of Barn Swallows *Hirundo rustica* and Yellowhammer *Emberiza citrinella* found road-killed and as prey of Sparrowhawk *Accipiter nisus* (means, SE and SD).

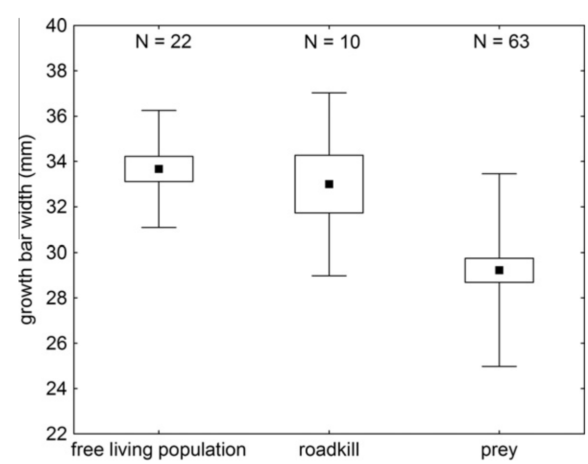

Fig. 2. A comparison of the growth bar width on rectrices of Chaffinch *Fringilla coelebs* found road-killed, prey of Sparrowhawk *Accipiter nisus*, and birds mist-netted from the free-living population (means, SE and SD).

3. Results

Nutritional condition, as evidenced by growth bar width, differed significantly between road-kills and those taken by Sparrowhawks in Barn Swallows ($t = 2.83$, $df = 21$, $p = 0.009$) and Yellowhammers ($t = 3.15$, $df = 31$, $p = 0.004$; Fig. 1).

Significant differences in growth bar width were found between three groups of Chaffinches (one-way ANOVA $F_{2,92} = 12.66$, $p = 0.000$; Fig. 2). The width of the growth bars in birds killed by Sparrowhawk was significantly smaller than those in road-kills (post hoc LSD test; $p = 0.005$) or in the free-living population (post hoc LSD test; $p = 0.000$). However, width of the growth bars did not differ significantly between road-kills and birds from the free-living population (post hoc LSD test; $p = 0.66$).

4. Discussion

Transport arteries, including roadways have become an essential part of our modern lives. They also play a role in that wildlife adapt to these human modified habitats and have to survive human inventions related to traffic, roadworks and upkeep, peripheral development as a result of a road paved through a virgin area, etc. (DeGeus, 1990; Reijnen and Foppen, 1994; Reijnen et al., 1995; Yosef, 1994, 2008; Kuitunen et al., 1998; Pons, 2000; Bélisle and Clair, 2001; Develey and Stouffer, 2001; Forman, 2001; Forman and Alexander, 1998; Forman and Deblinger, 2001; Erritzoe et al., 2003; Grzybek et al., 2008; Hoskin and Goosem, 2010; Laurence et al., 2009). Roads are a source of food, salt, macro- and microelements, and gastroliths in winter (Brownlee et al., 2000; Erritzoe et al., 2003). These sources are commonly used by birds (Gollob and Pulich, 1978), making them vulnerable to car collisions (but also see Hoskin and Goosem, 2010; Russsell et al., 2009; Barthelmess and Brooks, 2010; Laurence et al., 2009).

It is of interest that road-killed birds were in significantly better nutritional condition than those taken as prey by Sparrowhawks and did not differ from the natural population. This does not corroborate our predictions wherein we expected to find road-kills and Sparrowhawk prey to have similar values and for them to differ from the natural population.

Among numerous papers on road-kills, few authors have attempted to determine the body condition of the victims (Erritzoe et al., 2003). They used bird body mass, percent of fat in the body mass, and stomach content as indices of individual quality (Sutton, 1927; Gollob and Pulich, 1978; Massemin et al., 1998; Valkiūnas, 1998). Studies during breeding season showed that young road-killed Chaffinches had higher levels of blood parasites than birds caught at nests (Valkiūnas, 1998). Thus, the author concluded that birds with higher levels of blood parasites were more apt to become road victims.

In contrast, and that corroborate our findings, Gollob and Pulich (1978) studied road-kills from groups that foraged beside roads during the winter and found that they were extremely fat. Similar results were found for road-killed Screech Owls *Otus asio*, where most were in excellent condition (Sutton, 1927). Furthermore, Massemin et al. (1998) in their study during autumn and winter, found that road-killed Barn Owls *Tyto alba*, also did not support the idea that only birds in poor body condition were killed.

In our study, road-killed Barn Swallows, Yellowhammer and Chaffinches were in significantly better nutritional condition than conspecifics taken as prey by Sparrowhawks (Fig. 1). The differences between predated Chaffinches and those from the free-living population were significant, indicating selection pressure by hunting of the weakest of the prey population by Sparrowhawk. However, there was no difference between road-kills and birds from the free-living population. It suggests that the road-killed animals are healthy individuals, which are randomly eliminated from a natural population.

Prey-selection mechanism in predators is a stimulated process of foraging optimization, and is related to existing nutritional needs and prey availability and vulnerability (Křivan, 1996; Křivan and Sikder, 1999; Křivan and Eisner, 2003). Predators attempt to obtain as much energy as possible in relation to energy losses during prey catching, which includes foraging and handling (Stephens and Krebs, 1986). As a result, in the diet of predators are individuals that for various reasons are weaker than the average of a population (Møller and Erritzoe, 2000; Pole et al., 2004; Penteriani et al., 2008). Furthermore, if victims of road-kills are characterized as being in better condition than prey selected by predators, it means that selection on roads does not occur at all or is weaker than that found in predators. Therefore, the assumption that poor individuals are more apt to be killed on the road is incorrect and misleading. Hoskin and Goosem (2010) found that in rainforest frogs of Northeast Australia both call rate and dominant frequency were significantly higher closer to the road, and males were significantly smaller closer to the road and believe that these call and body size trends most likely reflect road impacts. These findings are important for conservation purposes and should be factored into future landscape planning and development.

However, we are aware of several shortfalls in our study and which could influence decision making and should be included in future field studies. Although we are convinced that our findings have important implications one must realize that we assumed that all the feathers collected were of birds that represent the population. It is possible that the birds killed by predators were smaller in body size (due to some prey choice of the predator), and this could have caused the difference in growth bar width. However, because of the circumstances of this study we used feather growth bars as the comparative parameter, because we are unable to present any other comparative biometric data, such as tarsus length, since no such remains are found at Sparrowhawk nests. Also, although true that the feather growth rate represents the previous season's post-breeding moult in studied species (Jenni and Winkler, 1994), we consider them to represent faithfully the regional population and can be safely assumed to represent their relative nutritional condition (cf. Yosef, 1996; Yosef and Grubb, 1992).

Our study illustrates how the non-invasive technique of ptilochronology can also be applied for conservation purposes (cf. Grubb, 2006). The conservation implications of our findings are far-reaching in our modern societies wherein roads are considered important arteries of transportation. If these human-created habitats are killing a significant proportion of the healthier part of natural populations in a non-selective manner as shown in our study, this could result in situations where fragmented populations could be driven to a critical stage, and/or the situation of declining or endangered populations worsened even further. In light of the ever-increasing road networks, and before it becomes too late for our wildlife populations, additional research is urgently required to adequately address this problem.

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