Title

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Abstract: The barrier effect of roads is now well documented and solutions such as fauna passages are readily implemented (Trocmé et al. 2002). Less well known is the mortality caused by specific engineering structures used along roads, such as drainage systems. This research focuses on censusing wildlife hazards caused by such structures and developing solutions. Structures such as drainage systems, kerbs, gullies, culverts, noise barriers, lighting, retaining walls, were all examined. Small fauna specialists and maintenance teams were interviewed to gather information on known impacts as well as solutions found. Wildlife hazards were identified. Drainage systems with gullies often provoke high mortality for amphibians and other small fauna. Other structures such as retaining walls increase fragmentation by creating complete barriers. Designs more permeable to wildlife need to be enhanced. Certain solutions such as escape ramps from drainage systems have been tested on a local scale.

After identifying the problematic structures an analysis of Swiss road standards was made underlining which ones needed to be completed or modified so as to limit the impact of transport structures on wildlife. Further studies will be necessary so as to develop standardised solutions taking into account wildlife, maintenance and safety issues.

Engineering Structures as Obstacles to Habitat Connectivity

In the past 50 years urban sprawl and fast extension and densification of transport networks have caused with the intensification of agriculture high fragmentation of open spaces and natural areas. Biodiversity continues to diminish as many natural areas are too isolated and small to sustain viable wildlife populations. In countries with transport infrastructure networks as dense as in Switzerland, the preservation of links between natural habitats and the restoration of ecological corridors has become a priority.

Part of the negative impact of transport networks can be mitigated through specific measures. The Swiss Association of Road and Traffic Experts (VSS) has emitted a series of norms on fauna passages with the goal of restoring as best possible connectivity (VSS 2004). However fauna passages do not solve all problems. A number of annexe structures cause high mortality and also have an impact on populations. The goal of this research was to collect field knowledge on the impact of various road and rail structures on animals and suggest mitigation measures. Depending on their design such structures can have negative effects, acting as traps (gullies) or positive effects, offering refuges for animals (stone walls) or movement corridors for wildlife along transportation axes (natural verges). The research report should serve as a reference for further standard revision and as a guide for engineers so as to avoid the use of structures dangerous to animals and diminish causes of indirect mortality.

Research Methods

The study focused on gathering as much available information as possible, collecting known data about the negative side effects of infrastructure elements of road and railway systems and investigating potential issues not described so far. The impact of the following structures was examined: avalanche galleries, central reservation, curbs, drainage systems, verges, fences, lighting, noise barriers, overhead contact wires, retaining structures, road pavement, track ballast and rails. To gain an overview a thorough study of literature was conducted. In a second step, around 100 telephone interviews were conducted to gather more information. For this, regional environmental authorities, scientists, conservationists, were contacted, as well as road maintenance personnel who are directly confronted with the results of the conflict between fauna and infrastructure. The large quantity of information that was gathered in this process was stored and processed with the help of a database system. Field investigations were undertaken to learn more about new ideas not documented so far.

Examples of Problematic Infrastructures

The following paragraphs present a selection of problematic structures with a strong impact on mortality and habitat connectivity of wildlife. The complete list of infrastructures and their main impact on the fauna is given in table 1. These structures are a problem when they cross natural habitat.

