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Review paper

On the origin of species on road warning signs: A global perspective☆

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ABSTRACT

Collisions of vehicles with animals are an increasing problem, and due to the loss of animal, as well as human, life is an active topic in applied ecology. One of the best-known mitigation methods to avoid collisions is the provision of dedicated road warning signs. However, due to changes in landscape, in the densities of cars and animals, and to changes in animal and driver behavior, there have been recent modifications to the style of signs and in the animal species featured on them. It is apparent that developments in the design of road signs, and the perception by humans that particular animals are important have changed in parallel. However, the situation regarding animal road signs varies between countries, and different legal systems, evolving from the 1968 Vienna Convention. We review the global situation of animal road warning signs, paying attention to the animals featured, and evaluate how the system works and what should be improved in the near future. We also provide some ideas on how a warning sign system can link to automatic driverless vehicles, which will probably develop much faster than we anticipate.

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☆ One sentence message: Road signs featuring both domestic and wild animals exist in many variants worldwide, and are undergoing rapid design changes due to the recent improved perception of animals.

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1. Introduction

Interactions between humans and animals take many forms, and sadly one of the most damaging, both for humans, as well as for wildlife, are collisions between animals and road vehicles (Glista et al., 2009; Gunson et al., 2011; but see: Morelli et al., 2014). These result in serious ecological and financial costs, and solutions to effectively solve the problem have been sought for many years (Huijser et al., 2015; Mrtka and Borkovcová, 2013). Since the beginning of modern car and other vehicle usage, warning signs have been provided according to international law conventions; the main two being the 1931 Convention on the Unification of Road Signals Geneva and the 1968 Vienna Convention on Road Signs and Signals, United Nations Economic and Social Council (more details in Supplementary Material). Warning signs were initially provided (see declaration in the 1931 Convention) because of the clear economic costs of collisions with large animals, calculated as the cost of car repair and the value of the animal; protection of drivers and passengers was a lesser concern. However, the system has evolved, and in order to be more effective the warning signs have varied in design between countries (or groups of countries linked into bigger political organizations, e.g. The Commonwealth) according to differences in cultures, natural resources and legal systems (Oppong, 2019), and have changed over time. When the road sign has been installed, the main human reaction to these warning signs is simply recognition of their presence, and this is a reason why some warning signs tend to be even larger than other traditional (e.g. prohibitory, mandatory, direction) signs (Farr et al., 2012; Huijser et al., 2015; Valerio et al., 2021). The presence of signs mainly provides psychological comfort to drivers but also reduces the costs of potential vehicle collisions (car repairs, hospitalization and other medical costs) to insurance companies (Bond and Jones, 2013; Found and Boyce, 2011). However, despite their widespread use, accurate information on the effectiveness of the mitigation provided by different designs of road signs, although dispersed among publications or anecdotal, is not clear, even in those publications which try to provide practical suggestions on how to use particular road signs to minimize wildlife-vehicle collisions (Huijser et al., 2015).

Recently, due to rapid changes in the environment, and focusing on aspects other than purely financial (collisions as costs), the function of signs has also changed as a result of a greater understanding of global biodiversity decline (Bennett, 2017). This behavior includes recent concerns for small animals, such as frogs, toads, and snakes, whose declines can be attributed to road infrastructure (Glista et al., 2008; Kolenda et al., 2019; Langley et al., 2006; Woltz et al., 2008). These concerns, mainly due to cultural and ethical reasons, can be quite topical, and one recent example is the need for signs displaying hedgehog *Erinaceus europaeus* in the UK (Pettett et al., 2018). Moreover, in some locations, such as in Africa, livestock signs have replaced those of large game animals (Hempson et al., 2017), with consequences for transport security, but livestock herds are more often fenced, and so the probability of collisions with domestic animals is better predicted both temporally and spatially (Creech et al., 2019; Gunson et al., 2011). Signs and their appropriate design can then be more precisely located. But, to the best of our knowledge, how these changes are incorporated into the legal system of road use across the world has not yet been reviewed or even closely checked.

