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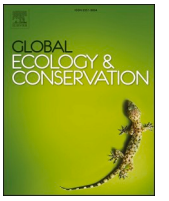

Short communication

Increasing mortality of European bison (*Bison bonasus*) on roads and railways

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ABSTRACT

Traffic mortality can pose a serious risk to endangered species that occur in small populations, are mobile and occupy fragmented habitats. This is the case for the European bison (*Bison bonasus*) yet, how traffic mortality affects this species is unknown. Here, we assessed patterns and trends of European bison mortality on roads and railways in Poland, which harbors a large share of the global free-ranging population of this species. We identified 70 records of European bison mortality due to roads or railways during 2010–2021, which involved three free-ranging populations: Białowieska Forest, Knyszyńska Forest, and Zachodniopomorskie. Most reported mortality (73%) was from the Zachodniopomorskie population, likely an effect of the high traffic volumes on a national road passing through the core range of that population. Furthermore, our analysis revealed an increasing trend of European bison traffic fatalities, which is likely associated with increasing European bison numbers in these populations. We conclude that traffic accidents may pose a risk to both European bison and people, and reintroductions should therefore prioritize roadless areas and avoid areas with busy roads and railways. Although traffic mortality of European bison has been a negligible threat to the species as a whole, our study shows that this threat may be substantial locally. As European bison numbers grow, which is desirable given the still small size of many free-ranging populations, effective mitigation measures are needed to ensure the safety of European bison and people.

1. Introduction

Road and railway networks, and more generally linear infrastructure, have expanded massively in the Anthropocene, with few roadless areas remaining (Ibisch et al., 2016). This results in the fragmentation of habitat for many species by cutting through habitat patches or natural movement corridors, with generally negative impacts on population viability (Di Giulio et al., 2009; Haddad et al., 2015). As a result, mortality on roads and railways can pose a serious risk to wildlife, especially for endangered species that typically occur in small or fragmented populations (Healey et al., 2020; Quintana et al., 2022). Likewise, traffic accidents with wildlife pose a serious risk to people, particularly where large-bodied wildlife is involved (Huijser et al., 2009; Niemi et al., 2017; Abra et al., 2019). Moreover, accidents with ungulates cause very significant economic losses, through damage to vehicles and trains, as well as road

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congestion and train delays (Apollonio et al., 2010; Morele et al., 2013; Krauze-Gryz et al., 2017; Gren et al., 2018). Therefore, understanding the patterns of animal mortality on roads and railways has become a core issue for wildlife management and conservation (Coffin, 2007; Borda-de-Água et al., 2017; Santos et al., 2017).

The frequency of vehicle/wildlife collisions on roads and railways primarily depends on traffic volumes (Smith-Patten, Patten, 2008; Visintin et al., 2017), traffic speed and thus speed limits (Smith-Patten, Patten, 2008), the topography of the landscape (Snow, Červinka et al., 2011, 2015), the shape of roads and railways, such as the presence of curves (Grilo et al., 2009; St. Clair et al., 2020), the presence of movement corridors and the habitat surrounding roads (Saeki, Macdonald, 2004; Nieszała, Klich, 2021) or the degree of urbanization (Seiler, Helldin, 2006; Jasińska et al., 2019). However, wildlife fatalities on roads and railways are highly dependent on the species, the season, and the time of day, all of which affect wildlife activity patterns (Krauze-Gryz et al., 2017; Lehtonen et al., 2021; Andrén et al., 2022). Among wildlife species, ungulates are particularly susceptible to collisions on roads and railways (Pagany, 2020), due to their high mobility and large home ranges, or the attraction of roadsides (e.g., providing grazing opportunities in closed forests).

Europe is particularly relevant in this context, as it is heavily bisected by roads and railways, with increasing traffic volumes (Haddad et al., 2015; Ibisch et al., 2016). Likewise, ungulate populations have been growing recently and expanding their ranges, to the extent that some of them are now overabundant in many landscapes (Apollonio et al., 2010; Neumann et al., 2022). Although some areas in Europe are experiencing rural outmigration, overall, there has been a major increase in road mortality with wildlife in Europe, mainly due to collisions with ungulates (Madsen et al., 2002; Grilo et al., 2020; Krukowicz et al., 2022). Better understanding wildlife mortality on roads and railways is therefore important for safeguarding both people and wildlife.

