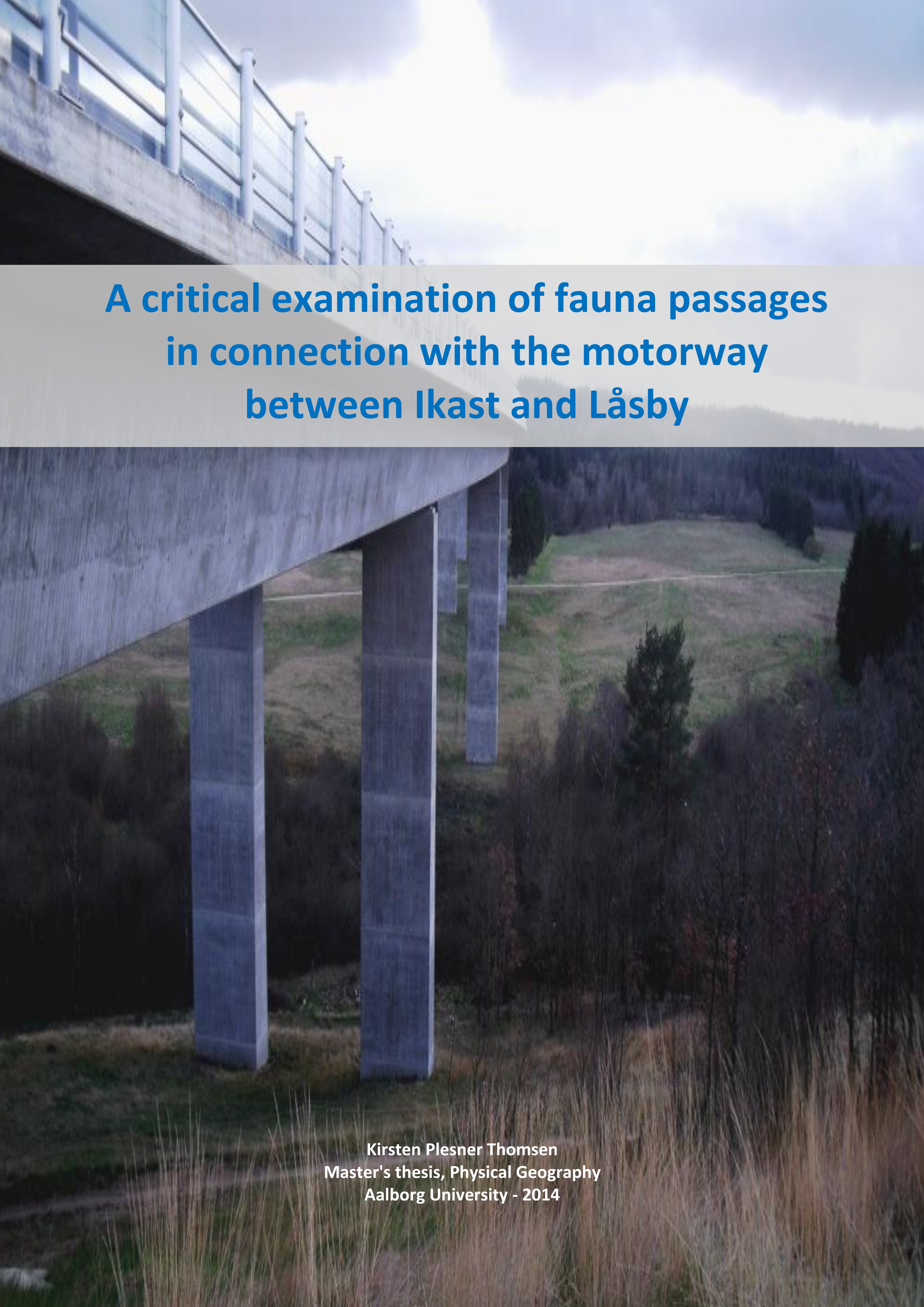

A critical examination of fauna passages in connection with the motorway between Ikast and Låsby

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Title page

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Preface

Much attention has been directed to the motorway between Herning and Aarhus, especially on the effect this large scale project will have on the surrounding countryside. Therefore, it is relevant to take a closer look at the initiatives taken in order to reduce the barrier effect which the motorway poses now and in the future.

This report provides a brief explanation of how fauna passages should be designed as well as a review of existing fauna passages on the motorway between Ikast and Låsby. These fauna passages have been studied and will be evaluated on their compliance with current requirements. An assessment of whether they may be able to be improved and whether there is a need for more fauna passages in this area concludes this report.

During the development of this report, several external sources have been consulted: Thank you to Aksel Bo Madsen, who assisted in shaping this project and suggested relevant literature, and to Niels Krogh Kristensen from the Danish Road Directorate, who provided maps and an understanding of the process behind the planning of a motorway. Also a thank you to the supervisor of this thesis, Morten Lauge Pedersen from Aalborg University.

Reading guide
A source refers to the text below the last source of that same section. Figures derive their number from the chapter they are presented in. The first figure in Chapter 1 is thus denoted Figure 1.1, the second figure Figure 1.2 , etc. This also applies to the tables in the report.

Aalborg University, 2^{nd} of June 2014

Kirsten Plesner Thomsen

Abstract

When motorways are constructed, the barrier effect may be so great that no further exchange of genes between populations on either side of the road takes place. This may result in a very small gene-variation, which in turn could threaten survival of the species in a given area. For some species the extinction of a given population can have major consequences, and it is therefore important to ensure that it is possible to cross the road.

Different guidelines of how to achieve this exist in different countries. This report examines the guidelines from Denmark, Austria and California. However, it is difficult to apply the lessons learned from other countries in Denmark, because nature reserves in Denmark are more affected by humans, and many natural habitats are highly fragmented.

This report takes the motorway between Ikast and Låsby as its starting point. Here, the fauna passages are investigated. From these studies, the quality of the fauna passages, the location of them and the need for placement of additional fauna passages are all analyzed. On the basis of both these analyses and relevant literature, new recommendations are given.

Although it is possible to detect an improvement in the development of fauna passages along the new route compared to older stretches, it is clear that there is still a lack of knowledge in order to place the fauna passages as optimal as possible. In this connection, behavioral studies of the different species in relation to motorways are of particular interest, yet still lacking.

Contents

Introduction 1

The construction of larger facilities such as motorways and wind farms, especially those which might have a negative impact on nature and the environment, are of special interest to the public. The establishment of the National Test Centre for Wind Turbines in Østerild, for instance, was met by several protests and complaints from the Danish Society for Nature Conservation and the public [Naturstyrelsen, 2012], as was the plan to construct a motorway between Herning and Aarhus in 1990: The government had decided to build a motorway connecting Herning and Aarhus and citizens from Silkeborg and the surrounding areas engaged in vehement resistance to this project in order to defend a large nature preservation area near the city of Silkeborg. Citizens who protested thought that they had good chances to win the case [Danmarks Radio, 2008], and protests continued until 2009, when the Danish parliament enacted the law "Forslag til Lov om anlæg af motorvej mellem Funder og Låsby (rute 15)". Now, the motorway is scheduled for completion in 2016 [Vejdirektoratet, 2014].

When large facilities like those mentioned above are established, there are several reasons for protesting. Protests are often led by environmentalists, whose main aim is to protect nature. Nowadays, fragmentation is considered to be one of the greatest threats to animal and plant survival, as well as one of the biggest factors affecting the distribution of species in the man-made landscape [Hammershøj og Madsen, 1998]. When roads are built, habitats suffer modifications and losses, which have an adverse effect on the populations that depend on those habitats. The road will lead to increased disturbance at the edge of the habitat and, since habitats often become smaller, this will result in a higher disturbance of the habitat core area. Roads passing through habitats will also divide and isolate populations, as they will act as a barrier for many animals. This can be an obstacle to the survival of certain populations. In addition, the expansion of the road network and increased traffic intensity may increase the number of road-killed animals [Andrews, 1990].

Since 1982, traffic levels in rural areas increased annually by 7% [Andersen et al., 2002]. According to Elmeros et al. [2014], there were 33,605 road-killed larger animals between 1st of January 2003 to the end of 2012. The distribution of animal groups killed by accidents on roads is shown in the chapter "The extent of road-kill". The difference in the distribution of road-killed animals is due to the method used for the records and calculations. This methodology shows the difficulties of procuring a clear picture of the total number of road-killed animals. This uncertainty is confirmed by the "SCHWEISS" register. Every year, this register receives approximately 5,500 calls with information about injured cloven-hoofed animals. Most of the damages to animals are reported by people that have seen the injured animal or by witnesses to the accident, and not from those responsible for the accidents [Danmarks Jægerforbund, 2013]. For insurance companies, accidents with animals often are included in the same group as other car accidents. Not only does this situation complicate the estimation of the real annual economic cost of road-killed animals, but it also makes it difficult to prove the need for wildlife passages in connection with the roads. However, in Sweden it is estimated that accidents with wild animals cost 1 billion Swedish kroner a year, while the cost is estimated to mount up to 120 million Norwegian kroner a year in Norway [Andersen et al., 2002].

Consequences of the fragmentation of the landscape 2

Fine patterned fragmentation creates areas that are smaller or the same size as the individual's home range. This is positive for organisms that can exploit new habitats such as roadside verge. However, it has a negative impact on species that are habitat specialists. Here, the new fragments can become too small for the survival of the species [Andrews, 1990] [Hammershøj og Madsen, 1998]. In addition, the small fragments lead to a greater edge effect, that will result in different wind and sun conditions and hence a different microclimate. It is therefore important not to disturb the core of the area of a given habitat and to place for instance roads at the edge of this area instead of closer to the core [Andrews, 1990]. Coarse pattern fragmentation results in bigger fragments which a local population can inhabit [Hammershøj og Madsen, 1998].

Smaller areas often have a small population, which means that the risk of a given population to die out is greater than in large areas, where the population tends to be larger [Hammershøj og Madsen, 1998]. When a habitat has few individuals, it is important that there are good opportunities for immigration from other populations to ensure that the species remains in the habitat without becoming extinct as a consequence of a lack of among other things recolonization and gene exchange [Hammershøj og Madsen, 1998] [Turner et al., 2001]. The distance between the two populations is often decisive for how good immigration is. Furthermore, the environment and matrix habitats (with due regard to their size, grade of isolation and position in relation to each other) play an important role in this connection [Andrews, 1990] [Hammershøj og Madsen, 1998]. When a motorway is constructed, the factor determining the immigration is the road, since it acts as a barrier. In this context, the distance between populations is of lesser importance [Hammershøj og Madsen, 1998]. This applies to fauna as well as flora, as several plants spread through animals by, among others, being eaten or caught in the fur. Therefore, the barrier effect created by a motorway will also have a negative effect on flora dispersal and gene exchange [Jensen og Vestergaard, 2007].

As has now been explained, the fragmentation of the source and sink habitats can have a major effect on the survival of the species. Particularly, the distribution and location of various habitats is important for the entire metapopulation [Hammershøj og Madsen, 1998]. Therefore, it is important to ensure that the fauna has access to the habitats situated on the other side of the road. This can be done via fauna passages. Fauna passages can contribute to maintain populations in sink habitats, since they provide better opportunities for individuals coming from a source habitat to immigrate to a sink habitat.

Apart from fragmentation, road construction also leads to major changes in the landscape. Digging the roads may result in increased sedimentation of water bodies. Furthermore, the vegetation in and around the future road will be affected by vehicles, among others. The new exposed areas provide the basis for the establishment of a different flora and fauna species. Vegetation on the roadside verge is often mowed and sprayed, which has important implications for the newly established plants and animals [Andrews, 1990].