Table 1: List of problematic structures and their main impact on wildlife

Infrastructure	Main impact	Description of impact
avalanche gallery	barrier	Terrestrial animals are unable to cross the structure.
central reservation	mortality	Central reservations with vegetation such as shrubs attract birds and expose them to a high risk of collision with vehicles.
curb	barrier	Small animals are unable to cross the structure.
drainage system	mortality	Small animals, mostly Amphibians, become trapped in the chutes.
culvert	barrier	Poorly designed culverts can't be used by animals to cross the traffic route.
fence	barrier/loss of habitat	Barrier if not used with fauna passage. Also can hinder, if placed far from the roadway, access to verges for large animals.
lighting	mortality/barrier	Insects are diverted from their flight path and often die in the process.
noise barrier	mortality/barrier	Birds risk mortality through collision with transparent barriers. Small animals are unable cross/by-pass the structure.
overhead contact wire	mortality	Birds risk mortality through collision or electrocution.
retaining structures	barrier	Terrestrial animals are unable to cross the structure.
road pavement	barrier	Insects and other small animals do not cross the structure.
track ballast and rail	barrier	Small animals are unable to cross the structure, if gaps are closed during maintenance.
verges	barrier	Poorly designed verges create additional barriers. Well designed verges possess great potential to improve habitat availability and overall habitat connectivity for the fauna.

Curbs as Obstacles for Small Animals

Local roads in Switzerland are often not drained over the shoulder into a ditch, but by means of curbs, sewers, and a subterranean drainage system as it is standard for roads in residential areas. As distances between villages are short, there may also be sidewalks following the road. Curbstones from sidewalks and drainage systems are strong barriers difficult or impossible to overcome for small animals (invertebrates, amphibians, reptiles, small mammals) trying to cross the road and wanting to leave the roadway on either side (Ratzel 1993). Even adult amphibians somehow feel compelled to follow the vertical structure instead of jumping over it (Ratzel 1993). Animals blocked from leaving the roadway are subject to traffic mortality, predators, climatic adversities, or may find an exit only far from the original destination.

Figure 1. This curbstone is known to guide Amphibians directly into the tunnel.

Figure 2. On this sidewalk excessive tidiness in the form of granite blocks prevents that small animals from habitat on the other side of the road can reach the meadow.

Retaining Walls as Barriers

Retaining walls, often built as smooth concrete walls, can pose similar problems as curbs but on a bigger scale. In natural surroundings such walls, often 2-3 m high, act as complete barriers for terrestrial wildlife. The barrier effect of the walls depends on height and length. Animals may become trapped on roads and therefore be more exposed to traffic mortality.

Figure 3. Retaining walls often border close to the roadway, blocking animal movements between habitats on either side of the road.

Figure 4. Even low retaining structures can be a strong barrier and prevent free crossing of a structure by small animals. (Photo courtesy to KARCH, Neuchâtel).

Drainage Systems as Amphibian Traps

Besides creating curbstone-barriers for small animals, the extensive drainage system along Swiss roads poses a second risk: small animals fall through the gully-covers when following the curb on the search for an exit. Amphibians are most threatened by this issue: searching moist shelter they intentionally let themselves drop into sewer chutes. Some wastewater treatment plants count several thousand amphibians each year, that come flushed through the drainage system (Bally 1998). These numbers are a minimal estimate as only survivors are found leaving the rest in the chute (Ratzel 1993).

Figure 5. This gully traps many amphibians each year, even though there is no curbstone guiding the animals to the entrance. The animals climb into the opening, expecting a humid shelter.

Figure 6. With no direct exit possibility, trapped toads and frogs either die in the chute or will, in the course of the next rain storm, get flushed into the sewer system via the siphon. (Photo courtesy to Amphibtec, Gelfingen)

Poorly Designed Culvert

Culverts, leading water underneath the transport infrastructure, are often barriers to both terrestrial and aquatic wildlife due to insufficient design. Fauna friendly culvert design is well illustrated in available publications (e.g. Iuell et al. 2003).

Railroad-tracks Blocking Migration

Similar to curbstones, railroad-tracks too can physically hinder animals from reaching habitat on the other side of the structure. Time and vibrations from trains usually create gaps between track ballast and rails that suffice for small animals to slip through underneath the rails (Roll 2004). Maintenance crews however regularly reshape the gravel bed meticulously, closing the gaps in the process and therefore eliminating crossing possibilities for small animals. As a consequence, animals may not cross at all or need to search long distances for a gap, risking high traffic mortality and exposing themselves to predators and climatic adversities. As on roads, the problem becomes most evident when amphibians mass-migrate in spring and mortality is high.