Hence, we here attempt to summarize available published information (including gray literature and Internet sources) on which, and what animal species are featured on road warning signs. We want to answer the main questions: 1) how are animals chosen for road warning signs and do we need different designs of signs?; 2) how effective is the proliferation of designs in practice and will it help in drivers' habituation? Moreover, we are also interested in the following: 3) has the number of types of road signs with animals changed since the 1968 Vienna Convention?; 4) do possible changes in road sign design concern domestic and wild animals equally? In particular we wish to understand what has to be changed in the future for the improved safety of human road users, as well as of animals. Moreover, because we present a global perspective, this may hopefully encourage a possible change in modern legislation for road signs.

2. Material and methods

We carried out a comprehensive bibliographic search of publications in different official languages, using the Scopus database to search up to December 2019 for articles using the following keywords: road*sign(s)*animal(s). Subsequently, we searched the references in each of these articles for published papers which might contain data useful for this review. However, due to the very limited number of publications, we also checked all possible legislative systems in official languages, mainly using links provided by Wikipedia entries for UN countries (available for 223 out of 227 possible countries and territories, representing more than 99% coverage, whether based on either human population size or on area). Further information was obtained from Google Scholar and Google Books (till December 2020). When a suitable publication was found, its references (backward search) and citation records (forward search) were used to identify other relevant articles. We also searched for information on animals on road signs in previously unused sources including internet searches for trip reports, images and

videos hosted by Google, Google Images, Flickr, Twitter and YouTube. We searched not only in English and Latin but also included numerous other national languages and scripts, although the search was restricted by our knowledge of particular languages.

In the most developed legal systems there are usually three acts of law concerned with road signs: a traffic code, a regulation on collection of road signs and their meanings, and a regulation on the application of road signs defining dimensions, location and reflectivity. Regulations are usually easier to change than laws. In less developed countries, the practice of designing road signs varies. Usually a catalog of road signs is a part of the law – a traffic code. Sometimes signs are just adopted customarily or by some form of administrative decision: decrees of the police, manuals of road managers etc. In the case where a country lacks their own catalog of road signs, the Vienna Convention (see Supplementary Material) can be applied directly.

3. Results

In the legal system of 223 countries and territories, animal road signs, both domestic and wild, have been coded by the Vienna Convention since 1968 and have also spread to countries who had not signed the convention (all indicated in the Supplementary Material). Interestingly, there are only a few countries that do not have animals on road warning signs (all are rather small islands, including Malta). Since 1968 the number of road signs featuring animals has increased greatly, mainly of wild animals (Fig. 1). In this time period, the number of types of road signs featuring domestic animals has increased from 1 to 6, while the number featuring wild animals has increased from 1 to at least 38. The proportion of all animal signs featuring wildlife is now significantly greater than that for domestic animals ($\chi^2 = 23, 27, p < 0.001$). The shape and color of road signs vary across the world following local traditions; sometimes these are heritage adopted from a previous political (e.g. colonial) system. For example, in Europe the color background of a sign (white or yellow) is related to snow cover; yellow signs generally in northern and central countries, and white in the south where snow is less of an issue in obscuring road signs. This is an example of how countries adapt to local climate and environmental conditions, and this is especially true in large countries (by area), provinces and states (e.g. Canada, USA, Japan) which differ in the animals featured on their signs. In an open system (where new warning signs are created by private or citizen initiative – Figs. 2–4) there is a greater tendency to feature more animals, especially wildlife, on road signs. In a citizen science project, Czech Republic road signs have been photographed by a motorcyclist (Fig. 2), and data are available from the web page: http://meli.cz/znacky.html. Giving details on location (including GPS coordinates) and date, this information can be used by other road users for the purposes of wildlife tourism. It is mainly local, well recognized and charismatic species that feature on road warning signs, based on local tradition and nature resources. Sometimes, information is added to other road signs, especially if not yet included in the legal system (e.g. amphibians, reptiles), and new, dynamic signs, related to the actual presence of an animal, for example brown bear *Ursus arctos* in Slovenia (Fig. 5), which work only if animals are in the vicinity of the road, a system operated by GPS tracking in the bear's collar.

