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Editorial: Amphibian and reptile road ecology

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Editorial on the Research Topic
Amphibian and reptile road ecology

Roads have complex negative impacts on biodiversity and may threaten the persistence of wildlife populations by acting as barriers to movement or sources of increased and sometimes substantial mortality (e.g., van der Ree et al., 2015; Moore et al., 2023). Amphibians and reptiles (herpetofauna) are known to be particularly susceptible to negative road impacts (e.g., Beebee, 2013; Andrews et al., 2015). Many species migrate among habitats to support basic life history requirements and must cross dangerous roads multiple times each year. Additionally, most herpetofauna species are relatively slow-moving and freeze in the presence of oncoming vehicles (Andrews and Gibbons, 2005; Mazerolle et al., 2005), resulting in an increased risk of mortality for the individual, and increased risks of decline or extirpation for vulnerable populations.

Road ecology and mitigation solutions have developed substantially in recent decades. However, progress in knowledge of their effectiveness has been hampered by a lack of post-mitigation research focused on individual and population-level responses to passage-barrier systems. Examples of critical knowledge gaps include quantified understandings of the proportions of individuals that successfully cross via passages or changes in population abundance over time (e.g., Soanes et al., 2024).

This Research Topic aimed to increase our understanding of both the effects of roads on amphibians and reptiles and the effectiveness of mitigation structures. We sought research from a diversity of regions, landscapes, and species that addressed meaningful road ecology science questions to help inform conservation. Contributed articles fell into three broad categories: 1) Characterizing road mortality and planning for mitigation; 2) Effects of roads, barriers, and passages on movement behavior; and 3) Design, efficacy, and maintenance of barriers and passages.

Road mortality hotspots are commonly used for prioritizing placement of fencing and passages; however, data available and approaches used can vary widely (Paemelaere et al., 2023; Ribeiro et al., 2023). Shin et al. compared citizen science (CS) roadkill data in the Republic of Korea to standardized published data and found advantages of widely available

CS data in increasing both geographic and temporal breadth. CS data also identified hotspots of mortality and captured observations on behavioral ecology of herpetofauna, such as temporal patterns and trends in breeding, hibernation, and habitat use. They concluded that the two types of data are complementary, and that recording spatial and temporal effort would benefit CS survey data in less-studied species. Gonçalves et al. published a standardized 6-step sampling and analytical framework for use in prioritizing mitigation actions for amphibians. The novel framework incorporates site selection, imperfect carcass persistence and detection probabilities, and higher priority values for natural areas with native cover types that are less prone to landscape transition. They then demonstrated the applicability of this approach along several roads in southern Brazil.

The probability of populations being extirpated due to road impacts may affect decisions on mitigation implementation. Wilkinson and Romansic conducted population viability analysis for California newts along a 6.6 km stretch of road with high annual mortality. Annual monitoring by citizen scientists (Parsons, 2021) coupled with a road mortality and permeability study allowed estimation of future population size in the absence of mitigation. Results predicted population extirpation in <100 years indicating a strong need for safe crossings.

Studies of species and individual movement patterns in relation to roads, barriers, and passages are paramount to informing connectivity and the design placement of these systems across the landscape. In this Research Topic, Hromada et al. recorded Mojave desert tortoise movements using GPS loggers and found that they were generally more active and made longer movements near off-highway vehicle (OHV) areas, dirt roads, and road barriers, and were less active and made shorter movements near an unfenced highway. Similarly, using accelerometers, Tipton et al. found timber rattlesnakes also made longer movements over greater time periods when encountering dirt and low-traffic paved roads relative to their movements in surrounding habitats. Both studies suggest that increased energy expenditures of reptiles near roads and barriers may be related to direct interactions to these features (e.g., avoidance, pacing back and forth) or to responses to habitat and resource modifications associated with these linear features.

Using temperature-sensitive transmitters, Sisson and Roosenburg were able to determine that timber rattlesnakes, particularly gravid females, easily breached an unmaintained barrier fence to access thermal refugia (open habitat, rock piles) available in the roadside right-of-way (ROW) habitat. In addition to fence maintenance, they suggested creating suitable thermal refugia away from the road to reduce risk of vehicle strikes and mortality from ROW maintenance. Testud et al. used PIT tags and multiple RFID antennas to monitor movements of great-crested newts within passages. They found that newts were more likely to move forward in the first meters of shorter passages, suggesting a need for research into the mechanisms responsible for this response (e.g., odor, brightness, temperature, ventilation, distance). These studies illustrate that understanding individual behavioral responses to roads, mitigation structures, and surrounding habitat may help to further understand broad-scale connectivity patterns and better inform mitigation strategies.

