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Habitat Fragmentation due to Transportation Infrastructure

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European Commission
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Chapter 1. Introduction

Fragmentation of natural habitats has been recognised as a significant factor which contributes towards the decline of biodiversity in Europe and has become a major concern for all those working in the nature conservation and management field. Previous research has established that linear transportation infrastructure (roads, railways and waterways in particular) can cause serious habitat fragmentation problems. In some parts of Europe, infrastructure development has been identified as *the* most significant contributor towards the overall fragmentation effect; other factors include intensive agriculture, industrialisation and urbanisation (which will not be considered in this publication). The European Review aims to provide an overview of the scale and significance of the fragmentation problem caused by transportation infrastructure in Europe, and to examine the strategies and measures that are currently being employed in an attempt to combat it.

Complete chapter In: Trocmé, M; Cahill, S; De Vries, J.G; Farall, H.; Folkeson, L; Hicks,,C; and Peymen, J. (Eds) (2003) *COST 341 "Habitat Fragmentation due to Linear Transportation Infrastructure:The European Review"*.Office for Official Publication of the European Community, Luxembourg. 253 pp.

Chapter 2. Key Ecological Concepts

This chapter introduces some specific ecological concepts that are relevant to the better understanding of landscape pattern and process in infrastructure planning. For further reading on the presented topics, see Forman (1995), Bissonette (1997), Farina (1998), Sutherland (1998), or Jedicke (1994). The most important principles can be summarised as follows:

- *The effects of infrastructure on nature cannot be evaluated solely from a local perspective; infrastructure planning must focus on the landscape scale.*
- *Habitat connectivity across the landscape is essential for ensuring the survival of wildlife populations. Connectivity can be provided by ecological 'green' corridors, 'stepping stones', or technical mitigation measures e.g. constructing a bridge between severed habitats.*
- *The impact of habitat fragmentation on wildlife is dependent on individual species and landscape characteristics. Where the impact is below a critical threshold, populations can be sustained, but beyond this threshold, seemingly small changes in the environment may cause unexpected and irreversible effects (e.g. the extinction of local populations). The larger the spatial scale concerned, the longer the time-lag until effects may be detectable.*
- *Infrastructure planning needs to integrate both regional and local-scale issues. A hierarchical approach can help to identify the most important problems and their solutions at each planning level. People should 'think globally, plan regionally but act locally' (sensu Forman, 1995).*

There is still a long way to go before ecological tools are fully developed and implemented in road planning, but since the problems and their solutions are universal, joint research and combined international efforts are required. Only through interdisciplinary work (between planners, civil engineers and ecologists) can effective tools for assessing, preventing and mitigating against the ecological effects of infrastructure, be developed and applied.

Landscape and wildlife ecology together provide a body of theories and methodologies for the assessment of ecological impacts such as habitat fragmentation. Empirical studies are, however, scarce and more research is needed to investigate the critical thresholds beyond which populations cannot be sustained. The construction and daily use of transportation infrastructure can result in wide ranging ecological impacts that need to be identified and addressed. The specific nature of these impacts is discussed in more detail in Chapter 3.

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Chapter 3. Effects of Infrastructure on Nature

In this chapter some of the major literature on the ecological effects of infrastructure is reviewed. There is a growing concern about habitat fragmentation caused by roads and railways all around the world. The increasing demand for avoidance and mitigation makes it clear that there is still much to be understood before the cumulative potential impacts can be assessed in an efficient and practical way. A considerable amount of research has been carried out already, yet many of the studies are descriptive, dealing with problems of individual roads or railways, but without considering the more strategic issues integral in the planning of ecologically friendly infrastructure.

How much habitat is actually lost due to construction and disturbance effects of infrastructure? How wide is the impact zone along roads and how does the width of this zone change with traffic intensity and type of surrounding habitat? How can transportation infrastructure be integrated into the 'ecological' infrastructure in the landscape without causing an increase in the risk of animal-vehicle collisions? Where and when are mitigation measures against road wildlife mortality necessary or affordable? How much infrastructure is too much in areas designated for wildlife? What are the ecological thresholds that must not be surpassed and how can the best use be made of the potential in a road or railway project to improve the current situation?

Finding answers to these questions is a challenge to landscape ecologists, biologists and civil engineers alike (Forman, 1998; Cuperus *et al.*, 1999). To develop effective guidelines and tools for the planning of infrastructure, research needs to be focussed on ecological processes and patterns, using experiments and simulation models to identify critical impact thresholds. Empirical studies are necessary to provide the basic data that will help to define evaluation criteria and indices. Remotely sensed landscape data, GIS-techniques, and simulation models offer promising tools for future large-scale research (see Section 6.4), but they must rely on empirical field studies at local scales. Clearly, a better understanding of the large-scale long-term impact of fragmentation on the landscape is required, yet the solution to the problems will more likely be found at a local scale. Richard T.T. Forman, a pioneer in landscape and road ecology at Harvard University, Massachusetts, put it simply: We must learn to 'think globally, plan regionally but act locally' (*sensu* Forman, 1995).

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Chapter 4. National context/European context

4.1. INTRODUCTION

This chapter provides an overview of the most important biogeographical regions of Switzerland and discusses the status of indigenous wildlife species that are of European significance. Recent developments observed in agriculture and in built-up areas are illustrated with statistics. This chapter also explains the responsibilities of the various institutions in the construction of new transportation infrastructure and gives details of the Swiss laws that are particularly relevant to such work. The last section of the chapter outlines the authorities that are involved and the instruments that can be used within land-use planning to resolve conflicts arising between transportation infrastructure and protected habitats or important wildlife corridors.

4.2. BIOGEOGRAPHICAL DESCRIPTION

Ursula Bornhauser-Sieber & Otto Holzgang

The surface area of Switzerland is 41’285 km^2. Between the country's lowest point (193 m, Lake Verbano) and its highest peak (4’634 m, Dufourspitze), a wide variety of landscapes, climatic zones and forms of agriculture are to be found within a relatively small area. Almost a third of Switzerland (30.3%) is covered by forest or scrubland, and about a quarter of the territory (24.6%) is used for agricultural purposes, with another 13.7% being used for Alpine farming (BFS 1999). 5.9% of Switzerland is covered by built-up areas (including transportation infrastructure), 4.2% by lakes and rivers, and the remaining 21.3% by unproductive land. Switzerland is divided into three main landscapes: the Jura, the Central Plateau and the Alps.

According to the biogeographical zones defined within the framework of "Natura 2000", the European Union's network of protected sites (Council of Europe 1992), Switzerland lies within the continental and alpine zones.

The following description of the regions is a much-abridged version of the account given in the Atlas of Breeding Birds of the Swiss Ornithological Institute (Schmid et al. 1998).

The Jura

The Jura is a relatively low mountain range folded out of limestone layers approximately 3 to 11 million years ago, towards the end of the Alpine folding. The climate is relatively oceanic, with annual precipitation of 1000-2000 mm. Only in the rain shadow of the mountain range, at the southern foot of the Jura, is the climate drier and warmer.

Most of the mid-altitudes (up to about 750 m) are used intensively as arable land and grassland. However, in many places on the shallow soil of escarpments, on the fringes of forests and on the plateaux there are low-nutrient meadows and pastures. As in the Alps, the higher altitudes are predominantly used for dairy farming. The climate at the southern foot of the Jura is so mild that this region is one of Switzerland's most important wine-growing areas. Parts of the tabular Jura in the cantons of Aargau and Baselland are characterised by their vast orchards. Compared with large parts of the Central Plateau, the cultivated area on and between the higher reaches of the Jura is quite varied.

As a result of the geological substrate (carbonate rock) and elevation (montane zone), beech and silver fir-beech forests predominate in the Jura. Extensive oak-hornbeam forests are found at the climatically favourable southern foot of the Jura and also in other mild areas, especially the northern part of the canton of Zurich and the Basel region.

The Central Plateau

The substrate of the Central Plateau consists of molasse rocks (particularly nagelfluh, sandstone and marl). The highest point of the Central Plateau is the Napf (1408 m above sea level). The climate of the Central Plateau is moderately oceanic. Annual precipitation amounts to 800-1200 mm, with the areas in the rain shadow of the Jura remaining relatively dry and mild. The entire region is characterised by lakes and rivers. In the past, many of the large plains, flood plains and lake shores of the Central Plateau were used primarily as hay meadows. Most of this land has now been improved and converted into arable land or grassland.

Due to its favourable climatic conditions and highly fertile soils, the western part of the Central Plateau is Switzerland's most important farming region and also a significant wine-growing area. The eastern part of the Central Plateau contains a number of industrial and commercial centres. This region has seen an above-average level of construction activity in recent decades. Here, crop growing is much less prevalent than in western Switzerland, and stock farming is more important. The dominant agricultural activities in the regions close to the Alps are dairy farming and cattle breeding.

The western part of the Central Plateau has a comparatively low proportion of forest. In the eastern part, however, the proportion of forest is relatively high. While beech trees were originally dominant throughout, many areas are now covered by monotonous-looking, shady spruce forests. Recently, however, greater importance has been attached to the planting of more natural types of forest.

The northern Alps

The Swiss Alps, which make up the central segment of the Alpine arch, are characterised by high-mountain relief, with deeply carved valleys and prominent chains and summits.

The geological substrate of the northern Alps is predominantly characterised by carbonate rocks. Deposits of flysch extending through the foothills and the calcareous Alps are impervious to water and are thus conducive to landslides, flooding, and the formation of mires.

The northern Alps are characterised by high levels of precipitation. The number of hours of sunshine per year is low in many places. The so-called föhn valleys, however, are marked by a different regional climate, with warm, dry southerly fall winds (föhn). The climate of northern and central Graubünden is more continental than that of the rest of the northern Alps.

Agriculture here takes the form of dairy farming and stock breeding. In many western regions of the northern Alps, the structure of the cultural landscape is particularly rich. At altitudes higher than 1500 to 1700 m above sea level, Alpine pastures predominate; these do not generally extend much beyond 2000 m. Parts of the landscape are used intensively for tourism (winter sports, hiking, mountain biking, paragliding).

Beech trees predominate in the calcareous areas up to about 1200 m. A belt of silver fir-beech forests is found between 800 and 1300 m, and in rare cases also at higher altitudes. In the subalpine zone, Norway spruce forests predominate in the calcareous areas, with mountain pines being the dominant species only on the solid flysch deposits.

In some eastern regions of the northern Alps, there are numerous raised bogs, transitional mires and fenlands, especially where the substrate is flysch. In the past, most of the large valleys also contained extensive wetlands, used primarily as hay meadows. Little now remains of these valley wetlands.

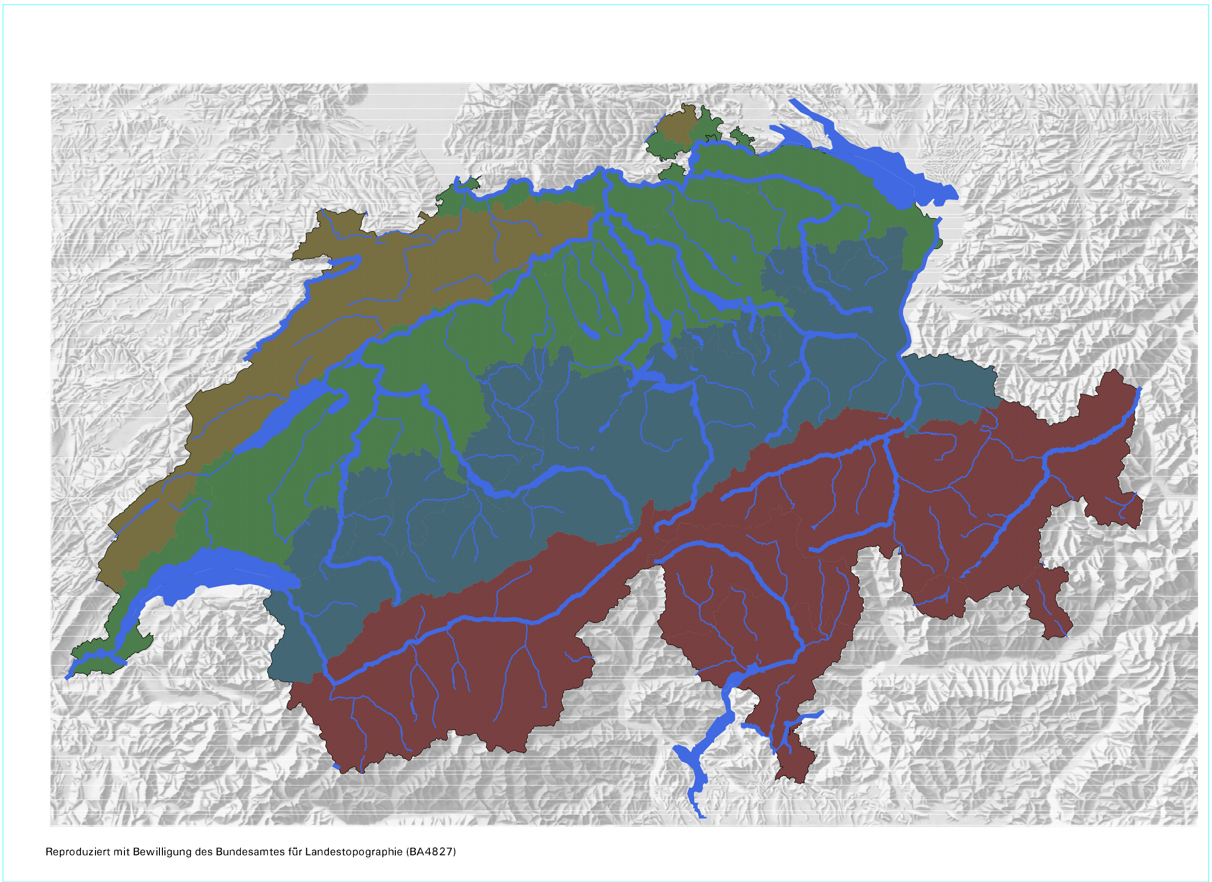


Figure 4.1 – Topography, main regions (brown: Jura; green: Central Plateau; blue: Northern Alps; red: Southern Alps), main rivers and lakes of Switzerland.

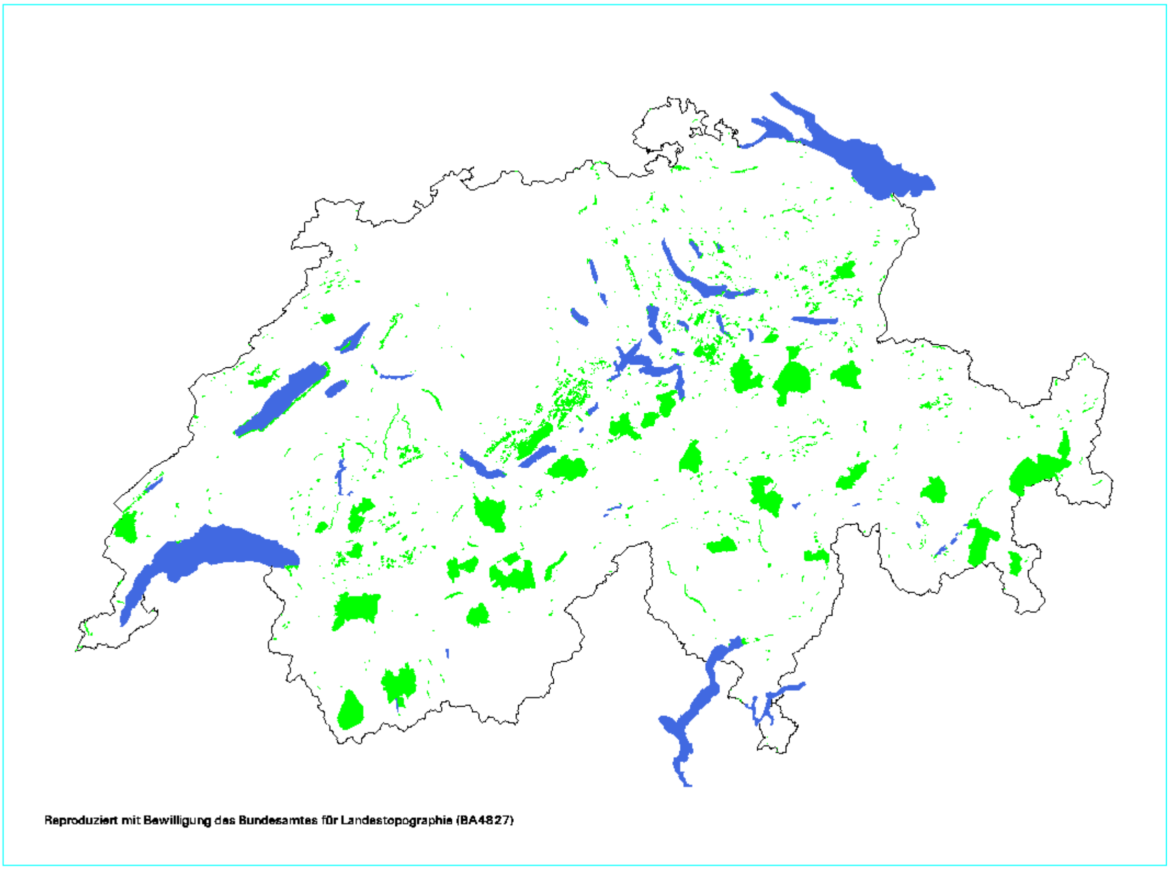


Figure 4.2 – Main protected areas of national importance (mires and bogs, alluvial zones, federal game reserves and the national park of Switzerland. Not represented are Ramsar sites and smaller reserves).

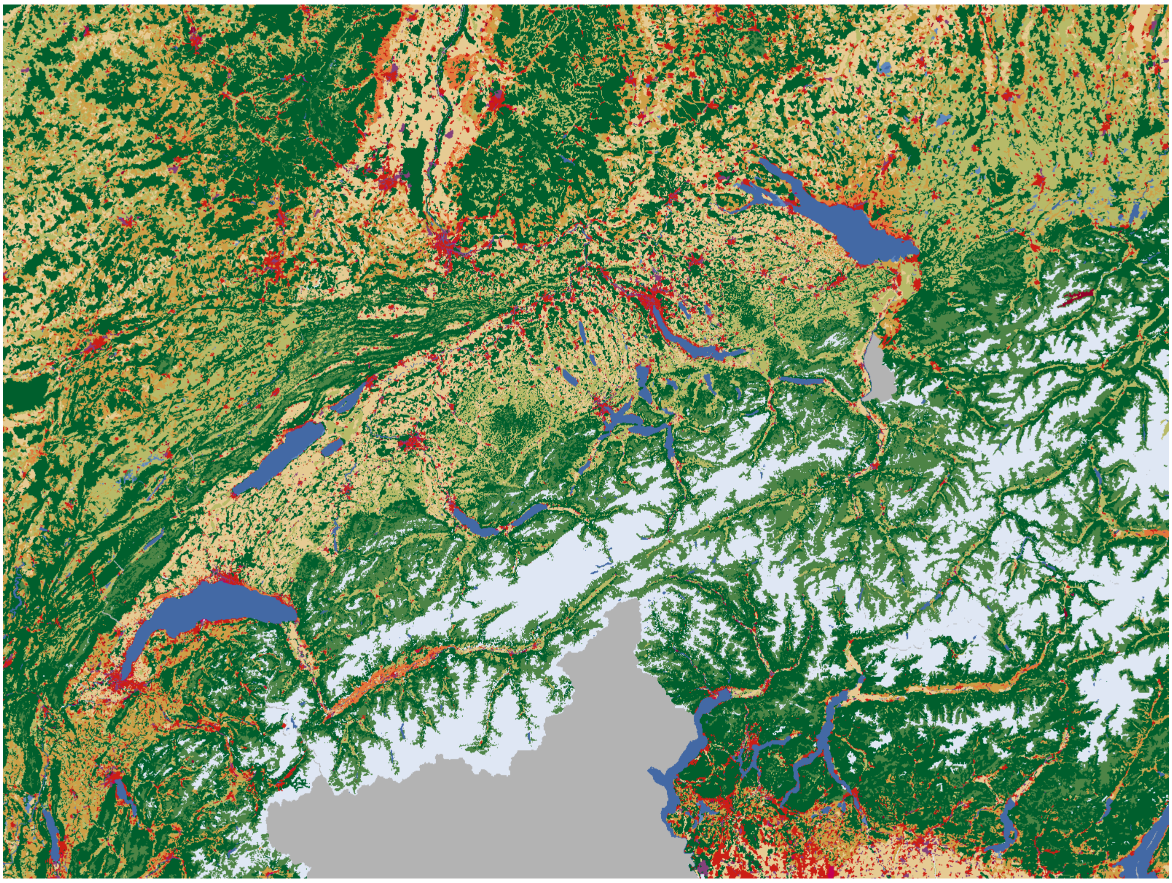


Figure 4.3 – Overview of land use in Switzerland. Of note is the density of built-up areas (red) around the lakes and inneralpine valleys as well as the many areas in the Alps covered by ice or snow (white). Forests are shown in green and other land uses of low-lying regions are shown in yellow.

The southern Alps, Valais and the Engadin

The gneiss rocks of the Pennine nappes predominate in almost all of southern Switzerland and in Valais. In the Engadin, the East Alpine nappes (crystalline rocks) that were thrust over the Pennine nappes are prevalent.

The climate of southern Switzerland is characterised by high levels of precipitation and abundant sunshine. The lower altitudes, in particular the regions around the larger lakes, enjoy an extremely mild winter (Locarno: mean temperature of +2.7°C in January). The climate in the central Alpine valleys of Valais and the Engadin is relatively continental, with considerably more sunshine than in the northern Alps.

Farming in the narrow side valleys of the Ticino is now confined to the most favourable sites; extensive areas have been reclaimed by forest. However, the plains of the larger valleys are used very intensively. Wide-spread residential areas are typical of many areas in the Ticino. The valley floor in the central and upper Valais is characterised by fields and meadows, while in the lower Valais low-growing fruit and vegetable plantations and vineyards extend over large areas.

In the driest areas of the lower Engadin, where the soil layer is shallowest, patches of dry and semidry grassland are found. There has been a sharp decline in the amount of arable land, which was widespread in this region until the 1960s.

Apart from agriculture, tourism is another very important form of land use in the Alpine region.

In the colline and lower montane zones of the southern Alps, the sweet chestnut has been grown intensively for centuries (woodland pasture). The landscape in the montane zone is characterised by beech forest. In many side valleys of the Ticino, broad-leaved forests give way to larch at higher altitudes. In Valais, very dry Scots pine forests grow on slightly elevated sandy/gravelly alluvial areas. The rocky steppes of the Valais — home to some Mediterranean plant species — are found on the southern slopes. On shady slopes, Scots pine is the dominant species of tree up to about 1200 m. Less dense Norway spruce or silver fir forests generally take over at around 1000 m, giving way in turn at the tree-line (about 2100 to 2300 m) to patches of larch and arolla pine, with a dense layer of dwarf shrubs. The shady slopes of the Engadin are characterised by spruce forests, which are among Switzerland's least disturbed and most extensive forests.

Biodiversity of the higher taxonomic groups in Switzerland

Table 4-1 - The number of species and the number (percentage) of endangered species of selected groups of organisms in Switzerland.

Organism group	Number of species	Endangered species (%)
Vascular plants	2’696	881 (32.7)
Mammals	82	45 (54.9)
Breeding birds	205	115 (56.1)
Reptiles	15	13 (86.7)
Amphibians	20	19 (95.0)

Some animal species of European importance in Switzerland

This section deals only with the larger mammals. All information on distribution and population sizes is taken from Hausser (1995).

Switzerland is involved in the "Emerald Network" of the Bern Convention (Council of Europe 1979), which aims to protect important species and ecosystems (according to the same system as Natura 2000). Among the larger species of mammals for which Europe has a particular responsibility, the beaver, the lynx and the wolf are found in Switzerland. The otter has disappeared from Switzerland, mainly as a result of hunting and the pollution of lakes and rivers. There has been no evidence of its presence in Switzerland since 1990. The lynx began to be reintroduced in Switzerland in the 1970s. Today it inhabits parts of the Alpine region and the Jura. Dispersal of the lynx and the connection of sub-populations are impeded in Switzerland by motorways and residential belts, especially in the Central Plateau. The wolf has been migrating from Italy into Switzerland sporadically since the mid-1990s. The European beaver was eradicated in Switzerland at the beginning of the nineteenth century. Since 1956, beavers have been resettled at 27 locations. Their current distribution is determined by the choice of release sites. Dispersal of the beaver is impeded in many places by unsuitable habitats, dams and artificial water margins along rivers.

Among the large mammals living in Switzerland, the wolf and the wildcat are strictly protected under the Bern Convention (Appendix II in Council of Europe 1979). The wildcat is very rare in Switzerland and is found only in the Jura. Its precise distribution and the size of the population are not known.

Switzerland is also home to a number of other species of large mammals protected under Appendix III of the Bern Convention. The Alpine region forms the habitat of the chamois and the ibex. While the ibex is only found in the heart of the Alpine zone, the chamois is widely distributed. The core of its range is the northern and southern Alps, although it is also found in the Jura and at higher altitudes of the Central Plateau. During cold winters, in particular, it descends to lower levels of the Central Plateau. The population of red deer has risen sharply in recent decades. This species has now become established in large parts of the Alps, and in some areas it ventures into the Central Plateau and the Jura. The roe deer is very common throughout Switzerland. The mustelids found in Switzerland include the pine marten, stone marten, stoat, weasel, polecat and badger. While the weasel and the polecat are widely distributed, they may have disappeared from certain regions. The pine marten is probably found in most forests in Switzerland, although its density is very low. The other species are very common in Switzerland.

Various animal species cover large distances when migrating between their summer and winter quarters or searching for new habitats. The following table shows the maximum migration distance of various species of mammals found in Switzerland. Such migration is often impeded, especially in the Central Plateau, by roads or built-up areas. The extent of the area of activity of non-migratory animals is determined by local conditions. The size of the home range of an individual animal depends on the habitat quality, food supply and population density.

Table 4.2 - Migration distances and home ranges of some species of large mammals (SGW 1995).

Species	Max. migration distance (km)	Home range (ha)
Wild boar	250	60-250
Red deer	120	30-350
Lynx	100	40’000
Roe deer	70	7-50
Red fox	50	50-350
Pine marten	50	50-350
Brown hare	10	5-35
Badger	5	50-200
Stone marten	5	50-300

4.3. Overview of Fragmentation

Otto Holzgang

In order to assess fragmentation, it is essential to distinguish between aquatic and terrestrial ecosystems. A measure taken to enhance the connectedness of terrestrial habitats, e.g. a dam made of earth, divides up the aquatic habitat. In keeping with the guidelines, however, we will confine ourselves here to the fragmentation of the terrestrial habitat. The following account first provides a general overview of the situation in Switzerland and then assesses fragmentation in the regions of the Jura, the Central Plateau and the Alps, as the problems within the various regions are quite similar (abridgement of SGW 1999).

By reducing the land available and separating formerly connected habitats, man-made constructions represent a major cause of fragmentation. Figure 4.4 shows the distribution of the human population in Switzerland. Of note are the concentration in the Central Plateau, the prominent plains of the main Alpine valleys and the major population centres of Geneva, Lausanne, Bern, Basel and Zurich. Before land-use planning became effective, the uncontrolled development that began in the 1950s created a jumble of built-up areas across the landscape. The area required each year for settlements, buildings and infrastructure was approx. 1'225 ha between 1972 and 1983, and increased to 1'685 ha in the period from 1987 to 1989 (BRP & BUWAL 1994), partly as a result of population growth (1970: 6.27 million, 1994: 7.02 million) but also because of the steady increase in the surface used per household. In 1950, households of five or more persons accounted for 25% of private households; by 1990, the proportion had fallen to a mere 6.5%. During the same period, the proportion of single-person households grew from 12.3% to 32.4% (BFS & BUWAL 1997). As a result of the revised land-use planning legislation approved by the Swiss people in 1999, the landscape may well be subject to further development.

Intensification of agriculture led, for example, to the creation of large-scale monocultures, highly fertilised, species-poor meadows and plantations of low-growing fruit-trees, and thus to a loss of land and the separation of natural habitats that had formerly been connected. For instance, between 1965 and 1985 the area used for cultivating maize (corn and silo/green maize) increased from 9'582 ha to 63'841 ha (BFS 1999); the stock of high- and medium-growing fruit trees, however, fell by 75% within a period of 40 years. In 1950, around 85% of natural meadows were deficient in phosphates and only 5% had excess levels. By 1980, the proportion of natural meadows with excess phosphates had increased to 55%, while the proportion deficient in phosphates fell to 25% (BFS & BUWAL 1997). Impoverished areas of this kind can effectively separate natural patches. Since 1993, subsidies have been paid to farmers in an attempt to promote or preserve patches of greater ecological value.

In Switzerland, a great deal of landscape and habitat fragmentation is due to the effects of transportation. In the west of the country, for instance, the total area covered by transportation infrastructure increased by around 12% between 1979/82 and 1990/94 (BFS & BUWAL 1997). Nevertheless, the annual requirement ("land consumption") has decreased over the past two decades. From 1972 to 1983 the land consumption for the regional road network was 1'000 ha per year, and from 1978 to 1989 it was only 250 ha per year. The land take for local roads and tracks also decreased, from 680 ha to 470 ha per year (BRP & BUWAL 1994). Figure 5.1 shows Switzerland's motorway and arterial road network. As motorways in Switzerland are fenced off, they play a highly significant role in fragmentation. The A1, which crosses the Central Plateau, separates the Jura from the pre-Alps and the Alps. Since the first section was opened in 1955, the Swiss motorway network has expanded to 1,638 km, representing 88% of the planned network (ASTRA 1999). While the completion of the motorway network will entail further fragmentation of the landscape, the effects could be reduced by building ecoducts. Figure 5.1 shows the railway network. The high density of infrastructure in the Central Plateau and the double-track sections in the main Alpine valleys are particularly striking. With the introduction of the planned high-speed lines, the fragmenting effect of the railways can be expected to increase. Apart from the actual infrastructure, the barrier effect of roads and railways is also determined by the volume of traffic. From 1990 to 1995 alone, traffic increased by 12.9% on national roads, and by 6.8% on all other roads (BFS 1996).

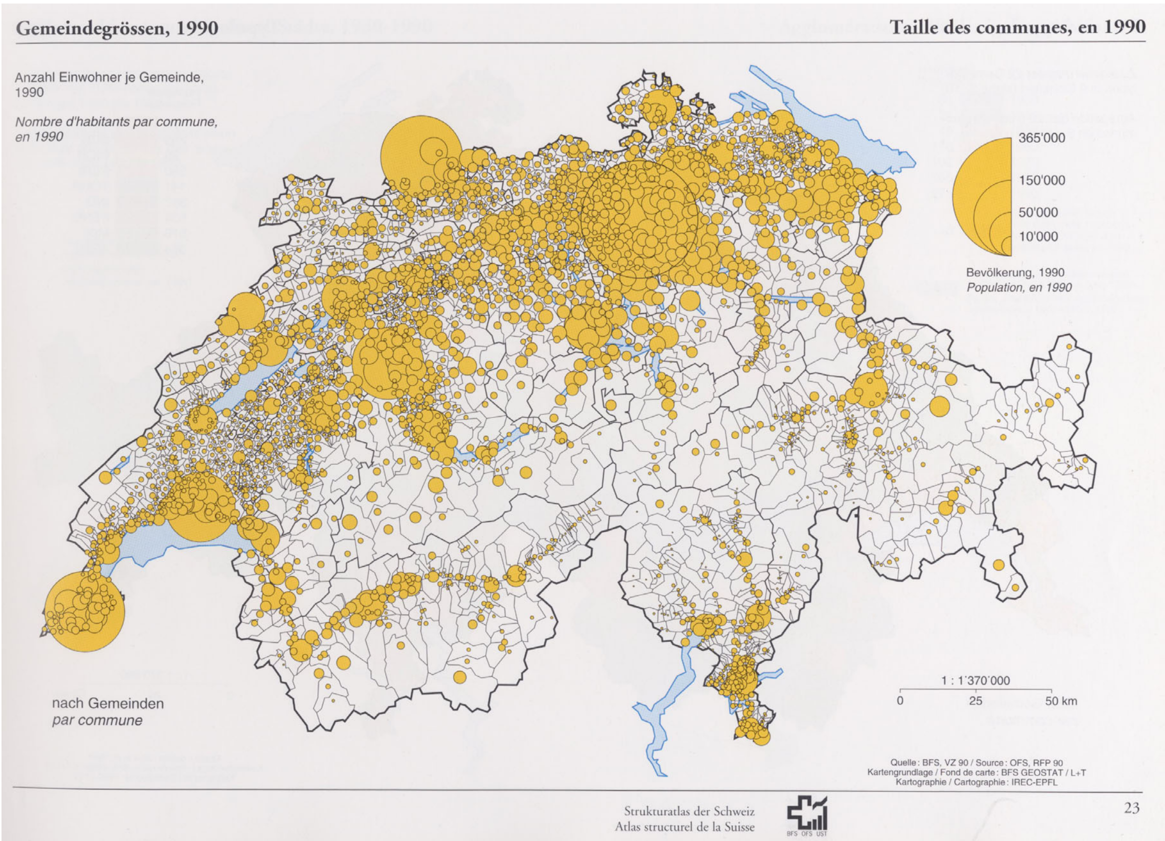


Figure 4.4 – Population density in the different regions of Switzerland

The construction of forestry and agricultural roads, in particular, can also contribute indirectly to fragmentation by introducing disturbances in areas that were once undisturbed (recreation, leisure activities). Some species, such as the capercaillie, are particularly sensitive to this form of fragmentation (Dändliker et al. 1993).

Leisure activities and tourism, especially in mountainous regions, do not normally create a permanent disturbance, but the areas are affected by the expansion of infrastructure. Since 1965, the number of tourist transportation facilities has grown more than threefold; during the same period, the hourly transport capacity has increased by a factor of 4.5 (BFS & BUWAL 1997).

In the case of connecting elements such as open watercourses or traditional orchards, the trend is in the opposite direction. Around 29 km of watercourses are sealed off and/or straightened each year in Switzerland (BFS & BUWAL 1997); according to BRP & BUWAL (in prep.), 85 km of open watercourses disappeared each year from 1984 to 1995. The land/water ecotone, which is also important for terrestrial species, disappears as a result. Furthermore, canalised streams usually have hard and steep banks, which are impassable for most terrestrial animals. Between 1981 and 1991, the number of fruit trees in traditional orchards decreased by about 25% (BRP & BUWAL 1994). In view of the increase in the overall length of hedgerows, it would appear that intensive conservation efforts have put an end to the losses experienced before 1970. Thus, the overall length increased by 33 km a year from 1972 to 1983, by 55 km a year from 1978 to 1989 and by 156 km from 1984 to 1995 (BRP & BUWAL, in prep.). Of course, these figures give no indication of the qualitative aspects of hedgerows.

