Bachelor Thesis

Is it more efficient to build a species-specific or a more general wildlife overpass?

An analysis focused on mammal behaviour near wildlife overpasses.

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Abstract
In the three years after construction, only five individuals have used a bridge for squirrels in The Hague. That raises the question if these species-specific wildlife overpasses are worth the money to build them. This thesis focuses on the behaviour of several mammal species in relation to wildlife overpasses. There are animals that are not afraid of roads and the only reason to build crossings for them is to avoid animal-vehicle collisions. Some animals stay near linear corridors for excellent living conditions or because they are aware that prey make use of the same corridors. Most mammals make use of wildlife crossings at night most likely because there are fewer vehicles and less noise.
Studies suggest that there are a few crossing individuals needed to maintain gene flow between populations. To get these few individuals it's probably not a good idea to build bridges (like the one in The Hague) that can only be used by one species, but more research needs to be done.
When building or expanding a road there are a few requirements to keep in mind to mitigate habitat fragmentation. There are different types of over- and underpasses, which are aimed at different species. Larger species need a wider overpass. Overpasses can't elevate too steeply because crossing animals must be able to see the other side of the bridge. Local studies are preferred to find the most suitable crossing, since there is no single best solution to mitigate habitat fragmentation.
Finally I could conclude that most Dutch overpasses are around the suggested size.

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Introduction

Last year only two individuals used a bridge for squirrels (figure 1) in The Hague. (NOS, 2016). According to Hennie Greven of the Dutch Society for the Protection of Animals the bridge was needed to connect two squirrel habitats (Omroep West, 2012), but opponents consider the 150,000 euros spent on the structure as wasted money because of the little use of the bridge.

Figure 1 Squirrel Bridge crossing the Benoordenhoutseweg in The Hague, NL. (Omroep West, 2012)

Most conservation biologists agree that landscape connectivity can enhance population viability for many species (Beier and Noss, 1998). There are several structures that connect fragmented habitats (Kintsch and Cramer, 2011), but little is known about their efficiency. In the present thesis, I focus therefore on the differences in behaviour of Dutch species in relation to wildlife overpasses or similar structures, since roads are a major contribution to habitat fragmentation (Beier and Noss, 1998 and Corlatti et al., 2009) especially in the Netherlands where urbanization is a big problem for several populations (Bank et al., 2002). Wildlife crossings can mitigate habitat fragmentation (Corlatti et al., 2009) by maintaining genetic diversity and reducing vehicular accidents with fauna (Bank, 2002). Specific solutions like fences, signs, habitat enhancing, underpasses and/or overpasses exist, but can also be combined into one general overpass (Bank et al., 2002). One problem with the general overpasses is the specific behaviour of every species. Different species possibly behave differently towards linear corridors and thus wildlife overpasses. Also species might interact with predators near the overpasses. (James and Stuart-Smith, 2000). There might be species that don't respond to roads as barriers and thus, assuming there is no high vehicular accident risk, don't need a bridge to cross them. Beier and Noss (1998) argue that money that goes into wildlife crossings might be better spent in improving current habitats. In this thesis I want to study the behaviours of several Dutch mammals that crossings are aimed at or make use of these crossings. Therefore I looked at several articles that described the behaviour of species near overpasses and similar structures. I aim to predict whether it is advisable to make species-specific wildlife overpasses or that it's more efficient to always build a (bigger) more general overpass that can be used by a broader range of species. To make this prediction I want to look at the current efficiency of wildlife crossings.

Name	Typical species to pass
Small Underpass	Amphibians, small mammals
Medium Underpass	Coyote, bobcat
Large Underpass	Deer, elk, black bear
Extensive Bridge	Most wildlife – wary species
Wildlife Overpass	**Most wildlife, including birds**
Specialized Culverts	**Reptiles & amphibians**
Canopy Bridges	**Flying squirrels, arboreal rodents.**

Table 1: Seven types of crossings with the typical species known to pass each structure (Kintsch and Cramer, 2011).

Wildlife crossings in the Netherlands

A study by Kintsch and Cramer (2011) defined seven different types of crossings of which three were overpasses. Those crossings are mentioned in table 1.