Once mitigation systems are constructed, it is vital to monitor their effectiveness, to verify their value, and improve future designs. Two studies in this Research Topic focus on wildlife barriers, intended to keep animals off roads and to lead them to safe passage(s). Conan et al. tested the efficacy of solid-panel permanent barriers of differing material, height, and shape (presence/absence of an overhang) with five amphibian species with different climbing and jumping abilities and in both dry and wet conditions. They found that a smooth 40-50 cm high concrete barrier equipped with a 10 cm overhang was effective in stopping the majority of amphibians. They also stressed the need for maintaining the vegetation near barriers for continued effectiveness. There is often high amphibian road mortality where barriers end (Helldin and Petrovan, 2019). Harman et al. tested the efficacy of experimental perpendicular and angled 'turnarounds' at fence ends in changing the movement trajectory of multiple amphibian species. They found that individuals of several amphibian species changed direction at the barrier turnarounds and oriented towards road passages, which supported their use for amphibian mitigation systems and corroborated their effectiveness in changing trajectories of snakes, lizards, and toads (Brehme et al., 2020). The authors cautioned that length of barrier is important, and more studies are needed to inform the design and orientation of barriers.

The permeability of under-road passages to amphibian movement can be widely variable based on biotic and abiotic passage characteristics, passage spacing, species, and location (Langton and Clevenger, 2017). In this Research Topic, enhancing the permeability of existing passages by modifying vegetation is suggested by the studies of Sisson and Roosenburg, Brehme et al., and Testud et al. also showed that enhancing permeability of passages for amphibians migrating to aquatic breeding habitats may be achieved through acoustic enrichment (playing frog calls).

Spacing passages in between long stretches of road lined with barriers can result in a large proportion of animals not finding passage entrances due to 'giving-up' (e.g., Ottburg and van der Grift, 2019; Brehme et al., 2021). Brehme et al. designed and tested a novel elevated road segment (ERS), similar to a low terrestrial bridge, that was placed on top of an existing road. The 20-cm high and 30-m long prototype was composed of road mats on top of billet support bars that were perpendicular to the road. The design negates or reduces the need for barriers as it creates open passages that are continuous across its length. Results of monitoring over four years showed this was effective for a large number of amphibian, reptile, and small mammal species and offered a new design option for crossings that can be deployed to any length.

Finally, maintenance of mitigation structures is extremely important and short-term studies may not be reflective of future effectiveness (e.g., Sisson and Roosenburg; Hedrick et al., 2019). One reason for changes in use may be due to accumulation of pollutants within passages. Over four sites across the UK, White et al. showed significant increases in a variety of chemicals in both closed-top and open-top passages over time, with most passages having elevated pH, copper, lead, and total petroleum hydrocarbon levels. As amphibians are particularly susceptible to chemical pollutants due to their permeable skin, this study highlighted important considerations for monitoring, maintenance, and design of amphibian passages.

The long-term conservation of herpetofauna requires adequate planning for habitat connectivity to facilitate movement and allow adaptation. This includes designing, installing, and maintaining safe and effective crossing structures for linear transport infrastructure. Often, when a target species is documented using a crossing, it seems natural to consider the problem solved. However, when high connectivity is needed, installation of inadequate passage-barrier systems may reduce the proportion of animals successfully crossing the road and result in population decline (e.g., Ottburg and van der Grift, 2019). In addition, passage use may increase or decrease over time, but this pattern is infrequently captured as long-term studies are rare. The studies in this Research Topic contribute to enhancing our understanding of reptile and amphibian response to roads, barriers, and passage systems, and further inform mitigation planning, design, and maintenance. Well-designed and prioritized research is needed to address the importance of passage system attributes in enhancing crossing rates, as well as long-term population monitoring of all life stages, to assess the effectiveness of these systems for maintaining viable populations.

Author contributions

CB: Writing – original draft, Writing – review & editing. SP: Writing – original draft, Writing – review & editing. VP: Writing – original draft, Writing – review & editing. TL: Writing – original draft, Writing – review & editing. KA: Writing – original draft, Writing – review & editing. RF: Writing – original draft, Writing – review & editing.

Conflict of interest

Author TL was employed by the company Herpetofauna Consultants International Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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References

Andrews, K. M., and Gibbons, J. W. (2005). How do highways influence snake movement? Behavioral responses to roads and vehicles. *Copeia* 2005 (4), 772–782.

