



“Future Environmentalists - Linking EU Natural Capital Management to Field Research”
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Habitat fragmentation

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Basic literature: *Primack (2004, 2006), Groom et al. (2006), Lindenmayer & Fischer (2006)*

Introduction

The main cause of global loss of biological diversity is natural habitat alteration and destruction (Noss et al. 2006). Human activities change the landscape and divided it into smaller and smaller areas with favourable conditions for organism survival. This process of decreasing biotope area and their reciprocal isolation is called **habitat fragmentation**. Isolated populations formed by fragmentation are at increased risk of extinction as a consequence of loss of genetic variability (genetic polymorphism) together with synergistic effects of demographic and environmental stochasticity (Primack et al. 2001).



Figure 1 Fragmentation in Czech agricultural landscape. Fields, meadows and pastures become landscape matrix instead of original forests in a great part of the country (© Markéta Hendrychová.)

In this text, causes and consequences of habitat fragmentation will be discussed and a brief description of the island biogeography model and its application in nature conservation is also included. Great attention is paid to the sensitivity of particular species (species group) to this phenomenon and to methods of fragmentation evaluation. Then legislative, methodical and technical solutions that lead to





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improved landscape connectivity for organisms are described, especially in the context of road infrastructure development.

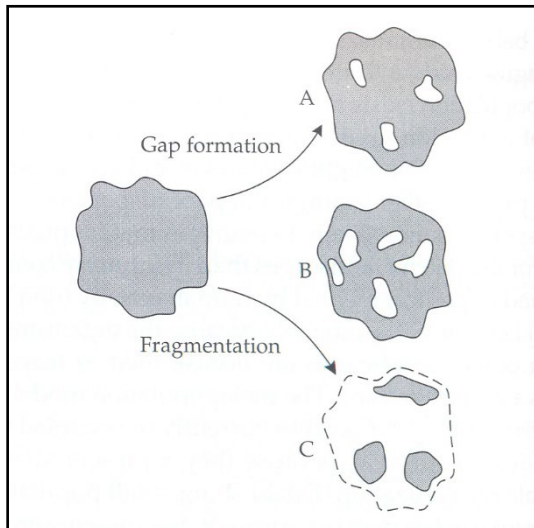


Figure 2 (left) The process of fragmentation. (Original from Wiens 1989.)

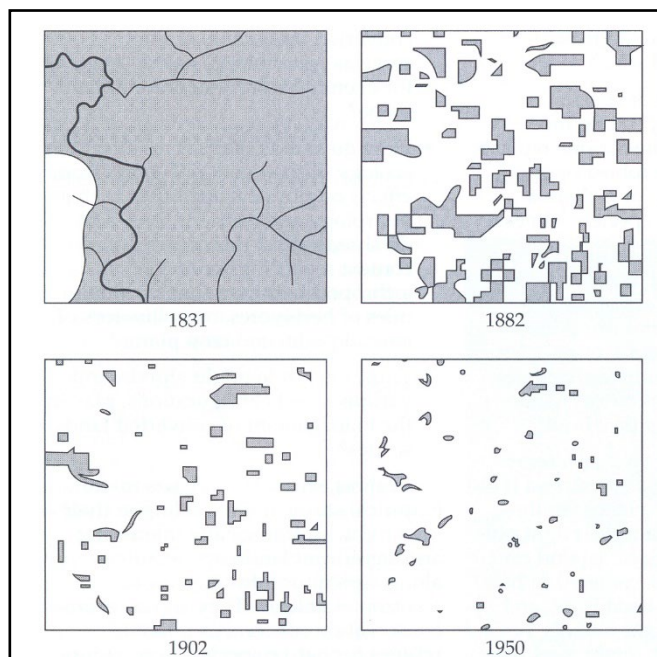


Figure 3 (right) Changes in a wooded area of Cadiz Township, Green Country, Wisconsin, during the period of European settlement. Shaded area represents the amount of land in forest in each year. (Original from Curtis 1956.)