Logically, different animals use different types of crossings. The larger the animal is the larger the structure has to be for the animal to cross it (Kintsch and Cramer, 2011; Beben, 2012; Corlatti et al., 2009).

In the Netherlands most overpasses have a width of 50 metres with the smallest having a width of just 10 metres (including a cycle path, see Figure 2).

Figure 2 Slabroek ecoduct (A50), North Brabant, between Oss, Uden and Nistelrode. The bridge is 10 metres wide and has a cycle path. It was constructed to mitigate the extension of the A50 (Bekker et al., 2011; photo: Wim van der Ende)

How do the Dutch mammals that crossings are aimed at behave in relation to wildlife overpasses?

There are currently 106 mammalian species that have visited or lived in the Netherlands the past 10 years (Dutch species register, 2016). In this research I only focus on species that currently live in or visit the Netherlands, or resemble species that do so. The species included in this research are: the wolf (*Canis lupus*), caribou (*Rangifer tarandus*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), moose (*Alces alces*), wild boar (*Sus scrofa*), European badger (*Meles meles*), red fox (*Vulpes vulpes*), canids, cats (*Felis* spp.), weasel (*Mustela nivalis*) and black rat (*Rattus rattus)*. Canids and cats were grouped because they were also grouped in the study of Mata et al. (2008).

Wolves

Wolves (*Canis lupus*) lived in the Netherlands until around 1897 (Gravendeel et al., 2013). In March 2015 however it has been spotted in Drenthe (NOS, 2015). Gravendeel et al. expect a re-appearance in the Netherlands to be likely, since European wolf populations have been expanding since 1950.

They are social animals that live in packs and when an individual is old enough it disperses from their natal pack (together with another individual of the opposite sex) to start a new pack. Even though they are social animals they are predators that tend to hunt solitary. As a predator it can have a big influence on other species (Mech, 1999).

The wildlife overpasses in the Netherlands are not aimed at wolves yet, but the Dutch government did look at similar designs for overpasses that are aimed at wolves in Poland (Bekker et al., 2011).

Wolves favour linear corridors over other landscapes since they were found more at and closer to linear corridors than expected by chance (James and Stuart-Smith, 2000). If they tend to live near or at linear corridors (like overpasses) they might be a big risk to potential prey species (Mech and Biotani, 2010) such as Red Deer (*Cervus elaphus*), Roe Deer (*Capreolus capreolus*) and Wild Boar (Sus scrofa). They can stay close to those sites making them uncrossable for these other species.

Red Deer

A huge population of around 3000 Red deer (*Cervus elaphus*) lives in the Oostvaardersplassen. They were introduced there in 1983 (Cornelissen et al., 2014).

They live in herds consisting of individuals from the same sex. Once a year mature stags try to attract the females during the mating season. Red deer tend to move the largest distance during the day compared to the night (Clutton-Brock et al., 1982).

All the overpasses in the Netherlands are aimed at Red deer (Bekker et al., 2011) and

they also make use of them (Mata et al., 2008; Corlatti et al., 2009).
Beben (2012) found that they almost only go over crossings at night time. Which isn't logical considering their normal behaviour, but can be explained by Frantz et al. (2012). They identified two genetic subpopulations whose borders matched a motorway. The motorway had no fences and the deer should be able to cross it. Somehow the deer did not cross the road, so there should be another reason why the deer were not able to cross it. Frantz et al. (2012) concluded that the deer are afraid of the fast moving vehicles and therefore see them as a barrier.

Roe deer

Roe deer (*Capreolus capreolus)* occur in the Netherlands (Lovari et al., 2008).
They are capable dispersers, have a high reproduction, high mortality and are constantly looking for new living space. They prefer to stay away from other animals, but can live in large herds (Geist, 1998).
Hepenstrick et al. (2012) suggests roe deer have no problems crossing unfenced railway tracks and roads. There was no effect of unfenced railway tracks and roads on gene flow, but fenced ones reduced gene flow. That possibly means roe deer are not avoiding roads like other animals seem to do, but are only blocked by roads because of physical barriers like fences. The overpasses in the Netherlands are aimed at roe deer in combination with fences to reduce animal-vehicle collisions (Bekker et al., 2011).
Corlatti et al. (2009) suggest that roe deer also make active use of overpasses. Roe deer crossed two overpasses in France even though the overpasses were small and also used by humans (Corlatti et al., 2009). No roe deer in a study in Spain made use of overpasses and instead used underpasses (Mata et al., 2008). There was a higher gene flow for roe deer between populations next to highways with wildlife corridors compared to highways without corridors (Burkart et al., 2016).