Figure 7. Newt and toad killed on migration. The tight alignment between gravel and rail did not permit crossing. (Photo courtesy of Esther Krummenacher, Hausen)

Mortality and Barrier Effects of Noise Barriers

Transparent noise barriers are well known to cause high casualties among songbirds as birds in flight often do not see the glass and collide with it (Schmid & Sierro 2000). However noise barriers also act as wildlife barriers, fragmenting habitat on verges. In Switzerland, the sunny, sparsely vegetated verges of the national railway network constitute an increasingly important refuge for reptiles amidst a landscape of urban sprawl and intensive managed farm lands (Meyer 2005). Herpetologists are concerned that the construction of noise barriers along the railway tracks may fragment this network by hindering movement both across the verge (barrier effect of the screen) and along the verge (barrier effect of the shade).

Figure 8. Noise barrier along a railroad line.

Examples of Fauna Friendly Infrastructure Design

The study (Rieder et al. 2007) gives a catalogue of more than 140 proposals of adaptations of engineering structures that reduce negative impacts to animals. Some of these mitigation measures still need testing. In the following paragraphs we summarize a selection of the most promising ideas.

Slanted Curbs

Drainage over the shoulder of the road is the best way to avoid increasing the barrier effect of roads on small fauna. If roads in natural surroundings require a curb, then the curb should be designed slanted, ideally at an angle of no more than 45 degrees (Weber 1998). Existing vertical curbs can be levelled by pouring concrete into the corner between road surface and curb. If the curb cannot be slanted as a whole, providing slants at regular intervals can be a functional compromise (Ratzel 1993). A less effective, temporary mitigation measure is to let adjacent vegetation overgrow the vertical curb, providing natural shelter and exit structures.

Securing Drainage Systems for Amphibians

Designing slanted curbs as described above is a good measure to reduce the risk that animals follow the curb and drop into drainage chutes along the way. Modifying the covers of sewers and their positioning along the curbstone are further measures to secure the drainage system from small animals. In order to reduce the risk of accidental trappings, the openings in sewer covers should be as narrow as the necessary water throughput permits. Ratzel (1993) recommends slits no wider than 16 mm. Drainage openings can be offset from the curb so animals following the curb will be guided around it.

Figure 9. An urban example demonstrating that storm water must not necessarily be collected at the edge of the roadway. For roads leading through more natural surroundings, such a design could serve as a measure to reduce animal mortality in drainage chutes.

In the case of amphibians, slanting the curb and offsetting the chute positioning does not fully resolve the problem because of the strong attraction the dampness of gullies exerts on those animals. In some gully systems it is possible to reduce this effect of attraction by improving the drainage of the chute (Ratzel 1993). Covering openings with a fine mesh is very effective but requires much maintenance work as the mesh usually does not last long or gets clogged easily, preventing proper drainage of the street. It is therefore only to be used as a temporary measure. In Switzerland, the best solution where amphibian habitats are concerned is the installation of exit ramps from problematic chutes. Different systems of exit ramps have shown promising results and are currently being tested more thoroughly, for functionality as well as for ease of maintenance (Schelbert pers. comm.).

Permeable Railroad-tracks

Railroad tracks in sensitive areas, e.g. cutting through amphibian habitats, should be maintained in a way that there are gaps present between track ballast and rails at all times, permitting small animals to cross the tracks. Studies from operating companies in Switzerland have shown, that it does not harm the stability of the rails, if at regular intervals the road bed is graded 5 cm below standard level (E. Krummenacher, pers. comm.). The result of this extra effort in maintenance is a permeable railroad line that permits annual mass migrations in spring (fig. 10) as well as individual migration throughout the year.