A biotope loss of more than 60% will result in isolated fragments in the landscape [Hammershøj og Madsen, 1998]. This impedes immigration and emigration, which will be reduced significantly. When the landscape is destroyed and there are less than 20% of a given biotope left, there is a risk for the specific species of the associated biotope to become extinct [Hammershøj og Madsen, 1998]. This is partly due to an increased distance between fragments, since the biotope specific fauna needs to use more energy to find food resources. Thereby, the risk of dying of hunger increases. This exposes them to greater risk of dying, partly between populations and partly within the animals' own home range [Hammershøj og Madsen, 1998]. The addition of small amounts of source habitats to the landscape can increase the size of the total population. However, if just a few source habitats for large populations are destroyed, population size can suffer major consequences [Turner et al., 2001].

The genetic distance between populations might increase with fragmentation [Hammershøj og Madsen, 1998]. Furthermore, the ability and willingness of some animals to cross roads might result in a greater distance between populations. This will result in a loss of genetic variation, which may have serious consequences for the population. When no new individuals immigrate to a habitat, genetic homozygosity can increase. This would make the population more vulnerable to impacts such as diseases. Therefore, a genetic variation between local populations can be an advantage if individuals are allowed to reproduce with other populations. The distance between them determines how much genetic variation exists between two habitats. The greater the distance, the larger the genetic variation. In the case of flora, it is habitat type, size and spatial distribution of the habitat that affects the extent and distribution of genetic variation. A significant loss of genetic variation can also occur if a population size (N) is relatively large and the genetically effective population size (Ne) (the amount included in the reproduction) is low [Hammershøj og Madsen, 1998].

2.1 The road as a barrier

Roads represent barriers to, among others, beetles and small mammals (see Figure 2.1) and thus can cause a reduction of the gene flow between populations. If the vegetation on the roadside is removed, the barrier is further increased [Andrews, 1990] [Hammershøj og Madsen, 1998]. Experiments have shown that even small roads can act as barriers. This has been demonstrated in Kansas with a 3 metres wide road, consisting of two strips of land with vegetation. It was used by 10-20 vehicles per day and it represented a barrier to prairie voles and cotton rats. The undisturbed vegetation of the roadside can serve as a corridor for many animals. Depending on the management of the roadside, it can also be subjected to the invasion of predators and plants [Andrews, 1990].

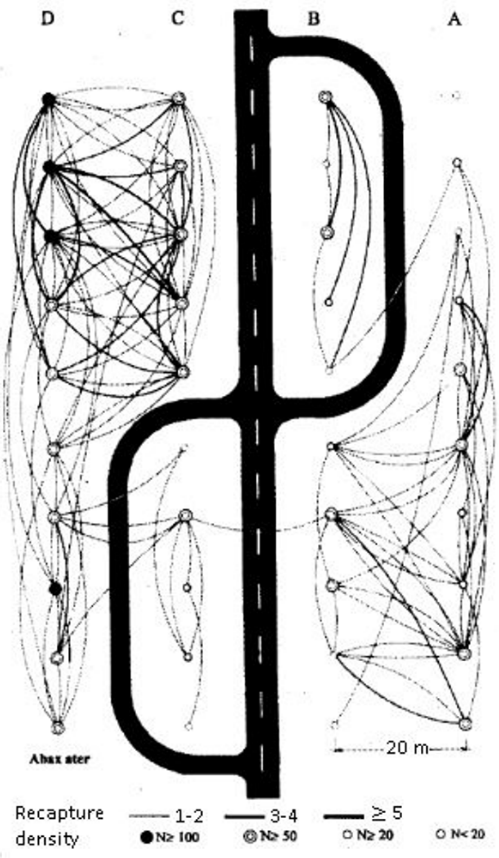

Figure 2.1: Mobility diagram showing the barrier effect of a road on a population of ground beetles. A-D = capture lines, circle = live catch traps. Curved lines indicate a marked animal movement between capture and recapture [Hammershøj og Madsen, 1998].

When a road is constructed, movement patterns of butterflies, arthropods and small mammals are altered, and they will move more along the road than across it. Amphibians are another group of animals which are negatively affected in their movement pattern by road construction. Furthermore, they are sometimes prevented from migrating between their natural summer and winter locations. In addition, studies show that populations of amphibians decrease as traffic intensity increases due to, among others, the death of several amphibians in traffic [Hammershøj og Madsen, 1998].

Studies have shown that bank voles and shrews are bad at recolonising areas after the establishment of a road. Moreover, in landscapes fragmented by roads, there are less inhabited badger's burrows and the number of occupied badger's burrows decreases after a road is built [Hammershøj og Madsen, 1998]. In Denmark, Pertoldi et al. [2001] establish that badgers can be divided in up to 5 subpopulations in Jutland. The gene variation in these populations are small and some places were the banding patterns monomorphic or close to. The reason for the small genetic exchange is partly due to motorways and therefore it is important to build fauna passgers where the gene flow is reduced or not are disturbed [Pertoldi et al., 2001]. Particularly motorways prevent small mammals from moving from one area to another across the road, which prevents recolonisation. Roads also have a negative impact on the population of breeding birds; these are impeded from recolonising areas [Andrews, 1990]. Even large mammals are disturbed by roads and often wander at quite a distance from the road. This means that their habitat is not only reduced by the road space, but also by an additional area beside the road [Andrews, 1990].

The most vulnerable animals to habitat fragmentation are animal groups containing species with relatively low population density, which breed slowly and are often less mobile. These are particularly mammals, whose hypothetical sequence of population size development with a disturbance is described below (see Figure 2.2) [Hammershøj og Madsen, 1998].

1. First, the population size decreases gradually and eventually it will die out if there is a certain fragmentation level [Hammershøj og Madsen, 1998]. This fragmentation level will probably depend on the species.
2. The population increases at first, then gradually diminishes. At a certain fragmentation level, the population will become extinct. This applies to many edge species [Hammershøj og Madsen, 1998].
3. In this hypothesis, an early marked increase of population is followed by a gradual decrease, and it occurs at an earlier fragmentation level than the hypothesis previously described. This occurs typically to species that inhabit different habitats, including both semi-natural and matrix habitats. This is due to the formation of new matrix habitats since they provide populations with new areas where they can forage [Hammershøj og Madsen, 1998].

The species that are least affected by increased fragmentation are r-strategists plus weasel, stoat and fox since these species can live in multiple habitats [Hammershøj og Madsen, 1998].

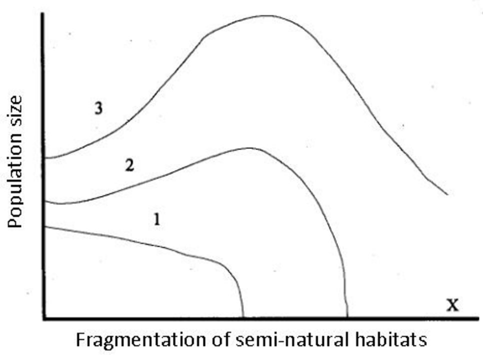

Figure 2.2: Hypothetical changes in population size in mammals relative to an increase in fragmentation of semi-natural habitats. (1) Species associated with semi-natural habitats, (2) edge species, (3) mosaic species, after [Hammershøj og Madsen, 1998].

2.2 Fragmentation in correlation to different habitats

With fragmentation, the proportions of each species fall in relation to the loss of a given habitat [Andrews, 1990]. The consequences of fragmentation depend on the type of natural habitats that are fragmented. These are briefly described below.

Forests

Studies have shown that fragmentation of forest may cause increased tree mortality, since it has a negative impact on the population of fertilizer beetles and beet carrion beetles as well as on the ecosystem processes such as decomposition. In addition, the distance between the fragments and the size of the fragments influences the number of forest bird species [Hammershøj og Madsen, 1998]. An increase in the isolation of forests also has a negative impact on, among others, squirrel and dormouse population size. Squirrels need several small forests within a radius of 500 metres to the forest that they inhabit. Besides this, the distance to the nearest forest with a size of less than 20 ha is a major factor influencing on the population size [Hammershøj og Madsen, 1998]. A motorway may act as a barrier for many animals and it is likely to have a major impact on the fauna because of the increased distance between habitats. There are also animals for which an increased fragmentation is an advantage. This applies to both fox and raccoon, where population size increases when there is an increased fragmentation of the forest [Hammershøj og Madsen, 1998].

Open areas

Fragmentation of open areas such as farmland, marshes and grasslands influences on butterflies, where studies have shown that emigration and immigration rates are less in small than in large areas [Andrews, 1990] [Hammershøj og Madsen, 1998]. This might be due to the fact that several butterfly species at certain times in their life cycle are dependent on a specific plant. Experiments have shown that the germination capacity of seeds obtained from a population of less than 150 individuals is less than when it comes from a larger population [Hammershøj og Madsen, 1998]. Fragmentation can also have a negative impact on certain bird species, as it may lead to increased predation on their eggs from the edge species [Andrews, 1990] [Hammershøj og Madsen, 1998]. Several species of bats are also affected because they avoid open areas or their habitat disappears [Hammershøj og Madsen, 1998].

Rivers

Fragmentation of rivers is extensive. Approximately 77% of the 139 largest rivers in the northern hemisphere are moderately or highly fragmented with, among other, dams and pipe laying [Hammershøj og Madsen, 1998]. These interventions in the natural course of rivers will complicate or possibly prevent the natural flora and fauna to immigrate to some places in the stream. It is therefore important that animals can pass through the pipe-laying path in order to reduce the impact that the road may have on the fauna. Streams are natural lines that animals follow in nature. When roads are constructed, some of the streams pass through. Hence, streams might guide animals to roads. If fauna passages are not designed in correlation with the fauna, animals will either avoid crossing the road or will try to cross it, thereby risking to be killed [Hammershøj og Madsen, 1998].

The extent of road-kill 3

Calculations show that approximately 5 million animals are killed in traffic each year in Denmark [Bruun-Schmidt, 1994]. Compared to the USA with about 1 million animals killed in traffic daily or compared to Europe, where the number of annual kills is estimated to lie between 350,000 and 27 million birds, the Danish number does not seem that big [Perkins, n.d.]. However, it has to be taken into account that Denmark is a small country compared to these large states/continents. The population density and road density is also very different (see Figure 3.1), therefore the figures cannot be compared directly. In Great Britain, where road density is close to Danish road density, no overview of the extent of road-kills exists [Perkins, n.d.]. It has not been possible to obtain an overview of the extent of road-kills in Hungary, where both population density and road density are close to Danish numbers [Vejdirektoratet, 2000e].

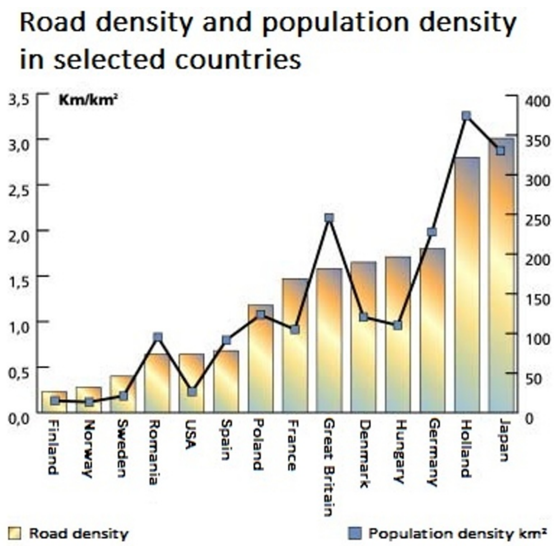

Figure 3.1: Overview of road density and population density in selected countries, after Vejdirektoratet [2000e].

In Denmark, there is uncertainty about the number of animals killed annually in traffic, the distribution of animals (see Table 3.1) and also about the extent of the economic costs that these accidents entail. Table 3.1 depicts numbers of killed animals obtained from two different sources, [Andersen et al., 2002] and [Elmeros et al., 2014]. The difference is due to the method used for the records and calculations. This methodology shows the difficulties of procuring a clear picture of the total number of road-killed animals. Different insurance companies have diverse products, and therefore record damages differently. To give an example, the collisions of animals are not all recorded as such, but are registered as hull-damage. In addition, the paid insurances for this type of accidents are kept a secret, so the insurers do not provide information about the economic costs of accidents involving animals. The Danish organisation "Dyrenes Beskyttelse" does provide that information and spends about 8 million dollars a year on animals that are injured in traffic [Andersen et al., 2002].