Caribou

The caribou (*Rangifer tarandus*) does not occur in the Netherlands, but is closely related to roe deer. They live in selfish herds, which means they attempt to reduce predation risk by putting other individuals between themselves and predators (Hamilton, 1971; Geist, 1998).
Similarly to roe deer they are capable dispersers. They quickly colonize uninhabited land because of their wide-ranging movements (Geist, 1998). A high mortality was linked to wolf predation (James and Stuart-Smith, 2000).
There are no overpasses aimed at caribous yet. Sweden avoids caribou-vehicle collisions with other measures like clear road verges and detection equipment.
Caribous avoid linear corridors in response to wolf activity since wolves move closer to these corridors. Caribous did not show this behaviour when high quality forage was available and risk of encountering wolves (or humans) was low (James and Stuart-Smith, 2000).

Moose

Moose (*Alces alces*) do not occur in the Netherlands. They are however occasionally recorded in Germany (Henttonen et al., 2008).
They also move over large areas like roe deer and caribou (Barzke et al., 2015). Not all member of a population will migrate. The distance an individual migrates differs a lot between individuals (Bunnefeld et al., 2010).
In Sweden there are several overpasses aimed at moose (Olsen and Widen, 2008). Olsen and Widen (2008) concluded moose bulls crossed wildlife overpasses more often than moose cows.

Wild boar

The wild boar (*Sus scrofa*) is widespread in Europe in most continental areas, including the Netherlands (Oliver and Leus, 2008).
According to Herrero et al. (2008) wild boars are able to live and feed in very diverse ecological conditions. Normally wild boars live in groups of around 20 individuals. Adult

males live alone outside of a breeding cycle (Aree protette della Valle Sesia, 2015). Wild boars are most active in late afternoon and the early morning, but are sometimes active at night in disturbed areas. Studies in southern France showed wild boars generally traveling around 2-15 km per night. (Oliver and Leus, 2008).

Overpasses in the Netherlands are aimed at wild boar (Bekker et al., 2011). Frantz et al. (2012) found a motorway in Belgium not to be a gene flow barrier for wild boar, so the aim of the overpasses is most likely to reduce animal-vehicle collisions.

Wild boars do not seem to have a problem with overpasses since they make actively use of overpasses all over Europe (Beben, 2012; Corlatti et al., 2009; Mata et al., 2008). In France they were observed crossing a small overpass that was also used by humans (Corlatti et al., 2009).

Eurasian badger

The Eurasian badger (*Meles meles*) is native in the Netherlands. They have very large home ranges with a mean of about 15 km^2 (Kranz et al., 2008). They spend most of their time underground in burrows, live mostly solitarily, but are able to recognize members of the same clan. They do not defend a specific area against other badgers (Kruuk, 1978). According to Kranz et al. (2008) their populations are not severely fragmented. Therefore the might not need wildlife crossings. In the Netherlands there are special underpasses, but they can use existing overpasses as well (Bekker et al., 2011). When given the choice between over- and underpasses they mostly use the latter (Mata et al, 2008)

Red Fox

The red fox (*Vulpes vulpes)* has the widest geographical range of all carnivores. They occur in the Netherlands and are observed in highly humanized environments (Macdonald and Reynolds, 2008). They are nocturnal-crepuscular, but most of their activity is dependent of the availability of their prey, the rabbit (Diaz-Ruiz et al., 2016).

Overpasses in the Netherlands are also aimed at red foxes (Bekker et al., 2011). Normally red foxes only go over wildlife overpasses at night time (Beben, 2012), but they use other structures like underpasses as well (Mata et al., 2008; Corlatti et al, 2009).