The Jura

Overall, the most important natural areas in the Jura are still fairly well connected and relatively undisturbed. However, natural obstacles (lakes, rivers) and anthropogenic barriers (motorways, busy railways, built-up areas) seriously impair the level of connectedness between the Jura and the Central Plateau.

In the central and northern Jura, roads have a moderate barrier effect. Fragmentation is particularly serious in the conurbations of Basel and Geneva and is aggravated by the ongoing expansion of residential areas and industrial zones. Intensive farming has also led to a certain degree of fragmentation in some valleys (lack of stepping stones).

The Central Plateau

The Central Plateau has very few open ecological corridors worthy of mention towards the north (the Jura). Southwards, towards the Alps, the situation is somewhat better, although many areas here are also difficult to traverse. The Central Plateau itself is characterised by a largely impenetrable network of obstacles. There is thus no large-scale connectedness to speak of, either within the Central Plateau or externally. With the exception of the lakes at the southern foot of the Jura, the barriers are largely due to man-made structures and human activities. In the Central Plateau, the main factors are the expansion of built-up areas, the intensification of agriculture and the increasing density of the road network.

The Alps

The situation in the Alps is influenced by two factors: the barrier effect of the high-mountain regions and the differing land uses at higher and lower altitudes.

The valley floors are heavily used, with a concentration of settlements and main transportation routes, as well as commerce and industry in the main valleys. Recent decades have seen an intensification of agriculture in the climatically favourable lowerlying areas. In the past, rivers, often flowing through ravines, already formed natural barriers in certain cases. Today, however, steep man-made banks make it even more difficult for wildlife species to cross the rivers.

These problems are much less prevalent at higher altitudes and away from the main valleys. Here, the landscape has an abundance of ecologically valuable structures and often a high degree of connectedness. Intensive exploitation is uncommon in wooded areas, on account of their isolation or inaccessibility or their protective function. Due to the topographical conditions at higher altitudes, roads and railway lines are often routed through tunnels or over bridges. With the exception of certain sections of motorway, the barrier effect of the transportation infrastructure with regard to wildlife is relatively small. Avalanche protection galleries, however, often represent an insurmountable barrier. The disturbance related to leisure activities and tourism is becoming increasingly significant in mountainous regions.

4.4. ADMINISTRATIVE AND LEGISLATIVE FRAMEWORK

Marguerite Trocmé

Switzerland is a confederation of 26 members (20 cantons and 6 demicantons), each with considerable autonomy. The distribution of power and authority is based on a tripartite organisation: the federal government, cantons and communes. The federal government is responsible for matters of foreign policy, monetary policy, and customs. It shares responsibility with the cantons for social and economic affairs and for justice, the police and public works. The cantons have sole authority in the fields of education and culture. As far as the environment is concerned, the cantonal authorities are obliged to implement most of the laws and regulations passed at the federal level (see also OECD 1998).

The federal government (Federal Council) is made up of seven members, each with responsibility for a federal department, and the Federal Assembly consists of two chambers directly elected by the people. The parliament elects the Federal Council and the members of the Federal Court. Each canton also has its own constitution, executive, legislature and courts. The extent of autonomy granted to the communes varies from one canton to another. Moreover, popular initiatives play an important role in Switzerland, exerting a substantial influence on the drafting of laws and also on major infrastructure projects.

Legislation

As regards the transportation infrastructure, the railways are governed by various federal laws and ordinances, such as the Federal Law (FL) of 20 March 1998 relating to the Federal Railways, the Federal Decree (FD) of 19 December 1986 concerning the RAIL 2000 project, and the FL of 20 December 1957 relating to the railways. The federal government acts as both project initiator and supervisory body for the Federal Railways network.

With regard to roads, the federal government is essentially the coordinating and supervisory body. The main legislative foundations are as follows: the FL of 8 March 1960 relating to national highways, the FL of 17 June 1994 relating to road transport in the Alpine region, the FD of 21 June 1960 relating to the national highway network, and the Ordinance of 8 April 1987 relating to highways. Cantonal roads are governed by the law of the canton in question. Moreover, the standards of bodies such as the Association of Swiss Road and Traffic Engineers or the clearance profile specifications of the Swiss Federal Railways play a crucial role at the infrastructure design stage.

The procedures derive from the tripartite organisation of the federal state: the public inquiry for a given project may be carried out at the communal level and decisions may then be taken at the cantonal and/or federal level.

The first legislation concerning the environment was the Fishing Act of 1875. The second, dating back to the early twentieth century, was the **Federal Law of 11 October 1902 concerning the Confederation's supervision of the forest police**. This law establishes the principle that the forested area of Switzerland should not be reduced, thereby theoretically prohibiting the clearance of forests. Wherever there is a predominant interest in the conservation of forests, any clearance should be compensated for by reforestation, covering the same area and fulfilling the same functions. The interests of forest conservation were thus integrated at a very early stage into the selection of infrastructure routes.

The **Federal Law of 1 July 1966 relating to the Protection of Nature and Landscape** (LPN) was one of the next important pieces of environmental legislation. Although, according to the Constitution, the protection of nature and the landscape is a cantonal concern, the Confederation should, in the course of fulfilling its tasks, e.g. when planning and building transportation infrastructure, "preserve the characteristic aspects of landscapes ... as well as of natural and cultural monuments, and ... leave them untouched whenever the general interest is predominant" (Art. 24^{sexies} para. 2 of the Constitution). Article 18 of the LPN stipulates that "the extinction of indigenous animal and plant species should be prevented through the maintenance of a sufficiently extensive habitat". Furthermore, according to Art. 18 1ter of the LPN: "If, taking all interests into account, it is impossible to avoid damage of a technical nature to habitats deemed worthy of protection, the originator of such damage should take care that appropriate measures are taken to ensure the best possible protection, restoration or, failing that, adequate compensation." This article is often invoked to obtain the restoration of ecological connections severed by infrastructure.

With respect to habitat fragmentation and the protection of ecological networks, three other pieces of legislation are also of importance:

- The **Federal Law of 20 June 1986 relating to hunting and the protection of wild mammals and birds** is designed to protect species diversity and the habitats of indigenous and migratory mammals and birds living in the wild.
- The **Federal Law of 22 June 1979 relating to spatial planning** stipulates a considered approach to land use through the coordination of activities affecting spatial planning. The Federal Council issued a report on the principles of land-use planning in Switzerland. The objective of this report was to stimulate debate on the future of the environment and to improve the coherence of federal and cantonal planning.
- **Article 21 of the Ordinance of 2 November 1994 relating to the planning of watercourses** calls for the preservation of a minimum space around watercourses to protect against flooding and for the preservation of ecological functions.

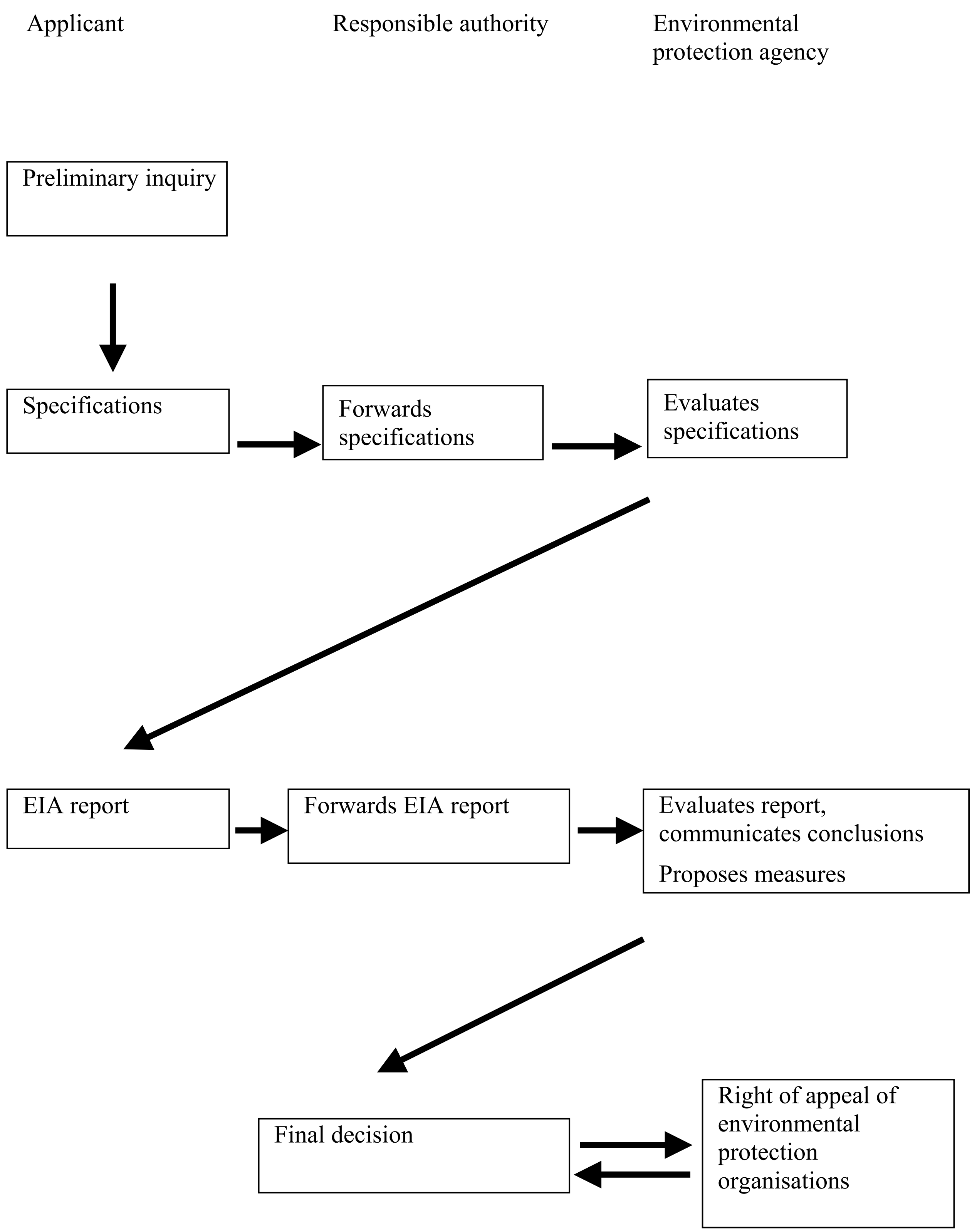
Since 1985, major infrastructure projects have been subject to an environmental impact assessment (EIA) in accordance with Article 9 of the **Federal Law of 7 October 1983 relating to Environmental Protection** and the **Ordinance of 19 October 1988 relating to impact studies**. This applies to national highways, main roads and other busy roads, new railway lines, the doubling or extension of existing lines where project costs are estimated to exceed CHF 40 million, and waterways. The EIA, which supplements existing authorisation procedures, is an analytical tool for determining whether an infrastructure project meets the legal requirements on the protection of the environment (including nature conservation) and for specifying conditions for approval of the project.

According to the LPN and the environmental protection law, non-governmental organisations (NGO's) concerned with the protection of nature, the landscape or the environment have the right, subject to certain conditions, to appeal to the administrative courts against any cantonal or federal decisions considered to contravene the environmental laws. Such appeals, originating either from public-interest groups or private individuals directly affected by the project, can significantly prolong the procedures and have a major effect on the final form of the project.

In summary, infrastructure projects are affected by the following parties:

- **Project initiator** – for transportation infrastructure projects, this is either the canton, the communes, private entities (for roads) or the federal government (for main railway lines) and sometimes private companies in the case of private railways
- **Decision-making authority** – coordination of consultations / project approval
- **Communes** – public inquiry for the project
- **Cantonal/federal administrations** with expertise in environmental matters – consultation
- Other specialised state departments (spatial planning, agriculture, etc.)
- **NGOs** – right of appeal

The following diagram summarises the procedure for the Environmental Impact Assessment.



4.5. Land-use planning in relation to nature and landscape conservation and transportation infrastructure

Eckart Lange

The objectives of land-use planning are to ensure that land is used economically, that settlements are developed in an orderly way, and that the natural environment is protected.

Land-use planning in Switzerland is organised in a federalist manner, i.e. each administrative level (Confederation, canton and commune) is assigned specific planning tasks. The instruments available for these tasks vary according to the planning level.

The federal government harmonises its various activities affecting land use by means of concepts and sectoral plans. These outline the concrete objectives in each case and specify general instructions for fulfilment of the tasks. Provided it has the authority to do so, the federal government can also issue geographically specific instructions, e.g. on questions of location, to the relevant federal authorities. Examples of such concepts and sectoral plans are the Swiss Landscape Concept, the plan of priority areas for agricultural land use, the civil aviation infrastructure plan and the AlpTransit plan (cf. BAV/BRP 1999), which contains the routing for the new railway lines and activities with land-use implications relating to implementation of the AlpTransit project.

According to the Constitution, the main responsibility for land-use planning lies with the cantons. In the cantonal master plan, which is binding on the authorities, activities affecting land use are coordinated so as to achieve certain planning goals. At the communal level, the communal land-use plan specifies permissible forms of land use, with binding effects for landowners. Land-use planning also includes zoning and building regulations. Other, more detailed plans drawn up at the communal level are the development and ground-plans, and design and district plans.

Land-use planning is dependent on certain basic information. At the federal level, the following inventories of objects of national importance should be mentioned in relation to nature and the landscape: landscapes and natural monuments, raised bogs and transitional mires, fenlands, floodplains, amphibian spawning areas, mire landscapes, and reserves for waterbirds and migratory birds.

With the exception of mires and mire landscapes, which are protected by the Constitution, the sites included in the inventories are not protected areas as such. Responsibility for implementation lies with the canton, and subsequently the commune, which ensures protection which is binding on the land owners. Examples of protected areas at cantonal and communal levels are nature conservation sites, landscape conservation zones, lake and riparian protection zones, development-free zones, etc.

In addition to those at the federal level, inventories are also drawn up at cantonal and communal levels, such as conservation or habitat inventories. The inventories also serve as a basis for a commune's building and zoning regulations or protection ordinances.

The Swiss Landscape Concept (passed on 19 December 1997) is an attempt by the Federal Council to integrate nature and landscape conservation more closely into the various areas of policy (agriculture, transport, etc.). The Concept (BUWAL 1999) stresses the need to "improve" as opposed to merely "preserving". In other words, apart from traditional conservation aspects, there should be a greater effort to improve and manage those landscapes that have suffered a loss of biological and landscape diversity in recent years. One important step towards realising these goals is the creation of landscape development concepts at cantonal and regional levels. However, it should be stressed that landscape development concepts are not legally binding and merely serve as a basis for all other planning.

For example, landscape development concepts are being drawn up in the Canton of Zurich in the form of pilot projects for the Hardwald and Albis areas (Amt für Raumordnung und Vermessung 1998). The idea is to protect and actively improve natural areas that form a unit and to treat the entire landscape area in a specific way. At a cantonal level, therefore, as well as the designation of protected landscape areas, this entails the preparation of guidelines for the development, improvement and restoration of entire landscape areas or individual landscape elements. In addition, as part of the partial revision of the cantonal master plan, protected areas, landscape development and landscape improvement zones are to be specified, together with corridors that are to be restored and development-free zones.

Thus, particularly in cantonal master plans, wildlife corridors are now being integrated into land-use planning, e.g. with the master plans indicating former and surviving corridors and/or dispersal axes of regional and supraregional importance. With regard to new construction projects, the aim is thus not only to maintain and improve the existing corridors but also to restore connections that have been destroyed or severed.

In the master plan of the Canton of Aargau (Richtplanung Kanton Aargau 1996), specific ecological corridors — some even extending beyond the cantonal boundaries — have been earmarked (see Fig. 4.5).

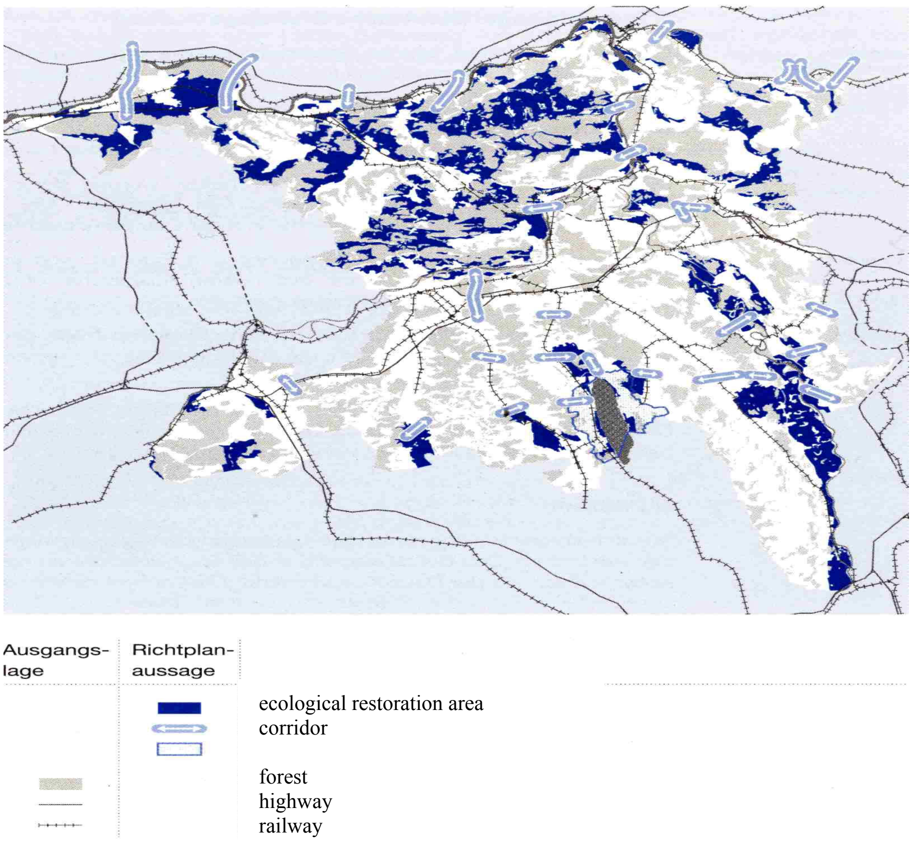


Figure 4.5 – Master plan of the Canton of Aargau with designated ecological corridors (source: Richtplan des Kantons Aargau, Herausgeber: Baudepartement des Kantons Aargau).

The landscape development concept of the Canton of Berne (Regierungsrat des Kantons Bern, 1998) also notes the supraregional wildlife corridors and obstructions to dispersal. The content of this concept – in relation to the avoidance of further barriers or the removal of existing ones – is binding on the authorities within the framework of cantonal projects.

The authorities have to ensure that the ecological corridors can be traversed. If plans and projects lead to serious fragmentation, appropriate measures must be taken to maintain and improve the passability of corridors for flora and fauna.

On the whole, Switzerland possesses the tools required at the various planning levels to incorporate the concerns of nature and landscape conservation into its infrastructure planning. Nevertheless, within infrastructure and other sectoral planning, a greater willingness is required to take due account of fundamental elements, some of which are not legally binding, such as landscape development concepts.

4.6. SUMMARY

Switzerland can be divided into three main landscapes: the Jura, the Central Plateau and the Alps. Over a relatively small area, the country displays a wide variety of landscape types, climatic zones and forms of agricultural land use. Habitat fragmentation, resulting from built-up areas, intensive farming and transportation infrastructure, is most pronounced in the Central Plateau. In the Jura and the Alps, the effects of habitat fragmentation are confined to the valley floors. Nevertheless, even in more remote regions of the Alps, the disruptive effects of human activities (leisure, tourism) are increasing due to the large number of access roads used for forestry and farming.

Switzerland is made up of 20 cantons and 6 demicantons, all of which are semi-autonomous. With regard to the construction of roads, authority is thus divided among the federal government, the cantons, the communes and private entities. The federal government only acts as both project initiator and supervisory body in the case of the Federal Railways.

Since 1985, major infrastructure projects in Switzerland have been subject to an environmental impact assessment.

According to the Constitution, the communes are primarily responsible for land-use planning, which is organised on a federal basis. With the new Swiss Landscape Concept, introduced in 1997, the Federal Council aims to integrate the protection of nature and landscape more closely into the various policy areas (agriculture, transport, etc.).

With the partial revision of cantonal master plans, wildlife corridors are now designated in addition to landscape protection areas.

Chapter 5. Habitat Fragmentation due to Existing Transportation Infrastructure

5.1. INTRODUCTION

This chapter first outlines Switzerland’s road and rail network, navigable rivers and mountain transportation systems, describing the various types, their length and density, and the estimated area which they cover.

The effects of the transportation infrastructure on the environment are then described. These range from direct loss of habitat, through many different kinds of disturbance and road casualties, to classic fragmentation effects such as the barrier effect and impacts on entire populations. Transportation routes may themselves serve as corridors for certain species, but most of them form barriers. The main wildlife corridors in Switzerland are therefore indicated, together with the main points of conflict with the national road network.

Finally, an account is given of the indirect consequences that are to be expected when a region is opened up by the construction of a new road.

5.2. EUROPEAN TRANSPORTATION NETWORKS

Will be completed in the European report

5.3. TRANSPORTATION NETWORKS IN SWITZERLAND

L. von Segesser, S. Schneider, A. Righetti, F. Borer

Switzerland has a dense road and rail network. In recent years, not all types of transportation infrastructure have been expanded to the same extent.

Table 5-1 - Increase in length of the main types of transportation infrastructure in Switzerland since 1960. All distances in km.

year	1960	1970	1980	1990	1998
rail	5'099	4'991	4'982	5'030	5'041
arterial roads (including motorways)	55'934	60'139	66'544	70'970	71'011
motorways	112	651	1'170	1'495	1'638

Thus, the rail network has remained virtually unchanged since 1950; its present length is about 5000 km. The only major additions will be the new lines being constructed under the RAIL 2000 and NEAT projects (see 8.5). In the national road network, on the other hand, only a few sections of the total length of 1855 km decided on in 1960 have yet to be completed. A total of 1638 km was already in operation by the end of 1998, representing 88% of the projected total length.

The cantonal road network comprises 18’238 km (1996 figure) and that of the communes 51’197 km, with about an additional 40’000 km of private roads. This gives a total road length of more than 111’000 km. As Switzerland has an area of 41’285 km^2, the road density is approximately 2.69 km per km^2 of national territory. If only the Central Plateau is considered, the density is even higher (3 to 4 km/km^2). The car ownership rate in Switzerland is high, with 613 vehicles per 1000 inhabitants (7.1 million inhabitants using 4.35 million vehicles). In the new national forest inventory (LFI 1999), the total length of forest roads, which are mostly owned by forest owners, is estimated at 29’000 km. Road density in the Swiss forest averages 26.2 running metres per hectare (m'/ha) of accessible woodland. The density is highest in the Central Plateau (58.1 m'/ha), the least developed areas are the Alps (11.6 m'/ha) and the southern Alps (7.8 m'/ha). Since 1985, 2’781 km of new forest roads have been built, and the development density has increased by 2.5 m'/ha. The numerous agricultural access roads should also be included in the calculation, but no statistics are available.

Some very general national definitions of roads are contained in the Road Traffic Regulations (VRV art. 1). All the rules of the road are specified by these regulations, e.g. speed limits on the various types of road (VRV art. 4a). Roads can be classified in several different ways. The administrative classification divides them into national, cantonal, communal and private roads, according to the operator. Within each category, the roads are graded according to how well they are equipped or how they are financed.

Roads are also classified according to their location (urban roads, bypasses, mountain roads, etc.), the type and volume of traffic carried (transit, tourist, etc.), the traffic structure, the installations (separation of traffic flows, parking regulations, conditions of access, etc.), vehicles permitted, etc.

On the basis of this classification, responsibility for maintenance, inspection, roadworks and financing of the public highways is allocated by means of a large number of federal, cantonal and communal laws. Depending on the individual canton, the classification may include pedestrian and cycle paths.

The conventional classification system used in Switzerland in the field of road engineering is defined in the Association of Swiss Road and Traffic Engineers (VSS) standards (SN 640 040 b). It consists of motorways (SN 640 041), arterial roads (SN 640 042), link roads (SN 640 043), collector roads (SN 640 044), and service roads (SN 640 045) (VSS 1998).

A clear overview of classification systems is given in §5.1 of TEA (Transport — Environment — Planning) booklet no. 8 (Jaeger 1995) and in Dumont (1997), both published by the Swiss Federal Institute of Technology in Lausanne (EPFL). Details of the typological classification can be found in the above-mentioned standards.

There is no direct correlation between the type of road and its permeability, as the latter depends on a large number of other factors, e.g. traffic volume, distribution over time, local topography and roadside obstacles such as fences, guard-rails or supporting walls.

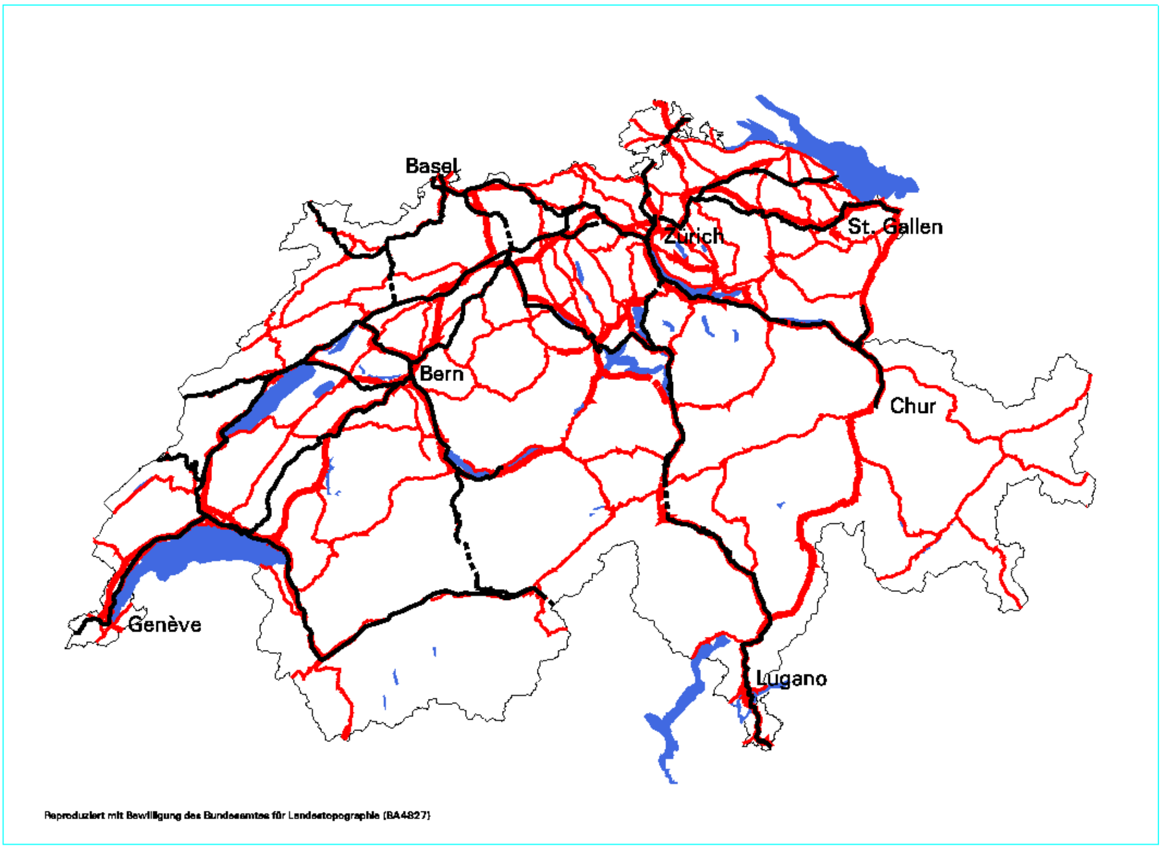


Figure 5.1 - Switzerland's motorways, arterial roads (red) and main railways (black).

5.3.1. Highways/motorways

However a distinction can be made between (generally national) motorways and other types of network. It is a legal requirement for Swiss motorways to be fenced in along their whole length, but this does not make them completely impermeable. As the Swiss landscape is made up largely of mountains and hills, a total of 26% of the network consists of engineering structures and these stretches are mostly permeable. The motorways are routed underground (approx. 10% tunnels and galleries), over bridges (approx. 10%), through underpasses (2%) or along overpasses (4%). Obviously, not all underpasses and overpasses can be used by wild animals (see chapter 7.7), but it is clear that the permeability of a road can only be defined in a specific situation, rather than according to the type of road.

5.3.2. Secondary road infrastructure

In analysing and planning road routes, the most important consideration is the function of a road within the network. Five types are distinguished according to their position in the network and the requirements they have to meet:

Motorways:	see 5.3.1
Arterial road:	connecting towns and regions and carrying a large volume of traffic
Link road:	providing secondary links and interconnecting conurbations and areas within a region
Collector road:	collecting traffic from residential/industrial areas and districts
Service road:	providing access to residential/industrial areas

5.3.3. Railways

In Switzerland, railways represent about 7% of the total road and rail network. The latter includes both public (i.e. Swiss Federal Railways, SBB) and franchised railways. The total length of the SBB network is 3000 km, and that of the franchised railways is 2000 km (excluding rack and funicular railways and cableways). Half of the network is double-track, and the SBB network includes 782 stations and halts (very high density). Since 1960, 99.5% of SBB lines have been equipped with overhead wires (AC 15kV, 16.2/3 Hz). The total length of railway tunnels is 364 km and the total length of railway bridges is 125 km, with respectively 215 km (266 tunnels) and 84 km (5491 bridges) belonging to the SBB. Some twenty SBB tunnels are over 2.5 km long. Traffic density is extremely variable according to the lines concerned. For the SBB, four broad categories can be defined:

– major rail junctions with 500 to 600 trains per day,
– main lines with heavy traffic, 150 to 250 trains per day,
– main lines with moderately heavy traffic, 80 to 150 trains per day,
– secondary lines with an average of 40 trains per day.

By 2005, at the end of the first construction phase of the "Rail 2000" project, train density at major rail junctions and on main lines should have increased by an average of about 30-50 trains per day, and on other lines by 10-20 trains or less (see 8.5). 15% of all journeys are undertaken on the SBB and franchised railways. 724,000 passengers per day or 264 million per year travel on the SBB. 153,000 tonnes of goods per day or about 48 million tonnes per year are transported, representing 37% of the total goods traffic.

On 1 January 1999, the old Federal Railways Corporation became a limited company (SBB AG).

5.3.4. Mountain transportation systems

The report entitled “The Environment in Switzerland” (BFS & BUWAL, 1997) states that: "Together with Austria, Switzerland has the most dense network of tourist transport installations in the world. It has over 1800 transportation systems of this type, including about 1200 ski lifts" (see Fig. 5.2).

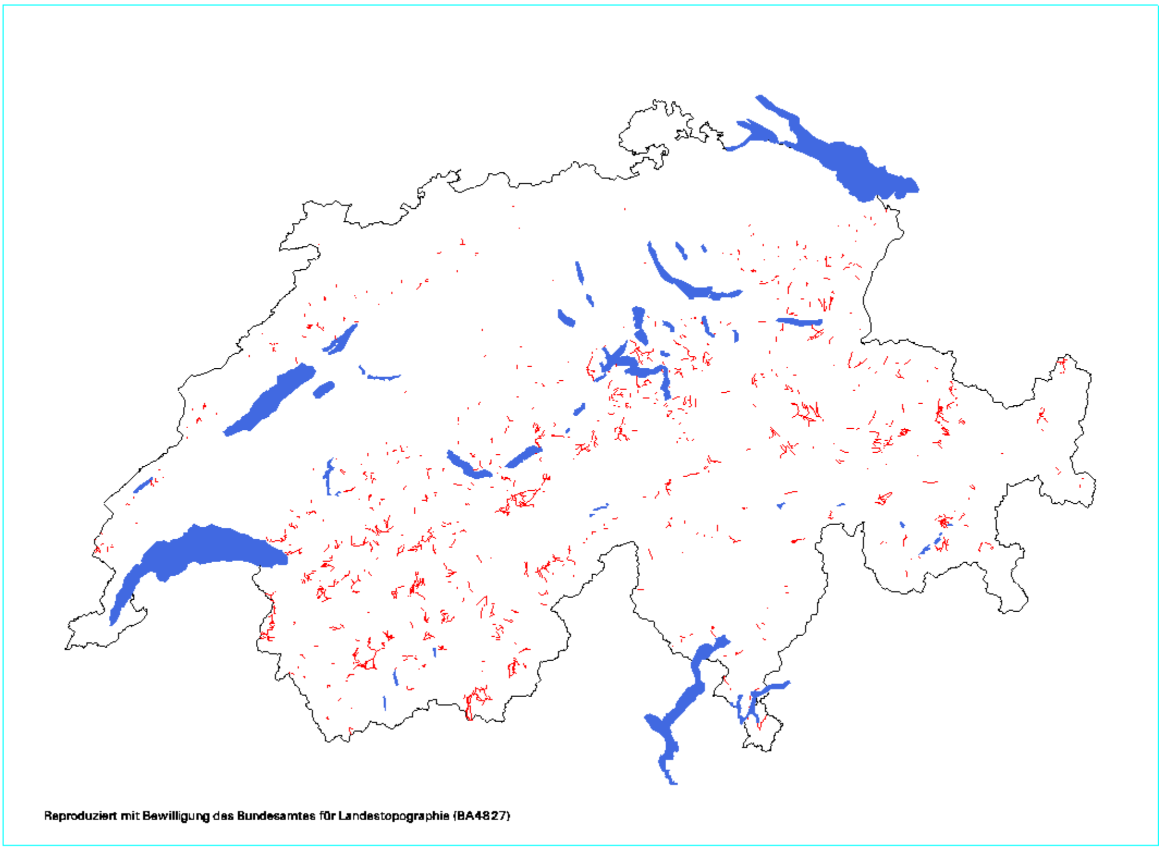


Figure 5.2 – Distribution of the mountain transportation systems in Switzerland

5.3.5. Waterways

Switzerland has no canals or other linear routes specially designed for transport. The only waterway navigable for large ships is the 21-km stretch of the Rhine from Basel to Rheinfelden. However, around 1200 km of natural waterways can be used by small and medium-sized vessels. Quite apart from navigation-related features, some of the waterways (as well as forming natural barriers) represent anthropogenic hindrances or obstacles to the dispersal of certain animal species.