Table 3.1: The results of two different estimates of the annual number of fatalities (animals). [1] are results from Andersen et al. [2002], [2] are results from Elmeros et al. [2014].

Stock[1]	**Road-kill**[1]	**Road-kills' share of the stock**[1]	**Road-kill**[2]	**Road-kills' share of the stock**[2]
Roe deer 500,000[1]	15,000[1]	3%[1]	2,970[2]	0.60%
Red deer 12,000[1]	100[1]	1%[1]	114[2]	1%
Sika deer			14[2]	
Fallow deer			144[2]	
Fox			59[2]	
Otter 800[1]	35[1]	5%[1]		
Badger 25,000[1]	2,500[1]	10%[1]		

In Denmark, there are traced approximately 5,500 cloven-hoofed wild animals each year by blood trackers, and in addition there have been more injured animals by cars that have not been reported [Danmarks Jægerforbund, 2013]. This confirms that there is some uncertainty about the number of killed animals by traffic, and thus it is difficult to estimate an average number for the different populations as well as the consequences for their size.

In Denmark, wild accidents are the cause of 0.2% of all personal injuries in traffic accidents [Andersen et al., 2002]. This is significantly higher in Sweden and Norway, where it is 2.3% and 6% respectively [Andersen et al., 2002]. These higher rates of road accidents are specifically caused by collision with moose. In Sweden, accidents with wild animals cost 1 billion Swedish kroner a year, while the costs in Norway mount up to approximately 120 million Norwegian kroner a year. In both cases, the economic losses associated with population losses are not included [Andersen et al., 2002].

Aims of the thesis 4

Based on the above, the main topic of this thesis will be the effect of existing and planned fauna passages on the stretch of motorway between Ikast and Låsby, built to - in theory - prevent the negative effects of the motorway as a barrier. In order to determine their effectiveness, the following questions are sought to be answered:

- Are the landscaped and planned fauna passages between Ikast and Låsby placed as favourable as possible in relation to lines which are leading animals to the passages and in relation to natural habitats in the area?
- Are the fauna passages modified to the fauna anticipated to be affected by the barrier and the increased degree of fragmentation that the motorway will bring?
- Could there favourably be located fauna passages elsewhere than in current and planned locations on the stretch between Ikast and Funder/Låsby?
- Based on the results and the literature discussed in this report, what recommendations should exist for the construction of fauna passages?
- If the motorway is extended between Herning and Ringkøbing, what type of fauna passages should be built, and where should they be placed?

5 Methods

In order to answer the posed research questions, different literature has been scrutinized. This has, among other things, given an overview of opportunities in relation to fauna passages as well as of the different guidelines in relation to design and construction of fauna passages that currently exist.

Furthermore, both literature and maps have been used to learn about the history of the motorway between Herning and Aarhus and to determine where the existing fauna passages between Ikast and Funder have been constructed and where the planned fauna passages on the stretch between Funder and Låsby are expected to be built.

Different literature has been reviewed to find out which mammals are located in the surroundings of the motorway, and if they are in any way protected as either Annex IV species or red-listed. Data from arealinfo.dk has been used to map the protected habitats affected by the motorway and to determine how these areas are placed in relation to existing and planned fauna passages. A map with protected nature reserves has also been used to suggest where fauna passages could be constructed with advantage. These suggested locations are used to find out which places should be checked out for habitats and location in the landscape.

The constructed fauna passages were measured on location on the basis of existing guidelines after Ujvári et al. [2011] to design and construct fauna passages. An attempt had been made to discover every fauna passage by walking along the motorway in the area where they are supposed to be located. At the fauna passages that were found, width and height were measured with a folding ruler and the length was measured on an orthophoto in QGIS. These measurements were used to classify fauna passages by Austrian, Californian and Danish instructions. The different classifications will be compared and discussed in the discussion part of this thesis. The knowledge that comes from studies of fauna passages and the comparison of different guidelines for fauna passages has been used to suggest new recommendations for fauna passages in Denmark and to propose what types of fauna passages should constructed if the motorway is extended between Herning and Ringkøbing and where they should be placed.

QGIS and data from arealinfo.dk is used to analyze how the fauna passages are located in relation to protected nature reserve and preserved nature. On the possible stretch between Herning and Ringkøbing, are also used height maps from kortforsyningen.dk to assess whether to place a fauna passage of type over-or underpass.

6 Fauna passages

In this part, various types of fauna passages will be described according to their use and requirements. Guidelines from three different countries (Denmark, Austria and California) will be used. This provides the reader with an overview of current possibilities within the field of fauna passages.

A report written by Salvig [1991] concludes that the limited knowledge of fauna passages in Denmark constitutes a problem. Back in 1991, most of the experience with fauna underpasses that Denmark was able to learn from stemmed from foreign countries [Salvig, 1991] . One of the problems of existing fauna underpasses landscaped at this time was that the bottom of the watercourse was flat, which could cause problems with the water depth and flow rate. Furthermore, the bottom was often slippery, which made it difficult for invertebrates to move against the current. Often, a difference in height existed between the underpass and the natural level of the river bottom, which made it difficult for several of the animals located in the stream to enter the pipe. Furthermore, these underpasses seldom took terrestrial animals into account, which often use rivers as migration corridors. The berms, where they would be able to walk along the river, were often too small and in some cases there was only a berm on one side of the river at high tide. This entailed that animals on the opposite side of the watercourse could not pass the road through the fauna underpass, but were led up to the road. Finally, there were several subways without berms entirely [Salvig, 1991].

Denmark's first larger fauna overpass was built at a motorway in Northern Jutland, and landscaped overpasses on this stretch were considered as a new tool to bind habitats together [Ogstrup, 2009]. Fauna passages at the motorway in Northern Jutland were established in the years 1996-2001 [Naturstyrelsen, n.d.], which means that Denmark, compared to, among others, The Netherlands, France, Germany and the United States, was lagging behind in constructing fauna passages built in connection to roads [Salvig, 1991].

There are generally two types of wildlife passages, overpasses (fauna bridges) and underpasses. Underpasses can be dry or wet passages and these can either be a tunnel under the road or a landscape bridge over a natural area. The landscape's typography is essential for the design and location of a fauna passage. Fauna bridges are good for binding dry habitats together, while landscape bridges and other underpasses are often suitable for animals associated with wet habitats. Fauna passages designed for one species can often be used by several smaller species (see Table 6.1), yet several smaller animals need hiding places/habitats at the fauna passage. In an area with many deer and on a stretch where the animals cannot cross the road because of fences, a minimum of one large fauna passage per kilometre should be built. Similarly, in areas with badgers, the distance should not exceed 250 metres [Ujvári et al., 2011]. The requirements for the dimensions of the various fauna passages depend on which species is expected to use the passages [Ujvári et al., 2011].

Table 6.1: Type of fauna passages as measured by their suitability for certain species/species groups. The suitability of each passage will vary with local conditions such as migration corridors, habitats, vegetation cover, etc.. +: Good. ∧: Can be used to a lesser extent. -: Not recommended. ?: Unknown. *: The species in this group have slightly different preferences in relation to passage types. **: because the type's dimensions with very long paths is less than type B2, ***: amphibian passages will typically be built on sites that are unsuitable for these predators, after [Ujvári et al., 2011]

	Dry passages							Wet passages				
Species/ Species group	**Overpass**		**Underpass**					**Underpass**				
	Fauna bridge type FB1/FB2	Treetop overpasses	Landscape bridges type LB1/LB2	Tunnel type TU1/TU2	Tunnel type TU3	Tunnel type TU4	Tunnel type TU5	Landscape bridges type LB1/LB2	Tunnel type TU1/TU2	Tunnel type TU3	Tunnel type TU5	Berms on existing bridges
Red deer and fallow deer	+/∧	-	+/∧	+/∧	-	-	-	+/∧	+/∧	-	-	-
Roe deer	+	-	+	+	-	-	-	+	+	-	-	-
Fox	+	-	+	+	+	-***	∧	+	+	+	∧	-
Badger	+	-	+	+	+	-***	∧	+	+	+	∧	-
Otter	-	-	-	-	-	-	-	+	+	+	+	+
Polecat	+	-	+	+	+	-***	∧	+	+	+	+	+
Pine- and beech marten	+	?	+	+	+	-***	∧	+	+	+	-	-
Weasel and stoat	+	-	+	+	∧	-***	∧	+	+	∧	∧	-
Hare and rabbit*	+	-	+	+	∧	-	-	+	+	∧	-	-
Beaver	-	-	-	-	-	-	-	+	+	+	+	+
Squirrel	+	+	+	-	-	-	-	+	-	-	-	-
Dormouse	+	+	+	-	-	-	-	+	-	-	-	-
Northern birch mouse	+	-	+	?	?	-	-	+	?	?	-	-
Other small rodents	+	-	+	+	∧	∧	∧	+	+	∧	∧	-
Hedgehog	+	-	+	+	+	+	∧	+	+	+	∧	-
Shrew	+	-	+	∧	∧	∧	∧	+	∧	∧	∧	-
Bat**	+	?	+	?	?	-	-	+	?	?	-	-
Reptile	+	-	+	∧	∧	+	∧	+	∧	∧	∧	-
Amphibian**	+	-	+	+	∧**	+	-	+	+	∧	-	-
Fish	-	-	-	-	-	-	-	+	+	+	+	+
Invertebrates in watercourses	-	-	-	-	-	-	-	+	+	+	+	+
Invertebrates in dry areas	+	-	+	∧	∧	-	-	+	-	-	-	-
Invertebrates in humid areas	∧	-	∧	∧	∧	∧	-	+	∧	∧	-	-

In Denmark, a guide for the construction of wildlife passages exists [Ujvári et al., 2011] and several of the passages presented in this guide will be described in the following sections, where they will be used to analyse migration corridors between Ikast and Låsby:

- Fauna bridges type 1 (FB 1) - meet the requirements of red deer and fallow deer
- Fauna bridges type 2 (FB 2) - meet the requirements of roe deer
- Treetop overpasses - meet the requirements of animals mainly living in trees and shrubs
- Landscape bridges type 1 (LB 1) - meet the requirements of red deer and fallow deer
- Landscape bridges type 2 (LB 2) - meet the requirements of roe deer plus medium-sized and small species (such as fox, hedgehog and hare)

- Tunnel underpasses type 1 (TU 1) - passages for red deer and fallow deer
- Tunnel underpasses type 2 (TU 2) - passages for roe deer
- Tunnel underpasses type 3 (TU 3) - meet the requirements of medium-sized and small mammals (such as fox, hedgehog and hare)
- Tunnel underpasses type 4 (TU 4) - special structures for amphibians
- Tunnel underpasses type 5 (TU 5) - can be used as remedial measures for hedgehogs and medium-sized predatory mammals (such as badger, fox, otter and beaver)
- Fauna/human passages

As is the case for all fauna passages, their efficiency is, among others, dependent on natural lines to lead the local fauna to the fauna passage. This is because the animals are less willing to cross areas that are intensive exploited or fenced, and therefore will the effectiveness of fauna passage be less if not established hedge through these areas. These hedges may consist of trees and shrubs that lead animals to the fauna passages and also act as a living and hiding place for several animals on their way from a habitat to the fauna passage. The natural lines should be solid connections that are linked to the nature areas nearby. In order to accommodate as many animals as possible, the fauna passages must be wide, and the longer they are, the wider they must be. Trees and bushes must be scattered to allow for herbaceous vegetation at the bottom, and there should be dead wood, stumps and logs close by to create hiding places for smaller animals. If hedges to lead the animals are meant to be used by amphibians and reptiles, there must also be established small hallows and ponds in connection with them. The vegetation planted in hedges must consist of at least 10-15 species found in the area and preferably more species that are attractive feed materials. Is the fauna passage intended for deer, the adjacent hedges have to be at least 15-20 metres wide, whereas a hedge to a fauna passage for small animals must be at least 8-10 metres wide [Ujvári et al., 2011].