European bison (*Bison bonasus*) are currently not very widespread in Europe and are confined to small populations in Central and Eastern Europe (Olech and Perzanowski, 2022). Once almost extinct, the species has been restituted throughout the 20th and 21st centuries, with > 7200 wild European bison roaming in about 50 populations (Raczyński, Bołbot, 2022). Some of these populations are growing and expanding their ranges, such as in parts of Poland (Plumb et al., 2020; Yanuta et al., 2021; Olech and Perzanowski, 2022), increasingly forcing them to cross roads and railways. Despite this, the road ecology of European bison remains weakly understood. The main concern raised in this context so far has been the effect of these linear infrastructures as dispersal barriers for European bison, as even local roads can constitute a significant barrier to the movement of European bison (Ziółkowska et al., 2016), and animals usually avoid habitats near roads (Kuemmerle et al., 2018). Assessments of habitat and movement suitability of European bison therefore often point to areas with sparse road networks, but these assessments usually cannot assess mortality due to the absence of traffic data (Lord et al., 2020; Dănilă et al., 2022; Bluhm et al., 2023). This is unfortunate, as mortality on roads can be substantial. For example, in Białowieska Forest, mortality on roads and railways may account for up to 8% of the total mortality of European bison (Krasińska et al., 2017). Moreover, road mortality of European bison might increase, considering the growing number of free-ranging European bison in Poland, and in Europe more generally (Olech and Perzanowski, 2022). Despite this, we know of no study that has assessed trends in European bison road mortality. Here, we aimed to assess trends and patterns in mortality of European bison on roads and railways in five free-ranging populations in Poland.

2. Methods

There are currently eight European bison populations in Poland, five of which are large (i.e., exceeding 100 individuals). These large populations were all established at least 40 years ago and differ not only in size, but also in the characteristics of the environment they occupy, including lowland and mountainous areas, more and less densely populated areas, and different land uses (for a detailed description of these populations please see Table S1 in the Supporting Information). Human population density was the highest in Knyszńska Forest (38.3 ind./km^2), followed by Zachodniopomorskie (33.6 ind./km^2), and the lowest was in Bieszczady and Borecka Forest (17.9 and 16.7 ind./km^2 respectively). The highest density of national roads was found in Zachodniopomorskie (5.52 km/100 km^2 in Zachodnipomorskie and 1.07–2.28 km/100 km^2 in all other populations), while the highest density of railways was in Białowieska Forest (9.39 km/100 km^2 in Białowieska Forest and 0.00–7.65 km/100 km2 in all other populations) (Table S.1.).

We obtained data on the mortality of European bison on roads and railways from several sources. Our basic data source was the European bison tissue database at Warsaw University of Life Sciences, where information on the cause of death of individuals and all associated information is stored. In addition, we submitted inquiries to different state institutions: the Police Headquarters (https://www.policja.pl), the General Directorate for Environmental Protection (https://www.gov.pl/web/gdos), the General Directorate for National Roads and Highways (www.gov.pl/web/gddkia) and the Western Pomeranian Nature Society (Zachodniopomorskie Towarzystwo Przyrodnicze – ZTP) that is heavily involved in European bison conservation (http://www.ztp.org.pl).

We then standardized information from all these sources (i.e., we homogenized the format of age, date and geographical coordinates) to obtain the time and location of the mortality event, as well as the age and sex of the animal involved. We collected data for the period 2010–2021 (i.e., starting from the year when the European bison tissue database at Warsaw University of Life Sciences began collecting samples). We obtained data from the following sources: the databases at Warsaw University of Life Sciences (43 records), the General Directorate for Environmental Protection (23 records), the General Directorate for National Roads and Highways (1 record), and the Western Pomeranian Nature Society (55 records). We compared the timing, location, and available metadata (i.e. sex and age) of the mortality events from these sources and omitted all duplicate records (i.e., a mortality event registered in more than one database) to avoid double-counting. We did not consider non-fatal vehicle collisions with European bison, due to the lack of data on such collisions. Finally, we used linear regression modeling to analyze the relation between the number of European bison fatalities and European bison population sizes.