Sometimes even warning signs, whilst informative for drivers, can be misleading by understating the dangers for local biodiversity, such as in Australia where (as reported in social media, Twitter) road signs in one location are dedicated to the protection of the local fauna of wombat (*Vombatus* sp.) and kangaroo (different species of Macropodidae) together with an invasive species – camel *Camelus dromedarius* (Wells and Lethbridge, 2020).

4. Discussion

Road signs featuring animals, both domestic and wild, are widely used in many countries and the number of different signs for wild animals is increasing. However, it is important to answer two basic questions: (1) how many different designs of signs do we really need (Occam's razor)? (2) how effective are they in practice? Although these (the latter question in particular) are crucial from a conservation point of view, we do not have direct answers to either, but rather both require further research. Consequently, we can only hypothesize and discuss the current situation, and make suggestions on how to develop future research to collect stronger evidence on how warning road signs play a role for biodiversity, and in the safety of drivers and passengers.

The first question above is not only related to potential collisions, but also to psychological issues, known as protection of the clear conscience, of the general public, NGOs and public agencies, and is at least a visible indication that they are doing something to protect animals (and road users). This type of argument was used in Ecuador, the global biodiversity hotspot, but which does not have a serious problem with animal collisions (Myers et al., 2000; Suarez et al., 2009). It fits in to a more general concept visible as a philosophy of road sign design, firstly to protect drivers and passengers from collision with animals, to the more recent emphasis on protecting animals, especially rare animals, from vehicle collisions. This view is strongly supported, not only by road administration, but also by the general public. A similar option to add new types of animals is allowed in the road rules of Switzerland and Liechtenstein. However, the Czech Republic gives road managers the decision in choosing the content of animal warning signs. As a result, local road managers usually show great creativity by featuring many different species of animals (Fig. 2). There is also no common practice of using the same graphical representation for the same animal species. Road warning signs are not only to protect road users, but increasingly act as a local tourist attraction (kangaroo signs in Australia, caribou in Canada, or moose and reindeer in Fennoscandia), and helps way remembering (Farr et al., 2012). But, even where greater freedom in road sign design is practiced, not all serious problems can be solved. For instance, in western Poland, the most important animal in vehicle collisions is the European Bison *Bison bonasus*, a very large animal often crossing roads and as such a serious problem for road users. To mitigate the system, according to national law, signs featuring deer (as a

