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Highway construction and wildlife populations: Evidence from Austria

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ABSTRACT

Fragmentation and destruction of ecosystems due to highways are key threats to habitat quality and biodiversity. In this article, we develop a theoretical framework and use a dynamic spatial panel data model to estimate how Austrian highway construction after 1968 has impacted the populations of roe deer, red deer and wild boar. The results indicate that a growing highway density leads to decreasing populations of roe deer and wild boar in their local district, contrasted with increasing populations in neighboring districts. Red deer populations were relatively insensitive to highway construction. Positive population effects in neighboring districts can be explained by the reduction of competition, disease transmission, and road kill. The results have important policy implications for Environmental Impact Assessments of infrastructure construction, particularly in the early stages of planning.

1. Introduction

The construction of highways diminishes resources for many wildlife species globally (Fahrig and Rytwinski, 2009; Forman and Alexander, 1998; Newbold et al., 2015; van der Ree et al., 2015; Völk and Glitzner, 2000; Völk and Wöss, 2001), and habitat fragmentation through linear infrastructure has been called the “single greatest threat to biodiversity” (Hess, 1996; Noss, 1991). In addition to the effects of habitat destruction, spillover effects from roads can reach far into the surrounding landscapes (Baylis et al., 2016; Haddad, 2015). Similar to most developed countries, Austria has established a comprehensive highway system over the past 50 years. To make environmental impacts of these large infrastructure projects more transparent, many countries have adopted Environmental Impact Assessments (EIAs). Austria adopted EIA in 1993 (Umweltverträglichkeitsprüfungsgesetz 1993) and first applied it to highway construction in 1996. By 1996, a total of 1619 km of highway were built without being subject to EIA. However, particularly in highway development, the EIA has often been criticized of being of inadequate quality in order to prevent possibly detrimental effects on the environment (Duinker and Greig, 2006; Jaeger, 2015).

Highways impact wildlife populations mainly through two channels: habitat loss, which describes the reduction in quantity and quality of habitat, and habitat fragmentation, which describes the breaking apart of habitat. In addition, highway construction has also increased the exposure of wildlife species to wildlife-vehicle-collisions globally (Kušta et al., 2017). While habitat loss almost always has a negative effect on ecology, the evidence has shown that the impact of habitat fragmentation per se can be positive or negative (Fahrig, 2017). In this paper, we study the effects of highway construction on three ungulate species in Austria: roe deer *capreolus capreolus*, red deer *cervus elaphus*, and wild boar *sus scrofa*.

Many factors influence the quality of a wildlife EIA in highway construction. First, there is uncertainty about the landscape scale effects and thresholds regarding infrastructure projects on wildlife, which often makes predictions difficult (Jaeger, 2015; Roedenbeck et al., 2007). These uncertainties are often not addressed in EIAs and therefore not incorporated into the decision processes. Second, wildlife species may be particularly sensitive to the cumulative impacts of a highway development project, which are often poorly addressed in EIA practice (Duinker and Greig, 2006; Masden et al., 2010; Piper, 2001; Smith, 2006). Third, assessment procedures may not always strictly follow scientific standards, either due to political pressures, insufficiency of EIA guidance documents published by the relevant authorities, or lack of time and funding (Morrison-Saunders et al., 2001), as well as lack of competence and training of the personnel (Zhang et al., 2013).

While the impact of highway development on wildlife has attracted plenty of research, the current literature mainly sheds light on the impact of infrastructure on wildlife habitat through specific channels and at small geographical scales. This is important from the perspective of ecological research. However, from a management perspective, the aggregate effect caused by a multiplicity of factors such as resource degradation, water and air pollution, noise, as well as impacts specific to the species under investigation such as changes in habitat size and

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fragmentation, and species interactions, is of more concern. This aggregate effect of road construction on animal populations has not been well studied at a national scale in a long time horizon, except for Roedenbeck and Köhler (2006), who studied the impact of landscape fragmentation on animal density in Hessen, Germany. In contrast, the present paper uses annual district level data from Austria after 1968 to evaluate the impacts of highway construction on the harvest densities of red deer, roe deer and wild boar, including neighborhood effects. In particular, we seek to (1) investigate methods and arguments used in highway construction EIAs in the context of wildlife in Austria, (2) propose a GIS-based method based on readily available data and an econometric framework to assess highway impacts on wildlife, that separates the dominating effects of habitat loss from fragmentation, and (3) discuss the results of the case study and give some recommendations for the future improvement of EIAs.

2. Background

In this paper, we investigate the ex post dynamic effect of highway construction on three ungulate species (roe deer, red deer, and wild boar) in Austria. These species have been subject to hunting for many decades, and therefore changes in populations will not only have ecological effects, but also economic effects as well.

2.1. Highway impacts on wildlife: ecological mechanisms from the literature

The impact of highways on wildlife has been studied comprehensively in the ecological literature, and a basic distinction is made between the effects of habitat loss and habitat fragmentation. The negative effect of habitat loss caused by highways can be explained by three mechanisms. First, constructing a highway causes direct habitat loss through sealing and hardening of surfaces and the removal of vegetation (van der Ree et al., 2015). Second, highways through animal habitat increase light and noise pollution, air pollution through gas emissions (Huang et al., 2009) and dust (Nanos and Ilias, 2007), and the runoff of salt and other chemical substances (Evink, 2002). Road avoidance as a behavioral response to noise and air pollution therefore may cause an additional loss of usable habitat (D'Amico et al., 2016; Laurian et al., 2008; Rost and Bailey, 1979). Depending on road width, traffic volume, the structure of the adjacent landscape, the nature of the prevailing wind, and the specific sensitivity of species to road effects, the road-effect zone (Forman, 1995) may extend far into the surrounding landscapes (Mäki et al., 2001; van der Ree et al., 2015).