There are two main causes:

Use of hydroelectric power

In relation to the use of hydroelectric power, the barrier effect is due in particular to the waterways leading to and from power stations and also to barrages. The former are often artificial, concrete-sided channels, which represent a barrier to ecological networks especially in the Central Plateau. For example, the channel built for the Gösgen power plant (canton of Solothurn) can be crossed by wild boars only at high water; the concrete bank protection makes it impossible for them to climb out at other times. The natural dispersal of the species towards the Central Plateau is thus made very difficult (Righetti, 1997). In recent decades, a potentially important ecological corridor for red deer, roe deer and chamois at Giswil (canton of Obwalden, cf. also SGW 1999) has become less significant, partly as a result of major construction work on the Dreiwässerkanal, which is used as a fast-flowing section (Righetti, verbal communication). But even mountain reservoirs may have a major impact on existing migration systems. For example, the Gigerwald dam (canton of St. Gallen), which was built in the 1970s, makes it difficult for the indigenous red deer to follow their traditional migratory patterns. The deer now swim across the lake but can only get in and out at a few places, as most of the banks are steep (Georgii et al. 1989).

Artificial water margins

Owing to the high degree of urbanisation, most river banks in the Central Plateau and the large Alpine valleys have been stabilised to a greater or lesser extent. Such flood-protection measures, frequently employing riprap, make it difficult for many animal species to disperse.

The tragic effects of enclosing streams in concrete channels in the Alps and pre-Alps are well known. In the Beckenried area (canton of Nidwalden), for example, many streams were enclosed in concrete to protect against erosion and were channelled into the Vierwaldstättersee by the shortest route. Any roe deer which got into these artificial channels were killed or were recovered from the lake with severe injuries (Antener, Jagdinspektorat canton of Nidwalden, verbal communication).

5.4. EFFECTS OF THE EXISTING TRANSPORTATION NETWORK ON NATURE

5.4.1. Habitat loss

Peter Oggier

Direct habitat loss is estimated by the Swiss Statistical Yearbook (BFS 1999) as follows. In 1999 the area of land covered by transportation infrastructure was 87’445 ha. This corresponds to 47.6% of the total area occupied by buildings and industrial plants (183’586 ha). Transportation infrastructure thus covers 2.1% of the country's entire surface area, with a significant concentration in the Central Plateau (Mittelland) and in the Alpine valleys.

On the basis of changes to notation in national maps, the following direct loss of habitat due to the construction of transportation infrastructure was determined from 1978 to 1989 (BRP & BUWAL in prep.). Each year saw the addition of 1’215.9 km of roads (1’364.3 km newly built, 362 km upgraded by a class, 510.4 km removed) and 8.4 km of new railway lines (21.1 km newly built, 12.7 km removed). There was a marked reduction in the construction of new roads within the regional network (motorways/highways and secondary roads) and in the expansion of the third-class road network (cf. also 4.3.), with a trend towards a greater number of more minor interventions. Meanwhile, the fourth- and fifth-class road network, which also includes the majority of forest and field tracks, continued to be expanded.

Recent studies have shown that the barrier effect of transportation infrastructure causes an indirect loss of habitat for the roe deer (see 5.4.6.) and the lynx.

Between 1971 and 1976, lynxes were reintroduced in the Jura and in the western part of the northern Alps. Some 10 years after release, lynx populations still survived in both of these regions (Breitenmoser 1983). At present, there are two populations of a total of 150 adult lynxes in the western Alps and in the Jura. There is currently a relatively high density of lynxes in the north-western Alps. Although hardly any free territories remain for the young animals becoming independent, there is no dispersal into other areas that would form a suitable habitat. Expansion of the population in the north-western Alps is impeded by both artificial and natural barriers: the Alpine ridge to the south, Lake Geneva and the intensively cultivated Rhône plain to the west, and the Aare valley with its lakes, built-up areas and motorway to the north and the east (Breitenmoser 1995). Since continuous expanses of woodland are important for the lynx, unwooded valley floors with human settlements just 1 km wide may represent a considerable barrier (Haller und Breitenmoser 1986); in heavily wooded areas, even high levels of construction had practically no adverse impact on the lynx (Breitenmoser und Baettig 1992). Particularly in extensive habitats, dispersal of the lynx is thus likely to be impaired or even prevented by fenced-in or busy sections of road, making suitable habitat on the other side of the transportation infrastructure inaccessible.

5.4.2. Corridor function

Peter Oggier

Hofer (1998) found that 150 (41.8%) of 359 pioneer areas inhabited by reptiles in the Bernese Jura and the Central Plateau were situated on the verges of roads/tracks or railways. Such verges have to be maintained properly if reptiles and butterflies are to survive there (Gonseth 1992). Road verges also provide an excellent habitat for small mammals (Bourquin & Meylan 1982). Some species are even found in the central reservation of motorways. In the case of the common vole *(Microtus arvalis)*, it was found that the individual territories on the central reservation are very long.

As verges and roadsides form long and linear habitats, it can be assumed that the animals' preferred migratory direction is along the transportation arteries. The verges thus become corridors.

This assumption was confirmed in the case of the medium-sized snail *Helicella itala* (Wirth et al. 1999). The direction of dispersal of this species (shell diameter 15 mm) was observed on several roadside verges in the Swiss Jura over two consecutive years. It turned out that only about 5% of all animals observed moved towards the road. The linear infrastructure thus led to the animals' movements being concentrated alongside the road.

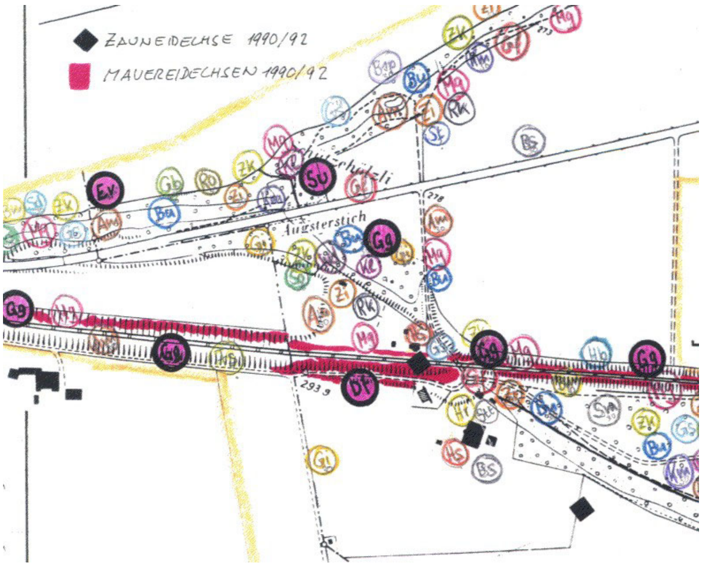
Plants can also use transportation arteries as a corridor for dispersal. For example, studies carried out to determine the environmental compatibility of the AlpTransit project (UNA 1993/1995) revealed a number of plant species in the area around the railway station at Frutigen which are normally found only in the canton of Valais. Their presence north of the Alpine ridge can only be explained by their seeds being carried along by trains through the Lötschberg tunnel.

An example of the corridor function of railway verges

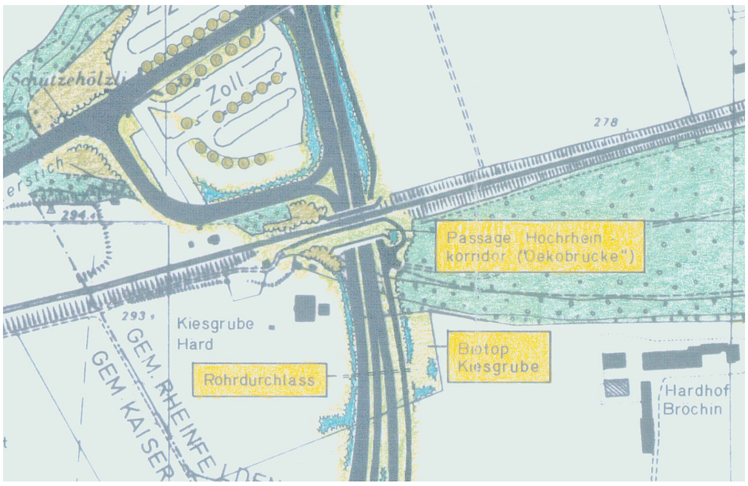
A3 - A98 feeder road, "Rheinfelden crescent"

Marguerite Trocmé

For plant and animal species that cannot cross the Alps and the Jura, the Upper Rhine plain represents the most important corridor of dispersal towards the northern Alps in Switzerland. A new section of motorway is planned between the A98 in Germany and the A3 in Switzerland. This cuts across the only remaining permeable landscape unit. Within the perimeter of the project, the railway verges probably represent the most important dispersal corridor (see figure on distribution of reptiles within project perimeter). In order to protect this corridor in the long term, a 13-m wide ecoduct south of the SBB line, planted with ruderal vegetation, was included as a requirement in the project. The bridge connects the south-facing verges.



Distribution of breeding birds and reptiles populations (red and black) within the perimeters of the project. The verge is an important habitat and an important corridor for reptiles.



Landscaping at the new motorway feeder road with a widened railway bridge. (Source: EIA, part 8 and 10, for the A3 - A98 feeder road near Rheinfelden, Baudepartement des Kantons Aargau, Abteilung Tiefbau, 1994)

5.4.3. Disturbance

Guy Berthoud

Habitat loss and the barrier effect created by infrastructure is compounded by the emergence of a significant zone of biological disturbance. Direct disturbance is caused by construction work, the presence of the infrastructure and traffic.

The general effects are described in a number of publications. The most widely used reference in Switzerland is the "Environmental impact assessment and road infrastructures" guideline (BUWAL, ASTRA, SVI, 1992). For more specific aspects relating to animal biology and landscape ecology, the booklet on "Fauna, road building and traffic" (SGW 1995) provides a good summary of the impacts to consider.

The possible adverse effects caused by traffic (noise, dust, fumes, light) can be modelled spatially using a Geographic Information System (GIS). Prediction methods of this type have been used extensively in recent impact studies and are particularly useful in analysing the options for routes. The ORL Institute at the Swiss Federal Institute of Technology (ETH) in Zurich in particular has developed some very effective models (Gfeller and Schmid 1990).

The possibility of spatial modelling of adverse effects may be extended to the assessment of environmental impact provided that the sensitivity of the habitats concerned is correctly evaluated. An empirical model often used to assess impacts caused by motorway traffic in Switzerland defines a cumulative impact gradient, distinguishing the following zones, starting from the edge of the carriageway (see Fig. 5.3):

– a highly disturbed zone, about 50 m wide, measured from the axis of the infrastructure, which is characterised by noise levels in excess of 65 dBA and high levels of particulate deposits (about 95 % of emissions) and accumulated gases, and

– a less disturbed zone, about 100 m wide, which receives the remainder of the particulates and a considerable proportion of the gas and noise emissions.

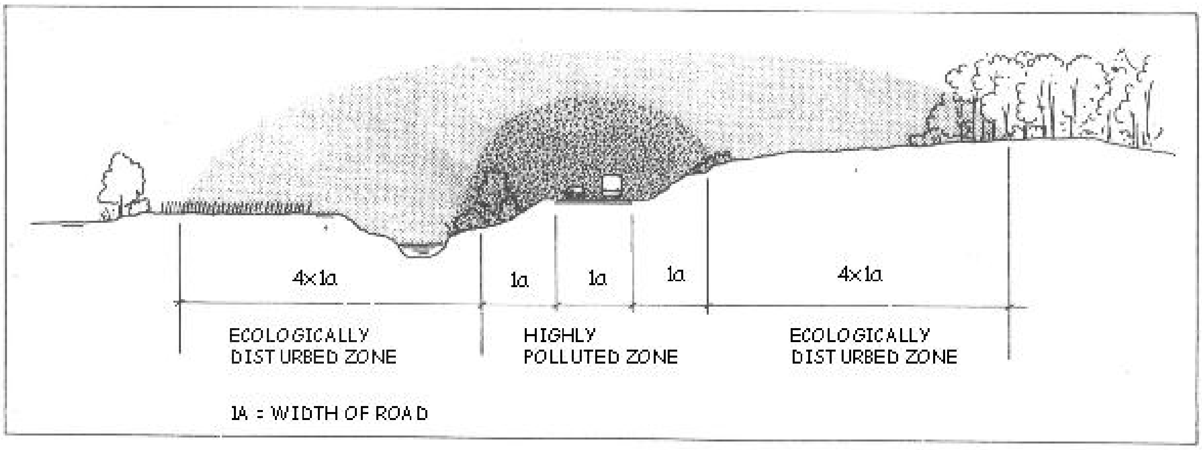


Figure 5.3 - Schematic distribution of gas emissions, particulates, noise, movement and light which affect the condition of habitats.

This standard scheme for classifying impact zones, which applies to a road built at ground level on subhorizontal terrain, has to be adjusted according to the slope, the relative position of ground and road, and the local prevailing winds.

This empirical model was validated in Switzerland on the first sections of the A1 motorway subjected to an Environmental Impact Assessment (Berthoud 1987), using birds in particular as bioindicators (see Fig.5.4).

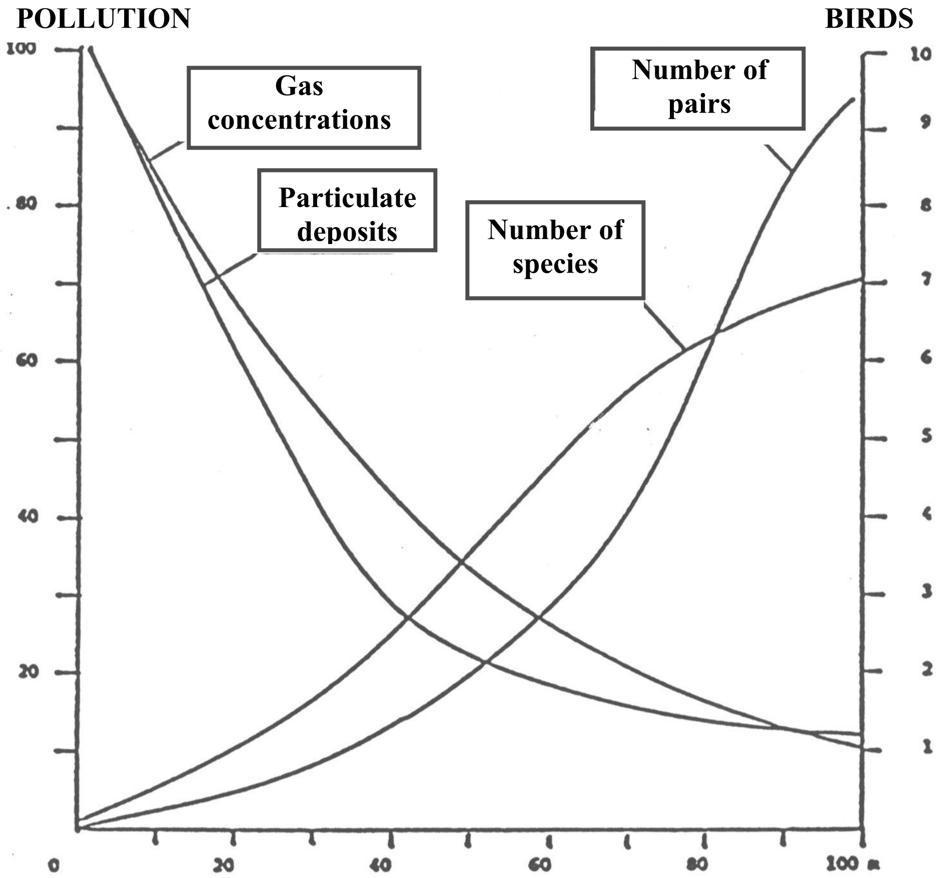


Figure 5.4 - Relationship between air and ground pollution and the presence of nesting birds alongside a motorway in cultivated habitats structured by hedgerows (after Berthoud 1987)

Another kind of significant disturbance is caused by the high density of forest roads in Switzerland (Meyer & Debrot 1989) and the large numbers of ski lifts. Here, the disturbance is due to the penetration of human activity into areas which are otherwise unaffected by major infrastructure (see 4.3.).

Thus, disturbance reinforces not only the barrier effect but also increases habitat loss and fragmentation (see Fig. 5.5).

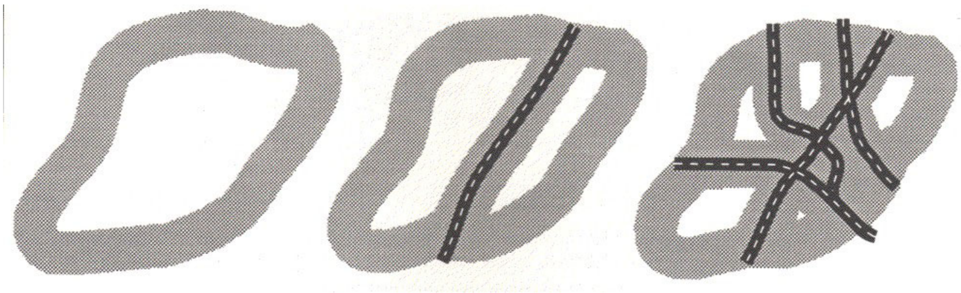


Figure 5.5 - Habitat fragmentation by transportation infrastructure considerably increases the loss of undisturbed areas (after Mader 1983).

5.4.4. Fauna casualties

Sébastien Schneider

In Switzerland there are numerous sources that can provide data on accidents caused by animals. These depend primarily on the type of transportation infrastructure to be studied. The two main types considered here are:

- roads
- railways

As far as **roads** are concerned, data are available from many different sources: police stations, maintenance centres, highways departments, automobile clubs, hunting associations, insurance companies, nature conservation associations, the Federal Office of Environment, Forests and Landscape (BUWAL), the Office for the Prevention of Accidents, and probably others. The level of detail of accident information depends on the source.

In Switzerland, each canton has its own policy on the collection and processing of data concerning accidents caused by animals. It is therefore difficult to know exactly who has what information and in what form. The highest level for information pooling is the Federal Statistical Office, which receives its information from the individual cantons. A major data-acquisition project which ran from the 1960s to 1997 resulted in the creation of a database of about 20,000 accident cases involving 27 species of mammals, including 19 wild species, and 37 species of birds. This database is at the Laboratory of Traffic Facilities of the Federal Institute of Technology Lausanne.

This database contains a variety of different information. The quantity in each case depends on the source (*italics show the data less frequently available*):

- type of animal, *its age, sex and weight*
- date, time and exact location of the accident
- type of road *and its traffic*
- hunting season or not
- weather conditions and state of the road (dry, covered in snow, etc.)
- cross-section of the road
- presence of fences
- roadside plant cover

- phase of the lunar cycle
- *behaviour of the injured animal*
- *speed of the vehicle before the accident*
- *point of impact*
- *colour of the vehicle's headlamps*
- *cost of the damage done*

Most information comes from standard forms (SNV 640 691, Association of Swiss Road and Traffic Engineers (VSS)), such as the one shown in Figure 5.6 below. These can be used to identify the blackspots in fauna/traffic safety and to determine the causes.

Please tick off							
Canton: *Zürich* Road section from *Türlersee* To *Hausen*					Accidants involving animals Rapport N° *11/8*		
Date	Time	Exact location of accident: coordinates etc.			Animal involved		
15.11.69	*21.05*	*682'220 / 234'620*			*Roe deer*		
Surroundings		Road profile			Miscellaneous		
Meadow	x		level		Time of day	Daytime	
Pasture			cut section			Dawn/Twilight	
Forest	x		1/2 cut section	x		Nighttime	x
Bushes			mixed		Fences	none	x
Orchards			cut and fill			On one side	
Residential area			fill section			On both sides	
Remarks: *600 Fr. material damage. One passenger slightly injured.*					Signature: *O. Müller*		

Figure 5.6 - Example of a report of an accident involving an animal

This database has been used to carry out a number of detailed studies on interesting topics, such as the behaviour of game (Müller & Siegrist 1981, Burnand et al. 1985) and its protection, and fauna/traffic safety (Müller & Mognetti 1992).

As far as the **railways** are concerned, train drivers must draw up a report in the event of a collision with an animal. Thus, such data do exist within the Swiss Federal Railways but have apparently never been the subject of extensive study.

Despite the existence of data for the two types of infrastructure mentioned above, it is clear that this does not cover all accidents involving fauna. In the case of roads, for example, insurance companies require a statement for reimbursement purposes whenever there is any material damage; most collisions with large animals are thus reported.

However, accidents involving small animals are rarely reported. The only information on these comes from the road maintenance departments that collect the carcasses, if these have not already been devoured by scavengers or thrown off the road at the time of the collision.

The federal hunting statistics provide the following figures for 1998 with respect to the causes of death of large and medium-sized mammals in Switzerland, putting into perspective the percentage of animals killed by traffic as opposed to hunting.

Table 5-2 - Non-natural causes of death for large mammals (BUWAL 1998)

Species	Sum of all animals killed	Killed in hunting	Killed by road traffic	Killed by rail traffic	Other causes of death
Red deer	21'293	6'896	339	91	909
Roe deer	130'579	43'839	8'213	563	7'158
Chamois	97'008	18'543	28	6	2'228
Wild boar	-	2'503	189	17	267
Ibex	14'928	1'646	3	0	562
Red fox	-	40'923	6'444	636	4'290
Badger	-	2'345	1'746	134	552
Brown hare	-	3'142	750	27	409

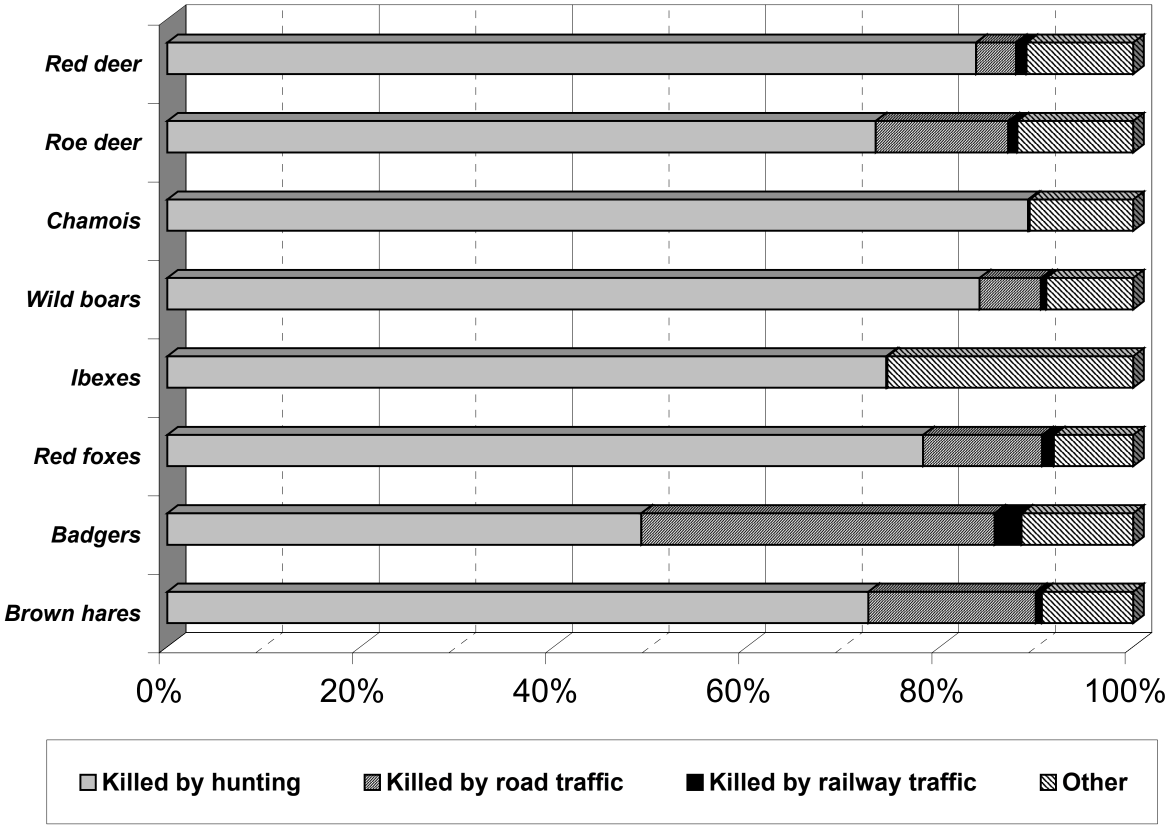


Figure 5.7 - Breakdown of different causes of death

In conclusion, a lot of data are available in Switzerland concerning road accidents caused by animals, but there seems to be a lack of systematic analysis, e.g. of the blackspots, the causes of such accidents, etc. (except for the studies mentioned before). How the data are collected, structured, stored and analysed is the responsibility of each individual canton. The current review by the Federal Statistical Office is chiefly concerned with recording the number of cases and deals with accidents that caused damage and, in particular, injury or death of vehicle occupants. The figures from the hunting department are probably the most complete, as they are based on the animals actually found dead and not on accident reports.

The same conclusion can be drawn for the railways, especially as the safety of passengers is at very little risk.

5.4.5. Barrier effect

Guy Berthoud

The barrier effect results from a combination of a physical obstacle (linear infrastructure), disturbances caused by the infrastructure itself as well as the traffic, and the general change in the landscape and land use near the carriageways. It thus reflects a series of direct and indirect effects.

As the barrier effect is progressive, it has been proposed by Müller & Berthoud (1994) to divide infrastructure into five major categories, according to the effects observed on biological interchanges:

Category 1: Service roads with light traffic, only occasional traffic at night.

Effect restricted to local movements of small animals, particularly invertebrates and small mammals which will not cross an exposed space.

Category 2: Link roads with light traffic, less than 1000 vehicles/day.

Maximum predation effect on wildlife as a whole due to accidental killing of animals by vehicles. Casualties proportional to traffic volume.

Category 3: Link roads with moderate traffic, from 1000 to 5000 vehicles/day. Equivalent to unfenced railways, rivers less than 10 m wide.

Selective effect on animals partly aware of the danger. Attempted crossings are no longer proportional to traffic volume.

Category 4: Arterial roads with heavy traffic, from 5000 to 10,000 vehicles/day. Equivalent to unfenced double or three-track railways, rivers over 10 m wide.

Marked effect of fear or refusal to cross, but only limited casualties.

Category 5: Arterial roads with very heavy traffic, over 10,000 vehicles/day and fenced-in motorways. Equivalent to fenced-in railways, canals with reinforced banks (concrete, riprap, piling) and avalanche protection galleries.

Virtually total barrier effect. Only panicking or stressed animals attempt to cross.

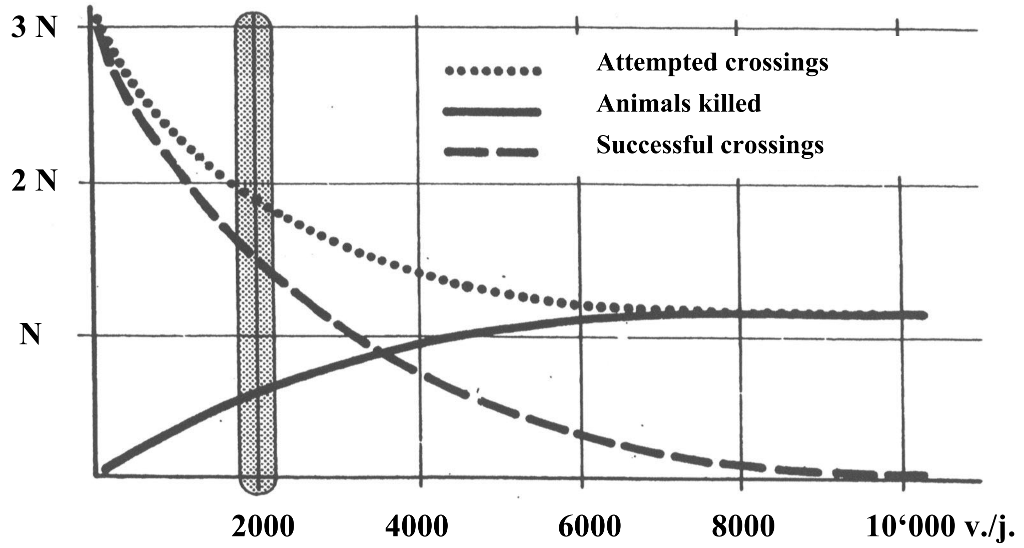


Figure 5.8 - The barrier effect of a road on the movement of animals is a combination of the number of attempted crossings, the number of animals killed and the deterrent effect of road traffic on the fauna. The situation becomes worrying when traffic exceeds 2000 vehicles/day.

Category 1 is based on observations of terrestrial invertebrates and small mammals which no longer regularly cross exposed areas. Categories 2 to 4 are based on the frequency of accidents involving animals analysed according to traffic volume (Burnand et al. 1985). Category 5 includes all types of infrastructure which cannot be crossed without specially designed constructions (see Fig. 5.9).

In fact, the barrier effect consists of two subeffects:

The diversion effect results from some animals' ability to change direction in order to bypass an obstacle. Thus, in some cases, red deer, wild boar and most carnivores may cover several kilometres to find a possible crossing point.

The inhibition effect concerns animals which rapidly turn back when confronted with a major obstacle or disturbance. This reaction is characteristic of most invertebrates but also, for example, of amphibians and reptiles.

The behaviour of migratory amphibians confronted with an artificial obstacle in the form of a plastic barrier has been studied by means of individual marking. The capacity for lateral movement varies from one species to another but is generally very limited. At distances of more than 20 m from the original line of movement and having gone back and forth several times, most species give up and turn back (see Fig. 5.9) (Berthoud 1975). Reptiles have a different problem: the lack of a habitat suitable for their type of movement blocks their progress. Thus, for 3 snake species (*Natrix natrix*, *Elaphe longissima*, *Vipera aspis*) which are commonly found on the banks of the Rhône and the verges of the A9 motorway, it was shown that a lack of vegetation or shelter made it completely impossible for them to cross more than about 10 m of exposed ground between two favourable areas. An area of dense or even permanently shaded woodland is another obstacle which they cannot cross (Berthoud 1982).

The barrier effect has occasionally been observed in some insects and especially in migratory diurnal butterflies (Berthoud 1968). Thus, several species of pierid butterflies were visibly incapable of crossing the wall of heat reflected by the road after a summer storm.

Although it appears to be easy for birds to cross roads with heavy traffic, the presence of a strip without any vegetation does seem to have a marked effect. Thus, Keller et al. (1996), observing the use of wildlife overpasses, found that nesting birds preferred to use the vegetated bridges to cross the road. Moreover, the use of transparent noise protection walls results in an important number of killed birds (Sierro & Schmid 2000).

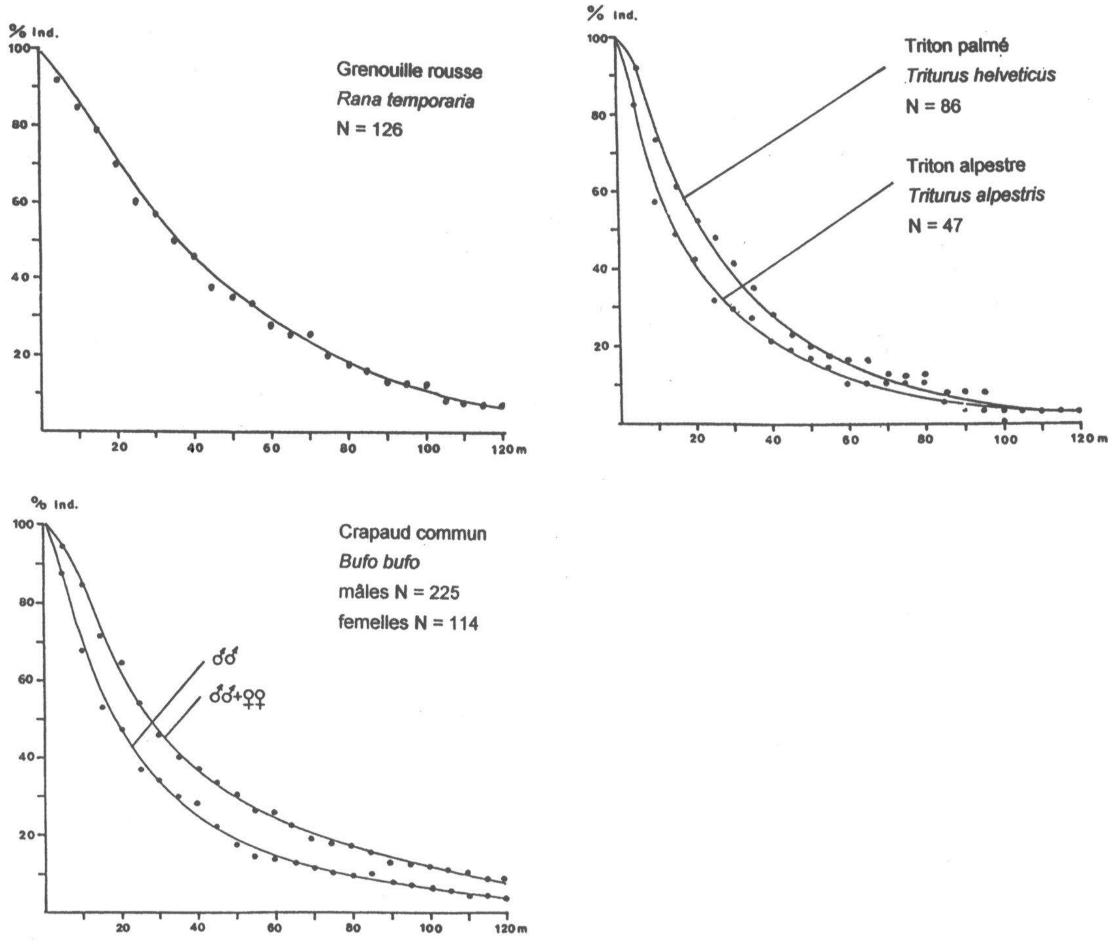


Figure 5.9 - Ability to move laterally from the original direction of movement for four species of amphibians confronted with a barrier along a road (after Berthoud 1975).

The barrier effect was presented schematically by Müller & Berthoud (1994) for didactic purposes (see Fig. 5.10).