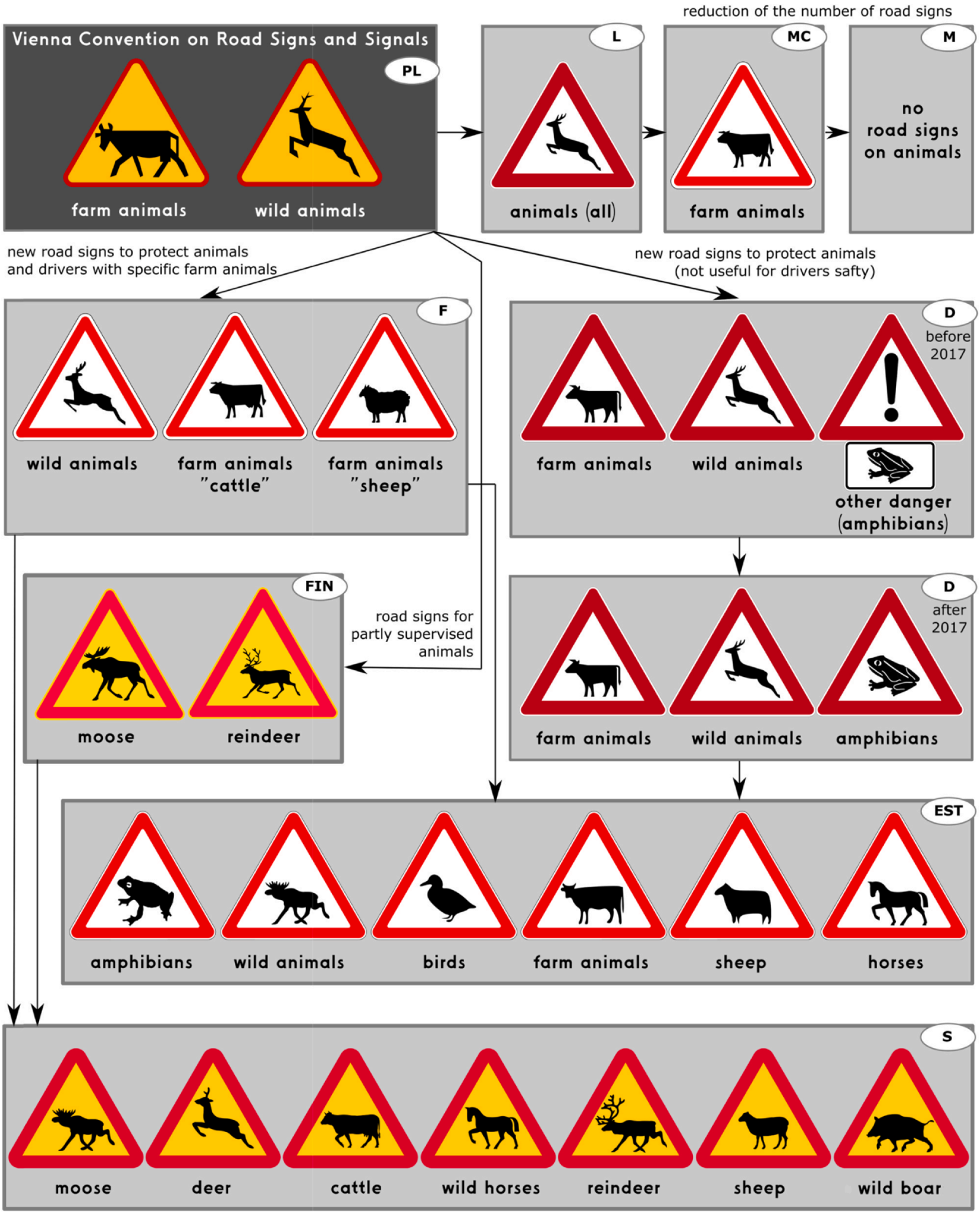

Fig. 1. Evolution of road signs in European country signatories of the Vienna Convention (country indicated by signs according to International vehicle registration code).
Source: own compilation based on countries' acts of law.