Andrews, K. M., Nanjappa, P., and Riley, S. P. (2015). *Roads and Ecological Infrastructure: Concepts and Applications for Small Animals* (Baltimore, MD: John Hopkins University Press). doi: 10.1353/book.39710

Beebee, T. J. (2013). Effects of road mortality and mitigation measures on amphibian populations. *Conserv. Biol.* 27, 657–668. doi: 10.1111/cobi.12063

Brehme, C. S., Tracey, J. A., Ewing, B. A., Hobbs, M. T., Launer, A. E., Matsuda, T. A., et al. (2021). Responses of migratory amphibians to barrier fencing inform the spacing of road underpasses: a case study with California tiger salamanders (Ambystoma californiense) in Stanford, CA, USA. *Glob. Ecol. Conserv.* 31, e01857. doi: 10.1016/j.gecco.2021.e01857

Brehme, C. S., Tracey, J. A., Kingston, J., Sebes, J. B., Edgarian, T. K., and Fisher, R. N. (2020)Effectiveness of turnarounds in changing the trajectory of reptiles and amphibians in San Diego, CA. In: *Research to Inform Caltrans Best Management Practices for Reptile and Amphibian Road Crossings*. Available at: https://dot.ca.gov/-/media/dot-media/programs/environmental-analysis/documents/final-caltrans-usgs-report-herproadresearch-rev.pdf (Accessed March 13, 2024). USGS Cooperator Report to California Department of Transportation, Division of Research, Innovation and System Information.

Hedrick, B. P., Vander Linden, A., Cordero, S. A., Watt, E., O'Roark, P. M., Cox, S. L., et al. (2019). Keeping salamanders off the streets: evaluating and modifying one of the first US amphibian road tunnels 30 years after installation. *J. Urban Ecol.* 5. doi: 10.1093/jue/juz023

Helldin, J. O., and Petrovan, S. O. (2019). Effectiveness of small road tunnels and fences in reducing amphibian roadkill and barrier effects at retrofitted roads in Sweden. *Peer J.* 7, e7518.

Langton, T. E. S., and Clevenger, A. P. (2017) *Amphibian and reptile highway crossings: state of the practice, gap analysis and decision support tool. Report prepared for the state of California, Department of Transportation, Division of Research and Innovation, Office of Materials and Infrastructure Research, June 2017*. Available at: https://westerntransportationinstitute.org/wp-content/uploads/2021/05/4W5589_Lit_Review_amphib-reptile-crossings_3July2017.pdf (Accessed May 02, 2023).

Mazerolle, M. J., Huot, M., and Gravel, M. (2005). Behavior of amphibians on the road in response to car traffic. *Herpetologica* 61, 380–388. doi: 10.1655/04-79.1

Moore, L. J., Petrovan, S. O., Bates, A. J., Hicks, H. L., Baker, P. J., Perkins, S. E., et al. (2023). Demographic effects of road mortality on mammalian populations: a systematic review. *Biol. Rev. Cambridge Philos. Soc.* 98, 1033–1050. doi: 10.1111/brv.12942

Ottburg, F. G., and van der Grift, E. A. (2019). Effectiveness of road mitigation for common toads (*Bufo bufo*) in the Netherlands. *Front. Ecol. Evol.* 7. doi: 10.3389/fevo.2019.00023

Paemelaere, E. A., Mejia, A., Quintero, S., Hallett, M., Li, F., Wilson, A., et al. (2023). The road towards wildlife friendlier infrastructure: Mitigation planning through landscape-level priority settings and species connectivity frameworks. *Environ. Impact Assess. Rev.* 99, 107010. doi: 10.1016/j.eiar.2022.107010

Parsons, A. (2021) *Mass mortality of Pacific newts at Lexington reservoir bearing witness to the decimation of two populations: Summary of four migration seasons (November 2017 – May 2021)*. Available at: https://4f81b87a-f0a5-4d8f-93b9-ca628f6c8f26.usrfiles.com/ugd/4f81b8_fb79203c08d14fa2802d76c42594b416.pdf (Accessed March 13, 2024).

Ribeiro, Y. G. G., Ascensão, F., Yogui, D. R., de Barros Ferraz, K. M. P. M., and Desbiez, A. L. J. (2023). Prioritizing road mitigation using ecologically based land-use planning. *Austral Ecol.* 48, 761–773. doi: 10.1111/aec.13295

Soanes, K., Rytwinski, T., Fahrig, L., Huijser, M. P., Jaeger, J. A., Teixeira, F. Z., et al. (2024). Do wildlife crossing structures mitigate the barrier effect of roads on animal movement? *A Global Assessment J. Appl. Ecol.* 61, 417–430. doi: 10.1111/1365-2664.14582

van der Ree, R., Smith, D. J., and Grilo, C. (2015). *Handbook of road ecology* (Hoboken, NJ, United States: John Wiley & Sons).