Permeability analysis of a transportation network, permitting a theoretical assessment of the barrier effect on wildlife, has seldom been used in Switzerland (see also 7.7.). A trial was carried out on the Yverdon-Avenches section of the A1 motorway in an attempt to explain two different approaches to ecoduct design and the results to be expected according to whether the road was in a hilly area with a large number of engineering structures (tunnels and viaducts) or an alluvial plain essentially devoid of major structures (Berthoud 1995). In fact, this method reveals the 'transparency' of the infrastructure analysed, but not the actual permeability for wildlife.

Several examples of barrier effects with a marked impact on populations of game species have been identified in Switzerland:

- Disruption of interchanges of ungulates between the Jura and the pre-Alps on the Vaud Plateau following the construction of the A1 from Lausanne to Yverdon, with a complete reorganisation of the traditional movements of the wild boar on the Plateau.
- Isolation of a roe deer population and marked decline in their numbers caused by the A1 Bern to Zurich road on the Grauholz, north of Bern.

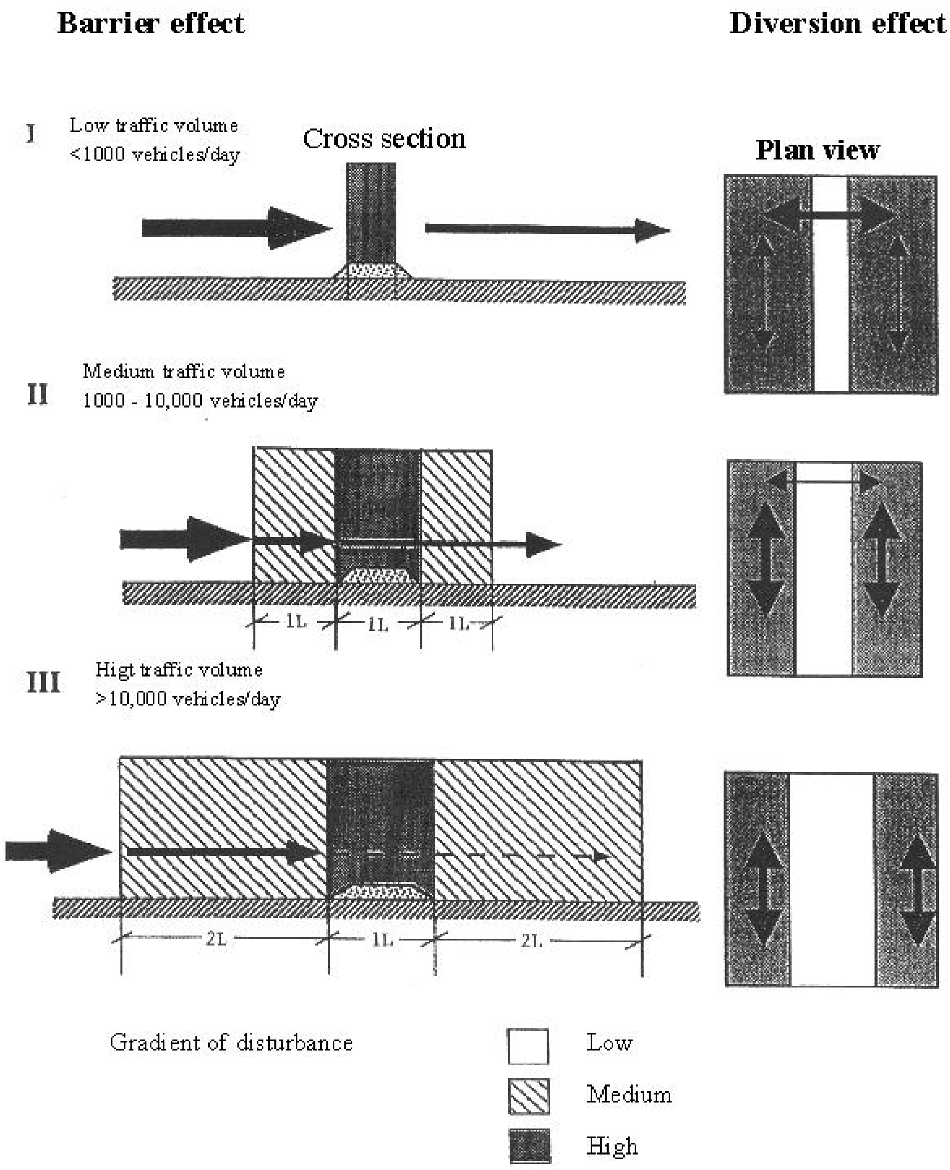


Figure 5.10 - Schematic presentation of barrier and diversion effects on wildlife movements according to three categories of road with increasing traffic.

5.4.6. Effects on populations

Otto Holzgang, Silvia Zumbach & Ursula Bornhauser-Sieber

Existing studies indicate the effects of habitat fragmentation on animals, such as local extinction, reduced mobility, higher mortality, lower density or prevention of dispersal. The authors are not aware of any Swiss studies dealing with effects on population genetics or the influence on the fitness of large mammals. As part of the COST programme, laboratory and field studies on carabid beetles are to be carried out at the University of Bern to determine the extent to which fragmentation effects have an impact on population size and gene flow.

Amphibians

Many Swiss lakes have a road running along the shoreline. In the past, amphibians were presumably to be found wherever there was a suitable hinterland, but these populations would already have died out by the time data were collected for the Swiss Amphibian and Reptile Conservation Programme (KARCH). Today there are long stretches along the Thunersee, Bielersee and Vierwaldstättersee where no amphibians are observed.

There is evidence from several districts that amphibian populations have become extinct as a result of road traffic. Generally, these were populations which had always used a lake for spawning and were then confronted with a road along the shoreline. In such situations, the animals could not bypass the danger zone and were forced to cross the road. At Riva San Vitale (canton of Ticino), for example, a common toad population (*Bufo bufo*) died out for lack of offspring, although temporary and permanent installations were set up to protect animals moving into the area. However, some of the areas of conflict are so elongated that it is impossible to implement countermeasures. For example, there is a 50-km stretch of road on the southern shore of Lake Neuchâtel where amphibians are run over by the increasing traffic.

In other situations, populations are not eradicated altogether but decline as the traffic increases, with some species being more vulnerable than others (Ryser 1988).

Brown hare

Between 1991 and 1996, as part of the Swiss Brown Hare Project, animals were counted using searchlights at least once in 198 areas (total area 1’208 km^2) in February or March. With regard to fragmentation, the following correlations were observed for the brown hare (Pfister 1998):

- The number of brown hares increased exponentially as the field area increased.
- The greater the degree of isolation, the lower was the brown hare density.
- There was a negative correlation between the settlement area or traffic/road network and brown hare density.

Generally speaking, it can therefore be said that fragmentation, whether caused by road traffic or other factors, has a negative effect on brown hare density.

In the case of both the roe deer (Müri 1999) and the lynx (Breitenmoser 1995), transportation infrastructure is assumed to seriously impede dispersal of the species (see 5.4.1.).

With data from the Swiss fawn-marking study, a long-term investigation by BUWAL, it has been possible to analyse the roaming behaviour of roe deer in the last few decades, which have brought radical changes to habitats (Müri 1999). The average distance between the place of birth and the place of death is a good indicator of the mobility of the deer. Between 1971 and 1995, huntsmen and hunt supervisors voluntarily marked a total of 3970 fawns. Of these animals, 719 were later found dead or were shot in the hunt. The study showed that roaming distances for roe deer populations in this country have decreased considerably during the last two decades. This tendency was found to be strongest among the does: in the period from 1971 to 1975 the site where the carcass was found was an average of 4.3 km away from the marking site, but from 1991 to 1993 it was only 0.6 km. In addition, the distance covered was found to be related to the degree of isolation. The greater the density of barriers in the immediate vicinity of the place of birth, the shorter was the roaming distance. Roads, railway lines, settlements and cleared land are responsible for the loss of mobility, dividing deer populations into largely isolated habitat compartments. Of 152 deer which were marked in the Central Plateau and later found as adults, only one had succeeded in moving to a different compartment from 1994 to 1995. Moreover, the proportion of deaths caused by accidents among roebucks of dispersal age also rose significantly from the first to the second half of the investigation period.

Other examples are:

- Isolation and disappearance of populations of roe deer, wild boar and brown hares as a result of the construction of the A1 beside Lake Geneva, between Geneva and Lausanne.
- Isolation and disappearance of a small population of chamois to the west of Bern when construction of the A1 from Bern to Murten prevented new animals from migrating from the main area of distribution in the Gantrisch region.

5.4.7. Overview of environmental bottlenecks

Otto Holzgang & Silvia Zumbach

The subject of bottlenecks, including points of conflict between traffic and fauna, has been dealt with in Switzerland primarily from the point of view of mammals and amphibians. The main bottlenecks for mammals were described in a recent report (SGW 1999) and will be discussed in the following section. Data on amphibians and problematic sections of road are collected and managed on a national basis by the KARCH coordination office.

Wildlife corridors in Switzerland

The BUWAL project on “Wildlife corridors in Switzerland” was carried out from 1997 to 1999 to identify the most significant former wildlife corridors and those still existing. The requisite data were collected in cooperation with the cantons and assessed by experts from the Swiss Ornithological Institute and the following environmental consultancies: Büro

UNA, CAPREOLA, Drosera SA, ECONAT, ECOTEC, faune concept and Maddalena & Moretti. The whole study is designed for terrestrial species.

As time and resources were very limited, existing data and experience were compiled. Particularly in cantons with a system of game preserves, hunting statistics provided valuable information on the chronological and geographical dispersal patterns of game. To obtain more precise data on the movements and occurrence of common species such as roe deer, red deer, wild boar, chamois and ibex, hunt managers, gamekeepers and/or huntsmen were personally consulted using a standard questionnaire. The information was marked directly on maps. To enable potential wildlife corridors to be identified as well, a geographical information system (GIS) was used to calculate a simple permeability model of the landscape, with the highest permeability for wildlife being assigned to forest, zones on the fringes of the forest and protected areas (see Fig. 5.11).

It is essential first to define the following terms:

- Axes of movement are lines based on topography, such as ranges of hills, valleys or stretches of woodland, along which animals (may) migrate, move or disperse. The exact routes taken are not usually known, and axes may therefore be designated on the basis of individual observations or on grounds of plausibility.
- Wildlife corridors are sections of the axes of movement of wild animals which are permanently bounded at the sides by natural or anthropogenic structures or intensively used areas. Within the area of distribution of a species, these corridors serve to connect distinct and isolated habitats of (parts of) populations, forming an extensive network. They thus facilitate gene flow between and within populations, the population and spatial dynamics peculiar to the species (e.g. seasonal migrations), and active dispersal to open up new habitats or recolonise former ones.

The network shown in Fig. 5.12 contains all the supraregional axes of movement, together with the wildlife corridors. It is intended to illustrate the extensive connectedness within Switzerland for terrestrial, forest-dwelling wildlife. It contains proven migration routes and known trails (e.g. along guiding structures such as groups of woodlands), trails represented schematically on the basis of their primary alignment (particularly in core areas where there are numerous paths, not all of which can be shown), and axes of movement or the shortest hypothetical links between established corridors. The axes of movement in particular illustrate the extensive connectedness and thus symbolise the supraregional network.

Condition of supraregional wildlife corridors

An overall assessment reveals that 47 (16%) of a total of 303 supraregional wildlife corridors are now largely disrupted and can no longer be used by wildlife. The functionality of more than half of the corridors is moderately to severely impaired (171 corridors; 56%). Approximately a third (85; 28%) can be classified as intact.

The corridors are distributed among the Swiss regions as follows (as classified by Swiss forestry statistics): 128 (42% of the wildlife corridors) in the Central Plateau, 84 (28%) in the Alps, 56 (18%) in the Jura and 35 (12%) in the pre-Alps.

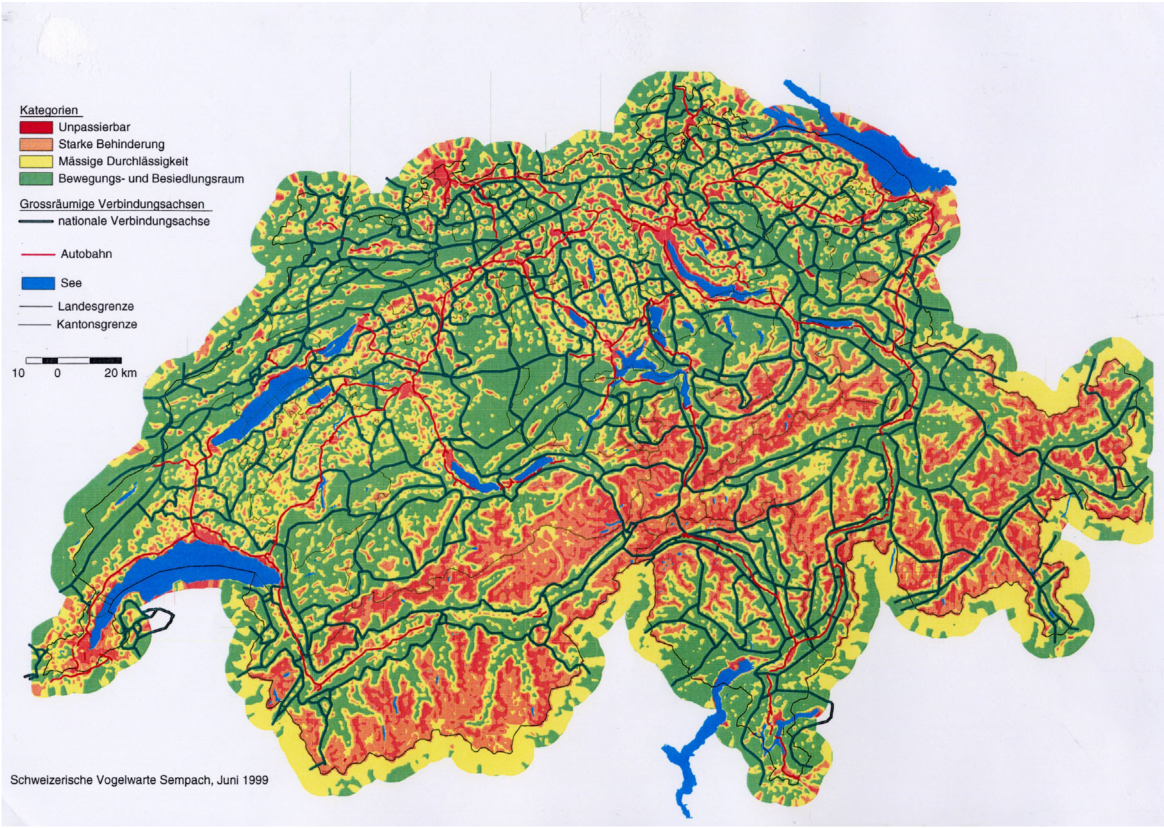
Measures to improve the current situation

A total of 78 supraregional corridors have been designated whose functionality depends on the construction of wildlife-specific structures such as wildlife overpasses or underpasses. In two cases, such structures have already been built, in eight construction is under way and in four others it is at the planning stage. Thus, another 64 corridors need to be restored by means of suitable constructions, although in four cases only passages for small animals are required. In another nine cases, the functionality of corridors can be restored or improved by modifying existing river culverts, motorway viaducts, etc. to meet the specific needs of wildlife. This leaves 51 corridors which would probably require more costly restoration measures.

Sections of road problematic for amphibians

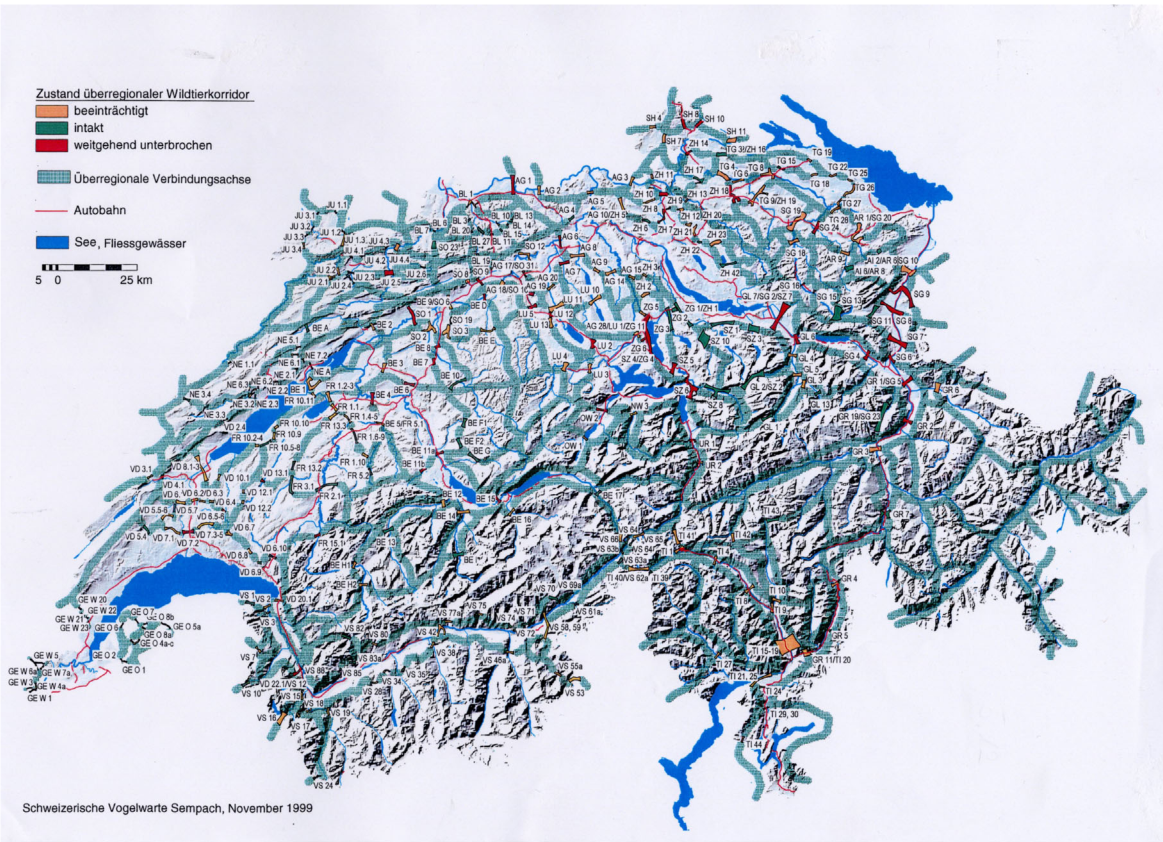
The KARCH office is aware of about 700 problematic sections of road. In reality, there are certainly more sites that have not yet been reported to KARCH or the cantonal authorities. Inventories of crossing points are available in 14 of 26 cantons, and over 80% of the problematic sections of road are in those cantons. In the whole of Switzerland, there are probably over 1000 places where the amphibian spawning run leads across a road and striking numbers of amphibians are run over.

Recorded points of conflict between amphibians and traffic in Switzerland						
	Action taken					
Number of known points of conflict	Alternative spawning sites	Permanent installations	Temporary fencing	Road barriers	No action	Not known
928	**19**	**126**	**262**	**14**	**324**	**183**



Legend: red: unpassable
yellow: limited permeability
orange: average permeability
green: permeable

Figure 5.11 - Permeability model and extensive network for forest-dwelling wildlife in Switzerland. The width of the barriers shown is no indication of the size of the barrier effect. Thus the Alps are shown as a natural barrier covering a large area, but in many places a motorway has the same fragmenting effect.



Legend: orange: impacted corridor
green: intact corridor
red: interrupted corridor

Figure 5.12 - Overview of the wildlife corridors of supraregional importance, showing Switzerland's extensive network for terrestrial wildlife, consisting of wildlife corridors and supraregional axes of movement.

5.5. Secondary effects of transportation infrastructure

Guy Berthoud

The construction of transportation infrastructure, more than any other installation, brings profound and lasting changes in land use. It entails a general land reallotment, the local infrastructure network and landscape structures. For example, surface or underground watercourses are modified by adding new diversion systems or new green spaces are created along the roadside. Transportation infrastructure also promotes the creation of new centres of industrial and the expansion of built-up areas. The result is a profound change in the landscape which had not always been planned or even comprehended when the infrastructure was designed.

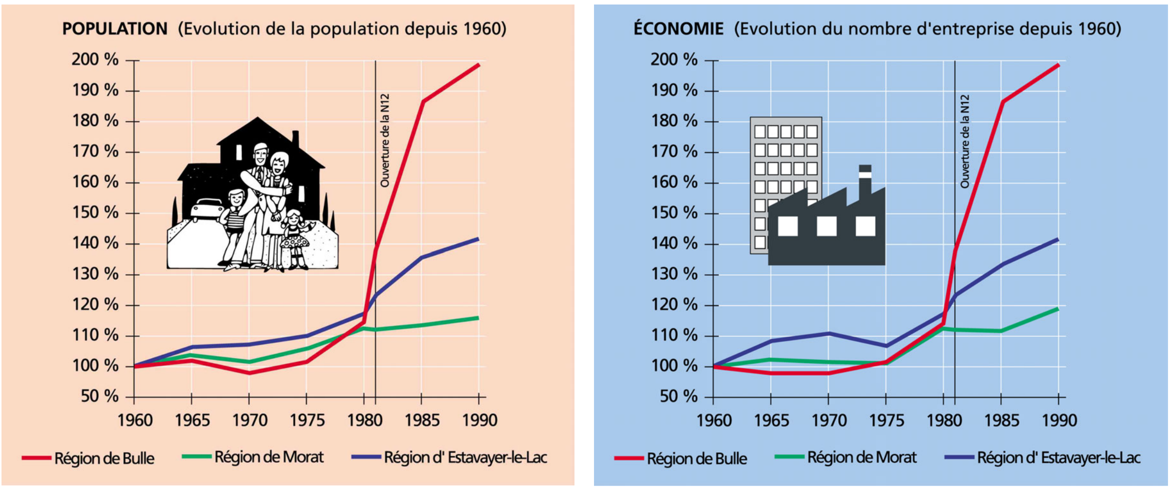


Figure 5.13 - Developments in the Bulle region after the completion of the A12, compared with two regions not connected to the motorway (from: N1 magazine, Tronçon Cheyres – Cugy No. 1, Directions des traveaux publics du canton de Fribourg).

Managing this transformation of the landscape is the real environmental challenge of this type of project.

As regards the problem of fragmentation, a new landscape concept has to be developed at a local and sometimes even a regional level.

In particular, the new concept should define principles for maintaining and developing new ecological networks resulting from the establishment of the transportation infrastructure. Whether or not passages are built for wildlife, it would appear that the original ecological network needs to be completely reorganised.

The landscape concept is generally outlined during the environmental impact assessment; thereafter it has to be refined, validated and above all included in a spatial planning document so that it can be put into effect (requirements in a master plan, regional plan for landscape concept, etc.).

This procedure is still not widely used in Switzerland, but it should be developed in the future.

Some cantons, including Aargau, Bern and Thurgau, having already outlined the basic principles for a landscape development concept, are now beginning to deal with the risk of progressive erosion of their natural heritage by taking into account the constraints imposed by the existence of regional ecological networks and in particular the corridors which are indispensable to wildlife.

The establishment of these new planning principles is now on the agenda of most cantonal environmental protection agencies. The case of La Plaine de la Broye, near the Payerne junction on the A1 motorway (Yverdon-Avenches), can be taken as an example. In this area, the development of three industrial zones, a combined civil and military airport zone and four property development schemes is threatening the effectiveness of the environmental protection measures taken and the existence of two regionally important wildlife corridors. These corridors near the Payerne junction have been re-established and managed precisely to compensate for the environmental impact of the motorway project.

The overall environmental plan covers two cantons, which complicates coordination considerably.

Under these conditions, the maintenance of a certain level of regional biodiversity will require coordinated planning, with the spheres of influence and long-term environmental restrictions being specifically defined. A regional ecological network concept taking into account the planned developments and the requirements of wildlife has been submitted to the relevant cantonal departments in Vaud and Fribourg (ECONAT 1999) as an “environmental constraints” section of the regional master plan.

5.6. On-going research

Baur, B. (Project leader), Habitat fragmentation: experimental assessment of population viability and changes in species diversity. Institute for nature, landscape and environmental protection, University of Basel-Switzerland, St. Johanns-Vorstadt 10/12, CH-4056 Basel.

Dumont, A.-G. (1997) *VOIES DE CIRCULATION 1 « Conception et réalisation du projet »*. Laboratoire des voies de circulation (LAVOC), Département de Génie civil, Ecole polytechnique fédérale de Lausanne (EPFL).

Gilliéron, C., Schlaepfer, R., & Pfister, H-P Modélisation de la dynamique du paysage: Outil d'aide à la décision pour une gestion du territoire tenant compte de la faune. Etude de cas: le lièvre en Suisse.
Laboratoire de gestion des écosystèmes, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne (http://dgrwww.epfl.ch/GECOS) and Schweizerische Vogelwarte, CH-6204 Sempach.
End of projet: Beginning of 2002

Nentwig, W: Effects of habitat fragmentation on vertebrates. Starting spring 2000. Universität Bern, Zoologisches Institut, Abteilung Synökologie, Balzerstrasse 3, 3012 Bern.

Sperisen, Ch. (Project leader) Effects of habitat fragmentation and isolation on the population genetics of roe deer. Beginning 2001. For further information contact: Martin Obrist, WSL, Zürcherstrasse 111, 8903 Birmensdorf.

5.7. Summary

The Swiss rail network is about 5000 km long and represents about 7% of the total transportation network.

A total of 1638 km of national highways were in operation at the end of 1998. If all the cantonal, communal and private roads are added on, the total length of roads is approximately 111,000 km, covering 2.69 km per km^2 of national territory. Extension of arterial roads is declining, while construction of secondary roads is increasing. Altogether transportation infrastructure covers 2.1% of Swiss territory. Car ownership rates are high in Switzerland, with 613 cars per 1000 inhabitants.

Roads are classified in various ways. For example, they are divided up according to administrative criteria, the degree of development, traffic volume or location. With regard to the degree of development, it is worth mentioning that all Swiss motorways are fenced in.

A number of Swiss studies show that habitat fragmentation caused by transportation infrastructure has adverse effects (e.g. local extinction, lower mobility, higher mortality, lower density or prevention of dispersal) on animals such as the roe deer, lynx, brown hare, wild boar and amphibians. However, the latter, as well as small mammals and plants, may also use transportation routes as dispersal axes.

As well as revealing the numbers killed, wildlife casualty figures for the whole country indicate locations where the risk is increased for drivers and animals. In 1999, on the basis of these and other data, the country's most important wildlife corridors were identified and

their condition was ascertained. Of a total of 303 supraregional wildlife corridors, 47 (16%) are now largely disrupted and are no longer used by wildlife. The functionality of more than half of the corridors is moderately to severely impaired (171 corridors; 56%). Approximately a third (85; 28%) can be classified as intact.

The side effects of a new road often have a greater impact on a region than its actual construction and operation. If all the developments within a region are to be properly coordinated, a regional landscape development concept will be required.

Chapter 6. Traffic Safety in Relation to Fauna Casualties

Sébastien Schneider

In Switzerland, the incidence of human fatalities in accidents involving animals is very low; nevertheless, it should not be ignored. Traffic planners and authorities should ensure that such cases are kept to a minimum.

Fencing is the ideal solution for ensuring the safety of those using the transportation infrastructure. As long as it is appropriately designed and maintained (Müller & Berthoud 1994), the effectiveness of fencing cannot be disputed. In fact, it is now used throughout the entire Swiss motorway system. However, while fencing protects both humans and animals from accidents, it also has the drawback of preventing any exchanges across the traffic route, which may well be vital for certain species.

While in the past railway traffic seemed little concerned, it would appear – with the advent of high-speed trains – to be reconsidering the problem of safety associated with collisions with animals (e.g. fencing-off of TGV lines in France).

According to the data from road statistics, accidents involving wildlife and reported to insurance companies accounted for 2% of all road accidents in the period from 1995 to 1997 (most recent data available). These can be broken down as follows:

- accidents causing material damage only 1.98%
- accidents causing physical injury to humans 0.06%
- accidents resulting in a human fatality 0.01%

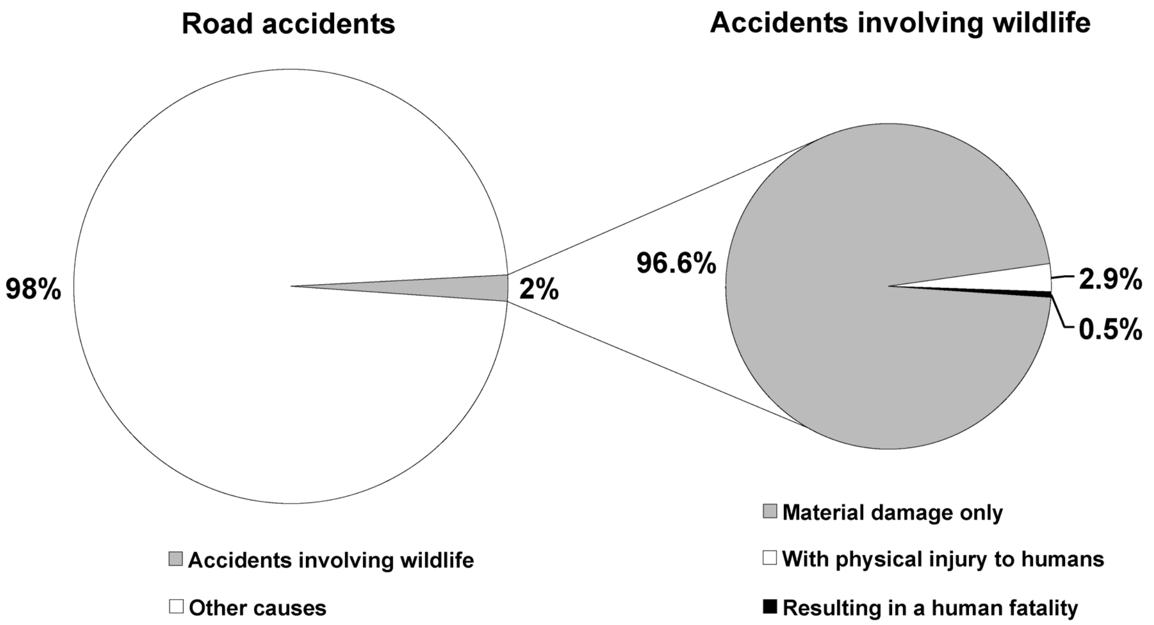


Figure 6.1 - Different types of accidents involving animals

In absolute terms, the Federal Statistical Office provides the following details for the years 1995 to 1997 (Table 6-1):

Table 6-1 - Types of accidents involving animals reported to insurance companies (BFS 1999)

1995 Type of accidents	Collision with a horserider	Collision with a domestic animal	Collision with a wild animal	Other accidents with animals	Total accidents with animals
with material damage	9	303	1'831	16	**2'159**
with human injuries	6	51	41	6	**104**
with human fatalities	1	1	0	0	**2**
Total number of accidents	**16**	**355**	**1'872**	**22**	**2'265**
1996					
with material damage	11	275	1'769	28	**2'055**
with human injuries	5	51	42	8	**98**
with human fatalities	0	2	1	0	**3**
Total number of accidents	**16**	**328**	**1'812**	**36**	**2'156**
1997					
with material damage	8	239	1'565	19	**1'812**
with human injuries	4	48	47	7	**99**
with human fatalities	0	0	0	0	**0**
Total number of accidents	**12**	**287**	**1'612**	**26**	**1'911**

While these figures represent the accidents actually reported, they do not reflect the total number of animals killed by traffic, since many accidents with animals are not reported.

Measures to protect fauna are taken primarily for the sake of the environment rather than for the safety of road users, with the exception of fences along motorways.

A Swiss standard (VSS no. SN 640 007) provides approximate values for the social cost of traffic accidents. It is therefore possible to estimate the social cost of accidents caused by wildlife taking the numbers of collisions with wildlife from table 6-1. The following table shows the mean values for the years 1995 to 1997.

Table 6-2 - Social cost of accidents caused by wildlife per year from 1995 to 1997

Type of accident	Mean number of accidents	Approximate value for the social cost per accident	Cost of accidents caused by wildlife
With material damage	1'722	CHF 37'000	CHF 63'702'000
With human injuries	43	CHF 80'000	CHF 3'467'000
With human fatalities	0.3	CHF 1'800'000	CHF 600'000
Total	**1'765**		**CHF 67'769'000**

It should be pointed out that the average figure of CHF 67.8 million Swiss francs per year is given purely as a rough guide.

In conclusion, fauna-related road accidents in Switzerland do not account for a major proportion of traffic accidents, compared with other European countries. Nevertheless, it would indeed be possible and desirable to lower the rate of such accidents by taking remedial measures at the main blackspots. Such action, however, does not appear to be currently under way in Switzerland.

(For the railway-related accidents with animals see Table 5-2.)

Chapter 7. Avoidance, Mitigation, Compensation and Maintenance

7.1. INTRODUCTION

The extent of mitigation measures in construction projects concerning transportation infrastructure depends largely on how strictly the provisions of the Federal Law on nature and the landscape (LPN) and the Federal Law on the protection of the environment (LPE) are applied with regard to impact studies. Swiss practice has improved greatly after about 15 years of implementation, and as a result the environmental restrictions imposed are sometimes considerable. The main achievements are as follows:

1st achievement : **In general, plans submitted are environmentally compatible.**

In justifying their plans, planners are forced to scale or adapt their constructions so as to make them environmentally acceptable. Improvements made to plans are often put forward as arguments in favour of implementation.

Examples :
- Relieving urban centres of through traffic.
- Redeveloping former industrial areas.
- Restoring riverside areas for leisure purposes.

2nd achievement: **Studies of alternative plans have become indispensable.**

Selection of appropriate options for routes is an important stage of preliminary planning. The environment is generally regarded as an important criterion, and environmentally sensitive sites are essentially avoided.

3rd achievement: **The plan is developed by interdisciplinary teams.**

Owing to the complexity of the choices and the need to take environmental restrictions into account, study groups generally include environmental experts.

4th achievement: **Once the impacts have been identified, appropriate mitigation and compensation measures are elaborated.**

At the general and final planning stages, project studies lead systematically to the elaboration of mitigation or compensation measures.