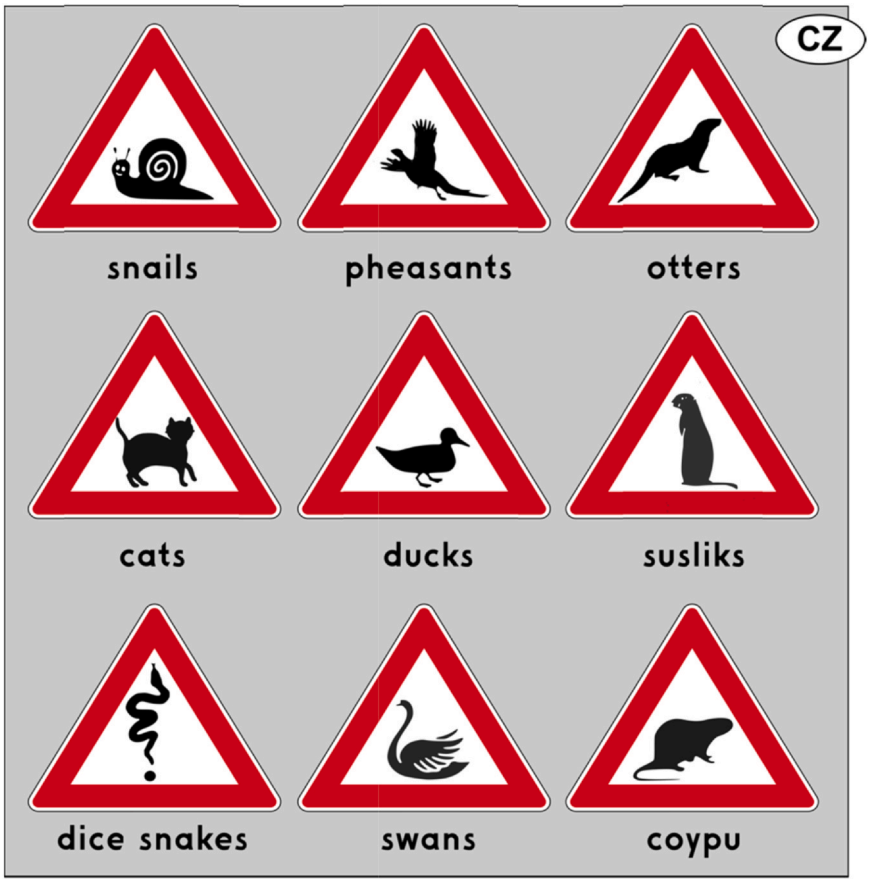

Fig. 2. Variability of road signs in the Czech Republic – an open road sign system (http://meli.cz/znacky.html).
Source: own compilation based on the Czech Decree No. 294/2015 implementing road traffic rules and photos taken by Milan Meli (http://meli.cz/znacky.html) and authors of this paper.

general wildlife warning sign) are provided alongside roads, but in fact, by sight, size and even biological relationships (Hayward et al., 2015; Łozicki et al., 2017), a sign featuring domestic cattle would probably be more appropriate in this particular situation.

The origin of new signs is interesting, not only from the viewpoints of collision reduction and of conservation, but also from a psychological perspective. Drivers have a tendency to become habituated to signs, but new ones are commented on in social media and more attention is paid to them (Al-Ghamdi and AlGadhi, 2004; Bazire and Tijus, 2009; Jones, 2018). Obviously, the number of animals on road signs represents only a tiny proportion of all global biodiversity, but their function is not to refer to local animal diversity. They do provide information, as well as warnings. Currently new technology, including dynamic road signs that become active only if a particular animal is close to the road, becomes important, especially if the animal is large (with greater costs, in all senses of the word, to road users) and endangered (costs to nature conservation), such as bears (Find'o et al., 2018; Skuban et al., 2017). However, there are few examples of how the system really works in practice, for example in unfavorable weather conditions, when the number of car incidents with the animals may increase greatly (Rowden et al., 2008; Druta and Alden, 2020).

It is also worth noting that warning signs work more effectively when a speed limit is set in addition to the animal warning sign (Found and Boyce, 2011; Langley et al., 2006). Recently, it is clear that more signs dedicated to wildlife than to livestock have been designed, which can obviously be related to the much higher number of wild than domestic species, but also to social changes and greater awareness of conservation. Furthermore, domestic animals (horses, cows, sheep) now cross roads in villages less frequently due to economic and social changes, at least in developed countries (Thornton, 2010).

However, warning signs play not only a positive, in fact an informative, role, even if ignored, but occasionally drivers can intentionally target wildlife on roads and kill some of them, such as feral cats or snakes (Beckmann and Shine, 2012; Collinson et al., 2019).

The function of warning signs in the future looks interesting, for example how will they work for full, automatic driverless vehicles, steered by computer? This problem cannot be ignored (Bendel, 2018; Mammeri et al., 2016), because although an algorithm can work for large animals and initiate changes in braking or steering, similar to open dynamic signs and virtual

Fig. 3. Examples of road warning signs in Venezuela. The system is open, but symbols of the most popular animals are defined.
Source: own compilation based on countries' acts of law.