For Zachodniopomorskie, where the number of mortalities was the highest, we carried out a more detailed analyses of mortality

cases. Using all available information, we mapped the location of fatalities, in relation to roads and railways. Moreover, to better understand the high number of traffic collisions in Zachodniopomorskie, we assessed the spatial activity patterns of European bison in this region. To do so, we created point density maps based on GPS tracking data from European bison in this region. The tracking dataset covered the timespan 2014–2019, comprising > 1.1 million GPS fixes. The GPS collars were self-manufactured by Western Pomeranian Nature Society. Collars were set to a 1-hour fix schedule. Each record included the date and time, location in geographic (WGS84) coordinate system, the number of active satellites, and dilution of precision values. 64 GPS-collared adult females could be clearly attributed to one of nine existing herds. Given the large variation in the number of collared individuals across herds, we calculated point density layers for each herd separately (using the *Point Density* tool in ArcMap v10.7), before normalizing the density values for better comparability. For a more detailed description of the GPS data acquisition and processing, we refer to Bluhm et al. (2023).

3. Results

We recorded a total of 70 cases of European bison mortality on roads and railways in Poland for the period 2010–2021. However, all cases occurred in the regions occupied by three populations only – Białowieska Forest, Knyszyńska Forest, and Zachodniopomorskie (12.5%, 14.3%, and 73.2% of all cases respectively) – and we did not find a single case of mortality due to traffic collision from the other two larger free-ranging populations in Poland during the studied period (i.e., Borecka Forest and Bieszczady Mountains), nor in the small, recently formed other populations.

Overall, there were more fatalities on roads (87.5% of all cases) than on railways, except for the Białowieska Forest area there were more fatal cases on railways (2 fatalities on roads vs 5 fatalities on railways; Fig. 1). The sex ratio (m:f) of animals killed by traffic was 1:1.2 and the age structure of killed animals revealed that mainly adult individuals were affected (calves (up to 1 year) = 12.2% of mortality cases; juveniles (2–3 years old) = 24.4%, adult animals (≥4 years) = 63.4%). European bison mortality on roads and railways occurred in all seasons but much less frequently in the summer: in spring – 26.8%, summer – 16.1%, autumn – 32.1% and winter – 28.6%.

We found an increasing trend of traffic mortality of European bison over the years, with the highest increase observed in 2020 and 2021 (i.e., a two-fold increase compared to 2019). The same trend was observed in all three regions, with the largest increase in Zachodniopomorskie in western Poland (Fig. 2A). Our regression model revealed that the number of fatalities was clearly and significantly ($p = 0.002$) correlated with the increase of the size of the European bison population in Poland (Fig. 2B).

All 55 mortality cases identified for Zachodniopomorskie could be accurately located, because ZTP had collected detailed data on all traffic-related mortality events for this population. Fatal vehicle collisions involving European bison in Zachodniopomorskie were spread over a large area (about 180 km from northeast to southwest; Fig. 3). Road fatalities occurred mainly on the national road #10 and close to the town of Mirosławiec. The majority of the European bison mortality events occurred in road sections overlapping with the main activity areas of European bison herds, as revealed from the extensive GPS tracking data (Fig. 3).

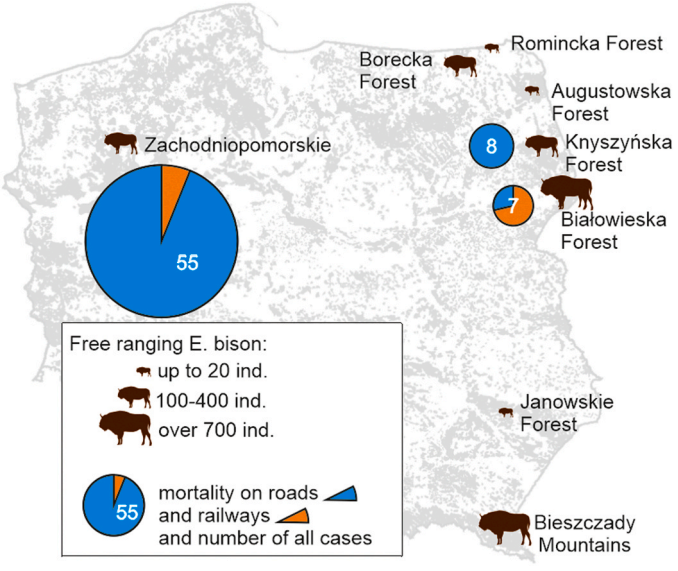

Fig. 1. Number of European bison fatalities on roads and railways between 2010 and 2021 for all free-ranging European bison populations in Poland.