At the opening of fauna passages, there must be a 50-metre entrance area (see Figure 6.1), consisting of open nature and scattered trees. In addition to the entrance area there should be a buffer zone of 150 to 500 metres, in which no constructions should occur, as this may frighten the animals. If agriculture and forestry within the buffer zone is to be accepted, it must be ensured that there are migration corridors to the fauna passages. In the buffer zone there should be no fences, hunting activities or other human disturbances that might scare the animals [Ujvári et al., 2011].

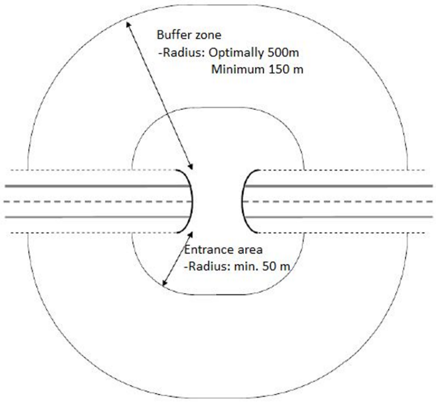

Figure 6.1: Buffer zones and entrance areas around a fauna overpass with openness ratio of 0.8 [Ujvári et al., 2011].

6.1 Fauna bridges

In this section the dimensions of the different types of fauna bridges as well as the recommendations concerning positions of, among others, plants and hiding places will be described.

There are two types of fauna bridges. Fauna bridges type 1 (FB 1) meet the requirements of red deer and fallow deer. Fauna bridges type 2 (FB 2) meet the requirements of roe deer. Roe deer can use a fauna bridge of type FB1, this is however more expensive to construct than a FB2 fauna bridge and therefore there are two types of fauna bridges.

In connection with fauna overpasses, openness ratios are used (see equation 6.1), which is an expression of the animal species that theoretically will use the passage. The width is the narrowest point between the fences, while the length is the distance between the fences along the road (see Figure 6.2). There are differences in the species' requirements for the width of the fauna bridge, openness ratio and the height of the fence that will guide the animals into the passage and across the bridge (see Table 6.2) [Ujvári et al., 2011].

$$Opennessratio = \frac{Width(m)}{Length(m)} \tag{6.1}$$

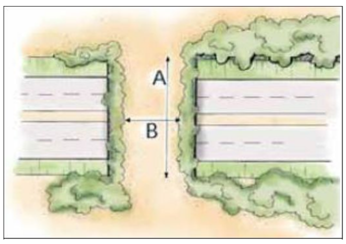

Figure 6.2: Definition of length (A) and width (B) of fauna bridges. The width is the minimum distance between fences along the sides of the passage. The length of fauna bridges corresponds to the distance between the fences along the road system when connected to the passage [Ujvári et al., 2011].

Table 6.2: Overview of the requirements for each of the two fauna bridges. * German studies show a ratio of more than 1.0 is advantageous [Ujvári et al., 2011].

Fauna passages	Width (m)	Openness index	Fence height (m)
FB 1	50 m	>0.8 *	2.2 m
FB 2	20 m	>0.8 *	1.8 m

To reduce the risk of animals crossing the road instead of the fauna passage, fences must be placed along the road and across the fauna bridge (see Figure 6.3). These fences must be adjusted to the species that are expected to use the passage in order to lead them safely towards the fauna passage [Cueto et al., 2011] [Ujvári et al., 2011]. In addition to various types of fencing suitable for different species, different heights should also be considered (see Table 6.2) [Ujvári et al., 2011]. The design, fence and vegetation have to act as one unit, which will provide the animals with a greater sense of security, thereby increasing the chances that they will use the passage [Cueto et al., 2011].

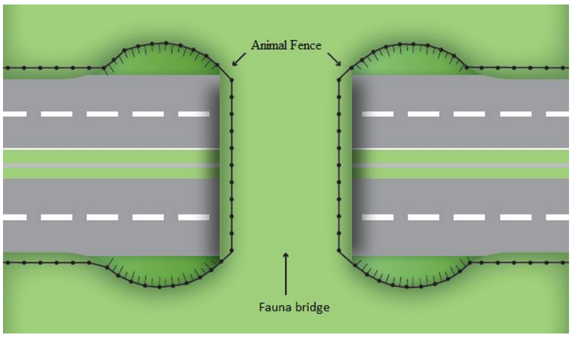

Figure 6.3: Location of the fence at a fauna bridge [Cueto et al., 2011].

On a fauna bridge, vegetation must be planted along the fence on both sides in order to shield from light cones deriving from traffic. The planting at the sides should cover at least 20% of the width of the fauna bridge. At the opening of the fauna bridge, there must be a few trees and shrubs, but the animals should still be able to see across the bridge (see Figure 6.4) [Ujvári et al., 2011]. Is the fauna bridge shorter than 50 metres, screens should be placed on the outside of the fence to block the light from vehicles on the underlying road [Cueto et al., 2011].

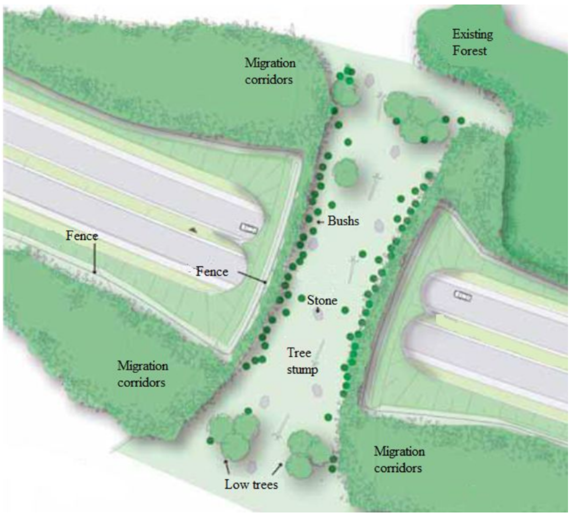

Figure 6.4: Arrangement of fauna bridges [Ujvári et al., 2011].

The vegetation on a fauna bridge must consist of local species to ensure that local populations of for example bats, butterflies, birds and other animals will use it. There should be continuous rows of stumps/logs to provide shelter for small animals. In addition, a combination of moist and dry soil may prove to be advantageous [Ujvári et al., 2011].

Fauna bridge type 1 (FB 1)
This type of fauna passage is suitable for species with low dispersal rate and links dry habitats together. The width of the bridge must be at least 50 metres and the size and location is very important in order for red deer and fallow deer to use it [Ujvári et al., 2011].

Fauna bridge type 2 (FB 2)
This type of fauna bridge is an asset in places where there is a need for a passageway for roe deer as well as for medium-sized and small animals. It is important to place natural lines to lead the animals to the passages and with suitable habitats for the animals that are going to use it [Ujvári et al., 2011].

6.2 Treetop overpasses

This type of fauna passage is suitable for small animals that live in treetops. The bridge is placed between canopies and consists of rope or steel cable with a net in between, pipes of wire mesh, wooden bridges or combinations of these. The width of the bridge is between 20 and 30 centimetres and there must be contact to the treetops [Ujvári et al., 2011]. Examples of such passages can be seen in Figure 6.5. This type of fauna passage has not yet been used in Denmark but in Great Britain and the Netherlands, has been constructed few, while they in Australia are used more [Ujvári et al., 2011].

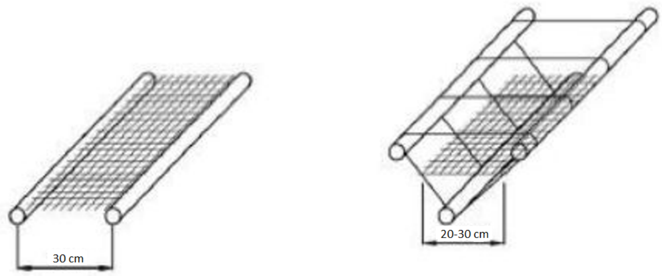

Figure 6.5: Examples of treetop overpasses [Ujvári et al., 2011].

6.3 Landscape bridges

Where the road leads across a strip of nature, landscape bridges are built. There are two types of landscape bridges: Landscape bridges type 1 (LB 1) meet the requirements of red deer and fallow deer. Landscape bridges type 2 (LB 2) meet the requirements of roe deer plus medium-sized and small species.

Landscape bridges are suitable for most animals and should be landscaped over river valleys or other important ecological habitats of especially large animals. By using landscape bridges, visual barriers for the animals may be avoided as there will be an opportunity to preserve natural soil and vegetation composition and a more natural correlation between the habitats of various animals. It is possible to plant vegetation types in accordance with local species, though it is important to remember the needs of heat loving animals and thus not to plant vegetation too close. Furthermore, it is recommended to add stumps and logs in order to establish hiding places and habitats for small animals [Ujvári et al., 2011].

Landscape bridges type 1 (LB1)
This type of landscape bridge is suitable for red deer and fallow deer. In a dry area, the height should be at least 6 metres and the width should be 20 metres. In case of a watercourse passing under the bridge, the height should still be 6 metres and the width should be minimum 20 metres + the width of the watercourse with the width of the berms no less than 10 metres and the height over the berms more than 6 metres (see Figure 6.6) [Ujvári et al., 2011].

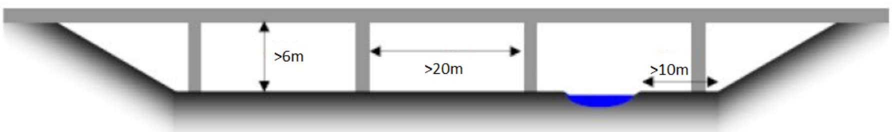

Figure 6.6: Dimensions for red deer [Ujvári et al., 2011].

Landscape bridges type 2 (LB2)
This type of landscape bridge takes roe deer as well as medium-sized and small animals into account. The requirements for the width of the passage and the berms are the same as LB1, but the height should be at least 4 metres (see Table 6.3) [Ujvári et al., 2011].

Table 6.3: Requirements for dimensions of LB1 and LB2 [Ujvári et al., 2011].

Fauna passages	**Height (m)**	**Width (m)**	**Width on berms (m)**	**Height over berms (m)**
LB 1 (dry)	>6	>20	-	-
LB 2 (dry)	>4	>20	-	-
LB 1 (wet)	>6	>20 + watercourse	>10	>6
LB 2 (wet)	>4	>20 + watercourse	>10	>4

6.4 Underpass (tunnel)

In this section, tunnels as fauna passages will be described in general, as will the five different types of tunnel passages. The five types are [Ujvári et al., 2011]:

- Tunnel underpasses type 1 (TU 1) - passages for red deer and fallow deer
- Tunnel underpasses type 2 (TU 2) - passages for roe deer
- Tunnel underpasses type 3 (TU 3) - meet the requirements of medium-sized and small mammals (such as fox, hedgehog and hare)
- Tunnel underpasses type 4 (TU 4) - special structures for amphibians
- Tunnel underpasses type 5 (TU 5) - can be used as remedial measures for hedgehogs and medium-sized predatory mammals (such as badger, fox, otter and beaver)

Since underpasses do not have continuous vegetation, they are generally less effective. To increase the usability for small animals, stumps and logs should be placed closed to the underpass to create hiding places and habitats for these animals. As a general rule, the berms of all tunnel underpasses should not be regularly flooded and there must be no ponds in front of the opening. Furthermore, in connection with wet passages there must be a berm on each side of the watercourse, so animals from each side of the watercourse have the opportunity to cross the road. At the opening there should be an undisturbed smaller area with a radius of at least 10 metres, and the openings for the passages should be as natural as possible with adjacent migration corridors. If the underpass is lowered, the slope to the entrance should not be steeper than 1:5 [Ujvári et al., 2011].