Table 1 Forest area and percentage of forest area in different fragmentation categories, by continent. (Original from Riitters et al. 2000.) [http://www.consecol.org/vol4/iss2/art3/.](http://www.consecol.org/vol4/iss2/art3/)

Continent	Forest area ^a (10 ³ km ²)	Percentage of continent forest area in fragmentation category					
		Interior	Undetermined	Perforated	Edge	Transitional	Patch
Africa	2732	28.7	1.9	31.8	13.9	11.1	12.7
Australia–Pacific	2135	27.1	2.2	35.1	16.1	10.9	8.7
Europe–Asia	9551	32.0	2.1	34.1	14.1	9.0	8.7
North America	8565	44.9	2.3	28.5	14.0	5.6	4.7
South America	6940	33.0	2.0	39.6	11.6	7.4	6.5





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Habitat fragmentation and the island biogeography model

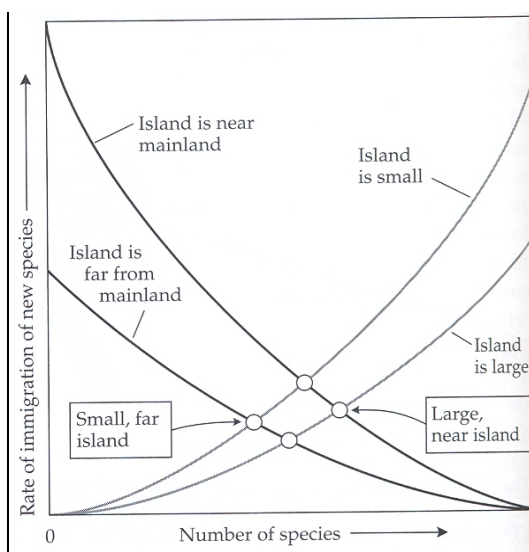
Landscape fragmentation consists of biotope destruction and natural habitat separation into isolated parts. These individual fragments, surrounded by altered and degraded landscapes operate as islands in a hostile environment (Fig. 5), comparably to real islands in a sea or an oasis in a desert (Primack et al. 2001). Island-based biological diversity studies have led to the formulation of the island biogeography model (MacArthur & Wilson 1967) that explains the number of species on an island in relation to the degree of isolation and island size. The extinction probability of a species is dependent on island size; smaller islands can retain only smaller populations that are more susceptible to extinction. The distance to the mainland affects the colonization intensity (Fig. 4). The bigger the island is and the closer to the mainland it is, the higher is the level of biodiversity (Storch & Mihulka 2000). Many empirical studies confirm this theory, others not with similar results regarding its application in landscape (Forman & Godron 1993, Box 1).

Box 1 The theory of island biogeography and nature conservation

This theory is used for the prediction of the number of species that would go extinct in cases of the destruction of their habitat (Primack et al. 2001) or planning for protected areas (Shafer 1997 ex Primack et al. 2001). Using this theory sufficiently large protected areas should be proposed that could guarantee the long-term existence of adequately large populations. This would enable the conservation of biodiversity and the genetic variability of populations. When this is not possible it is necessary to conserve at least the most valuable parts of the landscape and connect them via habitat corridors that can play a key role in improving the fragmented landscape for many species.

Figure 4 (left) The island biogeography model describes the relationship between the rates of colonization and extinction on islands. (Original from MacArthur Wilson 1967.)

Figure 5 (right) The island biogeography model in practice. Small island of bushes and trees in an agricultural landscape. The probability of colonization less viability species is really low and the risk of extinction of small