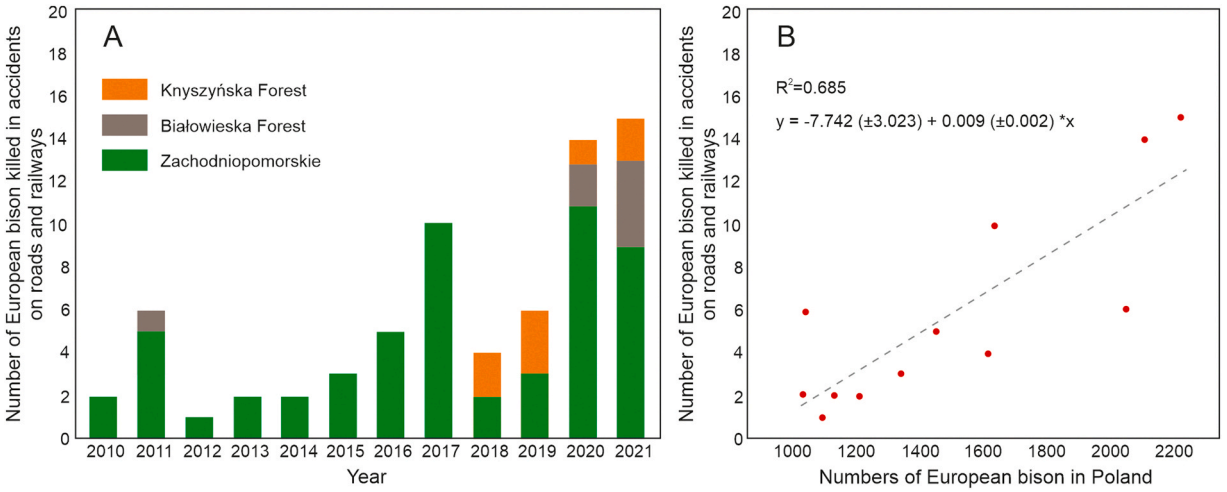

Fig. 2. European bison fatalities over time. A) Annual numbers of fatalities on roads and railways in Poland from 2010–2021. B) Relation between fatalities and the number of free-ranging European bison in Poland for the same period ($F=16.17$, $p = 0.002$).