7.2. AVOIDANCE OF HABITAT FRAGMENTATION

Marguerite Trocmé

Owing to the mountainous nature of the Swiss landscape, the routes of many road and railway infrastructure projects necessarily include tunnels and viaducts. This sometimes reduces the barrier effect of the infrastructure to a considerable extent. Problems of fragmentation caused by transportation infrastructure arise chiefly on the Central Plateau and in the valleys.

When a new infrastructure is planned, an alignment is sought which minimises new habitat fragmentation as far as possible. The principle of avoiding damage to natural habitats is set out clearly in Article 18 of the Federal Law of 1 July 1966 on the Protection of Nature and the Landscape. The same principle is developed with reference to prevention in the Federal Law of 7 October 1983 on the Protection of the Environment. The impact study procedure has also led to a considerable improvement in alignment optimisation, as the following examples show.

The alignment first projected in 1972 for the **A1 motorway** between Yverdon and Avenches ran along the southern shoreline of Lake Neuchâtel, and had the effect of completely cutting off the lakeside area from its hinterland. Following massive opposition from environmentalist groups, a new route was selected. In the course of the impact study for the general plan, the alignment was refined and a hillside location with numerous bridges and viaducts was selected, thereby avoiding excessive barrier effects.

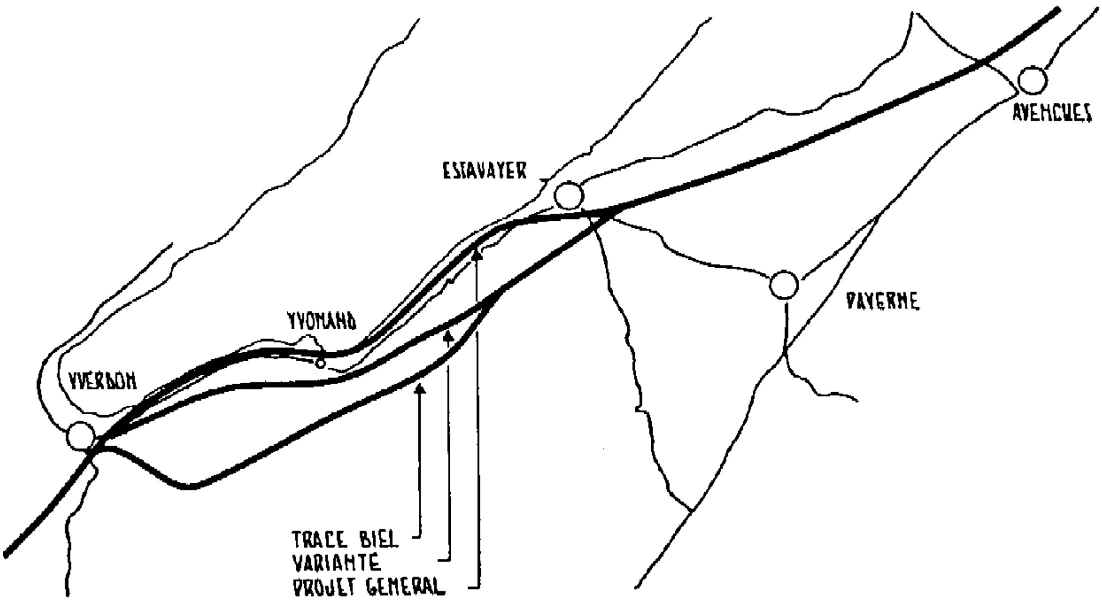


Figure 7.1 - Development of alternative routes for the A1 between Yverdon and Avenches. The original route alongside the lake was shifted to the hinterland. (Taken from the impact study for the A1, Yverdon to Avenches, Urbaplan, October 1988).

In the case of the **A5 between Bienne and Solothurn**, the motorway crosses an agricultural plain, the Grenchener Witi, which is included in the federal inventory of reserves for waterbirds and migrants of national importance (WZVV 1991). Here it was decided to construct a tunnel 1600 m long to avoid fragmentation.

Figure 7.2 - The underground route (broken lines) of the A5 in the Grenchener Witi. (Taken from: A5 Aare to Grenchen, EIA report, Amt für Verkehr und Tiefbau, Büro für Nationalstrassen, Kanton Solothurn, October 1992).

The Swiss Amphibian Inventory lists over 9000 spawning sites. This information is regularly consulted and taken into account when traffic routes are planned. For example, when the Heustrich loading station was planned in connection with the NEAT project, the location was changed to avoid an amphibian site of national importance.

During the construction of the A3 motorway, there were plans to build an embankment in a floodplain of national importance. This would have cut across wildlife areas along the Aare, considerably damaging the habitats of various endangered species. However, the plan was modified in order to reduce the damage. Instead of the embankment which had originally been planned, a bridge was constructed for this section of the A3, following the same route (cf. Fig. 7.3). The areas below the bridge where the construction work had been carried out were subsequently restored to a natural state.

Figure 7.3 - The bridge for the A3 in the Schinznach region, constructed instead of the planned embankment. (Source: Baudepartement des Kantons Aargau)

7.3. OVERVIEW OF MITIGATION MEASURES

Guy Berthoud

Several different types of mitigation measures may be distinguished, according to their acceptability, their effectiveness and the probability of successful implementation:

- **Project modifications** are often proposed when the study group includes environmental specialists. The technical solutions that are adopted are rarely regarded as an additional cost, but as a necessity or an adjustment to the project, if they are justifiable. This is by far the most effective type of measure since the majority of problems are avoided and the costs of the measures taken are often low.

  Examples:

  - modifications to longitudinal profiles
  - adjustment of alignment
  - watercourse realignement
  - extension of crossing structures
  - different operational techniques

- **Mitigation measures** are concerned with integrating the infrastructure in the landscape, restoring habitats that have been destroyed, concealing obvious aesthetic

damage and re-establishing certain obvious ecological or landscape functions. The project initiator is normally inclined to do no more than what is required by law or recognised standards. The costs may be high if project modification measures were not taken.
Examples:

- Replacement of roadside trees.
- Creation of hedgerows along the roadside.
- Development of verge habitats or natural balancy ponds.
- Adaptation of engineering design.
- Protection against light traps (use of sodium lamps, directional lighting and screens).
- Installation of wildlife detectors and alarm systems (CalstromWWA-12-S): Infrared detectors located at traditional wildlife crossing places along the road, allowing car drivers to be warned of the presence of wildlife by the triggering of light signals.
- Reflectors (used in the past, but of limited effectiveness).
- Installation of wildlife fences: obligatory along motorways
- Construction of wildlife passages.
- For amphibians, temporary and permanent preservation measures may be distinguished. Permanent measures include the creation of replacement spawning sites and the construction of tunnels.

Temporary measures include rescue campaigns organised by groups of helpers. In the spring, during the main migration season, fences and buckets are placed at appropriate points and the animals caught are carried safely across the road by volunteers.

At some points, the road sections concerned are closed to traffic during the spawning runs (for 4-6 weeks) so that the amphibians can cross the road freely. Often a ban is imposed only on driving at night (from 18:00 to 6:00).

- **Additional measures** are also provided for by the law (LPE). Such measures should make it possible to reduce the adverse effects of the project still further, without the costs necessarily having to be borne by the project designer. Measures of this type, warranted by pre-existing impacts, are often taken in a more regional context, involving other partners. Due to their complexity, they are applied relatively rarely, but they may prove useful for establishing local partnerships with pressure groups.

Examples: - cleaning up polluted land

- restructuring drainage networks
- contributing to the restoration of an ecological network
- adapting regional master plans, including new environmental requirements and, in particular, the modified ecological network

In the report on the impact of the project, all the measures associated with the project are normally recorded in a document comprising an overall plan of the measures proposed and detailed descriptions of the aims, the principles to be respected, the management methods to be used and the authorities responsible for implementation of the measures. The plan (see Fig. 7.4), the list of measures, and the content of the detailed descriptions are the subject of tough negotiations to obtain the approval of the residents and other users of the areas concerned.

After a public inquiry, the project plan is adopted with any final amendments. From this point on, it is legally valid and it becomes difficult to depart from it. The project initiator remains responsible for financing the measures and for their maintenance in the long term. In the case of motorway projects, monitoring and maintenance work is divided up among the various cantonal departments concerned.

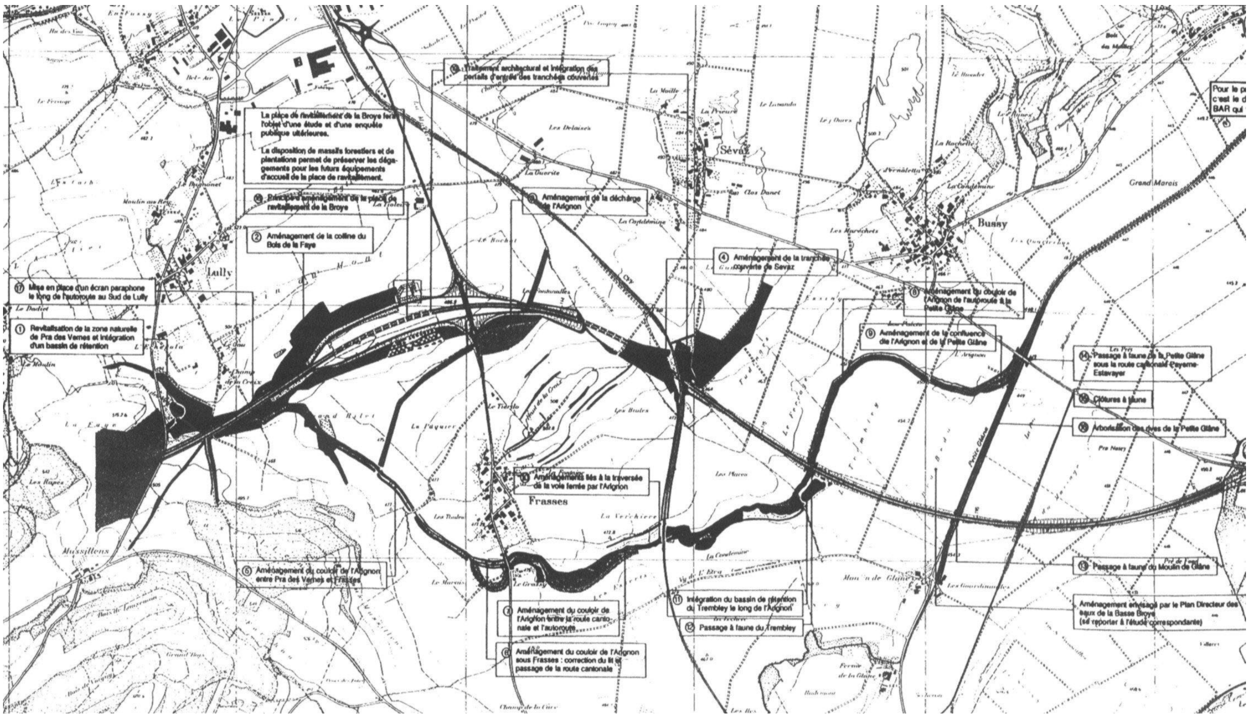


Figure 7.4 - Example of a plan of measures for a motorway project: the Cugy – Lully section of the A1 motorway. The plan shows the ecological network to be developed. (Source: EIA Cugy-Lully, Bureau des autoroutes, Fribourg)

Mitigation measures: Example 1: Farm lane with load bearing strips: an interesting alternative for flora and small fauna

Alain Ducommun

Farm lanes with load bearing strips are one of the alternatives to roadways that are completely covered with concrete or asphalt. They offer several advantages, both technically and from the point of view of the landscape. But are they beneficial for indigenous flora and small fauna? In particular, can they reduce the barrier effect attributable to traditional types of infrastructure?

In order to answer these questions, a farm lane with load bearing strips was studied between 1990 and 1991 at Bassecourt (Jura), i.e. immediately after its construction. Botanical surveys and surveys of selected groups of animals (spiders, Coleoptera, Hymenoptera, Diptera and some other groups of invertebrates) were carried out on several sections which differed in terms of the levelling substrate placed between the load bearing strips and the sown/unsown status of the substrate and the verges.

After two years, the plant cover was satisfactory, with a diversified, mosaic-type appearance (numerous pioneer plants). The space between the two load bearing strips was successfully used by small fauna. In total, it was used by 324 taxa, i.e. around 5000 individuals, for various purposes: as a hiding place and refuge (under stones), for foraging (predators, phytophagous and flower-dwelling insects), for burrowing or nesting (fossorial Hymenoptera), and for moving between habitats — refuges and prey reservoirs (Carabidae, for example). The site is particularly favourable for several types of invertebrates of dry pioneer habitats. Representing 63% of the taxa, predators and parasitoids are dominant: these include several agriculturally beneficial species.

Farm lanes with load bearing strips and a gravel-type levelling substrate satisfy expectations fully. In fact, this type of technical solution is not harmful to small animals and may even promote certain types of fauna. These paths do not constitute impassable barriers for most invertebrates: traffic is very limited, and the concrete surfaces are reduced to two thin strips. As a result, they represent an alternative solution that should be encouraged for land redistribution and land improvement projects.

An example of a farm lane with load bearing strips (photo: A. Ducommun)

Mitigation measures: Example 2: Measures for amphibians and small terrestrial animals

Silvia Zumbach

In many places, roadside drains represent a hazard for amphibians and other small fauna. Migrating animals usually fall accidentally through the grating into the (surface-) drainage system. They are often led into this danger zone by the kerbstone. Since it is usually impossible to escape from these passages, the creatures die here or are washed along with the drainage (run-off) to the rain tanks or sewage plants, where grates or pumps often prove fatal.

Most engineers are not conscious of this problem. Courses are held to raise the awareness of the professional groups concerned. Booklets on the topic are available (Kanton Aargau & KARCH 1996, Ryser 1990).

In the case of existing drainage systems, it is often difficult both to detect and to improve the danger zones. On the other hand, in construction projects it is not easy to predict where a danger zone may arise. Nonetheless, potential solutions have been elaborated and already put into practice in various places in Switzerland. Studies have shown that the measures proposed reduce the number of animals affected.

Measures for planned roads

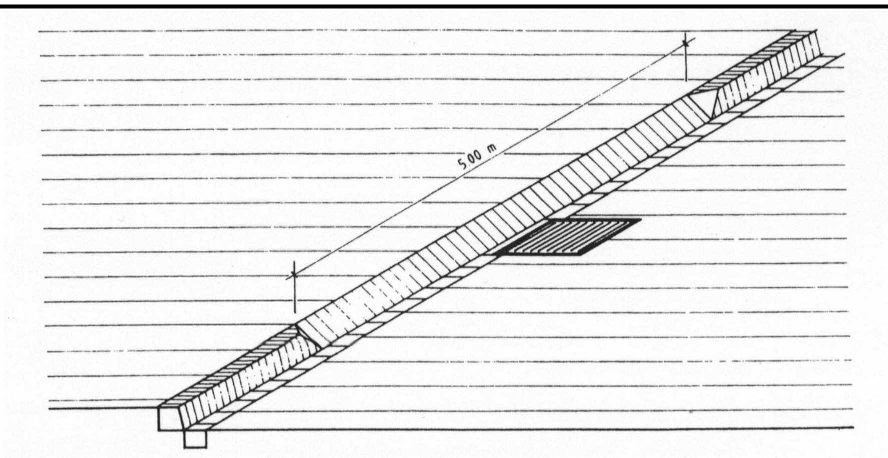
- Build road with drainage system safe for small animals, e.g. drainage via shoulder, seepage systems
- Position drain at a distance from the kerb
- Draped kerbstone over a distance of 5 m behind the drain

Measures for existing roads

- Install grating with small openings (<20 mm)
- Seal off grating parallel to the kerbstone with a cover 10 cm wide
- Draped kerbstone over a distance of 5 m behind the drain
- Install escape ramps in drain

Measures in rain tanks or sewage plants

- Install escape pipes
- Install escape ramps



Draped kerbstone permitting animals to leave the danger zone

Drainage via shoulder or with drain without kerbstone (photo: KARCH)

Escape ramp for drains (photo: KARCH)

7.3.1. Fauna passages

Guy Berthoud

7.3.1.1. General principles

The construction of a structure specifically designed to re-establish the movement of wildlife across transportation infrastructure is a mitigation measure designed to meet an environmental requirement. This measure is comparable in all respects to the creation of a hydraulic structure to avoid flooding of a road in the event of a storm. It is not, therefore, as is often said, a measure taken to compensate for the impact of a project.

Müller and Berthoud (1994) identified several types of wildlife crossings, which vary according to the type of animals involved and their needs. Included here are also possible adapations of man–used structures which can enhance their use by wildlife. These are as follows:

- Underpasses for small animals, ecopipes (type I)
- Amphibian tunnels (type II)
- Specific underpasses for large mammals (type III)
- Crossings underneath viaducts (type IV)
- Narrow overpasses designed for local ungulate populations (type V)
- Large overpasses or ecoducts (type VI)
- 'Landscape bridges' (type VII)
- Non-specific underpasses used by a variety of smaller mammals (type VIII)
- Non-specific overpasses (type IX)
- Hydraulic structures designed for wildlife, ecoculverts (type X)

The report on "Wildlife, road building and traffic " (SGW 1995) proposes a similar typology of wildlife crossings but is somewhat simplified and uses different numbering.

Along any traffic route, numerous crossing structures are also required for human purposes. The most frequent types are as follows:

- Pedestrian crossings
- Agricultural and forestry road crossings
- Culverts

Even if their effectiveness is limited (see Chapter 7.7), these structures are taken into consideration in the overall assessment of the permeability of a road to wildlife movements. The costs of designing them with a view to their being used also by wildlife are often low. However, they should be designed in such a way as to avoid the creation of potential traps for wildlife, such as:

- Crossings opening onto a road with heavy traffic
- Split-level underpasses with drains which can trap small animals
- Pedestrian underpasses with two sets of steps, which can trap amphibians and hedgehogs in particular.

Certain types of crossings described below are combined with a hydraulic structure or watercourse. Special design features supplementing or facilitating the use of hydraulic structures by animals are described later.

- **Choice of type of crossing structure**

The choice of the type of structure allowing wildlife to cross a road in safety depends, firstly, on biological requirements and, secondly, on technical requirements.

Figure 7.5 shows a selection grid which specifies the appropriate type of crossing according to the animal species concerned. For this purpose, animals are divided into four categories according to their size and mobility:

Category A: Small terrestrial animals that like light and warmth and that avoid underground environments, such as certain insects, reptiles, amphibians and certain small mammals.

Category B: Small and medium-sized (often burrowing) mammals that can readily use underpasses, such as foxes and mustelids.

Category C: Medium-sized and large mammals that will to a certain extent use underpasses over short distances, such as wild boar, roe deer, chamois, cats and possibly hares.

Category D: Large mammals that prefer to use overpasses covered in vegetation, or viaducts: all ungulates and in particular red deer.

- **Siting of wildlife passages**

The location of a crossing structure plays a decisive role in its acceptance by wildlife. It is therefore essential to site it on an existing wildlife corridor, the permanence of which has been checked in advance. Non-use of a wildlife crossing, often observed during monitoring after construction, is usually due to poor siting.

The choice of site is based on precise mapping of animal movements. The final position of the structure, and its size, are then determined by agreement between the engineer and the wildlife specialist. The decision will take into account not only the existing network of trails used by animals, but also subsequent restructuring of this network around the barrier created by the road, since animals always look for crossings that allow them to continue occupying the same territory and to maintain the same types of movements.

Crossing structures specifically designed for wildlife are considered to be “fixed points” on the route, in the same way as structures required by the presence of a watercourse or the network of existing roads that are to be maintained. The construction of some wildlife crossings may require modifications to the alignment or the longitudinal profile. These are established as early as possible so that they can be integrated into the project definition from the outset.

Wildlife passages, especially those for large wild mammals, are positioned in the most frequently used corridors. A tolerance of about 100 m on each side of the main axis is sometimes acceptable, depending on the type of terrain and the existing vegetation cover. Beyond this distance, the effectiveness of the crossing is rapidly reduced. Red deer are intolerant of changes to their dispersal paths. On the other hand, this margin of tolerance may be enlarged, depending on the local conditions, for roe deer and wild boar, since these animals have more marked exploratory instincts. For this reason, they may use crossings that are constructed outside their preferred range.

- **Size of crossing structures for large mammals**

The size recommended for crossings designed for large mammals depends on the following factors:

- The group of species concerned. If the group includes:
  - red deer → maximum size recommended
  - mainly roe deer and wild boar → reduced size can be recommended
- The biological functions that the structures concerned are to serve, and the desired frequency of interchanges. In principle, two levels may be distinguished:
  - the priority is maintenance of dispersal and gene flow, with occasional interchanges,
  - the priority is maintenance of habitats via regular interchanges
- The type of crossing:
  - overpasses and underpasses, divided into two groups: crossings specifically designed for wildlife and non-specific crossings.

Categories of wildlife / Types of crossings	A Small terrestrial animals liking light and warmth and avoiding underground environments	B Small and medium-sized mammals readily using underpasses	C Medium-sized and large mammals prepared to a certain extent to use underpasses over short distances	D Large mammals only prepared to use overpasses with natural vegetation	Extent of movements
I. Underpasses for small animals, ecopipes		■			Local, irregular
II. Amphibian tunnels	■	□			Local, concentrated
III. Specific underpasses for large mammals	□	■	■		Local, dense or Regional, intermediate
IV. Crossings underneath viaducts	❐	■	■	❐	Regional, irregular large-scale movements
V. Narrow overpasses designed for local ungulate populations	❐	■	■	■	Regional, irregular intermediate movements
VI. Large overpasses or ecoducts	■	■	■	■	Regional, concentrated large-scale movements
VII. „Landscape bridges“	■	■	■	■	Regional, irregular large-scale movements
VIII. Non-specific underpasses used by a variety of smaller mammals		■	□		Local, irregular
IX. Non-specific overpasses	□	□	□		Local, irregular
X. Hydraulic structures designed for wildlife, ecoculverts	□	❐	❐	□	Regional, irregular intermediate movement

Scale of effectiveness of wildlife crossings:
□ uncertain ❐ possible ■ optimal

Figure 7.5 - Selection grid specifying appropriate crossing structures in relation to the presence of various categories of wildlife (after Müller and Berthoud 1994).

Until 1990, construction methods for the few early wildlife crossings built in Switzerland were mainly based on experience in France, particularly with regard to the size of structures specifically designed for ungulates. For red deer, a difficult species, the width proposed varied between 12 and 25 m. For less problematic species such as roe deer and wild boar, widths between 7 and 12 m were considered sufficient. In the case of underpasses, the minimum height was set at 3 m on an empirical basis. Non-specific overpasses started to be adapted to enhance their use by wildlife on streches of the A9, A12 and A1. Greater widths were normally proposed. The recommended size was generally determined according to the ratio of cost of construction/expected effectiveness for wildlife, despite the absence of useful references on the effectiveness of such structures.

Following the second “Roads and wildlife” meeting at Beaune in 1991, new principles emerged for the design of crossings:

- Firstly, it was recognised that there was a need to construct structures that could be used by a wide range of species, including all vertebrates and certain terrestrial invertebrates.
- Secondly, in order to justify projects, the regional context was generally analysed so that the level of wildlife movements could be defined.

As practical experience has varied, two approaches have emerged:

- One proposes measures to optimise traditional wildlife crossings, including improvements to corridors favouring a wide range of wildlife, but generally involving modest widening, so as to obtain ecoducts that form part of developed corridors.
- The other proposes structures that function as ‘landscape bridges’, fully reproducing elements of the habitats linked, a strategy that requires the construction of structures of considerable width.

These two approaches are currently being widely debated in an effort to reach a consensus. This attempt to agree on basic principles, which is indispensable for coherent decision making, is being pursued in an interdisciplinary study commissioned by the National Highways Agency. The results of the study, which aims to define basic principles and guidelines (LAVOC project), is to be validated (UVEK group) and published in 2000.

- **Criteria that influence the effectiveness of wildlife passages (see also 7.7)**

Apart from overpasses and viaducts, which are the only structures permitting a form of crossing acceptable to all types of wildlife, most types of passages only allow certain categories of animals to cross the road. Therefore, different types of passages are usually planned along the route so as to take into account the diversity of the areas traversed and the various types of wildlife.

In order to guarantee that optimum use is made of wildlife crossings, a certain number of conditions must be fulfilled when they are constructed:

1. Most animals are sensitive to disturbances caused by human activities. Since noise, smells and light certainly have a deterrent effect on animals, crossings and their immediate surroundings are designed in such a way as to limit the effects of these disturbances on animals. For this purpose, hedgerows, wooden screens, walls, etc. are used.
2. In general, wildlife passages are reserved exclusively for this purpose. However, mixed use of crossings is sometimes possible when a stretch of land can be reserved exclusively for wildlife during certain times of the day or year.
3. A direct view of natural and attractive vegetation reassures moving animals, since it offers cover for refuge and possible foraging. The effectiveness of wildlife passages increases the wider they are, and the more they allow a direct view of vegetation on the far side of the structure. For the same reasons, underpasses and overpasses are not readily accepted by animals when they are not on the same level as the surrounding areas. A bird's eye view of the road seems to act as a deterrent.
4. Wildlife passages are generally situated on axes that are recognised as being habitually used for wildlife movements. In any case, they are in alignment with existing landscape structures that are favourable to the free movement of animals, such as forest edges, riversides and watercourses, hedgerows, hills, etc.
5. A mixed profile (excavation – embankment), associated with poor alignment, makes the crossing less attractive, which is never satisfactory for an important crossing site.
6. The choice of the type and size of wildlife passage also depends on the species concerned, the probable frequency of use of the area in question and the overall analysis of the road and its surroundings. Such an analysis allows a specialist to estimate the probable permeability of the structure for wildlife movements.

This approach has been applied systematically for all the sections of motorway that have been constructed over the last decade.

7.3.1.2. Description of the types of crossings used in Switzerland

- ***Underpasses for small animals, ecopipes (type I)***

Principle: Cavities of all kinds are spontaneously sought out by certain animals that burrow or use underground lairs (category B). A pipe through an embankment also serves as a cavity and is a preferred type of crossing.

Description of structure (Fig.7.7):

- cement or polyethylene pipe placed in an embankment; diameter between 40 and 200 cm, optimum diameter 100 cm,

- elements not pointed,
- effective length 40 m or more.

Species concerned: This type of crossing is used for animals of nocturnal or underground habits, such as foxes, badgers, stone and pine martens, polecats, stoats, hedgehogs, rabbits, voles, shrews, etc.

Examples of structures built in Switzerland: Very numerous along new motorway routes. On average, one crossing/km in plain areas, e.g. on the Payerne–Avenches section of the A1 road.

- ***Amphibian tunnels (type II)***

Principle: Most small animals are reluctant to make spontaneous use of small, dark crossings. However, it is possible to make it easier for them to locate the crossing and force them to use it. Thus, the crossing is combined with a guidance or capture system, parallel to the road.

General description of installations:

Several types of installations have been developed for amphibians.

Installations designed to protect amphibians constitute a special case among wildlife passages. The very specific behaviour of these animals in relation to the environment and, in particular, the road has made it necessary for complex structures to be developed.

Two types of amphibian crossings are used in Switzerland:

The first type of installation, called a double-pipe or one-way crossing, has been standardised in Switzerland (see box).

The other type of installation, called a single-pipe or two-way crossing, comprises a variety of simpler, and therefore less costly, systems using various types of pipes placed within the road, but enabling the animals to move freely in both directions.

In the single-pipe category, various types, sizes and materials have been used, with varying degrees of success. Rectangular pipes with a floor of earth seem to give the best results.

In Switzerland, more single-pipe than double-pipe systems have been constructed; nevertheless, the latter have been shown by long-term monitoring to be more effective, although single-pipe crossings can also be effective in certain conditions (Grossenbacher 1985; Ryser 1988).

General recommendations on temporary and permanent measures for the protection of amphibians along roads in Switzerland are currently being prepared by the KARCH office (Zumbach, in preparation).

Species concerned: All amphibian species, including newts and salamanders, use the installations successfully. However, they are less effective for newts, which tend to lose their way.

The double-pipe system is also remarkably effective in allowing all small terrestrial vertebrates and invertebrates to cross.

Examples of structures built: see box and page 56.

Amphibian protection installation SEPEY (double-pipe)

The system recommended is the result of extensive research and numerous applications both in Switzerland and abroad (Berthoud & Müller 1984,1987). It is the subject of construction standards issued by the Association of Swiss Road and Traffic Engineers (VSS). The effectiveness of the double-pipe system has been shown to be excellent by means of long-term monitoring carried out in Switzerland.

Description of the installation:

The complete installation is described in detail in the standards SNV 640697, 640698 and 640699, which should be consulted for further details and in particular for construction diagrams.

Principles: The installation is composed of two distinct parts:

- ♦ Collecting channels, positioned parallel to each side of the road, which are intended to prevent amphibians from gaining access to the road and to direct them towards the crossing.
- ♦ A crossing installation consisting of several pipes laid under the road.
- ♦ This "double-pipe" crossing has very precise technical characteristics which make it possible to force animals to use the pipes underneath the road (Fig. 7.7). The principles used for the crossing are as follows:
- ♦ In the longitudinal collecting channel, vertical capture pits are located at the centre of a covered part intended to obscure the entry to the pipes.
- ♦ The pipe underneath the road, made of cement or some other material and measuring 40 cm in diameter, is connected to the bottom of the entrance pit and leads the animals to the other side of the road.
- ♦ The system has an open-air exit to let in the maximum amount of light.
- ♦ Because of the one-way system, a second, parallel pipe is required to enable the animals to return.

Once they have fallen into the entrance pit, the amphibians are attracted by the residual light coming from the exit. Monitoring has shown that animals cross the installation in about ten minutes.

These systems are robust and reliable. They have been monitored for more than 20 years and only require cleaning once a year, at the beginning of spring, before the amphibians start their spawning runs.

Species concerned: This type of crossing is effective for all small animals that seek light and heat and avoid underground habitations: amphibians, reptiles, insects, voles, shrews, hedgehogs, etc.

Examples of structures built: 3 crossings along the Yverdon – Yvonand (VD) cantonal road, on the shore of Lake Neuchâtel.

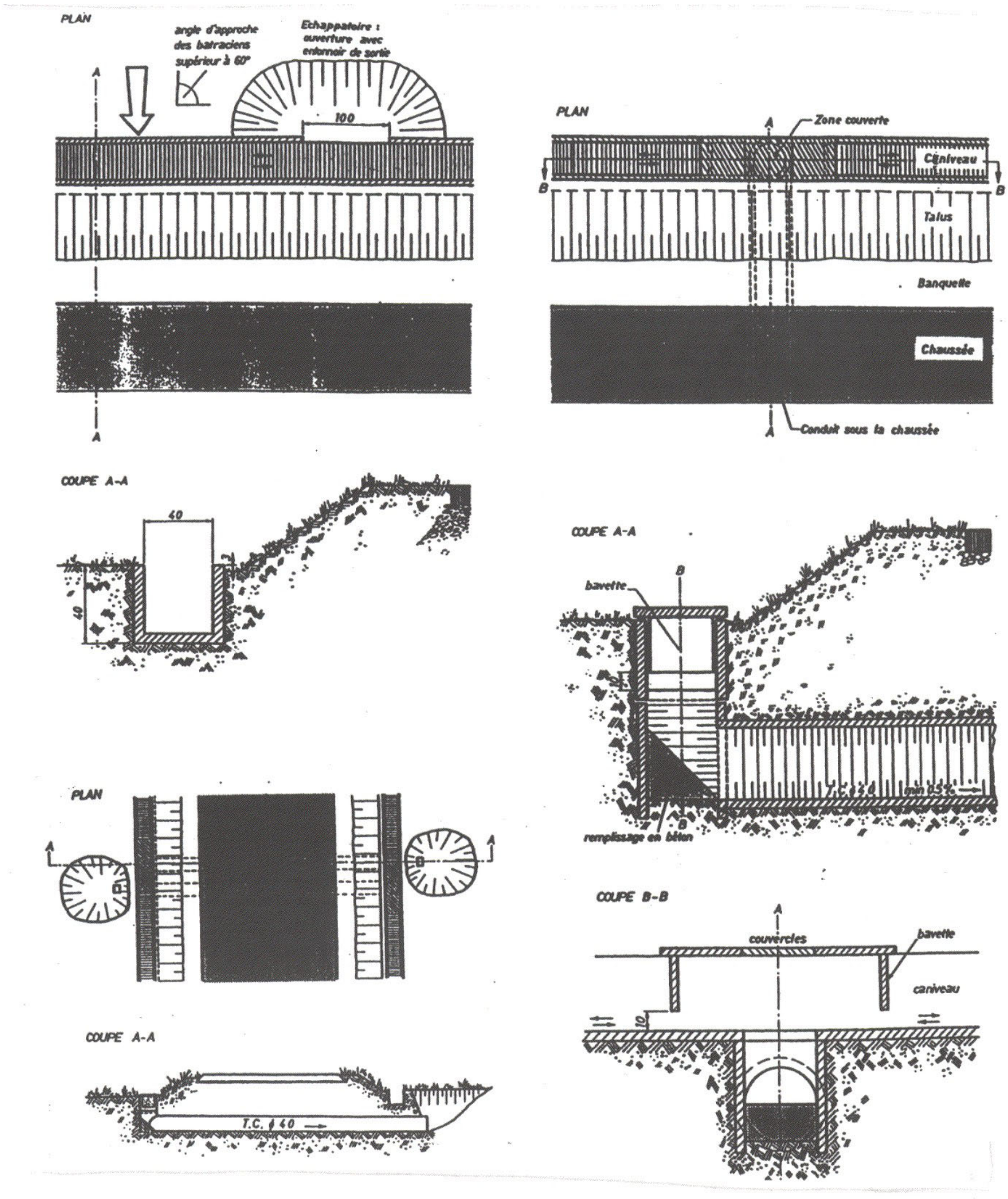


Figure 7.6 - Diagram of a crossing for amphibians. One-way system requiring two pipes to be laid, in parallel, under the road.

A Collecting channel with means of escape
B Connection between the channel and the pipe underneath the road
C Design of the channel to prevent leaping amphibians from escaping
D Cover obscuring the entrance pit
E Frontal view of the entrance pit
F Overhead view of a double-pipe crossing
G Cross section of a crossing

- ***Specific underpasses for large mammals (type III)***

Principles: The larger internal dimensions of the structure allow good lighting inside the crossing and a direct view of the vegetation on each side of the crossing.

Description of structure:

Underpass in the form of a bridge of varying size.