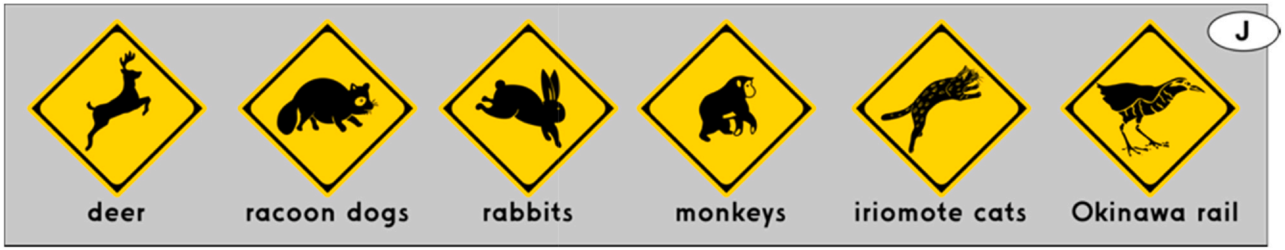

Fig. 4. Road warning signs in Japan. Open to change in each prefecture - Japan Road Association "Road sign setting standard - commentary".
Source: own compilation based on countries' acts of law.

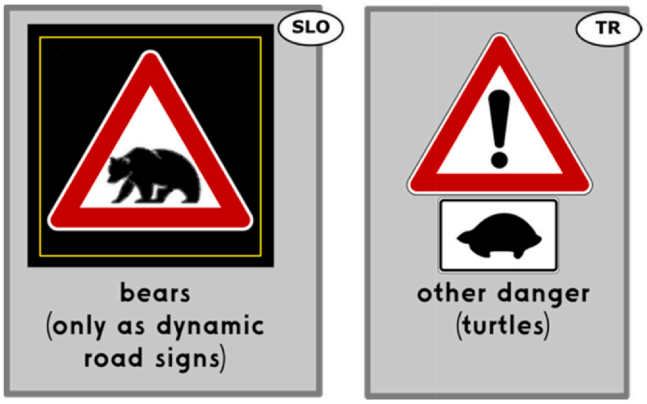

Fig. 5. Two solutions from Slovenia and Turkey.
Source: own compilation based on countries' acts of law.

fences for road-crossing animals (Englefield et al., 2019), for smaller, less visible animals, such as crabs, amphibians or reptiles, retrieving information from road signs may be better and more quickly adopted.

The great variability in road signs shapes, colors and forms complicates their recognition by traffic-sign recognition technologies which use image processing techniques to detect them. The task might be even more difficult when systems should recognize traffic signs under complicated conditions, such as variations in light conditions, deformation of signs, partial occlusion, the presence of shadows, surrounding clutter, rain or snow (Uçar et al., 2017; Wachenfeld et al., 2016). This problematic task can be fully eliminated by a new traffic control infrastructure that wirelessly communicates with the driverless vehicle (Knoefel et al., 2019).

To conclude, new signs featuring animals and new animals on road signs are evolving, but the situation is very dynamic, and we expect more dramatic changes in the near future. Moreover, we underline the importance of considering biodiversity when planning future transport infrastructure, including in road sign design and location.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

PT: conceived and designed the research, performed the research, analyzed the data, authored the paper, approved the final draft; **MB:** conceived and designed the research, performed the research, analyzed the data, contributed reagents/materials/analysis tools, prepared figures, authored or reviewed drafts of the paper, approved the final draft; **AMK:** authored or reviewed drafts of the paper, approved the final draft; **FM:** authored or reviewed drafts of the paper, approved the final draft, TS: performed the research, analyzed the data, contributed reagents/materials/analysis tools, authored or reviewed drafts of the paper, approved the final draft; **PS:** conceived and designed the research, authored the paper, approved the final draft. Competing interests: we declare no competing interests. Data and materials availability: All data are available in the main text or the supplementary materials.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2021.e01600.

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