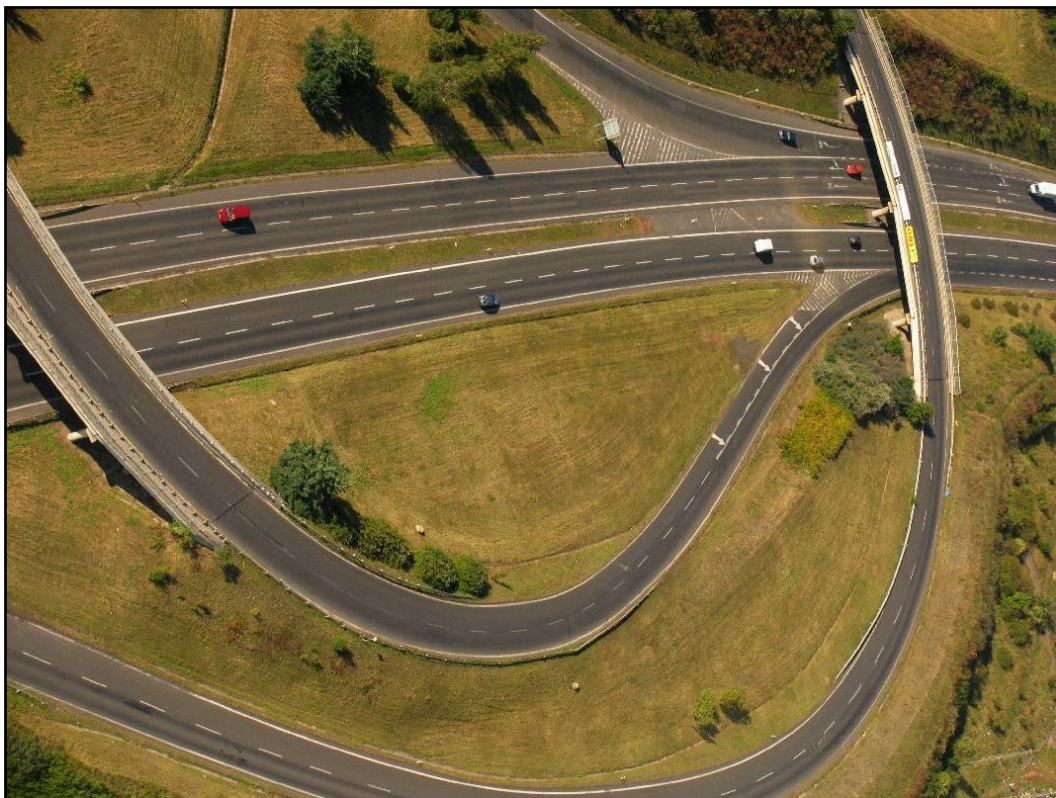


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Agreement № 2018-1-BG01-KA203-047962

Causes of habitat fragmentation

Landscape fragmentation is a process that is long a part of human history. People left the first significant imprints on the landscape during the Neolithic period through agricultural development, deforestation of large areas and permanent settlements forming. Then the process rapidly increased with mining, industrial development, and road and railway traffic. Traffic constructions cause a very serious fragmentation effect, because they form long linear barriers that are often impossible to pass (Fig. 6). Intensive development of these structures in the Czech Republic means that an increased fragmentation effect can be assumed in future (Anděl et al. 2005).

Figure 6 Fragmentation effect of highways is really serious. (Photo Markéta Hendrychová.)



Effects of habitat fragmentation

The effects of habitat fragmentation are as follows: natural habitat loss and reduction, change of landscape structure, habitat isolation and attendant negative effects of constructions (environment contamination, animal interruption, support of invasive species dispersal). Some of these effects might be quite obvious, others less evident with indirect or delayed impact (Anděl et al. 2005, Noss et al. 2006).





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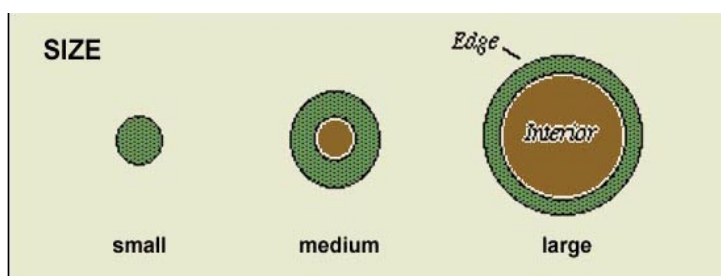
Habitat loss

Habitat loss has an apparent and immediate impact on the ecosystem; the most sensitive are rare or endemic species (Noss et al. 2006) and sessile or less mobile organisms (Trombulak & Frissell 2000). Whereas habitat loss due to traffic infrastructure development is in the first phase regarded as only local problem, extensive mining, residential zone development, industrial zone development and large-scale intensive agriculture have an impact at the regional or even national level (Trocmé et al. 2003 ex Anděl et al. 2005). However, the direct impact of traffic construction on organisms and their habitat should not be underestimated. For example in the United States, there are more than 13 million kilometres of road lanes of 3.5 m width that cover an area of 5 million hectares (Trombulak & Frissell 2000).

Edge effect

Small fragments and narrow lines of natural habitats are negatively influenced by the surrounding environment. Due to its small size there is often no interior environment that is essential for vulnerable (more specialized) species. The fragment or line then consists only of edge habitats that are exposed to microclimate fluctuations (light, heat, moisture and wind), disturbances (fire) and human exploitation (environment contamination, animal interruption, hunting etc.). These edge habitats are frequently inhabited by invasive species and species with wide ecological valence at the expense of more specialized species (Fig. 7 and 8). This leads to biodiversity reduction. The level of negative edge effect depends on the difference between the fragment and its surrounding. The edge effect is noticeable especially in forests and can be even several hundred metres to the fragment interior. The principle of ecological trap is well known: organisms attracted by the edge habitat and are then exposed to higher predation risk. Birds in edge habitat are moreover influenced by higher breeding parasitism (Primack et al. 2001, Anderson & Jenkins 2006, Noss et al. 2006).