Canids

Social behaviour is similar throughout the family of canids. They often don't hunt in groups with the odd exception like the dingo (Kleiman, 1967). Overpasses in the Netherlands are not aimed at canids (Bekker et al., 2011). Mata et al. (2008) found canids to be one of the most common users of overpasses when compared to other mammals.

Cats

The wild cat (*Felis silvestris*) is extinct in the Netherlands, but may be expanding its range from other parts of Europe and recolonize Europe. The domestic cat (*Felis catus*) is one of the worlds most numerous mammals and is very commonly found in the Netherlands (Yamaguchi et al., 2015).

Cats are active at day and night, but usually more active at night. They live close to human settlements and the size of their home-range is correlated to their own size (Germain et al., 2008). While wildlife overpasses in the Netherlands are not aimed at cats, they use wildlife crossings once per day, a little less than canids (twice per day) (Mata et al., 2008).

Weasel

The weasel (*Mustela nivalis*) is native in the Netherlands (Tikhonov et al., 2008).

Small mustelids like the weasel usually have large home-ranges and therefore have to cross roads often. They have a preference for covered areas (Van Vuurde and Van der Grift, 2005).

The weasel population is declining in some areas and might need crossings. In the Netherlands they mostly build underpasses, but overpasses are aimed at them as well (Bekker

et al., 2011). Weasels get used to wildlife crossings (mainly underpasses) very quickly (Van Vuurde and van der Grift, 2005).

Black Rat

The black rat (*Rattus rattus*) is an introduced species in the Netherlands. It is commonly seen as a pest. It can be found in a variety of natural and semi-natural habitats (Amori et al., 2015).

Overpasses are generally not aimed at rats as they are commonly seen as a pest (Bekker et al., 2011). Rats do however make active use of overpasses, more so than underpasses or other crossing structures (Mata et al., 2008).

It does not look like animals that naturally move or migrate a lot are using the bridge more than animals that don't. Wild boar and roe deer have no problem using overpasses and are also capable dispersers (Oliver and Leus, 2008; Geist, 1998), but roads do not seem to act as barriers to them (Frantz et al., 2012; Hepenstrick et al., 2012). Caribou are capable dispersers as well (Geist, 1998), but they avoid linear corridors (James and Stuart-Smith, 2000).

Bigger mammals such as red deer, caribous and moose have cross overpasses less often than smaller mammals such as wild boars, badgers, foxes, canids, cats, weasels and rats (Mata et al., 2008).

Roads as barriers

Roads can act as barriers for several reasons. They act as a physical barrier when high fences are present, as seen in the study of Hepenstrick et al. (2012) where roe deer had no problems with crossing unfenced railways, but they did not pass fenced roads. Sometimes fences are placed next to motorways to avoid animal-vehicle collisions, but they can also be placed to guide animals towards wildlife crossings (Bank et al., 2002).

Another way for roads to act as a barrier occurs in the case of animal-vehicle collisions. The animals near busy roads cannot make it to the other side alive and therefore there is no gene flow between populations on both sides of the road (Corlatti et al., 2008). The last effect is a behavioural one. Animals can start avoiding motorways because of several reasons. It can be a reaction to road kills (Clarke et al., 1998), but most animals like roe deer are generally shy of other species including humans and stay away from noises (Geist, 1998).

Not every species is affected by this effect. Frantz et al. (2012) found a motorway that was a barrier for movement for red deer, but not for wild boar. The same road was crossed by wild more very often while the red deer in the research were split into two populations which habitats aligned with the road. Moose were found not to cross combinations of linear structures like combinations of roads and pipelines, while they had no problems crossing single linear structures.

High road use by traffic discourages badgers to cross roads (Clarke et al, 1998). Wolves are found to be an exception and are attracted to linear corridors. As long as humans make little use of the roads wolves actually tend to make use of the straight and flat roads to move quicker (James and Stuart-Smith, 2000). According to Jaeger et al. (2005) small mammals tend to show road surface avoiding behaviour. Larger mammals show more car-avoiding behaviour on average.

Excluding some exceptions (that I mentioned before in this thesis) it is generally accepted that roads act as barriers for wildlife (Holderegger and Di Giulio, 2010).