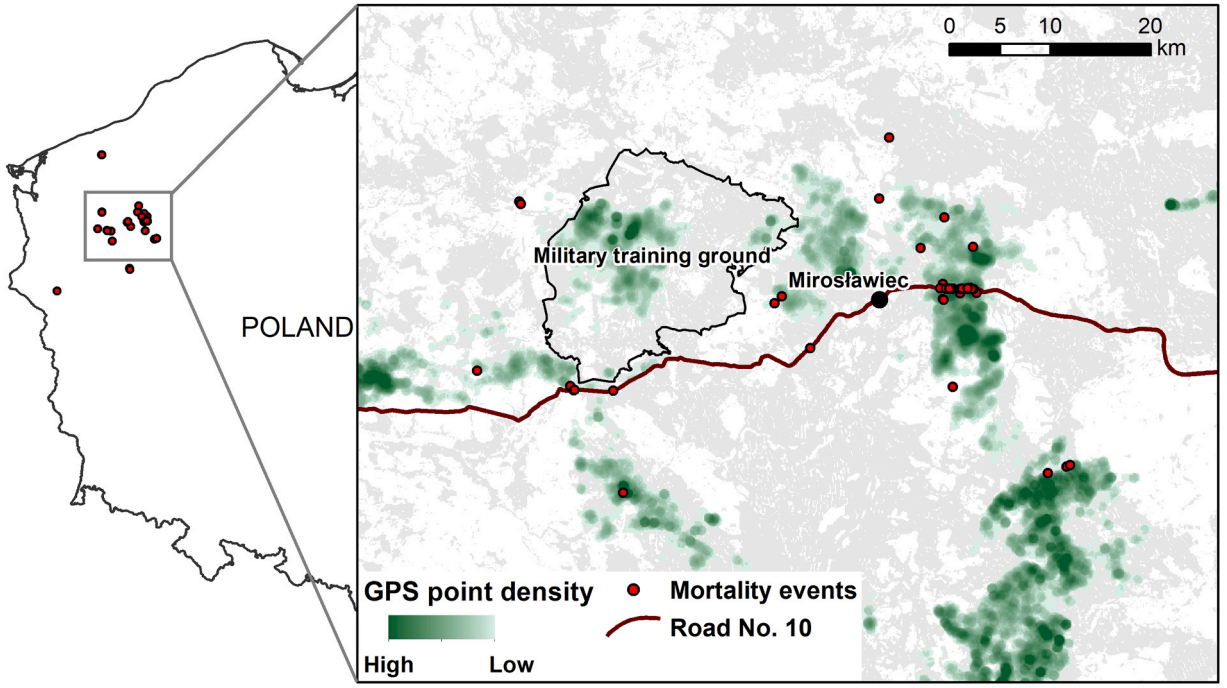

Fig. 3. Location of European bison fatalities on roads in the Zachodniopomorskie population in western Poland. Green colors signal the spatial activity patterns of European bison herds in the region, based on GPS collar data (most herds in this population contain animals with GPS collars).

4. Discussion

European bison, brought back from the brink of extinction, are growing in numbers where they have been reintroduced in Central and Eastern Europe, but they are still a species of conservation concern (Plumb et al., 2020; Olech and Perzanowski, 2022). Our study is the first to analyze the mortality of European bison connected to roads and railways. Focusing on free-ranging European bison populations in all of Poland, our analyses reveal two major insights. First, we found that most European bison fatalities occurred in only one population (Zachodniopomorskie in western Poland, Fig. 4), which is neither the largest nor the oldest population. High mortalities in this population appear to be mainly connected to a single, highly trafficked road, suggesting that local mitigation measures could address this issue effectively. Second, we found a generally growing number of European bison fatalities on roads and railways as the number of free-ranging European bison in Poland increased. This underscores the need for forward-looking wildlife conservation

Fig. 4. European bison herd crossing National Road #10 in the Zachodniopomorskie region (Photo: H. Reinke).

planning to avoid future road mortality as European bison expand their range.

Our study shows that mortality of European bison on roads and railways is overall fairly uncommon but may be a locally very important cause of death. For the population in Zachodniopomorskie in western Poland, the number of European bison killed on roads in 2020 accounted for 3.3% of the population, making it a major cause of mortality. For example, the natural mortality of European bison is also estimated at about 3% (Krasińska et al., 2017). Furthermore, according to Lizoń (2014), already in the period 1980 – 2014, fatalities of European bison on roads accounted for 35% of all deaths in Zachodniopomorskie. So far, the high number of killed European bison on roads and railways in Zachodniopomorskie does not seem to inhibit the continued growth of this population. Nevertheless, it should be noted that this population was for a long time augmented with individuals transported to it from other populations and breeding centers.

The relatively high number of European bison fatalities on roads and railways in Zachodniopomorskie can neither be explained by the size of the population nor the home range size. The population size of the European bison in Zachodniopomorskie is roughly half of the size of those populations in Białowieska Forest and Bieszczady (Raczyński, Bołbot, 2022), and the population home range is twice as large as in Białowieska Forest, and similar to Bieszczady (Kuemmerle et al., 2018), but the traffic mortality rate was almost six times higher in Zachodniopomorskie than in Białowieska Forest, and no fatalities were recorded in the Bieszczady Mountains. In our opinion, the main reason for the large differences in mortality is the occurrence of highly-trafficked roads within and near the European bison home range in Zachodniopomorskie. Specifically, National Road #10, with traffic volumes of 5000–9000 vehicles per day (https://www.gov.pl/web/gddkia) dissects through the central part of the population home range in Zachodniopomorskie (http://zubry.org). This road also passes through the main activity area of a part of that population, which is also where most mortality events occurred (Fig. 3). In the other populations we investigated, no roads with a comparable level of traffic exist, and heavily-trafficked roads are located at the periphery of the home ranges of these populations (Plumb et al., 2020). The threat from vehicles is particularly high in the autumn and winter periods when European bison are looking for a suitable forage, and this period coincides with increased collision frequencies of other large mammals (Neumann et al., 2012; Krauze-Gryz et al., 2017; Borowik et al., 2021). We also note that the pattern we find here for European bison has also been identified for American bison foraging near roads (Thomas et al., 2021).