Minimum dimensions generally used:

For a structure with a length of --> width x height of the crossing:

16 m --> 3 x 8 m ; 25 m --> 4 x 9 m ; 32 m --> 5 x 12 m ; 40 m --> 5 x 12 m

These relatively expensive crossings are installed at certain critical points along a motorway route, on regionally important corridors for large animals, or in all sites with large populations of ungulates.

Species concerned: This type of crossing is used by all types of large mammals, except for species that prefer light. Ungulates such as roe deer, chamois, wild boar and red deer will use this type of crossing after a certain period of adaptation, provided that the structure of the vegetation on the adjacent verges is as natural as possible. These crossings may therefore serve to re-establish local wildlife movements. However, if their purpose is to re-establish a seasonal migration corridor for animals that cover long distances, such as wild boar or red deer, they are not used sufficiently to be recommended.

Examples of structures built:

- A1, Yverdon-Payerne, Les Râpes, Musillens commune (FR).
- A16, Boncourt-Courgenay, Malavau, Courgenay commune (JU)

- ***Crossings underneath viaducts (type IV)***

Principles: Valley floors crossed by a watercourse or wetlands are often at a considerably lower level than a road traversing them. The construction of a viaduct, rather than an embankment, is often a desirable alternative for both technical and landscape-related reasons. In addition, within a regional ecological network, a thalweg or watercourse is always a preferred area for wildlife movements. A crossing beneath a viaduct — even a low one — is readily used by most animals. If it is appropriately designed, it is possible to reduce any disadvantages.

Species concerned: In principle, most viaducts allow freedom of movement for all of the species concerned. Only some light-seeking species, such as reptiles and certain insects, may be partly deterred by a shady area or an extensive area devoid of vegetation.

Description of structures:

- All types of viaducts with arches or pillars are suitable.
- The higher and narrower a viaduct, the more acceptable it will be for wildlife.

Examples of structures built:

- A1, Yverdon-Payerne, Lully Viaduct (FR).
- A1, Lausanne-Yverdon, Bavois Viaduct (VD).

- ***Narrow overpasses designed for local ungulate populations (type V)***

Principles: The shape, size and surface of this type of crossing are designed to give animals the best possible view of the vegetation on the other side, and to provide an attractive approach and crossing. The so-called “diabolo shape” crossing, developed in France, is significantly widened at the abutments, which means that the structure is effective for wildlife despite being relatively small. This design has seldom been used in Switzerland. The diabolo-shaped bridges in the Forêt de la Hardt investigated by the Swiss Ornithological Institute were found to be used less frequently than broader structures. It would appear that the relatively narrow central part has an adverse effect on the use of these bridges by wildlife despite the wider outer parts (diabolo shape) (Pfister et al. 1999). Structures of this type also pose serious problems as regards watertightness and deteriorate rapidly.

Description of structure:

- The length/width ratio is less than 2.4, with an angle of view from the centre of the structure greater than 45°, and the width less than 30 m.
- Lateral screens between 1.5 and 2.0 m high on each side of the crossing.
- The structure of the crossing has a maximum soil cover of 30 to 40 cm.
- Bushes are planted and guiding structures created.

Species concerned: Experience in Switzerland has shown that crossings of this type with a width of at least 25 m can be sufficient for local populations of ungulates.

Examples of structures built:

- Wangen - Eschenbach (SG) road, Klosterwald bridge.
- A5, Grandson-Vaumarcus, La Lance Bridge (VD).
- A1, Grauholz, 22 m, 6 lanes
- A8, Brienzwiler, 17 m, 2 lanes

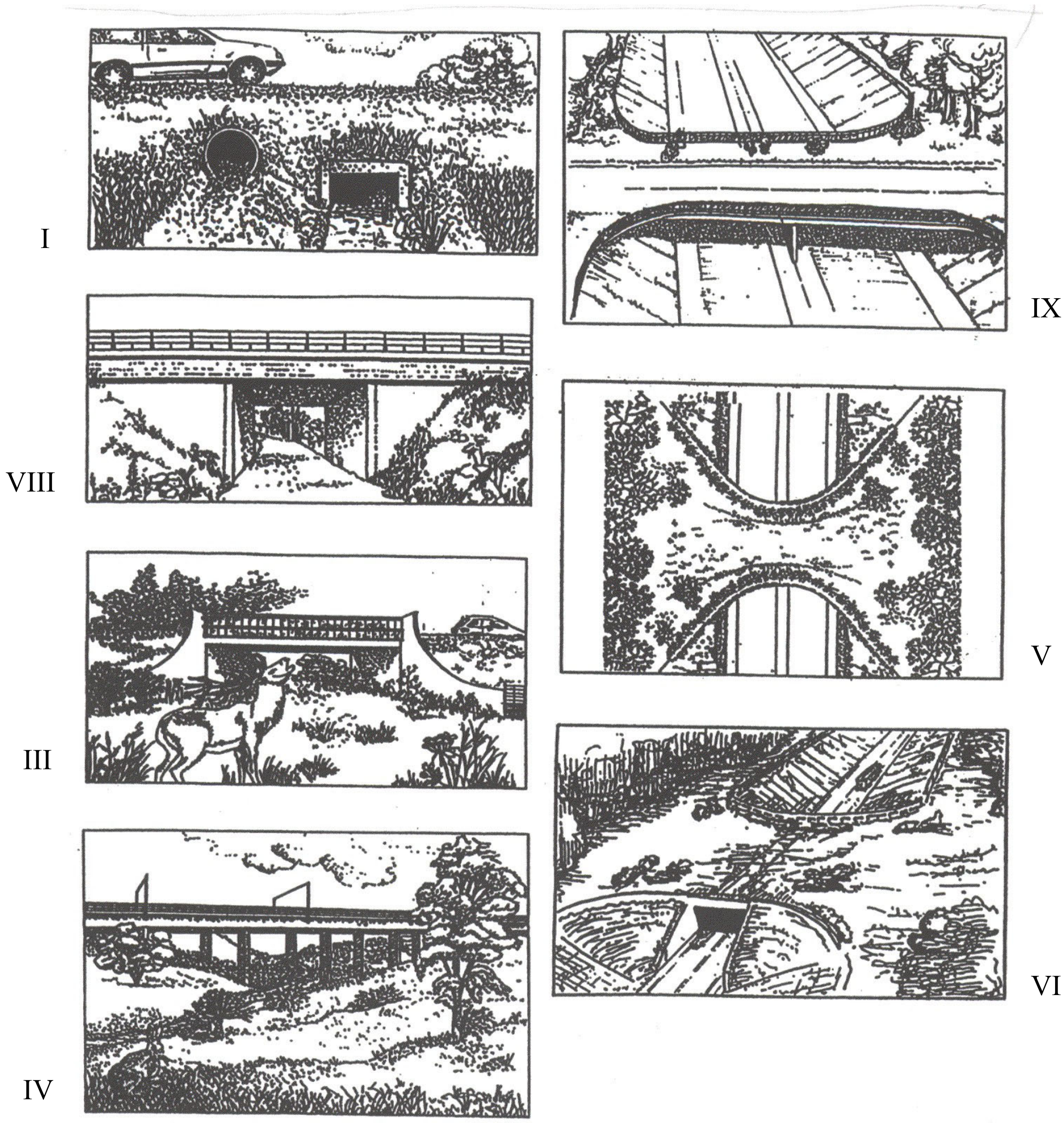


Figure 7.7 - Main types of wildlife crossings used in Switzerland.

Underpasses for small animals, ecopipes (type I)

Non-specific underpasses used by a variety of smaller mammals (type VIII)

Specific underpasses for large mammals (type III)

Crossings underneath viaduct (type IV)

Non-specific overpasses (type IX)

Narrow overpasses designed for local ungulate populations (type V)

Large overpass or ecoduct (type VI)

- ***Large overpasses or ecoducts (type VI)***

Principles: When a regionally important wildlife corridor is identified within the area of influence of a traffic route, and there is no possibility of avoiding it by rerouting, it is essential to preserve the corridor by constructing a tunnel or a covered cutting. The only way of ensuring that wildlife interchanges are maintained within a natural habitat is to preserve or restore the morphology of the landscape, the substrate and the initial vegetation. The structure should be long enough to allow landscape features that act as visual guides for wildlife to be maintained, and also to avoid situations of competition or predation between species.

Description of structures: The width of a ecoduct depends on the wildlife concerned, the morphology of the landscape and the habitats that are to be re-established. The width can vary between 30 and 100 m. Recent research advises against widths of less than 50 m (see 7.7). The presence of a dominant landscape feature (edge of a forest, bank of a watercourse, rocky crest, morainal hilltop, etc.) can allow the effective width of the structure to be limited. Depending on the morphology of the landscape, the structure will be constructed in the form of a bridge or tunnel.

The structure should be covered with backfill material and topsoil, corresponding as far as possible to the substrate of the surrounding natural areas. In particular, it should be possible:

- to re-establish the previous vegetation and landscape structures, such as hedgerows, forest fringes, wooded strips, natural meadows, wetlands, etc.
- to provide a central area that is not disturbed by traffic or human use,
- to create attractive vegetated areas or habitats suitable for the species present,
- to prevent predators from watching over the crossing of prey species (trapping effect).

The design of the structure and its approaches is included in the overall environmental design of the road project. Depending on the habitats traversed, it may include the following:

- graduated forest edge
- dirt tracks
- moist ditches
- heaps of stones
- a mosaic of herbaceous vegetation, scrub and trees

All these elements are arranged in such a way as to facilitate the movement of wildlife by forming structures that converge on the crossing.

Species concerned: The large overpass or ecoduct is considered to be the only type of crossing suitable for all types of wildlife without any restrictions. How well the structure is accepted by the various species will depend crucially on the design of the surface and the approaches.

Examples of structures built:

- A1, Yverdon-Payerne, Chèvrefu 100 m, Châble commune (FR)

- A13, St.-Gallen-Chur, Hirschensprung-Rüthi bridge, 50 m (SG)
- A5, Bienne-Grenchen, Stöck bridge 80 m (under construction) (BE)

- ***'Landscape bridges' (type VII)***

Principles: When a set of natural habitats with a rich biodiversity and rare species is identified within the area of influence of a traffic route, and there is no possibility of rerouting, a tunnel or covered cutting should be constructed that allows the habitats affected to be re-established on the surface. The only way of protecting certain sensitive and rare landscape units is to preserve or restore the morphology of the landscape, the substrate and the initial vegetation. The length of the structure enables all or part of the area concerned to be protected.

Description of structures: Depending on the desired objective, the structure may extend over several hundred metres. It should be covered with backfill material and topsoil, restoring as faithfully as possible the substrate of the surrounding natural areas. In particular, it should allow the previous vegetation and landscape structures to be fully re-established. Unlike green bridges, landscape bridges are intended to re-establish the continuity of habitats and networks specific to the ecosystem traversed.

Given the high costs, this type of structure can only be envisaged in the most exceptional cases. Preliminary studies on the impact of a project are carried out in depth so that a route can be selected which avoids natural sites and highly sensitive or rare landscapes.

Species concerned: The aim of this type of structure is to preserve all types of fauna and flora present in the surrounding habitats.

Examples of structures built: The two structures constructed in Thurgau are prime examples of landscape bridges in Switzerland:

- A7, Müllheim-Kreuzlingen, Aspiholz bridge (length 140 m), Müllheim commune (TG).
- A7, Müllheim-Kreuzlingen, Fuchswies bridge (length 200 m), Ober-Neuwilen commune (TG).

Other new landscape bridges are planned in various parts of Switzerland, notably:

- A9, Sion-Brig, Pfynwald/Bois de Finges covered cutting (length around 4,500 m), Leuk and Siders commune (VS).
- A5, Biel-Solothurn, Grenchenwiti tunnel (length 1,700 m), Grenchen commune (SO).

- ***Non-specific underpasses used by a variety of smaller mammals (type VIII)***

Principles: The internal dimensions of these structures vary widely. They provide an adequate view of the light and the vegetation on both sides of the crossing so as to be used also by wildlife.

Description of structures in this category:

- Pipes with a diameter of between 2 and 6 m,

- small concrete structures of pedestrian or agricultural underpass type with dimensions between 2 x 2m and 5 x 4 m, archways, etc.,
- other constructions of any type.

This type of structure is frequently used to re-establish footpaths, livestock crossings, agricultural or forestry roads, or for bridging streams. If it includes a verge with a natural covering, it is regularly used by small and medium-sized animals. A simple ecopipe serves the same function for small and medium-sized animals as a structure of this type.

The numerous crossings required for human activities can however be designed so as to permit occasional use by animals, thus increasing the overall permeability of the road for wildlife.

Species concerned:

Crossings of this type are effective for foxes, badgers, hedgehogs and various members of the weasel family. They are occasionally used by roe deer, wild boar and chamois at the most favourable sites.

Examples of structures built

- A1, Payerne-Avenches, Les Longs Prés, Payerne commune (VD).
- A9b, Chavornay-Vallorbe, Montcherand commune (VD)

- ***Non-specific overpasses (type IX)***

Principles: Overpasses designed for human-use (to restore agricultural road crossings) can be adapted so as to enhance their use also by wildlife. The shape and size of the surface provide a direct view of the vegetation on the other side of the crossing. However, visibility is normally too restricted, with blind spots, and this creates a sense of insecurity in animals, which leads to structures of this type being underused. Nevertheless, paths designed with natural substrates may encourage wildlife to use the crossing.

Description of structures:

- All types of bridges where the user's angle of vision, from the centre of the structure, is less than 45°.
- Presence of one or two grass verges and lateral screens 1 to 1.5 m high.
- The use of the crossing by wildlife depends on the quality of the verge design and the dimensions of the structure, as well as on the pedestrian and automobile traffic. Given their infrequent use, non-specific crossings, even those specially adapted for wildlife, are only used to re-establish local movements of animals that are accustomed to the presence of humans. On the other hand, as they are frequently constructed to re-establish pedestrian crossings, livestock crossings, and agricultural and forestry roads. It is therefore worthwhile to design them for use by wildlife as well.

Species concerned: Hares, foxes, mustelids and hedgehogs readily use these crossings when the approaches are suitable. However, they are only occasionally used by ungulates, particularly by local animals familiar with the territory.

Examples of structures built:

- A1, Avenches-Morat, Chandossel Bridge.
- A5, Grandson-Vaumarcus, La Raisse Bridge, Vaumarcus (VD).

- ***Hydraulic structures designed for wildlife, ecoculverts (type X)***

Principles:

A watercourse, even if only small, is not merely a flow of water, but also a preferred site for the movement of all types of aquatic and terrestrial animals. For wildlife movements, the riverside is just as important as the river bed. If only a certain number of wildlife crossings can be planned within the framework of a project, riparian is often given priority.

Depending on the space required for flood waters, a watercourse may pass underneath a transportation route through a simple culvert, or a more substantial structure may be required. The corridor function of even the smallest watercourses also has to be taken into account. The structure must therefore always allow free movement of aquatic and terrestrial wildlife.

The natural bed and riverside must not be modified by engineering structures. Pillars are therefore set back at a sufficient distance from the riverside. If this is not possible, the construction must nevertheless allow fish to pass freely. The culvert or bridge structure should be sufficiently wide to permit the passage of terrestrial animals along the side even at high water. When a wooded valley is traversed, the valley floor should, as far as the longitudinal profile of the road allows, remain free of any structures that could obstruct the movement of wildlife. A viaduct-type structure is often preferred to a long embankment.

Description of structures:

Various types of structure are used, depending on the size of the watercourse to be crossed:

1. Steep, fast-flowing streams:

- The space required for the flow of water can be used by terrestrial animals when the water level falls. No special design is necessary.

2. Streams and ditches with a moderate, but permanent, flow of water

- A simple archway with small steps is sufficient. A pipe installed out of the water, on the bank, makes it easier for small animals to cross.

3. Permanent watercourses with a medium to high rate of flow:

- A bridge is required to cross watercourses of this type. The structure must meet, at the same time, technical, hydraulic and biological requirements. In accordance with federal laws concerning the protection of water and the development of watercourses, the following conditions must be complied with:

- The abutments of the bridge must not encroach upon the main river bed.
- The natural bed of the watercourse must not be modified.
- The free movement of aquatic fauna must be guaranteed.

Species concerned: All species using watercourses and riparian vegetation, i.e. most types of wildlife. Nevertheless, invertebrates that prefer heat and light do not readily use this type of structure.

Examples of structures built:

- A1, Payerne-Avenches, Arbogne bridge, Domdidier commune (FR).
- A1, Yverdon-Payerne, Arignon bridge, Bussy commune (FR).

Inventory of wildlife crossings

In 1998, the Laboratory of Traffic Facilities (LAVOC) at the Swiss Federal Institute of Technology in Lausanne (EPFL) was commissioned by the Federal Highways Agency (ASTRA) to conduct a survey of cantonal departments responsible for highways and wildlife management in order to find out what road installations were used to protect wildlife. Although the results only partly take into account projects that are currently under way, it will be possible to provide statistics on the frequency of the various types of structure per canton.

The range of structures used corresponds broadly to those used in Europe as a whole; however, there are some interesting features peculiar to Switzerland.

The distribution is not completely homogeneous, with a concentration of structures in the French-speaking region of Switzerland, notably on the motorway network in the canton of Vaud. However, the overall total of 128 structures reflects a real willingness to take the problems of wildlife into account when new sections of motorway or major roads are built. Around 167 viaducts and 253 tunnels already existing within the whole Swiss road network should be added to this total. While these structures were certainly not built for wildlife, they may be used for the re-establishment of certain corridors in mountainous areas (cf. Chap. 4.3 and 5.4.7).

The hills and mountains that characterise four fifths of Swiss territory promoted the construction of large numbers of structures, such as bridges, viaducts and tunnels, which make it possible to cross natural obstacles. The Swiss transportation network includes an average of 0.23 engineering structures per km, offering significant potential for permeability, which may be partly exploited by wildlife once appropriate measures have been taken (BUWAL 1998). The open-mindedness of the highway engineers responsible for building engineering structures has facilitated the dialogue between engineers and ecologists when the construction of crossings specifically designed for wildlife has been discussed. An inventory of all wildlife crossings in Switzerland is underway (LAVOC, in prep.)

Given the cost of effective crossings, there is clearly a need to prove their effectiveness and to clarify the criteria for specifying appropriate widths and the general conditions for optimisation of their long-term use.

The aim of the ASTRA/LAVOC project, managed by an interdisciplinary working group of engineers and ecologists, is precisely to specify the criteria on which the approval of plans to build such structures will be based. The results of this research project will be published at the end of 2000.

7.4. Overview of compensation measures

Antoine Lieberherr

General framework

The legal framework and directives for the implementation of measures to compensate for the impact of construction projects on nature and the landscape are presented in Section 7.5 - *Existing quality standards for measures*. The problem of funding is dealt with in Chapter 9 - *Economic aspects*.

In Switzerland, the term *Ersatzmassnahmen* ("replacement measures") is used to refer to measures taken to compensate for the negative effects of specific projects.

A comparison of the initial state before the project with the expected final state after its completion is usually taken as a basis for the main compensation measures which are proposed as part of the general plan of environmental measures for the project.

As explained in Section 4.4 and in Section 7.5 below, it is essential to distinguish between measures compensating for necessary forest clearance, i.e. obligatory reforestation of the same area and quality in the same region, and on the other hand measures compensating for damage to other types of habitats or more diffuse effects, such as fragmentation.

The objectives of compensation measures are:

- to ensure the preservation of regional biodiversity
- to re-establish ecosystems of the same biological value
- to regenerate natural mechanisms for the regulation of natural habitats and species
- to restore the links between natural habitats

In particular, compensation measures should be of similar quality and perform functions equivalent to those of the habitats that have been destroyed (see also Section 8.4).

In practice, compensation measures often take the form of restoration of degraded natural habitats, reopening of streams that have been canalised underground, and recreation of hedgerow systems or of networks of wetlands with new ponds.

Projects for compensation measures describe the objectives to be achieved, the actions required, the costs of implementation, and the type of management and maintenance to be carried out. The initiator of a transportation infrastructure project also provides funding for monitoring and the long-term maintenance of compensation measures.

Retaining ownership of the land on which compensation measures are carried out is not a legal obligation; however, it does greatly facilitate implementation of the various measures and guarantees long-term maintenance of these sites.

Examples of compensation measures implemented in connection with the construction of transportation infrastructure are presented below.

A16 motorway in the canton of Jura

This 48-km section of motorway crosses a relatively undeveloped mountainous region. Its impact on nature and the landscape is limited by numerous tunnels and viaducts.

Environmental impact assessments revealed around thirty major impacts on natural habitats, which will be offset by a roughly equivalent number of compensation measures. The total area of compensation sites is just over 125 hectares. The cost of these measures (purchase of land, implementation and monitoring/maintenance for 30 years) is estimated, according to current figures, at around 0.4% of the total costs for construction of the motorway.

Les Condemennes (Courfaivre)

In the region of Courfaivre, the A16 cuts across an important corridor for game migrating between the forests to the north of the Delémont Valley and the Sorne, the main river. The barrier effect is limited by the presence of two large viaducts at this site, which makes the construction of a wildlife crossing unnecessary. Nevertheless, a compensation measure comprising the creation of a network of hedgerows and copses (1.5 ha) and nutrient-poor pastureland (9 ha) was implemented in order to minimise the environmental impact of the A16.

This compensation site of around 10.5 ha is located in an area of intensive agriculture, thus providing a degree of landscape diversity. The hedgerows and copses were regenerated and replanted on verges or on uncultivable former stone-clearance areas.

This ecological compensation measure in Les Condemennes has been in effect for several years. Regular monitoring by wildlife specialists has confirmed the success of these developments, especially for hares.

West Porrentruy (see Fig. 7.8)

West of Porrentruy, a motorway with an interchange for vehicles accessing or exiting the road cuts off an amphibian spawning site from the animals' wintering grounds. This habitat is listed in the inventory of amphibian spawning sites of national importance.

In an effort to safeguard these large populations of amphibians, various measures have been planned, in particular to promote:

- underpasses
- the establishment of wintering grounds beside the present spawning site so that the amphibians no longer have to cross the road (recreating one and a half hectares of wet/alder forest beside the pond).
- reproduction and maintenance of populations on the other side of the road in the traditional wintering forests, by creating ponds designed to serve as substitute spawning sites.

This complex set of measures thus aims to provide an amphibian underpass and at the same time to maintain populations on each side of the road. With the measures currently being implemented it will certainly not be possible to safeguard the populations in their present form. However, the objective that has been set is to preserve populations of amphibians in this area.

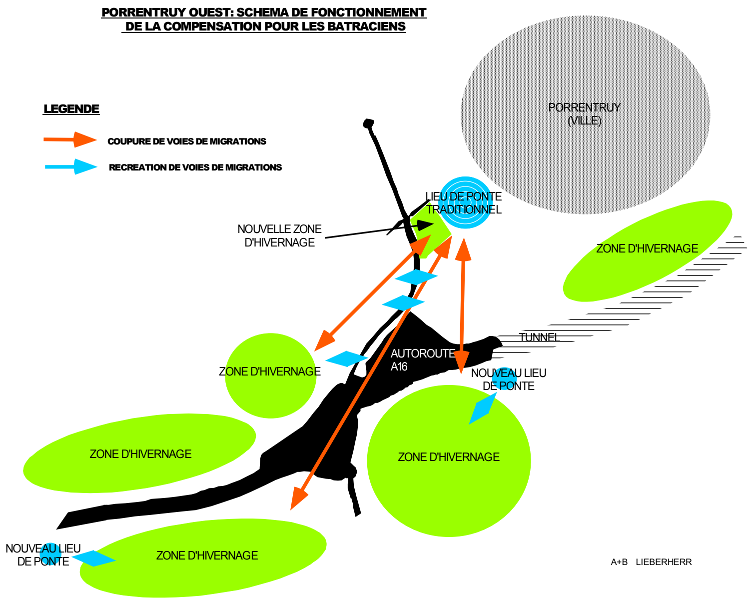


Figure 7.8 - West Porrentruy: diagram showing the compensation measures for amphibians like newly created migratory routes (blue rhomboids) and reproduction sites.

Regeneration of a stretch of the Inn to compensate for the construction of the Strada (canton of Graubünden) bypass (see Fig. 7.9)

The construction of the Strada bypass in the canton of Graubünden affects a floodplain of national importance (see Fig. 7.9). A natural area of around 3.1 ha will be destroyed.

The canton, the initiator of the project, has undertaken to compensate for this damage by enhancing the habitat quality of the whole site, which extends over nearly 30 ha, and which has deteriorated considerably due to inappropriate use (gravel extraction).

A project designed to re-establish the dynamics of the alluvial site has been launched in collaboration with the various local players concerned. A variety of measures have been implemented in order to re-establish the natural processes that give the site its value. These include:

- discontinuing gravel extraction operations

- reshaping the bed of the river, which has been widenedadjusting the surface layer of gravel to the future hydrological and geomorphological conditions

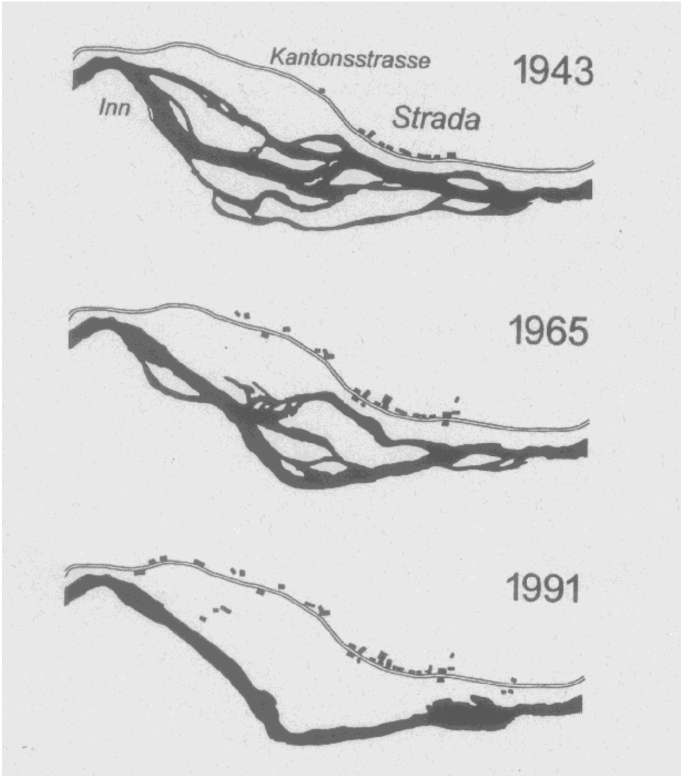


Figure 7.9 - Changes of the floodplain of the Inn over 50 years. The aim of ecological compensation measures is to recreate conditions similar to those of the 1940s.

The main railway station in Zurich: ecological compensation measures forming part of a railway infrastructure development plan

Within the city of Zurich, Swiss Federal Railways (SBB) owns large areas of land that are used in the operation of their infrastructure. As a result of a significant increase in rail traffic, a restructuring and development plan has been drawn up for this area.

This land also comprises extremely valuable natural habitats such as ruderal areas and pioneer habitats located in an urban zone, with rare and protected animal and plant communities.

By way of compensation for the development of new infrastructure in this area, it was decided to draw up a plan evaluating the ecological potential, providing for the development of substitute habitats for the various species. A number of scientific studies have shown that by coordinating the creation of compensation habitats with construction work, it was possible to preserve and safeguard the biological diversity of the site.

This project is currently under way.

7.5. Existing quality standards for measures; justification, minimum requirements

Marguerite Trocmé

Precise quantitative standards have only been defined for compensation measures in relation to forest clearances. The federal law concerning forests requires that the area of forest should not be reduced. In the event of forest clearance, compensation is required, covering the same area and in the same region. Reforestation measures must comply with clear quantitative (same area) and qualitative criteria (same quality). In certain cases, it is permissible to plan measures other than reforestation, such as the protection of other valuable natural habitats.

Outside forested areas, measures to compensate for the impact of construction projects on nature and the landscape are essentially covered by Articles 3 and 18 1ter of the Federal Law of 1 July 1966 on the Protection of Nature and Landscape (LPN) and Article 9 of the Federal Law of 7 October 1983 on the Protection of the Environment (LPE).

- Art. 3 LPN: "The federal and cantonal authorities… shall, in fulfilling the tasks of the Confederation, take care to preserve the characteristic appearance of the landscape … attaching conditions to licences and contracts"

- Art. 18 1ter LPN: "If, taking all interests into account, it is impossible to avoid damage of a technical nature to habitats deemed worthy of protection, the originator of such damage should take care that appropriate measures are taken to ensure the best possible protection, restoration or, failing that, adequate replacement."

- Art. 9 LPE Environmental impact assessment
  [1] Before taking any decisions regarding the planning, the construction or the modification of installations that could have a significant impact on the environment, the authority shall evaluate, as early as possible, their compatibility with the requirements of environmental protection; the Federal Council shall designate these installations.[1]
  [2] The impact on the environment shall be evaluated by means of a report that includes the information necessary to evaluate the project according to the environmental protection regulations. The report shall be prepared in accordance with the guidelines of the specialised departments for the competent authority; it shall include the following points:[2]
  …
  b.
  The project, including the measures planned for the protection of the environment and in the event of catastrophes; ...
  d
  Measures permitting these impacts to be further reduced, and the costs of such measures.

Art. 18 1ter is used specifically for measures to compensate for damage to habitats, while Art. 3 is applied more broadly to the tasks of the Confederation, enabling conditions to be imposed so as to improve the integration of installations into the landscape or enabling landscape compensation measures to be taken. Thus, particularly in landscapes of national importance (Federal inventory of landscapes, sites and natural monuments of national importance, BLN), damage to landscape must be "compensated for by other advantages" (6.2.13 of the BLN commentary).
Thus, no quantitative standards are prescribed by law or ordinance in the specific area of the protection of nature and landscape. However, Art. 18 1ter LPN sets a clear hierarchy for project design: the priorities are first to avoid any damage (protective measures, project modification) and secondly to restore the habitat at the same site, with replacement of the damaged site by a compensation habitat only if restoration is not feasible.
Various official manuals which give clear qualitative recommendations are cited in the bibliography. However, these recommendations are not binding, and experts are given considerable latitude.

Any proposal for measures is based, first of all, on an ecological evaluation of the current situation. "The ecological evaluation requires an inventory of the functions of the landscape, performance, and vulnerability to damage and an assessment of the degree of protection merited" (Information on the environmental impact assessment, no. 4, p. 3). The impacts are then analysed in order to determine what measures would enable the ecological balance, richness and biodiversity of the initial situation to be maintained or restored.

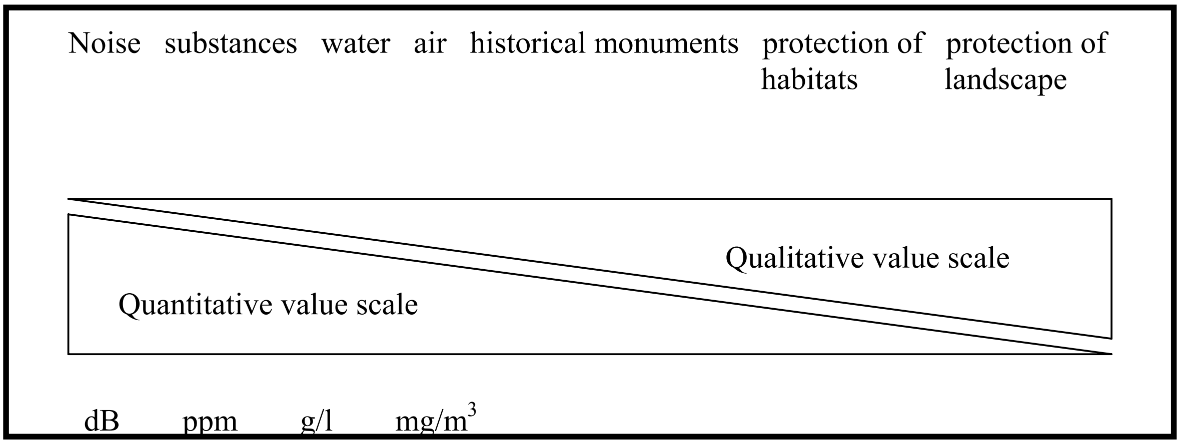


Figure 7.10 - Value scale, after Kaule (1986)

The following principle is broadly applied: "Prejudice to the interests of protection of nature and the landscape is considered to have been compensated for when the balance of nature corresponds to that which existed previously" (Information on the environmental impact assessment, no. 4, p. 30). The scope of a compensation measure will also depend on the type of natural habitat affected and the time required for re-establishment.

The current trend is to require the re-establishment of natural habitats of equivalent value and at least the same area and/or to attempt to restore the integrity of ecological networks in the region affected.

In practice, minimum standards are proposed by the specialised federal or cantonal agencies responsible for the protection of nature and the landscape. If the impact of a project is judged to be too serious, and mitigation and compensation measures inadequate, these agencies may recommend rejection. The final weighing-up of interests is carried out by the authority responsible for approving the project.

With their right of appeal, non-governmental organisations (NGOs) play an important supervisory role and sometimes manage to prevent any weakening of the minimum standards proposed by the specialised agencies. Case law established by the courts also exerts a significant influence on standards.

In order to clarify certain issues relating to the scope and quality of the protection, re-establishment and compensation measures required, the Swiss Agency for the Environment, Forests and Landscape (BUWAL) is currently preparing a document that specifies the minimum standards in more detail on the basis of numerous examples and experience accumulated in practice. This document covers questions of quality, area and the design of protection, restoration and compensation measures, as well as questions of ownership, funding and maintenance. Norms on fauna passages are also in preparation by the Association of Swiss Raod and Traffic Engineers.

7.6. MAINTENANCE ASPECTS

7.6.1. Verge management

Sébastien Schneider

The Swiss road network is very dense and, due to the country's relatively uneven topography, its construction has led to the creation of a large number of verges. The same applies to the railways, which are subject to greater constraints in terms of alignment and are thus less able to exploit the level of the natural terrain. Verges are also found alongside canals.

Nowadays, it is accepted that such verges are important landscape structures, partly because of their large surface area - equivalent to around three times that of Switzerland's nature reserves (not including the Swiss National Park) - but also because of their high ecological value. This was not always the case.

The post-war period saw an increase in industrialisation and urbanisation. Agriculture was intensified to a considerable extent, and chemical fertilisers were increasingly used. This led to a decline in nutrient-poor meadows in favour of nutrient-rich meadows of lower ecological value. Some species of plants and animals sought refuge in verges. Unfortunately, from the 1950s to the 1970s, systematic mowing, the application of herbicides, and slash-and-burn methods prevented many species from completing their reproductive cycle, and several of them became rare or even extinct.