Genetic isolation

Genetic isolation is a problem for small habitats. When a habitat is fragmented, genetic diversity falls considerably (Beier and Noss, 1998). There are studies that show habitat fragmentation by roads influence the population genetic structure of small- to large-sized mammals (Corlatti et al., 2009; Mansergh and Scotts, 1989; Frantz et al., 2012). Animal crossings are therefore necessary for the preservation of genetic diversity of mammals (Beben, 2012). Corlatti

et al. (2009) state that an overpass is only efficient if it will guarantee the survival of a population by preventing genetic isolation. The number of individuals that are needed is species dependent. Moose for example only need 5-7 individuals crossing to maintain gene flow (Olsson and Widen, 2008).

Negative effects of overpasses

There are also still some negative effects suggested by Beier and Noss. (1998) They noticed that the bridges might actually help spread diseases between populations or wildfires. They also mention that wildlife crossings might lure animals into areas with a high mortality risk, such as the habitat of a predator. Predators may also stay around the overpasses for easy prey like the wolves favouring corridors (James and Stuart-Smith, 2000). Black rats have been shown to stay around corridors that made bush rats more hesitant to cross those corridors (Downes et al., 1997).

How efficient are wildlife overpasses?

To know how efficient overpasses are we have to know the goals of wildlife crossings. Is the use of the structures by animals enough to call a crossing efficient and if so, how many individuals have to cross in order to make it efficient?

Wildlife crossings can have several goals. They can prevent animal-vehicle collisions by giving animals a safe way of traveling to the other side of a road. They can also be used to give the general public the feeling that something is being done for the wildlife (Bekker et al., 2011). They might also be able to mitigate habitat fragmentation by reconnecting populations and therefore maintaining gene flow (Corlatti et al., 2009).

How efficient an overpass is depends on the aim of it. You can't call an overpass that is aimed at mitigating habitat fragmentation efficient because there are less animal-vehicle collisions.

Another important aspect of the efficiency of wildlife crossings is time. Animals need time to habituate to the new crossing. It took five years after construction of a wildlife crossing in Poland for the first deer and wild boars to be observed to cross the bridge (Beben, 2012).

Requirements overpass

To make overpasses as efficient as possible they have several requirements.

The biggest factor for the number of animals that use the overpass seems to be size. Mammals use wider overpasses more often than narrow ones (Bank et al., 2002; Kintsch and Cramer, 2011; Beben, 2012; Corlatti et al., 2009), as seen in Figure 3. Another reason to go for a wide overpass seems to be the behaviour of mammals. Wider overpasses allow more natural behaviour (Bank et al., 2002). For example, there is evidence that large overpasses, with lots of active seeding and planting for cover, are actually used by animals not only to cross but also as foraging habitat (Bank et al., 2002).

There is some discussion about the minimum size of overpasses. According to Corlatti et al. (2009) overpasses have to be at least 60 metres while Beben (2012) states they only have to be 50 metres. Beben mostly derived his conclusion from the data (Figure 2).

Location, cover and visual appearance all affect overpass use by mammals (Corlatti et al., 2009). An overpass at location with few mammals will be crossed less often. Some mammals, like weasel prefer covered areas (Van Vuurde en van der Grift, 2005) and will therefore use less covered overpasses less often.

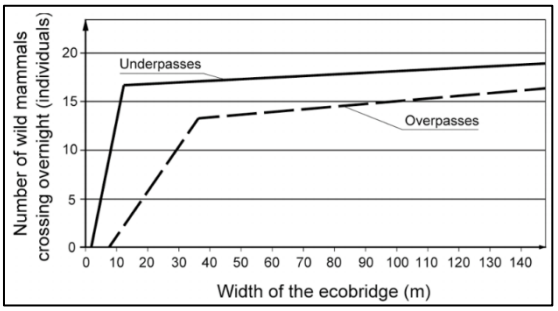

Figure 3: Frequency rates of using overpasses and underpasses by mammals (Beben, 2012)

When and where to build a wildlife crossing?

The populations most vulnerable to the negative impacts of roads are those with high noise avoidance (observable in many birds) and high road surface avoidance (observable in many small and large mammals (e.g. rodents and caribou respectively)) (Jaeger et al., 2005).