The second important phenomenon shown by this work is a substantial increase in the fatalities of European bison on roads and railways over time. This increase took place not only in Zachodniopomorskie, but also in Białowieska Forest, where six out of the total seven fatalities occurred in the last two years we assessed (2020–2021). Moreover, in Knyszyńska Forest all cases of road mortality were observed in the most recent four years (2018–2021). While the overall numbers of fatalities are small, they may have local significance for population recovery, and the increasing trends we identify might signal an emerging conservation problem for these populations.

This is even more important as these events seem to affect more female European bison than could be expected. The ratio of sex and age of individuals killed on roads and railways was close to those in the total population (Krasiński, 1978), which is inconsistent with what is usually found for ungulates, where males are typically more prone to road mortality (Bruinderink, Hazebroek, 1996). In European and American bison, long-distance dispersal is mainly observed in males, while females tend to move over shorter distances (Jung, 2017; Kowalczyk, Plumb, 2020). The relatively high rate of female individuals dying on roads in our case thus suggests that mortality occurs predominantly associated with movement within home ranges rather than with movement related to dispersal out of the home ranges.

Our findings also point to an increasing conflict between European bison and people, associated with vehicle collisions that can cause human injury and death, as well as considerable economic damage. The increasing road mortality of European bison was clearly correlated with the increase in the overall number of European bison in Poland (Fig. 2B). In our observation period 2010–2021, the number of free-ranging European bison in Poland more than doubled, and in Zachodniopomorskie it increased more than fourfold

(Raczyński, Bołbot, 2011, 2022). It can be expected that this trend will continue, suggesting that also mortality of European bison on roads and railways, and associated conflicts, will increase without effective mitigation measures. Such mitigation measures could include speed limits as well as creating wildlife over- or underpasses along with fencing of areas that are hotspots of road crossings (identified via telemetry data and/or movement models) or that are hotspots of accidents with European bison. Importantly, this would also benefit other wildlife, many of which likely also suffer from high road-related mortality in the same areas. We note that further research is needed to better understand European bison behavior in association with roads and road crossing, the health, economic and social costs of vehicle collisions, as well as how increasing collisions affect the attitude of local communities towards European bison, in Poland and other countries where European bison are again roaming freely.

Regarding European bison conservation planning, our study provides further evidence that European bison reintroduction areas should be primarily selected to minimize overlap with areas of high human pressure. Adequate habitat is essential, but it is increasingly becoming clear that the species is rather flexible in its habitat use (Kuemmerle et al., 2018), and taking into account the potential impacts of roads and railways is therefore necessary and possible (Ziółkowska et al., 2016; Kuemmerle et al., 2018). We suggest that reintroduction sites should seek to maintain an appropriate distance from heavily-trafficked roads, particularly considering that newly created populations may not stay in the areas intended for them but relocate to closeby areas or populations may expand as they grow (Tracz et al., 2008; Yanuta et al., 2021). A thorough analysis of potential traffic accidents and the effects of mortality on roads and railways on European bison population viability would be ideal to carry out prior to implementing reintroduction projects.

European bison and other large herbivores have been extirpated from our landscapes in many places, and with them the important ecological roles they play in ecosystems. Restoring them across their former ranges is therefore desirable from a restoration perspective and contributes to species' conservation. However, how to foster the co-existence of these species with people in shared landscapes is a challenge, and avoiding and mitigating the negative effects of wildlife-vehicle collisions, for people and wildlife, should be a priority in this context. Major steps in this direction involve proper monitoring of traffic collisions, assessments of the wildlife activity patterns and behavior close to roads and prior to crossing to identify critical locations where mitigation measures, such as speed limits, road fencing, wildlife bridges and other less expensive measures are effective in reducing accidents (Neumann et al., 2012; Huijser et al., 2016). However, nothing can replace drivers' education to increase their awareness of the possibility of European bison crossing roads and how to react in such cases. Though road signs exist it seems that they currently are not effective. Combining them with (enforced) speed limits would be a promising strategy, increasing drivers' chances of spotting animals entering roads. Moreover, pro-active assessments of where accident hotspots can occur, for already established populations or potential reintroduction sites, offer a window of opportunity to avoid escalating conflicts.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. Wanda Olech reports financial support was provided by Forest Fund (Poland). Tobias Kuemmerle reports financial support was provided by European Union.

Data Availability

Data will be made available on request.

Acknowledgments

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2023.e02703.

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