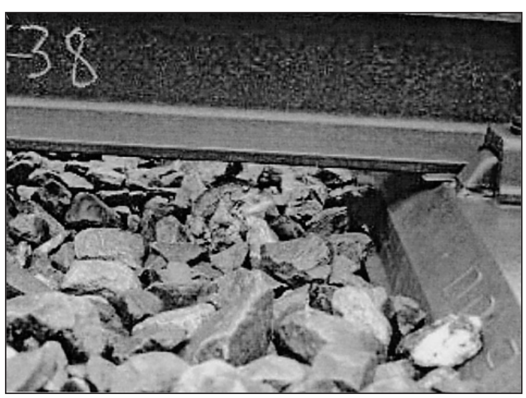

Figure 10. A pair of toads, slipping through the gap between rails and road bed.
(Photo courtesy of Esther Krummenacher, Hausen)

Fauna-Friendly Retaining Walls

If space permits, a strip of natural surface should be left between the pavement and the wall. Animals unable to climb can use this strip to leave the roadway and follow the vegetation to the nearest habitat. The barrier effect of the wall itself can be further softened by using structured materials such as natural rock that facilitate climbing. Gabions filled with coarse rocks allow reptiles, mice and other small animals to climb upward as well as inward. Walls created with such gabions not only reduce the overall barrier effect of the structure, but also create new habitat for plants and animals (fig. 11). By providing adequate substrate behind the gabions, the wall may even offer valuable, frost-safe shelter for reptiles in winter (KARCH 2005).

Another way to make walls more permeable is to break up the linear structure as shown in figure 13. As a mitigation measure, some walls can be improved by piling up a cone of rocks or by covering parts of the wall with gabions (fig. 12).

Figure 11. This retaining wall built with gabions can be climbed by various animals, reducing the strong barrier effect such structures normally exert. The crevices of the coarse material provide habitat to small animals and plants.

Figure 12. A pile of rocks (left side) or gabions filled with rocks (right side) can improve the permeability of a wall for small animals.

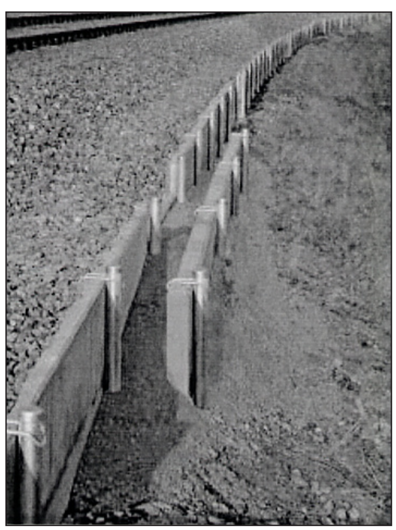

Figure 13. The barrier effect of the wall can be reduced by breaking up the linear structure. What's shown in this photo for a small structure along a railway line, can be achieved for walls with a height of several metres too. The example in the picture is currently being observed as it is not clear if it will successfully permit amphibian migration. (Photo courtesy of Esther Krummenacher, Hausen)

Designing Animal Friendly Noise Barriers

If noise barriers must be transparent, then the glass should be intensively patterned in order to disclose the obstacle to the birds eyes (fig. 14). Broad stripes (width of 1 or 2 cm) placed closely (gaps of 5 or 10 cm respectively) have been proven to work very effectively (note: the commonly used self-adhesive silhouettes of birds of prey do not show any effect). It is also very important that all trees and shrubs in the direct vicinity of the transparent barrier are removed to further reduce the attraction to birds (Schmid & Sierro 2000). Newly developed UV-reflecting glass may constitute a good alternative to patterned glass, but in the end, the best solution to avoid infrastructure mortality for songbirds is to renounce transparency entirely (Schmid & Sierro 2000) and work with opaque materials instead, which usually possess better acoustical characteristics and need less maintenance.