Towards the end of the 1960s, people in Europe became aware that such management methods were not compatible with the protection of nature. But it was only later, in the 1980s, that the ecological value of verges was recognised in Switzerland.

First of all, verges are species-rich habitats in themselves. Sometimes they are bushy, and therefore serve as a refuge for a large number of small mammals and as a nesting zone for various species of birds. When they are grassy, they may be classified as either lush grassland, with nutrient-rich soil (e.g. due to nearby agricultural use or mown grass that has not been cleared away), or lean, nutrient-poor grassland, which is of greater ecological interest.

The second aspect is the fact that verges can serve as a wildlife corridor and become integrated into an ecological network. While movements across transportation routes are sometimes restricted or even impossible for certain species, linear movements may be facilitated by a landscape structure consisting of verges, which can serve to interconnect various reservoir zones (see 5.4.2.).

In the 1980s, the Swiss League for the Protection of Nature, now known as "Pro Natura", carried out initial studies of roadside verges and also the first awareness campaigns concerning verge management for the authorities. It is still organising such activities today.

Another example is the canton of Baselland, which has recognised the ecological interest of its roadsides since 1985 and has developed guidelines for their management. This work led to the publication of two brochures by the *Tiefbauamt BL* (Department of Civil Engineering of Baselland) in 1988.

Following the example set by Baselland, the canton of St. Gallen (*Tiefbauamt- und Strassenverwaltung*, Department of Civil Engineering and Road Management) also published its own guidelines (TSVSG 1990).

The Department of Civil Engineering of Neuchâtel financed a major study for the ecological management of the canton's roadside verges. A report was published in 1989 (ECOCONSEIL 1989).

As a result of a campaign organised by the Geneva Association for the Protection of Nature (AGPN) in collaboration with the Department of Civil Engineering and the communes, an inventory was made of all the verges in the canton of Geneva and verge management was carried out in accordance with the recommendations listed below. A marked improvement was seen in the ecological potential of the verges. Of note is the publication of an outstanding brochure (AGPN & DTPE 1996), which served as a reference for this document.

At a national level, a survey of nutrient-poor grassland is currently under way. This should make it possible to make an inventory of sites worthy of protection.

The Swiss Federal Railways has published a manual on the creation of open spaces within railway infrastructure, which also deals with verges (SBB 1994). The maintenance measures are adapted to the existing or wanted vegetation. The time of maintenance is harmonised with the life cycle of the vegetation and the animals. On special sites where rare species exist, biotopes like rock heaps or piles of brances are created to help protecting them.

In Switzerland, the following practices are recommended for the management of grass verges (AGPN & DTPE 1996):

Human safety is the main priority.

In the case of roads, the shoulder should be tended intensively (10 – 20 cm maximum height for grass). The width of the mown strip depends on visibility and on local safety conditions (junctions, levelling-down at bends).

In the case of canals, the vegetation should not impair the hydraulic properties to such an extent that a canal can no longer absorb the rise in water level for which it was designed.

Mowing of the rest of the verge is delayed as much as possible.

The ideal period is towards the end of August, or even September, but even if the verges are not mown until the end of July, this can have some major ecological advantages. However, mowing too late in the year (November) is not advisable (damage to rosette plants). The cutting height should be at least 10 cm so as not to damage the plant cover, to spare rosette plants, and to preserve a sufficient habitat for the microfauna. One mowing a year is sufficient for nutrient-poor grasslands, although two mowings with removal of the cuttings are desirable for nutrient-rich verges, so as to accelerate the process of soil impoverishment. The use of herbicides is prohibited in Switzerland.

The cuttings should be removed so as to impoverish the soil.

In order to create nutrient-poor verges (for the reasons mentioned above), the mown grass should be removed in case it decomposes and progressively enriches the soil, with a risk of choking the remaining vegetation. It can be used as compost or as fodder if the heavy metal content is within accepted limits.

Although these recommendations are designed to cut the costs of verge management while protecting nature, they are by no means applied everywhere.

The management of verges is difficult to organise in Switzerland, given the federal nature of the country. Verges that form part of the roadside are maintained by the road maintenance departments, which differ for each canton (cantonal roads and national motorways within its territory). There are also the municipal roads, which are of course the responsibility of the communes, as well as private roads, for which the owner is responsible.

Apart from the organisational problems, bureaucratic apathy, deep-rooted habits, a lack of motivation or, more generally, ignorance of what is at stake ecologically make it very difficult and time-consuming to put these recommendations into practice.

Nevertheless, actions such as those mentioned above have proved that verges can indeed be managed in a more ecologically compatible manner.

In conclusion, despite the fact that the Swiss have been slower than other Europeans to recognise the ecological value of verges, there is a growing awareness among engineers, the authorities, and the general population of the ecological potential they represent. The national inventory of verges will probably give rise to new campaigns and the protection of the most notable verges.

Awareness campaigns and the perseverance of conservation associations will of course play a decisive role in the future progress of verge management.

However, one question must still be asked: should we really be improving the verge habitats, thereby attracting and favouring wildlife that may well be killed on the road?

This is particularly relevant for birds of prey, some of which are classified as endangered species and are drawn to verges as hunting grounds.

7.6.2. Management of other surfaces

Antonio Righetti

Measures taken for the benefit of flora and fauna generally have clear goals. For instance, if two fragmented patches of habitat are to be reconnected by a wildlife passage, special attention will be paid to the habitat requirements of selected target or indicator species when the structure is designed. The immediate and more distant surroundings may possibly also be considered in the plan. In view of the legal framework and previous experience, it has become almost a matter of routine to take this step and achieve this target state – assuming good cooperation with the initiator of the project.

However, the semi-natural habitats produced are by no means static and are subject to constant change in the absence of intervention. As a result of this natural development (succession), which may sometimes be desired, or from a lack of maintenance, habitats may however change over time to such an extent that a passage constructed loses its connecting function for one or more target species. The long-term objective will thus not have been achieved. However, such failures are predictable and can be prevented.

In the light of experience gained in recent years, which has not always been positive, the work can be divided into various stages. These are designed to indicate when a maintenance programme should commence and what players should be involved. In line with the chronological sequence, the following points may be distinguished:

- At the project design stage
  The problem: Projects must cover not only planning and implementation of measures but also maintenance. There are not (yet) any general regulations about the period for which the project initiator is obliged to provide maintenance. Experience with maintenance measures in the context of conservation suggests that long-term contracts should be concluded if possible – at least 20-30 years. Equally, there are no regulations concerning the continuation of maintenance after that period.
  Actors: primarily the project initiator.
- At the planning stage
  The problem: Maintenance of habitats is closely connected with their function and ecological requirements and therefore needs to be reconsidered and planned when each new structure is designed.
  Actors: the project initiator, the environmental team from the environmental impact assessments, bodies responsible for maintenance (e.g. forestry service, farmers, local conservation groups).

  - Development of maintenance plan
    Simple maintenance guidelines are established, based on the habitat requirements of target species – Example: Dry grassland with rocks as a structural element for a reptile habitat, to be cut every two years.
  - Calculation of maintenance costs
    The costs that will be incurred can be extrapolated on the basis of the maintenance outlay and the term of the maintenance obligation. The calculation may be partly based on legal regulations concerning the maintenance of habitats that are valuable from a conservation viewpoint (Art. 31b, Landwirtschaftsgesetz).
  - Arrangements for implementation of maintenance measures
    Maintenance measures need to be implemented on the basis of clear contracts, which not only regulate payments but also ensure continuity.
- At the operational stage
  The problem: Nowadays the operational stage of any major project includes monitoring. The efficiency of measures is monitored, e.g. in terms of acceptance of a structure by the target species. This process will sometimes highlight the need for changes in the design of a structure in general or maintenance in particular. In the latter case the maintenance plan would be suitably adapted.
  Actors: the project initiator, those responsible for monitoring and for maintenance. Since monitoring work is completed after 10 years at the latest, provision must be made for continuity of monitoring as well as of maintenance. This task could be done by an official environmental protection agency or by private organisations.

Table 7-2- Compilation of measures connected with road-building projects (wildlife overpasses) which help to illustrate the problems, show the development of planning stages, and summarise the experience gained and the conclusions drawn

Overpass	Brienzwiler	Grauholz	Rüthi	Stöck
Target species are all species present, especially those mentioned here	Red deer, roe deer, chamois	Roe deer, amphibians	Red deer, roe deer, reptiles, amphibians	Wild boar, roe deer, amphibians, reptiles
Location	East of Brienz, pre-Alps	North-east of Bern, Central Plateau	North-east of Rüthi, Central Plateau / pre-Alps	East of Biel, Central Plateau / Jura
Width	17 m	23 m	50 m	80 m
Traffic routes bridged	A8 (2 lanes)	A1 (6 lanes)	A13 (4 lanes), communal road	A5 (4 lanes), SBB
Completion date	1995	1995	1999	2001
Guiding elements present	Yes	no	yes	Yes
Guiding elements to be created	Yes	no	yes	Yes
Types of biotopes on the overpass (selection)	Woodland, species-rich high-nutrient meadow, ruderal areas	Hedges, ponds, clumps of bushes, ruderal areas	Hedges, ponds, clumps of bushes, ruderal areas, forest fringes, dry sites, rocks	Hedges, ponds, clumps of bushes, ruderal areas, maize fields (only at start), forest fringes
Existing types of biotope in the surrounding area (within 100 m)	Hedges, species-rich high-nutrient meadow, woodland	Forest	Dry site, ruderal sites, river (Rhine, canalised)	Woodland, stream, high-nutrient meadow, crop rotation areas
New types of biotopes in the surrounding area (within 100 m)	Hedges, species-rich high-nutrient meadow	-	Dry sites, rocks	Wetlands, species-rich high-nutrient meadow, dry sites
Maintenance measures planned	None	Maintenance of reforested area	Areas both with and without trees	Areas both with and

		next to structure and periodic work on structure by forestry service as required – no contract.	to be maintained by private concerns and forestry service according to certain specifications – partly secured by contracts.	without trees to be maintained by forestry service according to certain specifications – maintenance for 20 years secured by contract.
Results / Aims	The unplanted areas run wild. The number of habitats has declined – only homogeneous grassland and planted areas remain intact. Wild mammals use the structure regularly.	The ruderal areas have largely disappeared. The structure has become part of the landscape. The number of habitats has declined. Wild mammals and amphibians use the structure regularly.	The habitats created are to be retained in the medium and long term.	
Experience	The structure is (now) only used by the target species.		It is necessary to consider maintenance at an early stage and to ensure long-term continuity.	

7.6.3. Coordinating land-use in adjacent areas

Marguerite Trocmé and André Stapfer

Major transportation infrastructure projects are generally accompanied by land reallocation and improvement plans. Any replacement or compensation measures which are decided on as a result of the transportation infrastructure impact assessment but are situated outside the immediate project area are implemented in coordination with the plan. The land reallocation scheme should automatically take the planned measures into account. Often, other compensation measures associated with the plan are envisaged in addition to those connected with the transportation infrastructure. However, conflicts may arise between the various objectives.

The plots of land are allocated to the (cantonal or communal) authorities, to environmental protection groups, or to an association for maintenance, or return to private ownership, with an easement being entered in the land registry.

The main difficulty lies in the long-term coordination of land-use planning with the intended aims of the compensation measures. Thus, it is not uncommon for an ecological corridor deliberately set aside when planning transportation infrastructure to be jeopardised by the expansion of an urbanised area. In order to avoid such developments, the cantons, as part of their master plans, establish coordination files on ecological corridors which are to be preserved as a matter of priority. Essentially, the areas in question are to be kept free of any construction (see 5.5).

An example of such a step is the A5 at Grenchener Witi (see 7.2) in the canton of Solothurn (see "Specific ideas for nature and the landscape, cantonal concepts and instruments" in BUWAL 1998). The new motorway is to be built in a tunnel in order to protect an object included in the Federal inventory of reserves for waterbirds and migrants of national importance. To ensure that these objectives are respected in the long term, the canton has approved a cantonal allocation plan for the object concerned, covering 15 km^2. The aim is to preserve this area of open fields, promoting sustainable farming methods and achieving an area of 12% in a near-natural state on a voluntary basis.

The creation of a widened river bed corridor along the Arignon in the canton of Fribourg is another example of a possible step. Around the river, starting from an average width of 5 m including banks, a 15-m-wide zone has been created (see Fig. 7.11). The land required for this development was granted to the canton as part of the land reallocation plan accompanying the construction of the A1 motorway. The aim of this measure is to upgrade the ecological function of the stream and especially to strengthen its role as an ecological corridor.

Figure 7.11 - Widened river bed of the Arignon in the canton of Fribourg, which in addition to its ecological functions will provide flood protection.

The coordination which is required if supraregional ecological corridors are to be protected is complicated by communal and cantonal autonomy. However, work now being done on corridors for large animals and on the national ecological network should bring about a rapid improvement in the situation, with the establishment of a common knowledge base.

The task is often also complicated by the hierarchy of bodies responsible for land-use planning and for decisions on infrastructure. An order concerning a wildlife corridor is only binding on a landowner if it is included in the communal land-use plan. But conversely, inclusion in the communal land-use plan or even in the cantonal master plan does not guarantee absolute protection against infrastructure judged to be in the greater public interest. When nature protection interests are weighed up against the public interest in infrastructure construction, the outcome is still often unfavourable to the protection of nature.

7.7. EVALUATION AND MONITORING OF THE EFFECTIVENESS OF MEASURES

Daniela Heynen, Silvia Zumbach, Verena Keller & Hans Peter Pfister

In the last few decades, crossings for terrestrial wildlife in the form of overpasses and underpasses have been increasingly discussed and built, but little relevant knowledge was available to serve as a basis for planning and construction. For example, the design and dimensions of most wildlife crossings lacked any sound scientific basis, and over time some of them have proved to be ineffective. But from biological and financial viewpoints, the construction of wildlife underpasses and overpasses is only justifiable if they fulfil their purpose, i.e. if they are actually used by animals.

In order to evaluate the extent to which objectives have been achieved, monitoring is carried out. This monitoring also provides a valuable basis for the planning of future structures. Various reports (Berthoud & Müller 1984; Ryser 1988; Ryser 1989) are available concerning the monitoring of individual structures. These reports primarily evaluated the effectiveness of the structures for large mammals and amphibians. Other groups of animals severely affected by habitat fragmentation due to transportation infrastructure, such as small mammals and invertebrates, are only considered in a few reports (Kaden, 1993; UNA 1998). This may be because there is a greater awareness of the problems that arise for wide-ranging, migratory species or game than e.g. for small mammals and invertebrates. In most cases, large mammals and amphibians are the target species for which underpasses and overpasses specifically designed for wildlife are built.

Monitoring of measures designed mainly for mammals

The effectiveness of a structure can basically be evaluated according to how it is used by wildlife. However, the influence of a structure on animal populations in the surrounding areas should also be included in the evaluation of effectiveness. But as this requires long-term research, it is often necessary to draw indirect conclusions about the effects on populations on the basis of the observed frequency of use of the structure.

Are structures built for humans used by wildlife?

For humans, the barrier effect of major roads was mitigated at an early stage by the construction of overpasses and underpasses suitable for pedestrians or vehicles. On motorways, for example, a considerable number of bridges or underpasses have been built for such purposes (1-2 structures per km on the A1 as at 1992), and in theory these could also be used by wildlife. This would greatly reduce the barrier effect of a motorway. The extent to which structures built for traffic are used as crossing places by wildlife has been studied by observing medium-sized and large mammals with the aid of infrared video cameras (Pfister 1997). The findings indicate that engineering structures may mitigate the barrier effect for burrowing species, such as foxes, and martens. However, species which keep at a greater distance, such as the roe deer or brown hare, were seldom or never observed on structures not specifically built for wildlife, even if they were found in the immediate vicinity. For these species, the motorway still has a barrier effect, and their habitats are still fragmented even though engineering structures theoretically provide a possible crossing point.

Structures specifically designed for wildlife

When engineering structures were compared with three structures designed specifically for wildlife, the frequency of use was found to be considerably higher with the latter. Unlike the engineering structures, wildlife crossings were also used by roe deer (Pfister et al. 1997).

Detailed studies of the effectiveness of structures specifically designed for wildlife are rare. Often, the data for the structures studied are not comparable as different methods are used (e.g. tracks in sand, tracks in snow, counters, infrared video cameras). There are only a few studies in which several wildlife crossings of different widths were investigated using the same method and could thus be compared. One such study is the investigation by Pfister et al. (1997) of the effectiveness of five wildlife overpasses or 'green bridges' on the Stockach-Überlingen section of the German B31 (new) and 12 other overpasses in Germany, the Netherlands, France and Switzerland. Various groups of animals were included in the study (large mammals, small mammals and flightless insects such as ground beetles, grasshoppers and ground spiders, and diurnal butterflies). It was found that overpasses could only be used effectively by invertebrates and small mammals if the structure comprised a suitable habitat which was connected with habitats beyond the road area. For larger mammals, the effectiveness of an overpass depends primarily on its location and width, and less on the detailed design of the structure.

In a follow-up project, the existing data on larger mammals were supplemented by investigations carried out on other overpasses using the same method (infrared video cameras) (Pfister et al. 1999). Once again, the location and width of the structures were found to have a significant effect on the frequency of use by all the wild mammals studied: roe deer, fox, brown hare, badger, marten, wild boar and red deer. The animals were observed more frequently on structures at least 60 m wide than on crossings narrower than 50 m.

The conclusion drawn from both studies (Pfister et al. 1997; Pfister et al. 1999) is that the width of a bridge should be adapted to its purpose and to the requirements of the target species. There is no point in specifying a standard width, although it is helpful to give recommended values. In view of the frequency of use of the wildlife crossings studied and the observed behaviour of the animals, a minimum width of 50 m is recommended for overpasses designed for large mammals. However, as well as the width, the location of the structures and the frequency of occurrence of the species in the surrounding area are crucial. When structures of this type are planned, it is therefore extremely important to specify the target species, to consider the exact location, width and detailed design, and to plan connections between the bridge area and the surrounding habitats.

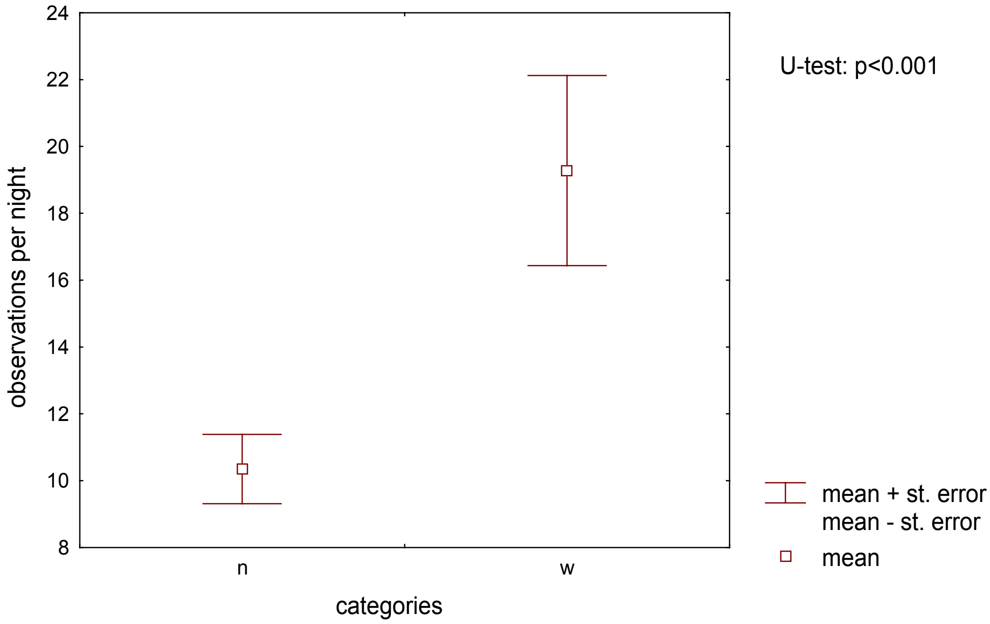


Figure 7.12 - Mean frequency of observation for individuals of all the animal species studied (roe deer, fox, brown hare, badger, marten, wild boar and red deer) on wildlife overpasses in the narrow to medium (3-50 m) and wide (64-186m) categories

Of the Swiss overpasses investigated by Pfister et al. (1999), four have also been independently assessed as individual structures (Kaden et al. 1993; Righetti et al. 1998; UNA (Righetti et al.), 1998). Shortly after they were opened, the two bridges in Thurgau, which are among the widest in Europe (127 m, 186 m between the fences), were studied in order to evaluate their effectiveness as a connecting element and a habitat for plants and for mammals, ground spiders, ground beetles, grasshoppers and diurnal butterflies (Kaden et al. 1993). They were rated as valuable from the point of view of animal biology.

Righetti et al. (1998) assessed the wildlife overpass on the A1 in Grauholz. The structure, which is 23 m wide, was used by the target species. The behaviour of the observed roe deer e.g. suggested that, although the structure represents a possible crossing point, it must be rated overall as too narrow. A structure of similar width (17 m) — but crossing a road with only two lanes — was studied near Brienzwiler (UNA/ Righetti et al. 1998). Only a short time after its construction, this structure was extensively and regularly used by all the larger wildlife species found in the area (badger, fox, marten, chamois, roe deer and red deer – the latter only in the winter).

Monitoring of measures designed for amphibians

Measures to protect amphibians are coordinated by the Swiss Amphibian and Reptile Conservation Programme (KARCH). In rescue campaigns reported to KARCH, an average of 1700 animals are carried across roads per year. Extrapolating for all known campaigns gives a total figure of about 325'000 animals per year. If the amphibians using permanent crossings designed for small animals are also included, the number helped across Swiss roads each year is about 500,000. Unfortunately, in the case of permanent installations, requirements for monitoring have only become widespread recently. The results show that many underpasses do not function satisfactorily, and that only a small percentage of amphibian populations use such crossings. They are not accepted by certain species, such as newts.

Monitoring should produce both qualitative and quantitative results. Defects in installations can be recognised and thus eliminated by observing the behaviour of migrating amphibians. The behaviour of the young should be observed in all cases, since an installation only fulfils its function if sufficiently large numbers of young animals pass through it. For methodological reasons, it is often only adults that are counted.

The KARCH office has produced a leaflet on monitoring (Zumbach 1999), which emphasises the following points:

- **Qualitative monitoring by observation of behaviour, including the use of marked animals:** The movements of adult and young animals (in both directions) are to be noted, in the guiding structures, in the crossings and on the road. The animals' behaviour should be observed to determine in particular whether they climb over or go round the guiding structures, whether — directed by the guiding structures — they find the crossings within a reasonable time, and whether they finally pass through the crossings.
- **Quantitative monitoring using traps:** Traps are used to determine how many animals pass through the crossings.
- **Determination of reproductive success in spawning waters:** With this additional parameter, a reliable assessment can be made of the extent to which any decline (or change) in a population is due to factors other than measures implemented on the road.

KARCH emphasises the importance of planning monitoring on a relatively long-term basis, with trapping and observation exercises repeated at intervals.

Monitoring carried out in Switzerland will not be described in detail here, as information is given in a list of publications which is available from the KARCH office (Bernastr. 15, 3005 Bern).

7.8. SUMMARY

Various types of mitigation measures can be distinguished: project modifications, improved integration of structures into the landscape and supplementary measures. In the case of amphibians, a lot can be achieved even with minor improvements.

The dimensions of a wildlife crossing will depend on the animal species concerned, the desired biological function and the type of structure. In Switzerland, a debate is currently under way concerning the optimum width of wildlife overpasses.

The existing crossing structures for wildlife in Switzerland range from underpasses for small animals to landscaped bridges.

In the case of compensation measures, cantonal and national authorities ensure that certain minimum standards are complied with. These standards are also influenced by the corporate right of appeal of non-governmental organisations (NGOs) and by the courts. On the basis of the experience accumulated to date, the Swiss Agency for the Environment, Forests and Landscape (BUWAL) is currently preparing a report which will specify the minimum standards in more detail.

In transportation infrastructure construction projects, verges are created which serve as new habitats and generally require long-term management. Even at the planning and design stage of the infrastructure project, it is therefore important to provide for management over a period of 20-30 years, and to ensure that monitoring is carried out so that the results can be fed back into maintenance measures or infrastructure design.

In order to weigh up ecological concerns against other interests following a construction project, coordination is required in the form of long-term land-use planning. This should help, for example, to protect wildlife corridors from the encroachment of built-up or industrial zones.

In the past, many wildlife crossings were built in Switzerland in the absence of a sound scientific basis. In particular, there was a lack of studies concerning the efficacy of structures of this type. Recent investigations have shown that overpasses and underpasses specifically designed for wildlife are more effective than crossings designed primarily for humans. In studies of wildlife overpasses of various widths, it was found that a minimum width of 50 m is to be recommended for large mammals. However, other factors, such as the siting of the structure or the development of animal populations in the surrounding areas, are also important.

Although amphibian tunnels have been established for a considerable period, monitoring has only been carried out in the recent past.

Chapter 8. Habitat Fragmentation and Future Infrastructure Development

8.1. INTRODUCTION

Are politicians aware of the fragmentation of natural habitats by transportation infrastructure, and are policies being developed that take this problem into account? These questions will be examined at the beginning of this chapter. We will then discuss indicators and models designed to facilitate assessment of the effects of habitat fragmentation. Finally, an overview will be given of the major transportation infrastructure projects that are planned or under way in Switzerland.

8.2. POLICIES AND STRATEGIES/TRENDS

Marguerite Trocmé

The fragmentation of natural habitats by transportation infrastructure is a problem of which the various authorities concerned are now well aware. “To minimise the biological barrier effect of existing or future transportation installations” is included as a directive in the transport section of the “Swiss landscape concept” approved by the Federal Council on 19 December 1997.

The Alpine Convention, which was signed in 1991 and ratified by Switzerland in 1999, also calls for a general reduction in “the volume and dangers of inter-Alpine and trans-Alpine traffic to a level which is not harmful to humans, animals and plants and their habitats” (Art. 2, paragraph 2, point j).

On this basis, an "environmental quality objectives" working group has been established, which could ultimately also have an influence on questions of fragmentation. More specifically, an initial strategic impact assessment has been undertaken by Switzerland, Austria and the Principality of Liechtenstein to examine the damage caused by traffic in the upper Rhine Valley. Questions of fragmentation will also be examined.

While the problems have thus been recognised, certain differences — some of them major — have emerged as regards the most appropriate solutions. The federal structure of Switzerland has not always facilitated coordination, which has sometimes led to the development of solutions differing considerably in scope from one canton to the next.

In order to harmonise the approaches and setting of priorities for future investments, the Swiss Agency for the Environment, Forests and Landscape (BUWAL) and the Federal Highways Agency (ASTRA) have initiated studies on a national level, the results of which are due to be published shortly.

An inventory and map of the main wildlife corridors (SGW 1999; cf. 5.4.7) have been prepared, with the aim being, among other things, to identify the current blackspots and to help the Confederation and the cantons to set their priorities for the remediation of existing fragmentation. This document will also facilitate the definition of clearer criteria for the selection of wildlife crossings for new infrastructure projects. At the same time, a study on the interaction between wildlife networks and traffic routes (ASTRA/LAVOC) is reviewing experience to date concerning the effectiveness of existing wildlife crossings; this should lead to practical recommendations for planners regarding the choice of effective measures and the criteria to be applied.

In view of budgetary constraints, a general controversy has arisen concerning the width of wildlife overpasses. It is no longer sufficient, in a study examining the impact of a new project, to specify the optimum width from the biological point of view, since infrastructure now has to be scrutinised from the point of view of cost-effectiveness. An interdepartmental working group has been set up to find a consensus between the biological and economic requirements.

In this context, research projects have been initiated with a view to proposing a key for economic analysis of the impacts of transportation infrastructure on the protection of nature and the landscape, including fragmentation. The project entitled "Costs and benefits of nature and landscape protection measures in the transport sector" (Infraconsult AG 1999) has provided some interesting results.

The Federal Department of the Environment, Transport, Energy and Communications is currently carrying out an analysis of the external costs of transport in the area of nature and landscape. This work could also be useful in the future for the application of strategic environmental assessments (SEA) to evaluate the impact of new transport policies.

Rail transport has largely avoided the problem of fragmentation as a result of the decision not to fence in railway lines. Thus, the measures taken essentially concern small animals or cases where road and rail infrastructures are combined.

In general, two tendencies can be discerned in Switzerland with regard to habitat fragmentation.

- On the one hand, the problem is continuing to worsen as urban areas are extended and become more dense and transportation networks are completed.
- On the other hand, as a result of (a) the implementation of ecological compensation measures in intensive farming areas, which tends to strengthen ecological networks, (b) remediation measures taken within the transportation networks, and (c) improved protection of wildlife corridors, connectedness is returning. However, the ecological links that have been re-established are more channelled and less diffuse than they were originally. (see "National priorities for ecological compensation in agricultural plains," environmental booklet no. 306, BUWAL 1998).

The preservation and restoration of ecological networks has thus become a priority. On the basis of the guidelines for the establishment of the Pan-European Ecological Network (see the Pan-European Biological and Landscape Diversity Strategy), BUWAL has launched a project designed to establish guidelines for a national ecological network (ECONAT/PiU 2000).

Project outline of the national ecological network

- Stage 1:

All the relevant information available is combined and represented cartographically: wildlife corridors, national protected areas and protected habitats, networks of lakes and rivers, forests or motorways. This not only provides an overview of the current situation, but also makes it possible to evaluate the landscape in terms of the existing ecological network. This in turn forms the basis for an outline of the potential national ecological network.

The results, which will be available at the beginning of 2000, will include an overview map on a scale of 1:300,000 — as a contribution by Switzerland to the Pan-European Strategy and for the information of the cantons — as well as maps on a scale of 1:100,000 and 1:25,000, which will serve as a basis for Stage 2.

- Stage 2:

The above information is investigated and analysed at the cantonal level so as to update and refine the basic materials, e.g. with regard to all the wildlife indicators of the ecological network. Thus, a pragmatic approach to the collection of data is adopted in this project.

The end result — the revised version of Switzerland's ecological network — will consist of maps (1:300,000 and 1:100,000), a georeferenced database and a final report, which will be available in 2002.

A resource will thus be available on which the cantons can draw for technical support — in developing strategies or in elaborating concepts for the implementation of the regional and national ecological networks. In addition, the GIS database will facilitate the processing and assessment of other project areas by the cantons (e.g. Environmental Impact Assessments, development concepts).

8.3. INDICATORS/INDEXES OF FRAGMENTATION

Guy Berthoud

Fragmentation indicators are useful for making comparisons between regions, cantons or sites; they facilitate progressive monitoring of habitat fragmentation and help to define gradients of habitat degradation.

The fragmentation of a region is the most visible aspect of general landscape transformation. In the simplest form of analysis, the preferred habitats of animals are mapped according to a specific gradient of potential habitats and all the possible obstacles to dispersal are then identified (cf. 5.4.7.).

This mapping will produce several measurable parameters which can be used as fragmentation indicators. Normally, types of habitat (geomorphology, vegetation cover, land use) and some quantitative values (species richness, density of transportation networks, intensity of disturbances, density of fragmenting elements) are mapped.

These indicators can be combined more or less judiciously to obtain fragmentation indexes.

Various methodological studies have been published, but these are generally unsatisfactory from the point of view of the ecology of natural habitats.

An analysis of the habitat fragmentation of a region should logically be followed by an analysis of the permeability of the elements creating the fragmentation effect. The natural ecological networks have to be superimposed on the network of transportation infrastructure and habitats in order to identify potential points of conflict and possible solutions.

This procedure was used in the "Swiss wildlife corridor" project (SGW 1999) to define the regional possibilities for the use of habitats by large mammals.

If one wishes to define a regional fragmentation index, the residual functional potential of the landscape is of final interest.

8.4. MODELS TO PREDICT FRAGMENTATION BY NEW INFRASTRUCTURES

Guy Berthoud

Once impact assessments were systematically applied to new transportation infrastructure projects, ecologists soon recognised the need to develop a model for the prediction of habitat fragmentation and the consequences for the ecosystems traversed.

In the end, it was a national research programme between 1985 and 1989, focusing on land use in Switzerland (PNR 22 SOL), that prompted an in-depth study designed to establish a method for the ecological evaluation of habitats (Berthoud et al. 1989). This method was tested on a number of motorway projects being examined at the time. Since then it has been perfected, incorporating in particular the new possibilities offered by use of the geographic information system (GIS), and applied to numerous projects in Europe.

As in the case of habitat fragmentation indexes (see 8.3.), the problem is to define what makes up the ecological value of a habitat and how it is to be evaluated.

Once this problem has been resolved, the analysis of the impact of a project, the choice of possible routes or the development of habitat fragmentation will follow automatically.

The method for evaluating the ecological potential of habitats is based on the following five principles:

First principle: The notion of the site user

The perceptions of the value of a site will vary according to the different notions of site users (foresters, farmers, ecologists, and developers). If evaluating the ecological potential of habitats, the evaluation of a site from an ecologist’s point of view should be considered.

Second principle: The multiple factors contributing to the value of a site

The value of a site is clearly influenced by the geographical location, environment, existing pressures, and functions in relation to neighbouring sites.

Third principle: The need for multi-level analysis

The most useful levels for this analysis are the habitat, the landscape unit and the region.

Fourth principle: The contribution of a unit to a group

In the evaluation of a group of elements (habitats or landscape units), not all the elements contribute in the same way to the overall biological diversity of the group under analysis. Thus, the various habitats that make up a landscape unit are not all of equal importance.

Fifth principle: the multifactorial value of a site

The value of a site is not determined by simply adding together the major factors, since the removal of one of the factors would entail overall devaluation of the site.

In practice, it has been possible to define 3 main factors of the site: the **quality** (examples for the habitat level: diversity of flora and fauna, rarity) **capacity** (surface area, abundance of structural elements) and overall **function** (refuges, reproduction sites, foraging grounds, interchanges with neighbouring habitats). In keeping with the third principle, the value should be estimated at several levels in order to appreciate the role of the site in relation to all the sites in the sector or region.

For the analysis, the three determining factors are weighted, making optimum use of the available indicators.

The data obtained during the evaluation are of interest in three ways. Firstly, they confirm intuitions that are often difficult to prove by other means. Secondly, they offer guidance in the search for better solutions with regard to the choice of routes. Finally, they stimulate reflection on compensation or regeneration measures that will be required to make a project of this type acceptable.