According to Jaeger et al. (2005), roe deer are relatively insensitive to traffic mortality because they can compensate the high mortality rate with a higher reproduction rate. Thus building an overpass to keep roe deer population size intact is thus unnecessary. Overpasses that reduce vehicle collisions and thus increase the safety of drivers might be a better option, but fences are cheaper and easier to make. Fences are physical barriers, which reduce gene flow. This can be increased again by building wildlife overpasses (Burkart et al., 2016).

Jaeger et al. (2005) made several predictions about when populations are most vulnerable to roads. They predicted that a population sensitive to habitat loss, with animals that need big habitats (e.g. wolves, because they need a large area to hunt), would be most vulnerable to roads if the individuals tend to avoid noise. A population sensitive to mortality (with a small population and/or low reproduction rate) would be most vulnerable to roads if individuals do not avoid crossing roads (e.g. wild boars (Frantz et al., 2012)).

Before building a wildlife crossing it is important to do a lot of research about what animals live near the (new) road and which ones are most affected. Mammals with a high sensitivity to mortality are not influenced a lot by low speed and low use roads, while the same roads can fragmentize habitats. So a population sensitive to habitat loss would need an overpass.

Beier and Noss (1998) suggest that sceptics of corridors should prove disvalue of each crossing. They should prove that not building new overpasses does not harm animal populations.

Discussion

Roads seem to be a widely accepted source of habitat fragmentation (Corlatti et al., 2009). This fragmentation is a threat to a lot of species (Vermeulen, 1994). While it is uncertain if wildlife overpasses are able to prevent genetic isolation (Corlatti et al., 2009), there is no doubt that lots of animals actually make use of them (Beben, 2012; Mata et al., 2008; Corlatti et al., 2009, James and Stuart-Smith, 2000). Most animals seem to make use of them at night time when there are less cars and thus less noise.

There is little research available on (species-specific) overpasses, because most studies focus on other structures like underpasses or culverts. The only things known about species-specific overpasses are some examples like the squirrel bridge in The Hague (NOS, 2016; Omroep West, 2012).

I don't agree with Beier and Noss (1998) that sceptics have to prove the disvalue of wildlife overpasses. There is too little research to really conclude that overpasses are the best option while there is enough evidence that underpasses do work. There are few studies with a good before-after design or comparing similar treated and untreated sites (van der Grift et al. 2012). If corridors get placed at specific patches that are already "better", it is difficult to conclude that the benefits are due to corridors or other factors in these patches (Beier and Noss, 1998). The few studies show different behaviours by the same species at different locations. Which makes it hard to make clear conclusions. As a society we have to ask ourselves what we expect from wildlife crossings.

A big concern of sceptics is that overpasses are of questionable or unproven value and that money is better spent at more proven solutions like improving the quality of habitats (Beier and Noss, 1998).

The last questions that arise are:

Are overpasses only effective when they mitigate the genetic isolation as Corlatti et al. (2009) suggest? Or do other uses like feeding

or connecting living areas also make overpasses more efficient?
How long do we have to wait before we can call an overpass (in)efficient?
Five years is a long time and might be too long for governments (or possibly companies) as they want to see results as quickly as possible.

Conclusion

Although local research is preferred, we can make some general conclusions for when there is little time and / or money.
Wider overpasses are used by more and larger species than small overpasses (Kintsch and Cramer, 2011; Beben, 2012; Corlatti et al., 2009). Some mammals tend to show more natural behaviour on very large overpasses (Bank et al., 2002). It might be a good idea to build wide overpasses to get animals as close as their natural behaviour as possible.
Most of the Dutch overpasses are around the suggested size (Bekker et al., 2011) of at least 50 – 60 metres.
If we want large numbers of animals pass them we can go for underpasses. And if we want animals to behave as closely to their natural behaviour as possible it's best to go for as large overpasses as possible, but those might be too expensive or too difficult to build.
Almost four years have passed since the construction of the Squirrel Bridge in The Hague. Other small rodents like the black rat make active use of overpasses, so although the five years Beben (2012) found haven't passed yet I think it's safe to conclude that this bridge isn't efficient.

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