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Letter to the editor

Reply: Modeling scenarios of population response to roads as a conservation risk assessment strategy

Wildlife is under increasing pressure from environmental change, including habitat loss and fragmentation with increasing additional non-natural mortality due to roads. To understand the effects of roads on wildlife populations, and identify critical areas to prioritize actions, transportation and conservation managers and policymakers need to know how species respond towards roads. For decades predicting the effects of roads on wildlife populations has remained a challenge for conservation biologists due to the complexity of species data and the analysis of species-road interactions. We see an urgent need to move beyond the quantification of road-kills and evaluate the population-level consequences using advanced modeling approaches to address species vulnerability to road systems and where population viability risks are highest. We suggest using a high level assessment and macroecological approach as an important first step of a planning strategy that target areas for further testing at a finer-scale resolution and ultimately site-specific recommendations for road mitigation.

The giant anteater (*Myrmecophaga tridactyla*) is listed as Vulnerable by the IUCN Red List and is already extinct or on the verge in many regions of South America. The main causes for population declines are habitat degradation and loss combined with illegal hunting, mortality from vehicles and extensive wildfires. Currently Brazil lacks information on how this endangered species responds to roads at throughout their range. Thus, there is an urgent need to assess large impacts of roads on this species at a national scale to identify high risk landscapes for more in-depth local-scale research.

We applied theoretical models developed by Borda-de-Agua et al. (2011) using species data namely observed road-kill rates, population densities and demographic parameters to evaluate the effects of roads on giant anteater populations in Brazil (Pinto et al., 2018) by estimating the Minimum Patch Size (P_{min}) and Maximum Road Density (D_{max}), below and above which a population may not persist, respectively. There are uncertainties and methodological limitations when applying simple models to decision-support situations (Ferrier et al., 2016). Some of the parameters we used are valid only for the environmental conditions under which they were measured and therefore population models do not fully translate the range of population dynamics and environmental contexts within the species range. By definition, no model can represent reality, however, it is important to validate models to determine how well they reflect the system. One approach would be to estimate population density in different habitat patch sizes surrounded by roads and at different road densities. Unfortunately, no such studies exist yet due to their large financial and time costs. In reality, a parallel can be established with the use of Species Distribution Modelling (SDM) in projecting the impacts of climate change on biodiversity. Originally most SDM studies did not use any independent validation of their projections (Araújo et al., 2005). The ability of SDM to project species distributions for different climate conditions is now known to be lower than their predictive ability for current conditions, but it is still an active area of research. Such research was made possible by the wide adoption of SDM in the scientific community.

To overcome the lack of validation and some concerns with the Borda-de-Agua et al. (2011) model we ran simulations from the most pessimistic to optimistic scenarios (Pinto et al., 2018). For Minimum Patch Size (P_{min}) estimation we ran two contrasting scenarios to obtain the range of P_{min} estimates by using minimum and maximum dispersal capacity values (P1–P4 in Pinto et al., 2018). For Maximum Road Density (D_{max}) estimate, the Borda-de-Agua et al. (2011) model assumes infinite dispersal as a pessimistic scenario and therefore it corresponds to a lower bound estimate of the maximum road density. Species will persist in denser road networks than D_{max}, as real populations disperse less thus minimizing road-related mortality (Jaeger and Fahrig, 2004). Additionally, Borda-de-Agua et al. (2011) model assumes that roads act as a barrier and all individuals die when crossing the road to estimate the P_{min}. Since there are no data on how species perceive the road during movement we also ran the model considering that roads were permeable (patches were not intersected by roads, thus all individuals crossed successfully the road) (P1 and P2 in Pinto et al., 2018). Infinite carrying capacity is one of the assumptions to estimate P_{min} which does not change the critical patch size calculation (Pereira and Daily, 2006). The reason is that the criteria for population persistence in a given landscape is that it must grow when the population density is low, and when the population is low the growth in a logistic model is similar to an exponential model.

However, we conducted a post-hoc analysis taking partial derivatives of the P_{min} and D_{max} with respect to input variables. This allowed us to examine the impact of parameters variability on the results of P_{min} and D_{max}. The analysis showed that when changing 20% of the parameter values the highest influence on the results for P_{min} came from dispersal capacity and litter size that changed 40% and 38% of P_{min}, respectively. A similar approach for D_{max} showed that the highest influence on the results for D_{max} came from road-kill rate and population density by changing 19% of D_{max}.

Simplified models of ecological systems can play an important role providing first insights of ecological phenomena that incites further research and testing. We recognize that simple models may not be of use when high resolution and local scale research results are needed to inform site-specific conservation actions or mitigation plans. That is not their function. However, macroecological models do provide specific opportunities to test and refine the population models at a local scale with site-specific data. These model scenarios provide opportunities to evaluate key risk hypotheses and analyze the relative importance of different road effects on population persistence of species of conservation concern.

In our study, habitat fragmentation *per se* appeared to have a greater impact than road-related mortality, which we explained by the low road density in Brazil. We underscored in our paper that the results

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should be interpreted with caution. We recognize the need for improved methods and information to support decisions for mitigation. However, we do not agree with the authors' statement that these results can lead road managers to make ill-informed decisions regarding mitigation measures selection since the most effective measures to reduce road-kill also reduce barrier effects. Ignoring macroecological modeling approaches because of a lack of high-resolution local-scale data or because we are unable to validate them would overlook an important tool in the conservation toolbox. Macroecological approaches can bring important conservation attention to not only to species at high risk of disappearance, but also the increasing proliferation of roads and their harmful effects on wildlife populations.

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