Migration corridors for tunnel underpasses intended for smaller animals must be 10-15 metres wide and vegetated with bushes and a few trees [Ujvári et al., 2011]. To lead the animals into the underpass, the fence along the road has to be passed across the tunnel underpass to ensure that the animals will not jump on the road at the transition from the fence to the underpass [Ujvári et al., 2011] [Cueto et al., 2011]. Fencing is to be combined with vegetation so the animals feel safe and thus will use the fauna passage. Mesh on the fence must be of a size which allows amphibians to pass, unless there is a fauna passage for amphibians and reptiles in connection to the fence [Cueto et al., 2011]. Various types of fencing can be seen on Figure 6.7 and Figure 6.8.

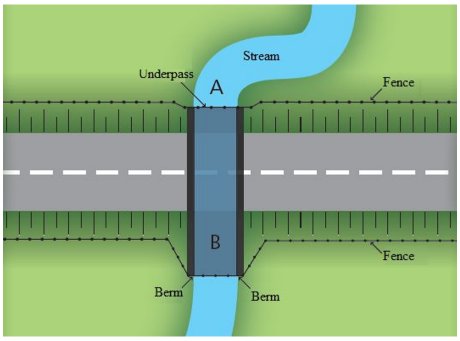

Figure 6.7: Fencing at fauna underpass in connection to watercourses [Cueto et al., 2011].

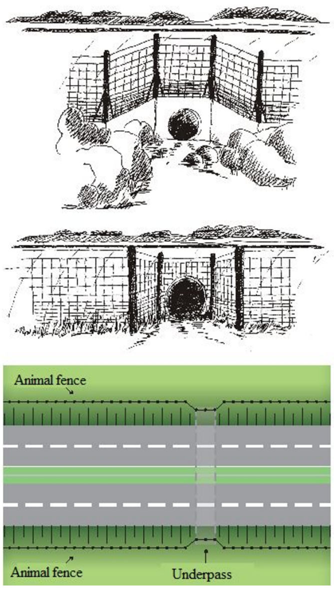

Figure 6.8: Fencing at dry fauna underpass [Cueto et al., 2011].

On already existing bridges, it is possible to create a passage for animals by making artificial berms. These can be used by otters and other medium-sized mammals. In places with large fluctuations in water level, fixed berms, shelves on the bridge foundation or floating pontoons may be mounted. In places where the water level is low and more stable, contiguous giant stones or gravel and earth fillings along the inside wall of the underpass may be used. For renovations and new constructions there must at least be constructed TU3 or TU5 [Ujvári et al., 2011].

The different animals need different dimensions for using fauna passages. To calculate this index for the tunnel, equation 6.2 is used. Under each kind of underpass described in the following, the tunnel ratio is given.

$$Tunnelratio = \frac{Width(m) \times Height(m)}{Length(m)} \tag{6.2}$$

Underpasses type 1 and 2 (TU1 and TU2)
These underpasses should be constructed where traffic crosses migration corridors and habitats for deer and there is no possibility of building a fauna bridge or a landscape bridge. They should be square or oval with an open entrance. TU1 is suitable for red deer and fallow deer, while the dimensions of the TU2 are smaller (see Table 6.4) and thus suitable for roe deer as well as medium-sized and small mammals [Ujvári et al., 2011].

Table 6.4: Requirements for dimensions for TU1 and TU2 and their tunnel ratio [Ujvári et al., 2011].

Fauna passages	Height (m)	Width (m)	Tunnel index	Width on berms (m)	Height above berms (m)
TU1 (dry)	>6	>12	>1.5	-	-
TU2 (dry)	>4	>6	>0.75	-	-
TU1 (wet)	>6	>14 + watercourse	>1.5	>7	>6
TU2 (wet)	>4	>7 + watercourse	>0.75	>3.5	>4

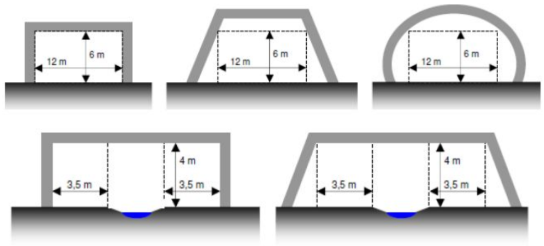

Figure 6.9: How to measure height and width of an underpass type 1 and 2 [Ujvári et al., 2011].

Underpass type 3 (TU3)
This type of underpass is for small and medium-sized mammals such as fox, hedgehog and hare. TU3 should as a minimum be placed anywhere where a watercourse is crossed by a road, since rivers act as natural lines leading animals to the road. The tunnel should be square or oval with an open entrance. The opening must be connected with the surrounding environment, and hiding places in the form of stumps and logs may be placed in the tunnel to the benefit of the crossing animals. Berms leading down to anticipated watercourses should be sloped gently to allow animals to get out of the water from anywhere. Concurrently, the river bottom should have a natural shape and flow rate [Ujvári et al., 2011].

Table 6.5: Requirements for dimensions for TU3 [Ujvári et al., 2011].

Fauna passages	Height (m)	Width (m)	Tunnel index	Width on berms (m)	Height above berms (m)
TU3 (dry)	>1	>1.5	-	-	-
TU3 (wet)	>1	>3 + watercourse	-	>1.5	>1

Underpass type 4 amphibian (TU4)
Amphibians often migrate on the same routes and it is therefore important for this type of fauna passage to be landscaped on the amphibian migration route. The tunnel should be square or oval-shaped with an open entrance, and the humidity of the ground should reflect the surroundings. Is the passage intended for frogs, the bottom should be moist, while toads prefer a dry bottom. Use of underpass type TU4 by predatory mammals in the migration corridors is limited. The dimensions of the tube vary according to the length of the pipe and the type of pipe used (see Table 6.6) [Ujvári et al., 2011].

Table 6.6: Recommended dimensions for passages for amphibians. The recommendations are based on experiences from foreign countries and professional assessment [Ujvári et al., 2011].

Type of pipe	Length (m)	Minimum height (m)	Minimum width (m)
Rectangular pipe	<20	0.5	1.0
	21-30	0.6	1.0
	31-50	1.0	1.5
	51-70	1.5	2.0
Semicircular pipe	<20	0.55	1.0
	21-30	0.65	1.2
	31-50	1.1	1.7
	51-70	1.6	2.4

To lead the amphibians to the fauna passage, it is important to have an amphibian fence (see Figure 6.10) along the road to the entrance of the underpass [Ujvári et al., 2011] [Cueto et al., 2011]. In addition, there must be fences close to the population of amphibians, either to lead them into the underpass or to prevent them from moving onto the road. If the latter is the aim of constructing a fence, it is only necessary to put an amphibian fence up on the side of the road where the population is. If the fence is supposed to lead the population into the underpass, fences should be put up on both sides of the road to prevent crossings during their migration back (see Figure 6.11). At the entrance to the underpass, there must be a barrier for amphibians and reptiles that forces them to change direction. To make the underpass as short as possible, the fence should be placed as close to the road as possible. This will also make it possible to cut the vegetation on the roadside verge along the fence, to prevent the vegetation from lying over the amphibian fence and thus to prevent the amphibians from climbing over the fence instead of walking to the underpass. Reptiles in the area are generally retained by the same types of fencing as amphibians [Cueto et al., 2011]. It is often a good idea to have several underpasses on a stretch of road, preferably 50-60 metres apart. The outermost tunnel should be at least 50 metres from the end of the fence [Ujvári et al., 2011] [Armstrong et al., 2011].

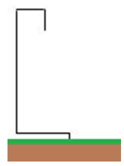

Figure 6.10: An example of an amphibian fence.

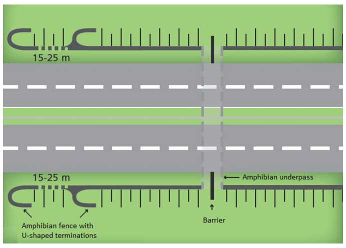

Figure 6.11: Sketch of amphibian fence. There should be a barrier at the entrance of the fauna underpass and the end must be double U-shaped [Cueto et al., 2011].

Underpass type 5 (TU5)

This underpass is for predatory mammals and hedgehogs. It is difficult to adjust this type of underpass to other animal groups. As a minimum, this type of underpass has to be placed where watercourses are crossed by roads or railways [Ujvári et al., 2011].

Table 6.7: Requirements for dimensions for TU5 [Ujvári et al., 2011].

Fauna passages	Height (m)	Width (m)	Tunnel index	Width on berms (m)	Height above berms (m)
TU5 (dry)	>0.5	>0.5	-	-	-
TU5 (wet)	>0.5	>1 + watercourse	-	>0.5	>0.5

6.5 Fauna/human passages

These fauna passages may be landscaped due to economic reasons or because it is not possible to build a fauna passage nearby. The human disturbance, however, makes these fauna passage less used as the animals are often frightened more by people on foot than in vehicles. These passages should be wide, as the width of the passages must increase with the width of the human passage (see Table 6.8). For example there may be built pathways/trails on one side of the passage and fauna passages on the other side. To separate human and fauna passages, landscaped bushes and stumps between the passages may be used to create an open and low fence (see Figure 6.12) [Ujvári et al., 2011].

Table 6.8: Increased requirements for dimensions of wildlife passages if they are combined with a path of recreational use or trail or forest roads [Ujvári et al., 2011].

Fauna passages type	Requirements for dimensions when fauna passage is combined withpath/trail
FB1 (red deer)	No changes. Red deer are very shy, and therefore this type cannot be combined with a path or trail.
FB2 (roe deer)	Width increases with the width of the path/road, but at least 10 metres.
LB1 (red deer)	Landscape bridges >80 metres in length are increased by the width of the path/trail, but at least 10 metres. Landscape bridges <80 metres cannot be combined with human passage.
LB2 (roe deer)	Landscape bridges <50 m in length are increased by the width of the path/trail, with a minimum of 6 metres.
TU1 (red deer)	No changes. Red deer are very shy, and therefore this type cannot be combined with a path or trail.
TU2 (roe deer)	The width increases with the width of the path/trail plus 3 metres.
TU3 (Medium-sized and small mammals)	The height is increased in order to meet requirements for human passage. Width increases with the width of the path/trail.

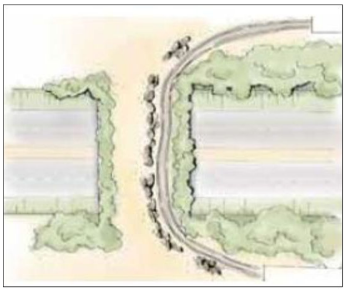

Figure 6.12: Example of a fauna/human passage [Ujvári et al., 2011].

6.6 Recommendations from Austria

An Austrian study divided the fauna passages into five categories, where both species and the animals' migration routes had international or local interest [Woess et al., 2002].

Passageways of type A have a width of 80 metres or more. They are built where migration routes of international importance are located. These types of passages can be used by all game species. The recommended width of the passages built where a motorway fragments an international habitat is 80-100 metres [Woess et al., 2002].

Type B fauna passages have a width of at least 30 metres and should be placed where migration routes of national or local interest have been registered. This type of fauna passage can be used by all wild animals. To ensure a minimum of motorway crossings and to reduce fragmentation as much as possible for sensitive species, it is recommended to place at least five fauna passages with a minimum width of 30 metres on a motorway segment. They should be placed away from settlers and it is also recommended that the maximum distance between a fauna passage of Type A and Type B must not be more than 20 kilometres. If the motorway section is longer than 75 km, a fauna passage (width >30 metres) should be landscaped for every stretch of 20 kilometres [Woess et al., 2002].

Fauna passages of type C have a width of at least 15 metres and are used in areas with an increased local fragmentation. This type of fauna passage can be used by roe deer and small mammals. In a few cases, they are used by larger species that have become accustomed to the fauna passage. It is recommended to place five of these fauna passages on a motorway segment. The average distance between fauna passages of type A, B and C should not exceed 10 kilometres [Woess et al., 2002].