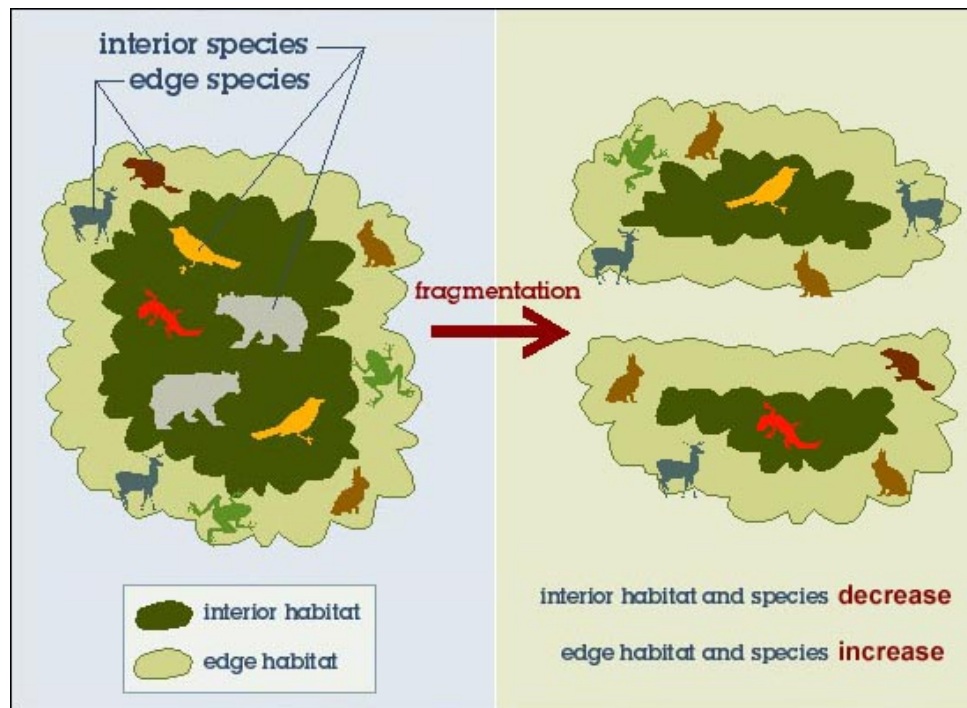
Figure 7 During fragmentation the total area of remnant habitats is decreasing (© Groom et al. 2006)





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Figure 8 During fragmentation the total area of remnant habitats is decreasing. In some cases, such habitats can consist of only edge environment, which is unsuitable for sensitive interior species. (© Groom et al. 2006)



Direct harm, animal mortality

Animal mortality caused by collision with cars is the most transparent of the negative road effects (Anděl et al. 2005). The road effect endangers most animal species. This problem is best documented for large mammals (Trombulak & Frissell 2000) for which are often proposed underpasses or green bridges when roads are constructed (e.g. Hlaváč & Anděl 2001). Road traffic threatens also small mammals, birds, reptiles and recently the negative effect on invertebrates has even been documented, especially insects. Regular migrations between aquatic and terrestrial biotopes make amphibians very vulnerable to the road effect (Mikátová & Vlašín 2002). Collisions with bigger animals can moreover cause traffic accidents and threaten road traffic safety.





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Agreement № 2018-1-BG01-KA203-047962

Box 2 Road-kill mortality

Road-kill mortality is a very real problem. For example, more than 20 000 large mammals are annually killed on the roads in Switzerland. Road-kill mortality can make up to 23 % of total mortality of the Eurasian Lynx (*Lynx lynx*) but is significantly lower (around 5 %) in other common species such as fox, roe deer or wild pig (Trocmé et al. 2003 ex Anděl et al. 2005). However, other studies conducted in Switzerland have proved that road-kill mortality is the most important cause of death for European roe deer (*Capreolus capreolus*) and Red Deer (*Cervus elaphus*) with fractions of 49.3 % and 33.2 % of total mortality respectively. The serious negative impact of road mortality has been also documented on the population of [Moose \(*Alces alces*\) in Alaska and on the](#) Barn Owl (*Tyto alba*) in Great Britain.