The method of evaluating the ecological potential of habitats essentially imposes restrictions on the approach to be taken. However, it is primarily a working tool for the production of a numerical evaluation. The resulting documentation — grids, graphs and maps — is of no use for comparisons with other areas, even if the latter have been analysed using the same method. It may be used only to support a case, and is valid for a project at a particular time. It is produced only to back up verbal reasoning and to guide negotiations concerning possible landscape modifications.

With the experience gained from numerous applications, current work on the identification of ecological networks, the publication of specifications for a typology of habitats (Delarze & al. 1998) and the various biodiversity research programmes under way in Switzerland, the method of evaluating the ecological potential of habitats is becoming increasingly precise and relevant.

GIS-based modelling and 3D visualisation of effects of habitat fragmentation

Sigrid Hehl-Lange

If high-resolution spatiotemporal data are wholly or partly unavailable, or are too costly to obtain, procedures for model generation and simulation are required.

Using GIS-based analysis, spatial-functional relationships of animals which use different habitats for different functions, as outlined in models by Blab (1993) and Riecken (1992), are presented in concrete terms for the Arth-Goldau area.

Various animal species (greater mouse-eared bat [*Myotis myotis*] and several species of amphibians) are taken as examples to investigate how the use of land for agricultural, settlement and transportation purposes affects wildlife. These species are dependent on various types of habitats and therefore could react particularly sensitively to interventions that alter the character of the landscape.

The GIS-based simulation of the use of space by the greater mouse-eared bat involves a number of elements. Information in the literature and local expert knowledge is used to create a GIS-based simulation model. This computer model is then used for the calculation and subsequent 3D visualisation of potential foraging habitats, starting from the known nursery colony in Steinen. Important data that have to be integrated into the model are the home range of this species of bat and various vertical landscape elements (edges of forests, individual trees, buildings) which the bat uses for orientation in order to reach its foraging habitat (see Hehl-Lange 1998).

The virtual landscape consists of the digital terrain model DHM25, a LANDSAT satellite image and a colour orthophoto (Swissphoto), together with the 3D-objects, such as individual trees, forest and buildings, derived from the digital topographical map

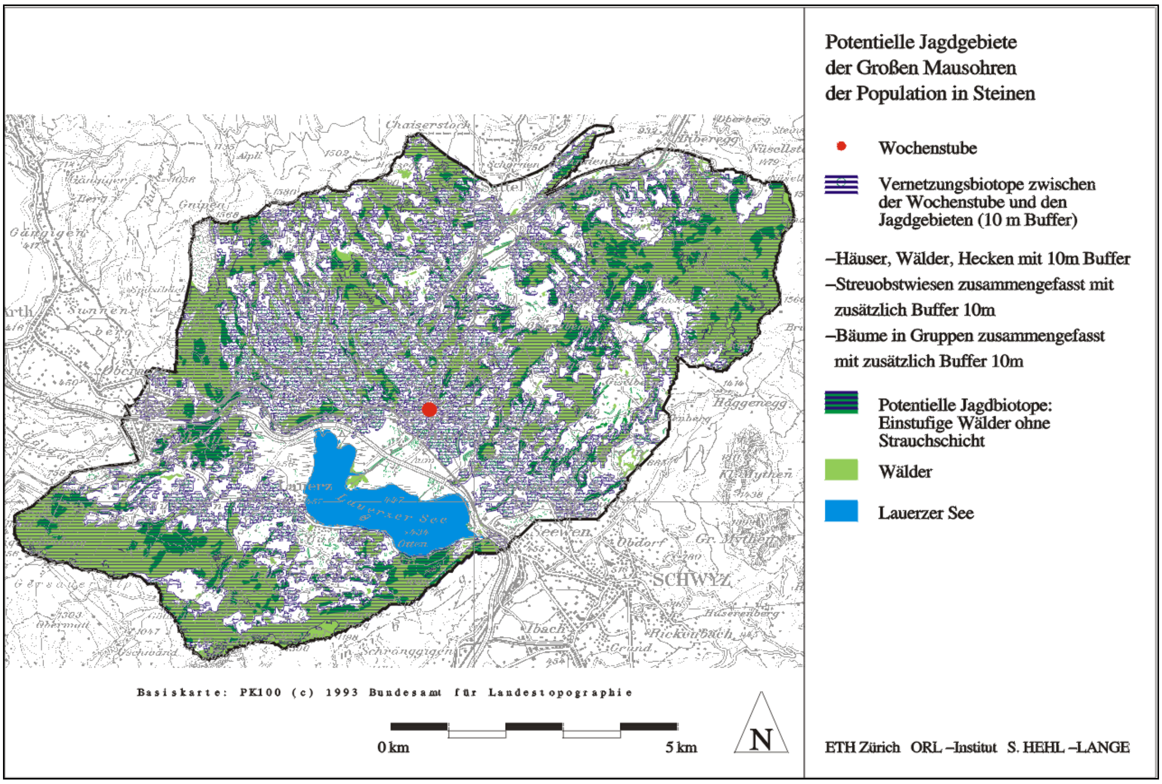
Taking the example of various amphibian species, other functions of the various habitats in the landscape can be shown (Hehl-Lange 2000). The GIS can be used to calculate and represent the barrier effect of roads and railway lines. As for the calculation of the potential flight path for bats, the dispersal of amphibians, starting from the spawning sites, is calculated using the ARC/INFO GRID module, with the resistance assigned to each type of land use varying according to the barrier effect. For example, this type of model can be used to represent the positive effects of amphibian underpasses under motorways and the related guiding systems.

Results

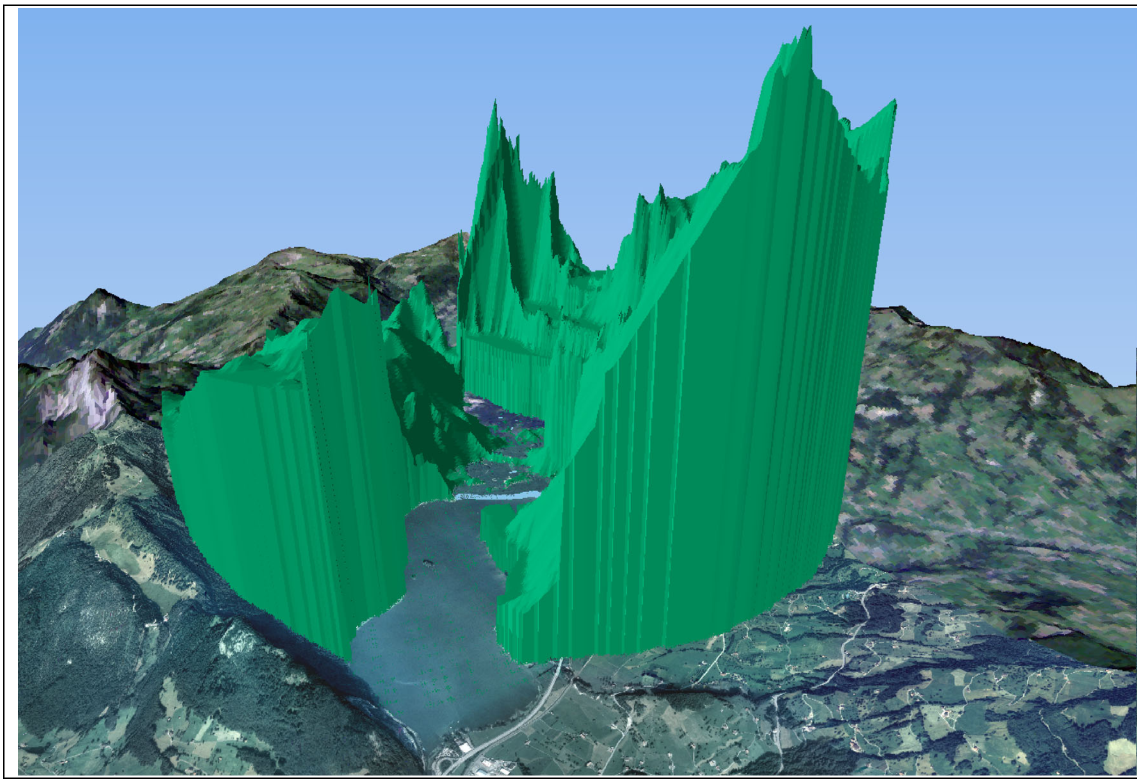
The habitat use of all structure-dependent flying bat species, such as the greater mouse-eared bat, is affected by the ongoing clearance and fragmentation of the landscape. It is becoming clear that greater mouse-eared bats are avoiding the cleared, intensively used valley to the north of Lake Lauerz. In the model, the motorway is only crossed in the area where the forest adjoins the motorway on both sides (see Figure).

For the annual habitat use patterns of amphibians, it is important not only to preserve, maintain and re-establish spawning sites but to take into consideration all plans that could affect habitats by creating a barrier effect. In the area under study, the transportation infrastructure adjoining the spawning site is the main barrier, particularly for the common toad and grass frog (see Figure).

The GIS-based model is a flexible instrument that can also be used to simulate the effects of possible future changes in land use. Not only can the effects of habitat fragmentation due to the construction of new transportation infrastructure be modelled but also the positive effects of habitat linkages.



Potential foraging habitats (dark green) for the greater mouse-eared bat (*Myotis myotis*). Connecting biotopes are in violet, forests in light green.



Barriers and possible dispersal routes for the common toad (*Bufo bufo*), 3D visualisation

8.5. DATA ON TRANSPORTATION NETWORKS DEVELOPMENT

F. Borer

The policy priorities of the federal government for infrastructure plans in Switzerland are as follows (as at July 1999):

Rail 2000: The RAIL 2000 concept will produce a national improvement in public transport provision. It is based on hourly Intercity and express services, with services every 30 minutes if there is sufficient demand. The trains are all to arrive at the large interchange stations at approximately the same time and depart again a few minutes later. This will provide optimum opportunities for connecting with Intercity and express services and, in particular, with regional trains. Wherever the capacity of the existing network is insufficient for the planned additional services, extensions or new lines are proposed. RAIL 2000 will be implemented in two stages: the ongoing first phase, to be completed by 2005, primarily involves the construction of a new 45-km line between Mattstetten and Rothrist, of which 14.3 km is routed through tunnels. The aims of the subsequent second stage include improvements to regional transport and the removal of bottlenecks.

New transalpine railway line (NARA): The decision to build a new railway line through the Alps was taken in 1992 as a step towards closer integration between Switzerland and the EU, which was also reflected in Switzerland's commitment to construct a temporary transalpine corridor for combined transport. The NARA project primarily involves the construction of two base tunnels (Gotthard and Lötschberg). The Lötschberg axis was started first, in 1999, and is to be completed by 2006. The Gotthard base tunnel has also been under construction since 1999 and should be ready for operation in 2012.

Combined road/rail transit corridor: On the Gotthard route, a corridor with an annual capacity of 360,000 unaccompanied vehicles was completed on 1 January 1994. A second stage to increase the capacity of the rolling road on the Lötschberg-Simplon route to 110'0000 vehicles per year is nearing completion.

Completion and maintenance of a high-quality national road network: Completion is scheduled for 2007 (except for the Zurich and Biel bypasses). The total length of the motorway network will then be 1'855 km.

Rail network noise abatement: New noise barriers could reinforce fragmentation.

Swissmetro: A new underground metro project has been developed by the Swiss Federal Institute of Technology in Lausanne. In a tunnel under vacuum, the trains should be able to travel at 400 km/h. A pilot section between Geneva and Lausanne has been presented for authorisation at the federal level, but no decision has yet been taken.

8.6. On-going research

GVF & BUWAL: External costs of transport in the area of nature and the landscape. Preliminary studies completed. Start of main study in summer 2000, ending approx. end of 2001.

LAVOC. Inventory of wildlife crossings on cantonal road networks. Auftrageber: ASTRA 1998.

Oekoskop/Econcept: Externe Kosten des Verkehrs im Bereich Natur und Landschaft. Auftraggeber: GVF/BUWAL. Pretest, Gelterkinden, April 2000. Hauptstudie bis Ende 2001.

Righetti, A.: Monitoring of the wildlife passage at Rüthi (canton SG) along the N13. First results 2002.

Righetti, A.: Monitoring of the wildlife passages at Neueinschlag and Birchiwald (canton BE) along the N1 and the new Rail 2000 line. First results 2004/05

Righetti, A.: Monitoring of the wildlife passage at Stöck (canton BE) along the N5 and SBB. First results 2004/05

Righetti, A., Berthoud, G., in preparation: The effect of unfenced (high-performance) train lines on wildlife populations. COST 341: Research project BBW no. C98.0114, preliminary project

8.7. Summary

Although the problem of habitat fragmentation due to transportation infrastructure is appreciated by all the parties concerned, the federalist structure of Switzerland has led to the proposal of different solutions by different cantons. This has understandably made it difficult to achieve standardisation. On the basis of studies already completed (wildlife corridors) or more recent studies (interactions between ecological networks and traffic routes), it is hoped that practical recommendations can be proposed for the planning of effective measures.

In order to obtain indicators or an index of habitat fragmentation, the simplest approach is to superimpose the ecological network on the transportation network, thereby highlighting any conflict points. In order to describe habitat fragmentation in quantitative terms, the following parameters could be used: density of barriers, biodiversity indexes, disturbances.

With the accumulation of experience from environmental impact assessments, there is an evident need for models which would enable to predict the consequences of habitat fragmentation. Here again, the main problem is to assess the ecological value of a region. Once this has been determined, the effects of various options and of the project can be assessed using GIS.

The following major transportation infrastructure projects are being planned or implemented in Switzerland: Rail 2000, a new transalpine railway line, a combined road/rail transit corridor, the completion and maintenance of a high-quality motorway network, and rail network noise abatement installations.

Chapter 9. Economic Aspects

Mark Egger

Financing of conservation measures in Switzerland

In Switzerland, there is a clear legal requirement (based on e.g. the Federal Law on the Protection of Nature and the Landcape, LPN) to take the interests of nature and the landscape into consideration in construction projects involving transportation infrastructure. Appropriate conservation measures are thus an integral part of any transportation infrastructure project and are to be financed as such. They include all measures designed to compensate for habitat fragmentation due to transportation infrastructure. The following three types of conservation measures should be distinguished:

1. In (transportation) infrastructure projects, **replacement and restoration measures** are to be financed by the project initiator, in accordance with the "polluter pays" principle. The costs of conservation measures are included in the project budget and are mainly financed by *petrol and oil taxes* in the case of motorways and major roads, and by tax revenues in the rail sector. In Switzerland, unlike other European countries, fuel taxes are *earmarked*, i.e. they may only be used for expenditures on road infrastructure, which includes replacement and restoration measures. These funds cover not only the capital investment but also future maintenance and upkeep costs, provided these are claimed for within the framework of the transportation project. Maintenance and upkeep costs are an important aspect of nature and landscape conservation measures (cf. 7.6).
2. **Ecological compensation measures** that go beyond replacement and restoration linked to infrastructure projects serve to improve areas that are used intensively, and have to be taken *independently* of the construction work. They are also a legal requirement under the LPN. These measures are financed by the cantonal and federal government from general tax revenues, e.g. in the form of ecological subsidies for agriculture.
3. **Supplementary conservation measures** go beyond legal requirements. These are *voluntary* measures, which usually have to be financed by third parties (state funds, private foundations, contributions from environmental organisations and private enterprise, etc.).

The first two types are obligatory measures based on legal requirements (in particular Art. 18, LPN), while the third involves voluntary contributions (SIA/BUWAL/BLW 1998).

Current debate on the costs of conservation measures

As a result of legal requirements obliging the project initiator, among other things, to document the environmental impact of a project, the protection of nature and landscape has become an important aspect of transportation infrastructure projects in Switzerland. In recent years, considerable investments have been made in measures of this kind. Critics regard environmental protection in general as the main cause of the massive increase in construction costs for transportation infrastructure over the past few decades. E.g. motorway construction: in 1960, the cost of a kilometre of motorway was estimated at CHF 2.4 million. At the end of the 1970s, it was approx. CHF 20 million, and at the end of the 1990s approx. CHF 50 million. Environmentalists, however, take the view that environmental protection is sometimes used as a pretext for other construction- and transportation-related extra costs in road and railway construction projects. Specific information on the level and proportion of environmental investments in transportation infrastructure projects remains unavailable. When environmental interests are weighed up, cost-benefit analyses are seldom or never performed (ASTRA 1997).

Approaches to economic optimisation of conservation measures

In the past, economic aspects in the area of nature and the landscape have been largely overlooked. However, with calls for the internalisation of external costs on the one hand, and with increasing constraints on public spending on the other, greater importance is now generally being attached to economic models and methods of optimising conservation measures and evaluating nature and the landscape.

Model for evaluating costs and benefits of conservation measures

In a project conducted as part of Swiss National Research Programme 41 (Infraconsult 1999), the costs and benefits of nature and landscape conservation measures were examined in detail. An assessment model was developed which allows the benefits of conservation measures in transportation infrastructure projects to be determined, evaluated and compared with the costs of these measures.

With this model, it is possible to evaluate the ecological effects of potential conservation measures for flora and fauna and for the rural and urban landscape by means of eleven indicators, and to assign “utility points”. The “willingness to pay” approach is then used to express the benefits in monetary terms. According to various Swiss and foreign studies, individuals are prepared to pay about CHF 30 per month for significant improvements in nature and the landscape. This means that the Swiss population as a whole is prepared to pay about CHF 2.5 billion per year. In the model, this figure is then divided by the area of Switzerland with potential for ecological compensation, which leads to the conclusion that the environmental improvement of one square meter by one utility point yields a benefit of CHF 0.025 per year.

By evaluating the efficiency (cost-benefit ratio) of nature and landscape conservation measures and also their effectiveness (proportion of the damage compensated for by conservation measures), the model can reveal shortcomings in the planning and implementation of transportation projects. It thus provides a sound basis for optimising individual conservation measures and for increasing the effectiveness of expenditures on nature and landscape conservation in general.

Costs and benefits of nature conservation measures: case studies

Effects and cost-benefit ratios were evaluated by means of six case studies. These revealed e.g. that improvements to the alignment of a highway could result not only in a yearly nature protection benefit of CHF 0.3 million but also reduce construction costs by CHF 0.5 million yearly discounted costs. An action package in connection with the development of a regional railway from single to dual track would result in yearly costs of CHF 27,000 and benefits worth CHF 20,000, which represents an acceptable efficiency. Extending the length of a railway tunnel, on the other hand, would cost about CHF 0.8 million per year with benefits worth only CHF 25,000 – an action that, according to the authors, could only be justified by other (e.g. political) arguments.

External environmental costs

A study commissioned by the GVF (in prep.) is currently investigating the external environmental costs of transport. The aim of the study is to estimate in monetary terms the costs for flora and fauna directly or indirectly caused by transportation infrastructure. On the basis of a comparison between the condition of the environment in 1950 and the present in selected regions of Switzerland, the impact of transport is determined in the areas of air, water, climate, soil, fauna, landscape, noise and light, and an attempt is made to extrapolate the results to the country as a whole. The (hypothetical) re-establishment costs will probably be used to express the transportation-related environmental damage in monetary terms. The main study is due to be completed at the end of 2000.

Open questions (ongoing research)

Conventional scientific methods are of limited use for the evaluation of nature and the landscape. The scientific measurement and economic evaluation of environmental changes are new fields, with only a small number of methodologically sound studies available as a basis for research.

There is a notable lack of research in the area of economic evaluation methods; here, the concept of a "willingness to pay" for environmental improvements represents a promising approach. Empirical studies are required to provide a broader basis for this concept, e.g. also taking into account the visual/aesthetic aspects of the landscape. It would also be important to carry out methodologically harmonised studies of the "willingness to pay " for various landscape types, regions and countries so as to give due consideration to the extremely important social and cultural differences that exist between the groups surveyed. Further research is also required in the area of systematic measurement and assessment of the impacts of projects on humans, plants and animals.

Chapter 10. General Conclusions and Recommendations

Antonio Righetti

Fragmentation: a priority issue

As a result of the major differences in elevation (193-4634 m above sea level) within a small area, Switzerland is characterised by a wide variety of types of landscape. Climatic features of interest include the continental, intra-Alpine and Insubrian regions of the south and the regional climate of the föhn valleys of the precipitation-rich northern Alps. The Central Plateau is characterised by a temperate climate, while oceanic elements are seen in parts of the Jura. These variations in climate, together with widely varying geological conditions, promote the growth of a large number of different types of vegetation, thereby providing potential habitats for a rich variety of species of flora and fauna. Animal species particularly worthy of mention — considering only medium-sized or large mammals in view of our current knowledge of fragmentation — include the badger, pine and stone marten, brown hare, lynx, roe deer, red deer and wild boar. For some years, the wolf (coming from Italy) has been a regular visitor in Valais, in the southwestern part of Switzerland.

The country's great ecological potential is offset by an extremely high density of development. In Switzerland, the mean road density is 2.69 km/km^2, with values rising to almost 4 km/km^2 in heavily populated areas. In addition to the road network, there are some 5000 km of railway lines (0.13 km/km^2). Combined with a high traffic density, this has led to an extremely fragmented landscape.

In these circumstances, unrestricted use of natural habitats is difficult or impossible not only for small creatures but also for most of the above-mentioned wild mammals. The barrier effect is most evident in the case of the 1638 km of fenced-off motorways. Also noteworthy are the several hundred kilometres of cantonal roads with traffic volumes in excess of 10'000 vehicles per day and a correspondingly high incidence of wildlife casualties — in 1997 alone 19'186 medium-sized or large wild mammals were killed on Swiss roads and railway lines. This figure does not include the large numbers of unreported cases. The heavily used roads mentioned above are implicated to a significant extent in the large number of traffic-related casualties. The barrier effect of these roads thus approaches that of a fenced-off motorway.

Finally, the large number of cableways and ski lifts, predominantly used by tourists, should also be mentioned. In this case, the habitats concerned are less affected by the barrier effect of the infrastructure than by the new or increased potential for disturbances arising from the users — e.g. unregulated mass tourism. Especially within areas that are otherwise relatively undisturbed, this adverse influence produces significant degradation of habitats.

The adverse effects that result either directly or indirectly from (linear) transportation infrastructure are exacerbated by an above-average population density (more than 170 inhabitants/km^2) and frequently intensive agriculture. In addition, there are 1200 km of natural watercourses, which, in some cases, as a result of man-made structures (e.g. sheeting, concrete enclosures), represent considerable obstacles for terrestrial and aquatic animals.

As would be expected, fragmentation of natural habitats is at its greatest in the intensively used Central Plateau. This central region of Switzerland offers no large-scale connectivity either within itself or externally. It thus largely prevents interchanges of wildlife between the Jura and the Alps. The Jura itself is largely free of barriers to animal movements, with the exception of the valley regions. In the Alps, the populated valleys and the high mountainous regions represent barriers to interchanges for most animal species. However, the region between these two altitude bands shows a considerable degree of connectivity. Thanks to the large numbers of tunnels, bridges and viaducts in this region, even transportation infrastructure does not generally represent an insurmountable barrier.

Recent studies have confirmed the critical situation with regard to the impairment of large-scale networks: of the 303 main wildlife corridors known to be of supraregional importance in Switzerland, 47 (16%) are now largely disrupted, 171 (56%) are significantly impaired, and only 85 (28%) remain intact. The functionality of 78 corridors depends on the construction of wildlife-specific crossings. The statistics for restoration measures show that to date two structures have already been built, eight are currently being built and four are at the planning stage. Restoration measures are still outstanding in the other 64 cases.

A recognised problem

Discussion of the problems associated with linear transportation infrastructure and habitat fragmentation began some decades ago in response to criticism voiced by environmental and hunting circles. The evidence required for sound arguments and lobbying has been assembled on an ongoing basis since the beginning of the 1980s. The topics addressed include evaluation of the fundamental problems, suggestions for solutions and monitoring, and the economic consequences of road and rail traffic. As a result of these efforts, clear guidelines now exist, for example, for the construction of amphibian tunnels, a number of wildlife overpasses between 17 and 186 m wide have been built, and the implementation of monitoring measures (to verify the effectiveness of structures) has become standard. However, the experience accumulated in the course of planning, implementation and monitoring has highlighted the importance not just of the individual measures in themselves, but of the way leading to these measures — specifically, the fact that the parties involved in such projects work together rather than against each other.

Over the same period, the legal basis has been expanded and refined. The problems are now addressed in various laws and ordinances: for example, the protection of habitats has been improved, the relationship to land-use planning has been established, and criteria have been developed for the assessment of conflicts.

A global strategy remains to be implemented

Despite the knowledge which has been gained in the past or will soon be available — information on the external costs of traffic and guidelines on the dimensions and design of wildlife crossings — numerous questions remain unresolved. In brief, these include the following:

– Basic research on the effects of fragmentation: as mentioned above, research in recent years has produced fundamental insights into the effects of habitat fragmentation on vertebrates. Further research on the population level is needed. At the same time, invertebrates, and insects in particular, should increasingly be included in such studies so as to close the considerable gap that now exists.

– Practical regulations concerning the implementation of measures: the implementation of environmental protection measures is often thwarted by the opposition of land-owners. Expropriation measures in the interests of nature and landscape protection, as provided for by the LPN, are rarely taken. If these aspects are not given due consideration, the dimensions of a crossing structure, adapted to the design of the surrounding area, may no longer be valid at the end of a project if the structure itself is all that remains of the original package of measures.

– Application of knowledge of the ecological network in Switzerland: the wildlife corridors have been identified, together with the restoration measures required in some cases. Further data on the required expansion of the ecological network will be available in a few years' time. However, more detailed information on the proposed solutions is currently lacking, and there is no prioritisation or systematic protection (e.g. through comprehensive, harmonised master plans).

– Clarification of the influence of the railways on habitat fragmentation: as indicated by the statistics on animal casualties, railway lines also exert a certain barrier effect. Systematic investigations are required to establish the relevance of this effect and whether there is a need for fencing.

– Decision support for the selection of structures: in future, the selection of a suitable type of crossing will be facilitated by the various ecological effectiveness studies and the above-mentioned guidelines. However, the question has yet to be resolved whether — regardless of measures taken in the surrounding area — a small number of large structures or several smaller structures are more effective. An overall answer, optimising both ecological and economic aspects, remains to be determined.

– The optimal conception of verges is still not always clear. How does one balance the positive corridor effect they offer with the negative sink effect they can have on other species?

– The secondary effects of a transportation infrastructure can have as much or more impacts than the infrastructure itself. New infrastructures must be linked to landscape development schemes that maintain the ecological corridors.

All these points should help to defuse current or foreseeable conflicts associated with habitat fragmentation due to linear transportation infrastructure. They represent an indispensable basis for counteracting the continuous increase in factors endangering natural habitats, e.g. increasing fragmentation of the landscape due to changes in the law on spatial planning in agricultural areas or the rise in noise pollution due to increased traffic, together with measures to reduce traffic volumes.

Despite a number of issues that remain to be resolved, most of the parties in Switzerland concerned by the problem of habitat fragmentation due to linear transportation infrastructure are endeavouring to arrive at universally acceptable solutions. In view of this experience and the large amount of important fundamental work that has been done on this topic, Switzerland can play a major role in the search for solutions throughout Europe.

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Chapter 12. List of Abbreviations

ASTRA	Bundesamt für Strassen
OFROU	Office fédéral des routes
FEDRO	Swiss Federal Roads Office
BAV	Bundesamt für Verkehr
OFT	Office fédéral des transports
FOT	Federal Office of Transport
BFS	Bundesamt für Statistik
OFS	Office fédéral de la statistique
SFSO	Swiss Federal Statistical Office
BRP	Bundesamt für Raumplanung
OFAT	Office fédéral de l'aménagement du territoire
FOSP	Federal Office of Spacial Planning
BUWAL	Bundesamt für Umwelt, Wald und Landschaft
OFEFP	Office fédéral de l'environnement, des forêts et du paysage
SAEFL	Swiss Agency for the Environment, Forests and Landscape
GS UVEK	Generalskretariat des Departementes für Umwelt, Verkehr, Energie und Kommunikation
SG DETEC	Secrétariat général du Département fédéral de l'environnement, des transports, de l'énergie et de la communication
GVF	Dienst für Gesamtverkehrsfragen
SET	Service d'étude des transports
KARCH	Koordinationsstelle für Amphibien- und Reptilienschutz der Schweiz Centre de coordination pour la protection des amphibiens et reptiles en Suisse Swiss Amphibian and Reptile Conservation Programme
LAVOC	Laboratoire des voies de circulation Laboratory of Traffic Facilities of the Federal Institute of Technology Lausanne
SGW	Schweizerische Gesellschaft für Wildtierbiologie Société suisse de Biologique de la Faune Swiss Society for Wildlife Biology
VSS	Vereinigung Schweizerischer Strassenfachleute Union des professionnels suisse de la route Association of Swiss Road and Traffic Engineers

Annex I Illustration and location of wildlife overpasses in Switzerland

motorway	commune	coordinates	width	completed
A7	Kreuzlingen	728’130 / 277’030	50m	1999

Contact person: Walter Ebinger, Tiefbauamt TG, Nationalstrassen, Postfach, CH-8510 Frauenfeld

motorway	commune	coordinates	width	completed
A7	Wigoltingen	719’3000 / 273’900	140m	1992

Contact person: Walter Ebinger, Tiefbauamt TG, Nationalstrassen, Postfach, CH-8510 Frauenfeld

motorway	commune	coordinates	width	completed
A7	Neuwilen	726'450 / 276'150	200m	1992

Contact person: Walter Ebinger, Tiefbauamt TG, Nationalstrassen, Postfach, CH-8510 Frauenfeld

motorway	commune	coordinates	width	completed
A8	Brienzwiler		17m	1995

Contact person: U. Schaerer, Tiefbauamt BE, Abt. Kunstbauten, Reiterstr. 11, CH-3011 Bern

motorway	commune	coordinates	width	completed
A1	Bern/Grauholz	603'700 / 205'200	23m	1995

Contact person: U. Schaerer, Tiefbauamt BE, Abt. Kunstbauten, Reiterstr. 11, CH-3011 Bern

motorway	commune	coordinates	width	completed
A4/A3	Feusisberg	697'420 / 225'035	40m	2000

Contact person: Albert Rohrer, Tiefbauamt, Kantonsstrassenbau, Postfach 61, CH-6431 Schwyz

motorway	commune	coordinates	width	completed
A10	Chaumes	550'352 / 202'106	40m	in construction

Contact person: Mukhtar Hussain-Khan, Service des Ponts et Chaussées, Case postale 1332, CH-2001 Neuchâtel

motorway	commune	coordinates	width	completed
A10	Replanes	549'635 / 201'764	40m	in construction

Contact person: Mukhtar Hussain-Khan, Service des Ponts et Chaussées, Case postale 1332, CH-2001 Neuchâtel

motorway	commune	coordinates	width	completed
N4.2.9	Henggart/Loterbuck	694'100 / 268'050	100m	

Contact person: Jean Thiry, Tiefbauamt, National- und Hauptstrassen, Walcheturm, CH-8090 Zürich

motorway	commune	coordinates	width	completed
N4.2.8	Henggart/Rütibuck	613'700 / 270'700	50m	in construction

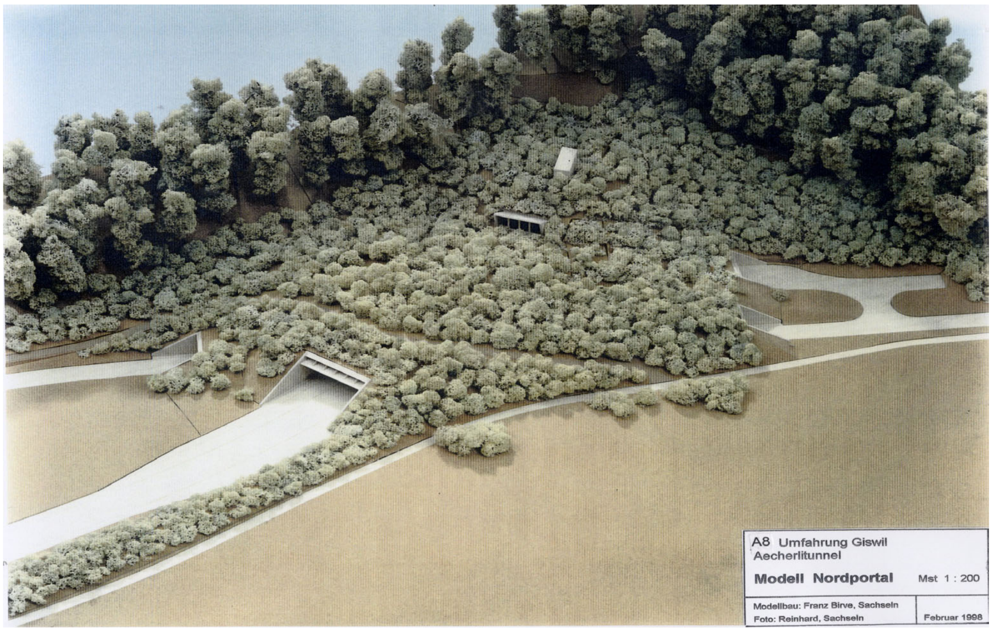
Contact person: Jean Thiry, Tiefbauamt, National- und Hauptstrassen, Walcheturm, CH-8090 Zürich

motorway	commune	coordinates	width	completed
A13	Rüthi	760'483 / 241'248	50m	1999

Contact person: Friedrich Wieland, Tiefbauamt Kanton SG, Abt. Brückenbau, Lämmlisbrunnenstr. 54, CH-9001 St. Gallen

motorway	commune	coordinates	width	completed
A1	Font	553'800 / 186'300	111.85m	in construction

Contact person: M. Wéry, Bureau des autoroutes, Case postale 118, CH-1706 Fribourg



motorway	commune	coordinates	width	completed
A8	Giswil	657'850 / 188'100	80m	in construction

Contact person: Jörg Stauber, Bauamt OW, Abt. Strassenbau, Postfach 1163, CH-6061 Sarnen, e-mail: bauamt@ow.ch

motorway	commune	coordinates	width	completed
A2	Beckenried	Ischenwald	10-18m	completed

Contact person: Josef Eberli, Tiefbauamt NW, Breitenhaus, 6370 Stans

During the building of the highway, a number of streams in the steep wooded slopes crossing the road had to be chanelised. It was later discovered that animals who fell in could no longer get out and were swept out into the lake. To remediate this problem small passages over the chanelised streams were built. Simple fencing along the streams directs animals to the passages.