Type D fauna passages have a width of at least six metres and at least 1/3 of the passage should not be paved. This type of fauna passage is usable only for small mammals, though in a few cases they are used by roe deer [Woess et al., 2002].

Fauna passage of type E have a width of at least three metres and are only used by small animals and roe deer [Woess et al., 2002].

6.7 Recommendations based on studies in California

Cavallaro et al. [2005] also divide fauna passages into five categories, but here they are divided according to which animals are expected to use the passages.

Fauna passages for large mammals (FLM) are for animals with a shoulder height of at least 0.46 metres and a length of at least 0.61 metres, which are animals like deer and wolves. The height of the fauna passages for these animals must be at least 1.83 metres, and the tunnel ratio (see equation 6.2 on page 23) must be at least 0.75; however, 0.9 is preferred. The entrance should be easily accessible and there must be natural lines to lead animals further out on the other side of the passages. There must be fences with a minimum height of 2.44 metres to the fauna passages in order to ensure that the animals use the passageway. The fence should be buried in the ground to avoid animals from digging underneath it. For large mammals it is important that there is a free view of the openings of the fauna passage [Cavallaro et al., 2005].

Medium-sized mammals such as fox and rabbit have a shoulder height of 15-46 centimetres and a length between 41 and 61 centimetres. They can use various forms of fauna passages, but prefer the larger tunnels. The requirements for fauna passages for medium-sized mammals (FMM) are a minimum height of 0.91 metres and have a tunnel index of at least 0.4. The fauna passage must be easily accessible with natural lines such as streams and hedgerows, which may lead the animals to the other side of the road. Around the entrance there must be natural vegetation if the animals are expected to use the passage. If the road is more than 23 metres wide, it is recommended that the opening is 2.79 m^2. The fence along the road and to the passage should be between 0.91 and 1.83 metres high and preferably dug down to a depth which prevents the species in the area from digging underneath it. On roads that are more than 805 metres long, this type of fauna passage must be placed at a distance of 152-395 metres [Cavallaro et al., 2005].

Fauna passages for small mammals (FSM) are meant for animals that are only a few centimetres high and up to 40 centimetres long. They prefer larger box and pipe tunnels, but may also use small pipe tunnels. The fauna passages must be at least 0.3 metres high, the opening must be 0.19 - 0.37 m^2 and with shelters. The passage must be easily accessible and there must be natural lines to guide the animals across the fauna passage. At the opening there must be natural vegetation, which contributes to a higher number of animals using the passage. The fence has to be between 0.91 and 1.22 metres high and must be buried at a depth that prevents animals from digging underneath it. Since small mammals are less mobile than medium-sized ones, passages should be placed at a distance of at least 46-91 metres from each other [Cavallaro et al., 2005].

Fauna passages for amphibians and reptiles (FAR) are for animals that prefer a moist environment, which among others are frogs and salamanders. Studies have shown that this group of fauna prefers small pipe tunnels as well as larger box and pipe tunnels. The height of the passage must be at least 0.3 metres, have an opening of 0.19-0.84 m^2 and provide small hiding places close to the opening. The fauna passages should be easily accessible with a moist substrate at the bottom. Throughout the passage, shelters must be made for the animals as hiding places and to shield against heat. The shelters can be rocks, tree stumps and logs which lie throughout the passage. This type of fauna passage should be placed at a distance of 46-91 metres in areas where amphibians and reptiles are likely to wander. To make the passage more efficient, there must be natural lines that can guide the animals safely to the other side. There must be fenced with amphibian fence (see Figure 6.10) with a height of 46-76 centimetres, and the vegetation along the fence must be removed to minimize the risk of the animals climbing over the fence [Cavallaro et al., 2005].

The last fauna passage is for upland reptiles (FUR) such as lizards and vipers. The height of the fauna passage must be at least 0.3 metres and have an opening area of at least 0.9 m^2, with small shelters at the opening. The passage should be easily accessible. They should be placed at a distance of 46-91 metres near relevant habitats. Throughout the fauna passage, hiding places must be provided for the animals to protect them from enemies and heat. These shelters may consist of low vegetation, large rocks, logs and stumps. Amphibian fence with a height of 0.46 to 0.76 metres should be used to lead the animals to the fauna passages [Cavallaro et al., 2005].

7 The motorway from Ikast to Låsby

This chapter describe the history of the motorway between Ikast and Låsby. It also clarifies where the constructed fauna passages on the stretch between Ikast and Funder are to be found and where the fauna passages between Funder and Låsby are going to be built.

In 1990, a majority in the Danish parliament decided to build a motorway connecting Herning and Aarhus. From the beginning, there was concern about nature reserves around Silkeborg. In 1991, several initiatives were carried out to halt the project. Despite the strong opposition against the planning of the motorway around Silkeborg, the project continued on other parts of the motorway between Herning and Aarhus. In 1993, the parliament agreed on the construction act for the stretches Herning-Bording and Låsby-Aarhus. The construction of bridges began in 1996, the digging and construction work in 2002 [Vejdirektoratet, 2002].

In 1998, the Danish Road Directorate presented three proposals for the placement of the motorway around Silkeborg, one leading around the city to the south, one to the north and one leading through Silkeborg. These proposals were submitted for public consultation and led to many protests. Politicians eliminated the route south of Silkeborg, as it would have led through a protected forest area and would be inexpedient for the traffic back and forth to Silkeborg [Danmarks Radio, 2008]. The two remaining routes were also problematic. One would pass through Silkeborg and would thus be quite expensive, since buildings would have to be expropriated and noise barriers would have to be built. The last option, which would be placed north of Silkeborg, passed through Gudenådalen, a protected nature site, which provoked environmentalists [Danmarks Radio, 2008]. Before the route between Herning and Bording could open in 2002, the Danish Road Directorate conducted an EIA investigation for the two routes and presented the results at a public hearing [Vejdirektoratet, n.d.a] [Danmarks Radio, 2008]. Here, a citizen proposal to combine the two routes (the "combiroute") was made to circumvent the protected area of Gudenådalen and some of Silkeborg city. However, there was also controversy about this new route, since it passed through an EU protected forest [Danmarks Radio, 2008].

In 2003, route 15 of the motorway, which runs between Låsby and Aarhus, was opened, and by now there was a motorway on both sides of Silkeborg without a connection [Vejdirektoratet, n.d.a]. In 2006, the Prime Minister, Anders Fogh Rasmussen, held a public meeting where he endorsed the combiroute near Silkeborg. In 2007, the Construction Law of the motorway with the government's list of legislation followed [Danmarks Radio, 2008]. On the 6th of May 2009, the Danish Parliament enacted the Construction Law [Barfoed, 2009] and the work on the stretch between Funder and Låsby could begin [Vejdirektoratet, 2014].

In 2012, the route between Bording and Funder was opened [Vejdirektoratet, 2012]. Hence, only the section between Funder and Låsby was left before the motorway connecting Herning and Aarhus would be completed. It is expected that the route between Haarup and Låsby will open at the end of the year 2015, and the line between Funder and Haarup will open at the end of the year 2016 [Vejdirektoratet, n.d.a].

7.1 Ikast to Funder

The motorway section between Ikast and Funder is 26 metres wide and busy, which means that there is a high number of animals that do not dare to pass or, if they did, would most likely die in the attempt [Vejdirektoratet, 2002]. Therefore, it is important that there are fauna passages to reduce the effects of the habitat fragmentation that the motorway has caused.

On the stretch between Ikast and Funder there are several §3 protected streams and other protected nature sites (see Figure 7.1 and Figure 7.2). During the construction of the road, it was attempted to place the motorway in combination with the major landscape features that are on the route [Vejdirektoratet, 2002]. Since this area was not covered by ice during the last ice age, the melt water filled the valleys with sand and gravel, and hills from the previous ice age emerged as small islands. In the large outwash plain between Ikast and Bording the motorway crosses Storå, which has many ramifications [Vejdirektoratet, 2002]. In connection with these ramifications, a fauna passage has been constructed, with another fauna passage placed by the §3 protected streams south of Ikast. The majority of fauna passages from Ikast to Funder are allegedly fauna tunnels (see Appendix A). Furthermore, there is the landscape bridge (nr. 23 on Figure 7.2) over the river valley Funder which may include use of fauna and finally, closest to Funder, there should be a fauna bridge (nr. 26 on Figure 7.2) which at its narrowest point should be 20 metres wide [Vejdirektoratet, n.d.b]. In total, there are located 20 fauna passages on the route from Ikast to Funder (see Figure 7.1 and Figure 7.2) to reduce the impact of the increased fragmentation.

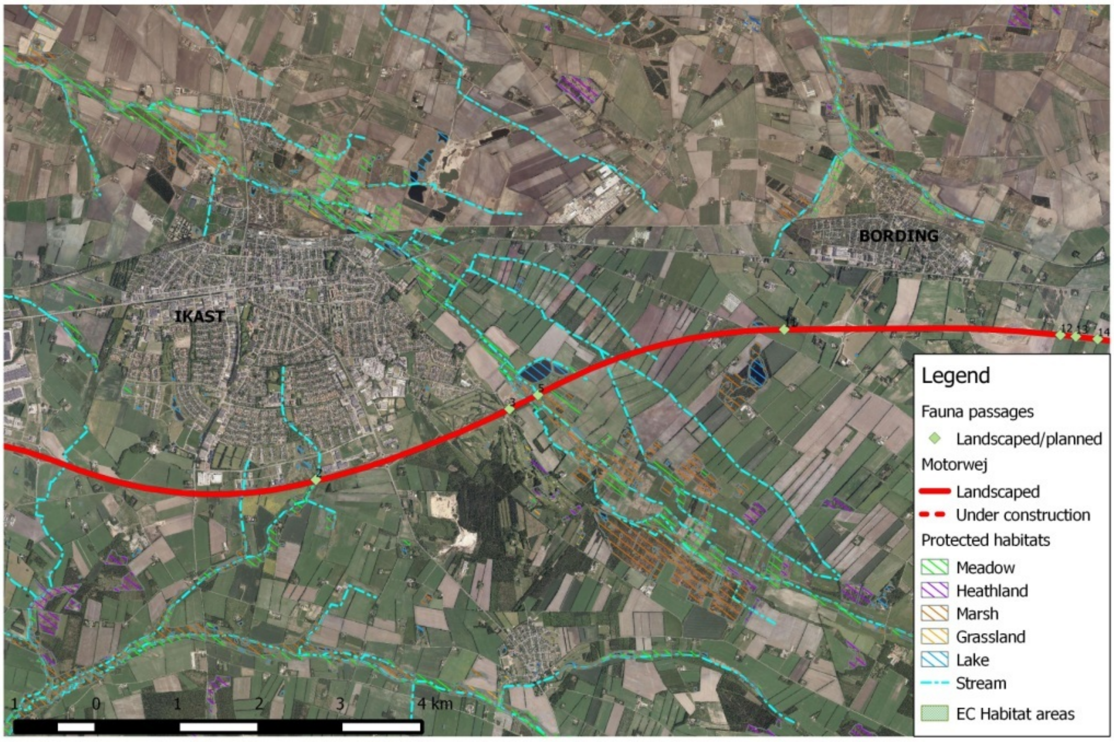

Figure 7.1: The landscaped fauna passages on the stretch between Ikast and Bording, [Vejdirektoratet, 2000a] [Vejdirektoratet, 2000c] [Vejdirektoratet, 2000d] [Vejdirektoratet, 2000b] [Vejdirektoratet, 2010].