Third, as a further effect, highways may lead to increased development efforts in their vicinity (Selva et al., 2015). In the literature, roads have been identified as being one important determinant of deforestation (Chomitz and Gray, 1999; Deng et al., 2011). Mothorpe et al. (2013) find that the construction of the interstate highway system in Georgia, U.S. has caused substantial losses in agricultural land due to residential development. For Austria, Fig. 1 indicates a similar relationship by showing a positive relationship between the density of highways (km/km^2) and human population density.

Classical ecology assumes that fragmentation reduces an animal's potential to move freely according to the availability of the fundamental resources food, water, and shelter (Benz et al., 2016; Morrison et al., 2012). Several studies have tried to link population decline to habitat fragmentation, e.g. for European hare in Switzerland, Austria, and Czech Republic (EEA, 2011), or badgers in the Netherlands (Fahrig, 2002). In Germany, roe deer densities were positively correlated with effective mesh size (Jaeger, 2015), indicating that less fragmented landscapes support larger roe deer populations (Roedenbeck and Köhler, 2006).

Contrasting these negative effects, a review article by Fahrig (2017) finds that 76% of 381 significant ecological responses to habitat fragmentation per se in 118 case studies were positive. Hess (1996) argues that fragmentation might stop the transmission of contagious diseases among animal populations. Studies on infectious diseases in wildlife in Austria suggest that swine fever and brucellosis are a problem in wild boar (Reimoser and Reimoser, 2010), while paratuberculosis has been found in red deer (Fink et al., 2015; Schoepf et al., 2012) and roe deer (see Duscher et al. (2015) for a recent review of the literature).

Additionally, highways in Austria are fenced, so that road kills on highways are practically negligible compared to those on rural, lower-order roads. As highways also offer more convenient ways of transportation than lower-order roads, a diversion of traffic may reduce road kill. Kušta et al. (2017) find that ungulate-vehicle collisions are most frequent on first-class, second class roads compared to motorways and expressways in Czech Republic. Fig. 2 shows that road kills in Austria decrease with a higher highway density for roe deer and red deer, but increase for wild boar. Given regular fence maintenance, fencing may be particularly beneficial for population persistence when road avoidance of a species is low and traffic mortality is high (Jaeger and Fahrig, 2004).

Finally, separating two habitats by a highway may decrease the intra-and inter-specific competition effect that a species experiences (Fahrig, 2017). Separation of habitats could lead to a sudden decrease in interference competition (Begon et al., 2005), which could in turn increase population densities. Predator-prey dynamics will change if the predator is more negatively affected by a road than the prey species. In this case, there may be a positive abundance effect for the prey species (Fahrig and Rytwinski, 2009; Liao et al., 2017).

Nevertheless, whether or not a species responds to highway construction depends on home range size, habitat characteristics (vegetation, geology and climate), movement patterns (e.g. seasonal migration) and other (e.g. human) interference (e.g. feeding or hunting), as well as the ability to adapt to new conditions.

2.2. Highway construction in Austria

Austria is a country in the center of Europe with around 8.5 million inhabitants and a total land area of about 84 thousand km^2. As of 2012, Austria is separated into 95 districts. We use the term highway for both top order road types, "Autobahnen" and "Schnellstraßen", which are similar in width, construction, fencing, and speed limits, and therefore likely to have similar effects on wildlife populations. The first sections of highway were built during the Nazi regime along the Salzburg – Linz – Vienna connection (today highway A1 "Westautobahn"). Building activities were suspended by the end of 1941 with only 16.8 km finished close to Salzburg. Highway construction was continued from 1954. The Austrian Federal Road Act of 1971 (Bundesstraßengesetz) marked the peak of highway planning activities, leading to a planned total of 1874 km of highways on the Austrian territory (ASFINAG, 2012a).

The first critical voices about highway construction were echoed during the early 1980s. The rising ecological movement, as well as funding problems, led to open protests against motorways that were currently in the planning or construction stage. According to a report by the Austrian road construction and financing authority (ASFINAG), new highways were reassessed and environmentally less harmful features (tunnels) and highway overpasses to compensate for their ecological impacts were introduced. The trend is shown in Fig. 3, where up until around 1990, a sharp rise in the density of highways can be observed, with a leveling off of new highway openings after 1995 in most provinces.

Today Austria is an important transit country between western and eastern Europe, as well as from north to south (Zink and Reimoser, 2008). This includes four corridors of the core Trans-European Network Transport (TEN-T), with a total length of 1072 km: Baltic-Adriatic, Rhine-Danube, Scandinavia-Mediterranean, and Orient/East-Mediterranean. The total comprehensive TEN-T in Austria is 1689 km (CEDR, 2016). Therefore, the construction of suitable highways is a priority not only nationally, but also at the European level. 2185 km of