Disturbance and environmental contamination

Physical and chemical characteristics are changed in construction areas and their surroundings. Soil structure, surface temperature, water content in soil or evaporation can be changed. Dustiness and exhalant emission from traffic can influence photosynthesis, respiration and transpiration of plants (Trombulak & Frissell 2000). Animals are disturbed by noise, vibration, street lighting and car lights. These negative effects can be apparent even several hundreds metres from a road (Anděl et al. 2005). A number of studies have focused on chemical contamination of road vicinities with heavy metals, aromatic hydrocarbons, dioxins or petroleum products discovered. A high concentration of stratospheric ozone from vehicle exhalants causes photochemical smog. The negative impact of these chemical pollutants depends on the pollution rate and the ability of pollutant dispersal that is influenced by water and wind direction (Trombulak & Frissell 2000).

Dispersal of invasive species support

Due to fragmentation and traffic infrastructure development, the landscape is more vulnerable to expansion of alien species of plants, animals and pathogens (Noss et al. 2006). Disturbances and barriers in landscape handicap autochthonous species whereas alien species may profit and can easily access new areas (Trombulak & Frissell 2000).

Organism vulnerability to habitat fragmentation

As was already mentioned above, habitat fragmentation leads to habitat loss and isolation with many consequences for organism populations. The effects operate on different levels (from influence on genetic variability within populations up to changes in landscape structure). There are several important points on the species level that point to enhanced probability of survival in highly fragmented landscapes (Noss et al. 2006): (i) the ability to survive or even prosper in a modified landscape matrix (ii) the ability to prosper in fragments that involve mainly low mobile species with





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modest ecological requirements. It is necessary to take into account that the effects of habitat fragmentation may be delayed in species with limited mobility compared to those with higher mobility (Cushman 2006). (iii) The next strategy represented by high mobility species is based on the ability to migrate between isolated fragments. However, the longer the distance between fragments the longer time spent in a hostile landscape matrix and therefore a consequently higher risk of death (Cushman 2006). It is a good time to mention that gamete transfer is essential for preservation of genetic variability, and not mobility of their holders. In this context sessile plants may be very successful when dispersing gamete through wind, water or other animals.

A dissimilar degree of susceptibility to habitat fragmentation can be found among different species or populations. It is difficult to evaluate the habitat fragmentation effect due to its complex character (Anděl et al. 2005). For instance, high mobility species can profit from their mobility when searching for new habitats but are at higher risk of vehicles, predators and contamination during this migration. On the other hand, low mobile species are at lower risk of that type but they can easily lose their natural habitat.

Generally, species with larger territorial requirements or with regular daily or seasonal spatial dynamics are more endangered, for example amphibians, some reptiles and number of mammals (Noss et al. 2006). In addition, the habitat fragmentation effect is enhanced by the following characteristics: low mobility of individuals or gametes, special trophic or habitat requirements, low fertility and long-term development to sexual maturity.

When attempting to realise conservation plans it is impossible to satisfy the ecological requirements of all species. Then it is necessary to determine one priority species group. Big mammals are usually chosen in our conditions because of their large territory, long distance migrations, easier visibility in landscape and foreknowledge of their biology (Hlaváč & Anděl 2001).

Landscape continuity preservation

The roots of migrating animal protection and collision prevention on roads in Europe start in the 1970s. The first underpass (tunnel) with a guidance system was built in the Netherlands for badgers. The first report including the technical parameters of migration objects was created in 1978 in France. There are several studies in the Czech Republic (Hlaváč & Anděl 2001, Anděl et al. 2005, Anděl et al. 2006). Legislative protection is guaranteed there by Act no. 114/1992 on Nature and Landscape Protection, where special protected areas and the area of the Natura 2000 system are protected including their connections. When the significant effect on the environment is expected then an environmental impact of assessment according to Act. no. 100/2001 should be processed. Migration study solves permeability of given transect by proposal of migration objects. A zoological survey and area appraisal on a local, regional and national level should be completed before migration study (Hlaváč & Anděl 2001).





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Box 3 **Ecological corridors**

It is apparent that ecological corridors are fundamental features for the long-term existence of viable populations and biodiversity conservation. They can reduce the extinction risk in small populations (Gilbert et al. 1998). Ecological corridors can be easily defined as linear habitats distinguishable from surrounding a landscape matrix that play a key role in connecting separated habitats. Besides their positive significance in landscape continuity maintenance they can also work as corridors for spreading fire, pathogens and alien predators and so on. But their positive function prevails (Anderson & Jenkins 2006).

Technical parameters of migration objects

The proposal of particular technical measures should arise from the detailed zoological survey and evaluation of migration routes in accordance with the behaviour and needs of the species concerned. Migration measures comprise technical constructions (tunnels, underpasses, overpasses and ecoducts) and additional measures such as fencing arrangements to funnel animals or vegetation.





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