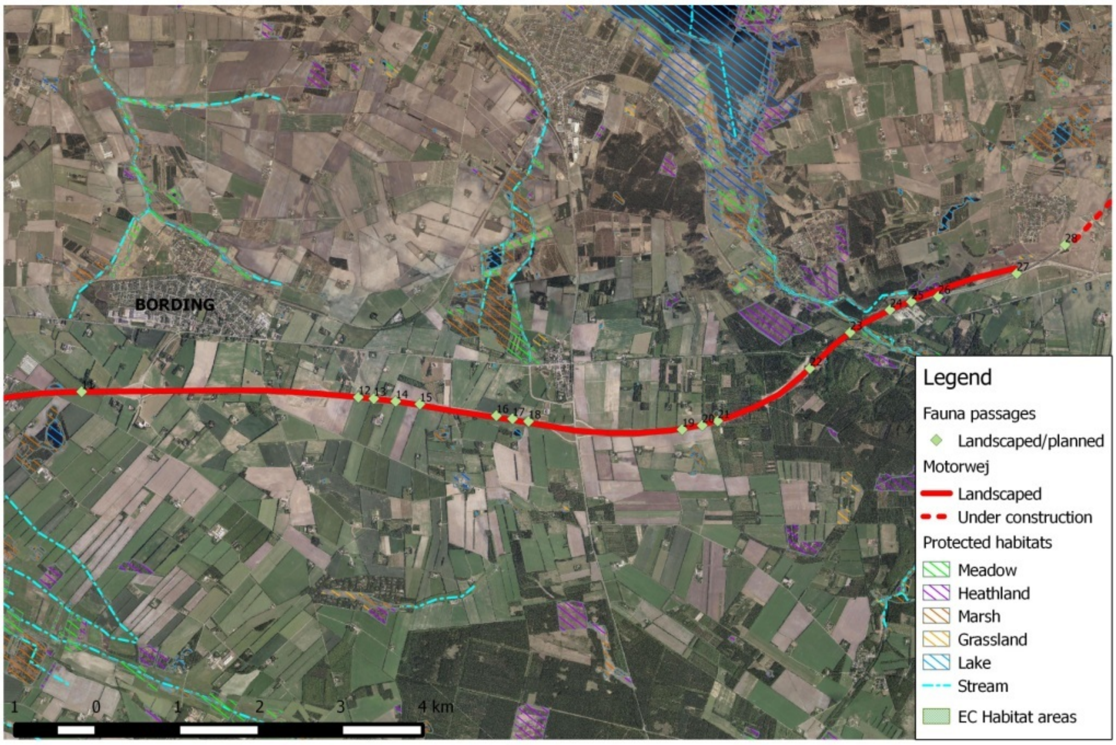

Figure 7.2: The landscaped fauna passages on the stretch between Bording and Funder, [Vejdirektoratet, 2010], [Vejdirektoratet, 2011b], [Vejdirektoratet, 2011c], [Vejdirektoratet, 2011a].

7.2 Funder to Låsby

The motorway on this stretch is not yet built, but there are plans for its designs and locations of fauna passages. The motorway between Funder and Låsby will in average be 28 metres wide and pass through several valuable nature reserves [Munch og Thaarslund, 2008]. Therefore it is necessary to place migration corridors, so animals in the area can pass freely across the motorway.

The planned migration corridors and their locations are described in Barfoed [2009] and can be seen in Figure 7.3 and Figure 7.4. More of them are designed according to the standards presented above so red deer can pass, and thus most animals can use these passages. The detailed locations and designs will be finished in the detailed design phase, which is why changes in the number of fauna passages and designs may yet occur. For all underpasses in connection with rivers, otters will be considered. To the extent that the fence can help guide animals into the passage, fences will be erected in connection with the fauna passages. Fauna passages for amphibians and those placed in areas of marsh and ponds will be supplemented with amphibian and reptile fencing [Barfoed, 2009].

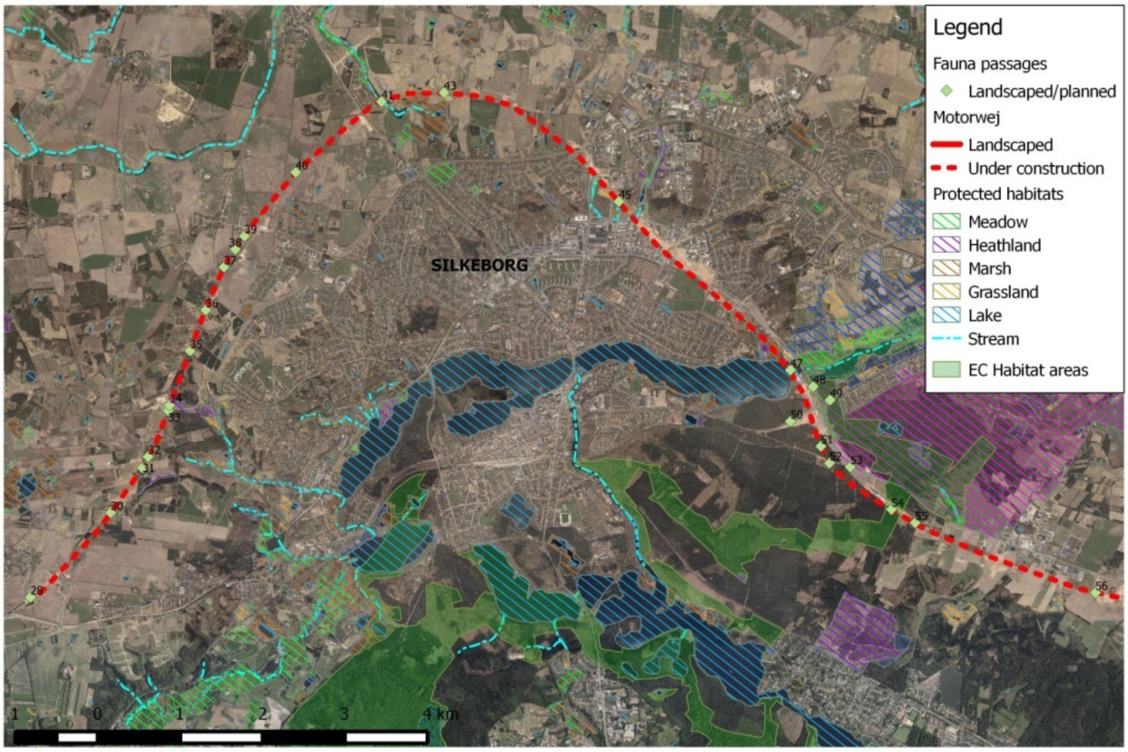

Figure 7.3: Map of planned fauna passages. The location of the fauna passages are from [Vejdirektoratet, 2013a], [Vejdirektoratet, 2013c], [Vejdirektoratet, 2013b], [Vejdirektoratet, 2013d] and [Vejdirektoratet, 2013f].

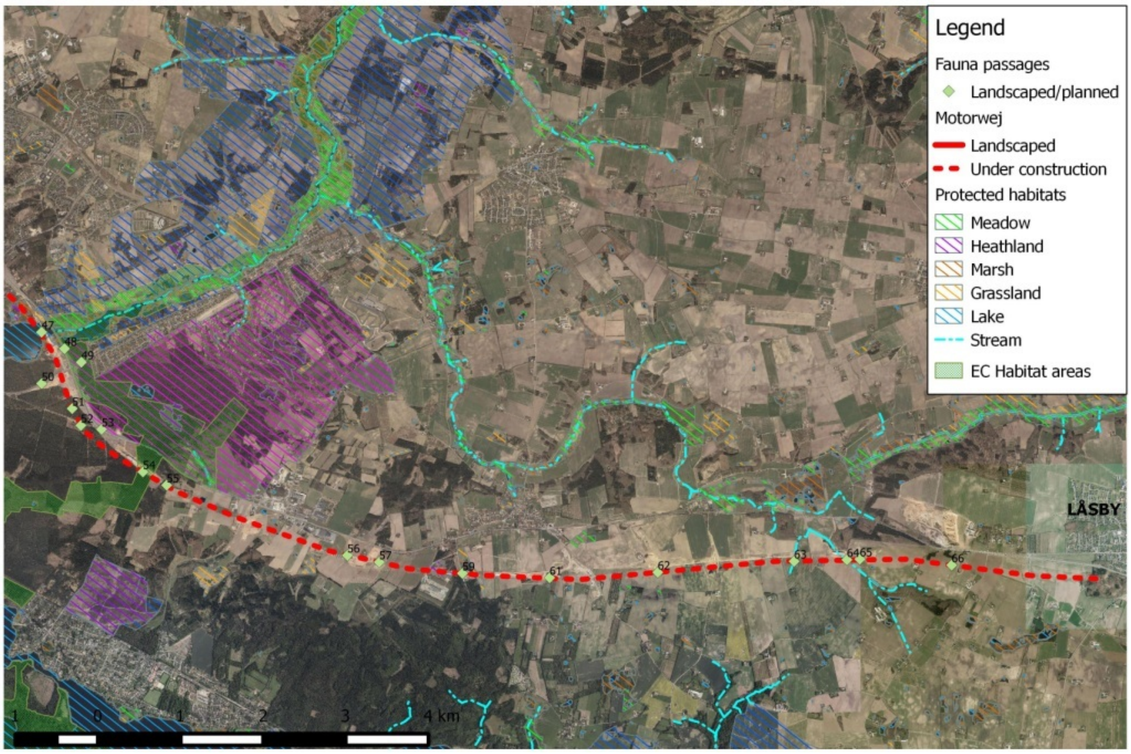

Figure 7.4: Map of planned fauna passages between Silkeborg and Låsby. The location of the fauna passages are from [Vejdirektoratet, 2013f], [Vejdirektoratet, 2013e] and [Vejdirektoratet, 2013g].

Studies of fauna passages on the motorway between Ikast and Låsby 8

In this section, methods and results from the studies of animals, nature reserves and fauna passages in the surroundings of the motorway will be presented.

The landscaped fauna passages have been measured in order to assess whether they meet the requirements that have been established in order for animals to use the passages according to Ujvári et al. [2011]. Based on these measurements, it will also be assessed how the planned fauna passages between Funder and Låsby should be designed and positioned based on knowledge of the fauna in this area. In studies of fauna passages and the surrounding nature, lines that may lead the animals to the fauna passages will be analysed. Apart from natural habitats in the area and landscaped and planned fauna passages, it will be assessed whether the establishment of more fauna passages would be of an advantage and, if so, where these migration corridors could be located.

8.1 Animals in the area

In this section, mammals in the surroundings of the motorway and their protection status are described based on reviewed literature. By studying which mammals are to be found in the area, it becomes possible to take them into account in the construction of wildlife passages on the stretch between Ikast and Låsby.

In the area around the motorway from Ikast to Låsby, there are several Annexes IV and red-listed species [Baagøe og Jensen, 2007] [Stoltze og Pihl, 1998b]. There are also hares [Baagøe og Jensen, 2007], which are yellow-listed [Stoltze og Pihl, 1998a], and several large and medium-sized mammals [Baagøe og Jensen, 2007]. When constructing fauna passages, it should be taken into account that these species can use the passages. A list of these mammals can be seen in Table 8.1. Near Silkeborg, the motorway passes through Silkeborgskovene, an EC Habitat Area No. 181 due to the presence of Annex IV species (the European brook lamprey, the crested newt, otters and pond bats). Their area of distribution has to be ensured, which means that their breeding and rest areas must not be impaired [Naturstyrelsen, 2012] [Rådet for de europæriske fællesskaber, 1992].

Table 8.1: These animals are according to Baagøe og Jensen [2007] found in the area of the motorway from Ikast to Låsby. Wolfs have, according to Jensen et al. [2014], been recorded in the area. There are only included large and medium sized mammals in the table. The animals are categorized as Annex IV and/or Red listed species based on Stoltze og Pihl [1998b]. The hare is yellow-listed according to Stoltze og Pihl [1998a].