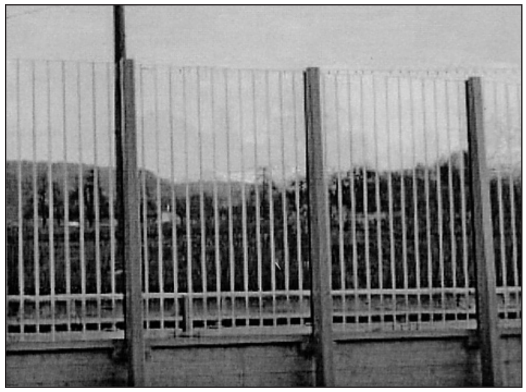

Figure 14. Example of a transparent noise barrier with a striped pattern as recommended by Schmid & Sierro (2000) to disclose the glass to birds eyes. (Photo courtesy of Joggi Rieder, Kaden und Partner AG)

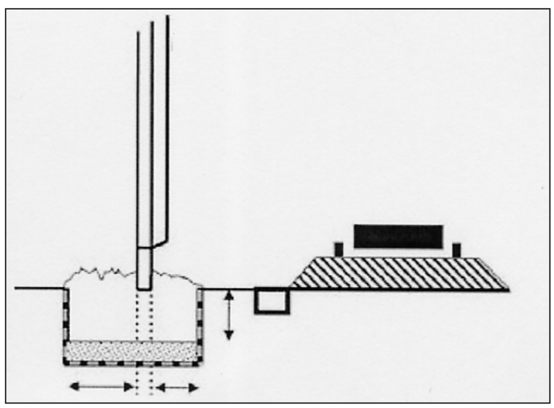

Figure 15. Design study for a reptile-friendly noise barrier. A well drained trench filled with sand and coarse rubble would be permeable for reptiles and other small animals and could serve as hiding-, nesting-, or winter-habitat. (Image courtesy to KARCH, Neuchâtel)

Noise barriers in sensitive areas should feature openings of some sort in order to break up the strong barrier effect of this structure for small animals. The Swiss Association for the Conservation of Reptiles and Amphibians (KARCH) has developed different ideas, how such openings could be implemented (see figure 15; Meyer 2005). The effectiveness has not yet been tested.

Fauna Friendly Engineering – A New Standard?

Fauna friendly engineering should no longer be an exception but become a rule. It's important that the awareness of conflicts between traffic infrastructures and the fauna rises, not only among conservationists, but most importantly among engineers. The fauna expert group of the Swiss Association of Road and Traffic Experts (VSS) aims at improving the standards for the construction of road infrastructures in promoting fauna friendly designs. The fauna expert group provides information to other expert groups and critically reviews drafts of new standards and revisions of old standards. The latest product of this collaboration is a new technical standard on the construction of curbs, that now includes considerations on the influence of curb design on habitat connectivity of small animals as well as recommendations on how to mitigate the negative impact (VSS 2006). Other VSS norms that need to be updated in terms of fauna friendly design are technical standards about verges, drainage systems, noise barriers, retaining structures, central reservation. Standards about fences and the renovation of culverts are currently being revised and developed under the guidance of the VSS fauna expert group.

Biographical Sketch: Christof Elmiger, born 1977 in Switzerland, has studied biology at the University of Zurich and the Swiss Federal Institute of Technology Zurich attaining a master's degree with a thesis on the ecology of blennies and gobies in Switzerland. Today he is working as an environmental consultant for Kaden und Partner AG, a small company in Frauenfeld.

Born in Paris in 1961, Marguerite Trocmé grew up in Canada before moving to the U.S. and received her bachelor of science degree in biology from Brown University in Providence, Rhode Island in 1983. In 1985, a master's degree in environmental engineering from the Ecole Polytechnique Fédérale (EPFL) of Lausanne, Switzerland followed. She then worked both for the Swiss World Wildlife Fund and the Swiss Ornithological Institute before joining the Swiss Agency for the Environment, Forests, and Landscape in 1989. She is responsible for the impact appraisal of federal infrastructure projects on nature and landscape. She was vice-chairman of the European COST 341 Project. She has led and edited studies and publications in the areas of the impact of high tension lines, roads, and aviation on natural ecosystems. She is president of the VSS fauna expert group.

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