Annex IV	**Red list**	**Annex IV and red list**	**Other**
Common pipistrelle	Pine marten	Pond bat	Hedgehog
Serotine bat		Brandt's bat	Hare (yellow-listed)
Otter		Daubenton's bat	Badger
Wolf		Natterer's bat	Red deer
		Nathusius' pipistrelle	Fallow deer
		Noctule bat	Sika deer
		Brown long-eared bat	Roe deer
			Beech marten
			European polecat
			Weasel
			Stoat
			Red fox
			Red squirrel

8.2 Nature in the area

Here, the nature reserves in connection with the different constructed, planned and suggested fauna passage are described. In Appendix B., the landscaped, planned and suggested fauna passages plus the protected habitats can be seen. The suggested fauna passages are suggested on the basis of position of protected nature near the motorway. The suggested fauna passages no. 1, 4, 6, 7, 8 and 9 are all in connection with a §3 protected stream. Therefore degradation of flora and fauna associated with those streams must not be impaired. Without spreading opportunities, there will be a deterioration of plants and animals associated with streams. The same applies to fauna passages 2 and 5. Fauna passages 4-9 are all placed in the valley where there are §3 protected streams, meadows and marshes, so the fauna passages are also constructed for animals associated with these nature types.

The suggested fauna passage no. 10 has been placed between two §3 protected lakes. Therefore it is important that there are passages for animals whose habitats are lakes and wet nature types.

Fauna passage 23 is a landscape bridge over Funder Ådal, where many different types of §3 protected nature areas are to be found. The animals are not likely to feel intimidated by this fauna passage, as it is very large. This makes the barrier effect very small, affecting animals and nature as little as possible.

It has been suggested to build fauna passage 29, because there are §3 protected lakes on both sides of the motorway, as well as a fauna tunnel at fauna passage 30. The fauna passages might not be built at the location of no. 29, because there will be an entrance and an exit to the motorway there, and the passage will thus be very long.

On the east side of Silkeborg, several fauna passages of different types have been planned. This will lessen the barrier effect that the motorway will have on some animals. There are many small areas of §3 protected nature reserves here, and the motorway might therefore affect several different species.

North of Silkeborg, several §3 protected meadows, streams, marshes, lakes and grasslands are to be found. Therefore it is important to decrease the barrier effect that the motorway will have and build fauna passages to allow the animals to wander between the habitats. The suggested fauna passages no. 42 and 44 have been placed on the basis of §3 protected nature reserves. They might be placed more favourably, if animal tracks are found and followed.

On the east side, the motorway goes through the city, and therefore it is limited how many nature reserves will be affected. South of Silkeborg Langsø, several fauna passages have been planned, because there are quite many §3 protected nature reserves here. Most of the passages will be constructed for red deer and can therefore be used by almost all species.

South of Linå it has been suggested to place 2 fauna passages (58 and 60) due to §3 protected heathland and grassland, which the motorway is going to pass through.

Fauna passage 64 is a landscape bridge in connection with a stream. Since animals often wander along a stream, this fauna passage will reduce the barrier effect for several species.

In general the fauna passages at the motorway between Funder and Låsby are placed better than between Ikast and Funder, probably due to the large amount of attention that has been directed at the motorway around Silkeborg. It may also be due to the fact that guidelines for the construction of fauna passages where presented in 2011 [Ujvári et al., 2011], providing greater knowledge on the subject.

8.3 Landscaped and suggested fauna passages between Ikast and Funder

Here, the different landscaped and suggested fauna passages on the stretch between Ikast and Funder are described.

The height and width of the fauna passages has been measured with a folding rule while the length has been measured on a map in QGIS. It was also attempted to measure coordinates with a Garmin etrex, but these coordinates were very imprecise and are thus not included. All fauna passages are indicated by a number in Appendix B and this number is used in the description to indicate the fauna passages described. Fences were observed on both sides of the motorway at all the fauna passages except for numbers 15, 16, 17 and 18. The fence was 164 cm high and the lower 75 cm mesh was 15 cm long and 5 cm high. After these initial measurements, the height of the meshes gradually increased until they were 15 cm high. Over the fences with meshes, a thick metal wire had been placed. At fauna passages 12, 13, 14, 15 16, 17, 18, 19, 20 and 21 there was an amphibian fence (see Figure 8.1). The results for the various fauna passages can be seen in Appendix C and a broader description can be found in Appendix D.

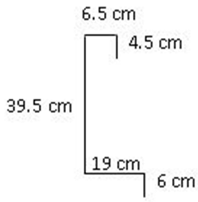

Figure 8.1: Results of the fauna passages between Ikast and Funder.

8.4 Planned fauna passages between Funder and Låsby

Not all fauna passages on this stretch have been constructed, and since the road has not been built most of them are placed as bridges spread throughout the landscape. Therefore not all fauna passages could be found. Several fauna passages were under construction and the localities were therefore a construction site which was closed to the public. The measurements of fauna passages are therefore taken from the maps which the Danish Road Directorate has given permission to use. Since the motorway has not been finished, it is impossible to assess the final result in relation to the animals' opportunities to be led to the fauna passage. Fences had not yet been placed and their effect could therefore not be assessed. The location of the planned fauna passages plus the suggested and the found fauna passages is shown in Appendix B. A more thorough description of them can be found in Appendix E. The results are shown in Table 8.2.

Table 8.2: Results from the found fauna passages on the stretch between Funder and Låsby. There's only measurement on one of fauna passages as there was no opportunities to enter the remaining passenger as they were still a construction site. Information on which animal they are dimensioned for has been provided by the Danish Road Directorate.

Fauna passages	Type	Height (m)	Width (m)	Length (m)	Animals
90	Tunnel				Roe deer
91	Landscape bridge				Red deer
92	Tunnel				Maybe roe deer
93	Possible fauna passage				
94	Possible fauna underpass				
95	Landscape bridge				
96	Fauna bridge				Roe deer and fallow deer
97	Landscape bridge				Roe deer and otter
98	Tunnel	2.76	2.44	16	Otter
99	Landscape bridge				Red deer
100	Tunnel				Red deer
101	Tunnel				
102	Landscape bridge				Red deer
103	Landscape bridge				

8.5 Comparison with recommendations from other countries

There are fewer fauna passages that can be classified according to Woess et al. [2002] than according to the instructions in Denmark [Ujvári et al., 2011]. However, the existing fauna passages live up to the recommendations given by Woess et al. [2002] (see Table 8.3) The data and results can be seen in Appendix F.

Table 8.3: Comparison between the recommendations and what is relevant for fauna passages on the stretch between Ikast and Låsby.

Recommendations according to Woess et al. [2002]	Current implementation
There should be at least 5 fauna passages with a minimum width of 30 metres.	6
There should be no more than 20 km between type A and B passages.	There is only 1 type B passage, but there are not 20 km between fauna passages of type A and B if they are assessed together.
There must be at least 5 type C passages on a motorway	6
The average distance between A, B and C must not be more than 10 km	3.7

In relation to Cavallaro et al. [2005], the distance between the small fauna passages is too large (see Table 8.4). Moreover, fauna passage 35 was scheduled to become an FMM, but after measuring it on location it has been assessed to be a fauna passage type FLM. Therefore, this is treated as an FLM. There is only one fauna passage of type FAR, as most small wildlife passages are categorised as FUR. This is because the area of the opening exceeds 0.84 m^2 which is the maximum requirement for fauna passages of type FAR, and because they exceed 0.37 m^2 which is the requirement for FSM fauna passages. It has been estimated, however, that amphibians and reptiles might be able to use FUR passages, particularly if they are moist, and that small mammals will be able to use FUR passages as well since the remaining requirements are very similar.

Table 8.4: Comparison between the recommendations of Cavallaro et al. [2005] and what is relevant for fauna passages on the stretch between Ikast and Låsby.

Recommendations according to Cavallaro et al. [2005]	Current implementation
The distance between fauna passages for small mammals must be between 46 and 91 metres.	The distance between the four planned fauna passages for small mammals is on average 1.4 km. None of the distances between the four passages meet the requirement.
Near habitats for upland reptiles, fauna passages of type FUR should be located at a distance of 46-91 metres.	There are four sections with wildlife passages of type FUR. None of the distances meet the requirements. The minimum distance between two wildlife passages of this type is 221 metres.

Recommendations for construction of fauna passages 9

This chapter will provide recommendations that are the result from the literature and studies of fauna passages processed in this report.

Large fauna passages (Type A)
Currently, the largest mammals in Denmark are wolves and red deer. The wolf can walk hundreds of kilometres in a few days [Madsen et al., 2013] and thus search for passages on a relatively long stretch. Red deer on the other hand walk typically 7-10 kilometres within their range of 200 hectare each day [Baagøe og Jensen, 2007]. Experiments with a GPS placed on a female red deer showed that after leaving its range, it walked along a motorway in three places without crossing the road. The distance between these three places was respectively 15, 5 and 20 kilometres [Olesen et al., 2009]. Fallow deer are smaller, move across shorter distances and are not as shy as red deer.

As red deer and wolves are both shy animals, it is recommended that wildlife passages for these animals are placed away from areas where there is much human activity. In addition, it is recommended that these types of fauna passages in connection with motorways are located at a minimum distance of 20 kilometres. To minimize the risk to animals passing the road, fences must be placed along the road and to the fauna passage with a 2.2 metre animal fence. There are three types of wildlife passages which can be constructed for wolves and red deer, and recommendations for the sizing of these can be seen in Table 9.1.

To improve the efficiency of fauna passages, natural lines of the landscape must be established to lead animals to the fauna passage. In addition, vegetation has to be planted across the fauna passage and hiding places for smaller animals have to be built. The location of hedges, trees, shrubs, hiding places and more can be accomplished according to Ujvári et al. [2011].

Table 9.1: Recommendations for fauna passages for wolves and red deer.

Type of fauna passages	Height (m)	Width (m)	Width of berms (m)	Openness/ tunnel ratio
Fauna bridge (FB-A)	-	≥50	-	>0.8
Landscaped bridge (dry) (LB-A(d))	>6	>20	-	-
Landscaped bridge (wet) (LB-A(w))	>6	>20 + watercourse	>10	-
Fauna tunnel (dry) (TU-A(d))	>6	>12	-	>1.5
Fauna tunnel (wet) (TU-A(w))	>6	>14 + watercourse	>7	>1.5

Medium fauna passages (Type B)

This type of fauna passage is for deer and medium-sized mammals such as fox, hedgehog and hare. As several deer species are shy [Baagøe og Jensen, 2007] and constitute prey for other animals, they require relatively large passages with a clear view. Fallow deer and roe deer are less shy than sika deer, and therefore the location of these wildlife passages, in correlation with areas of human activity, have to be assessed on the basis of the deer species that already are and/or are likely to become established in the area. Since small deer do not walk nearly as far as red deer [Baagøe og Jensen, 2007], fauna passages of type A have to be supplemented so there are never more than 10 kilometres between fauna passages of minimum type B on a motorway, and on a motorway stretch there have to be at least five fauna passages of type A and B in total. The relatively high tunnel index required for sika deer is due to the fact that sika deer are very shy and therefore have almost the same requirements for fauna passages as red deer. Moreover fallow deer are not territorial like roe deer [Vildtforvaltningsrådet, 2007], thus they do not instinctively have the same need to cross a road, and therefore the fauna passages have to be greater than type C. In order to lead animals to the fauna passage, there must be natural lines of the landscape, such as streams and hedgerows, from nearby habitats and to the passage. The passage must also provide cover of trees and hiding places for smaller animals in the form of rocks, logs and stumps. Recommendations for placement of trees, shrubs, hiding places and fencing (1.8 metres) can be seen in Ujvári et al. [2011].

Table 9.2: Recommendations for deer and larger mammals.

Type of fauna passages	Height (m)	Width (m)	Width of berms (m)	Openness/ tunnel ratio
Fauna bridge (FB-B)	-	>30	-	>0.8
Landscaped bridge (dry) (LB-B(d))	>4	>20	-	-
Landscaped bridge (wet) (LB-B(w))	>4	>20 + watercourse	>10	-
Fauna tunnel (dry) (TU-B(d))	>4	>12	-	>1.5
Fauna tunnel (wet) (TU-B(w))	>4	>14 + watercourse	>7	>1.5

Small fauna passages (Type C)

This type of fauna passages is for roe deer and medium-sized mammals. Roe deer are territorial with territories of 8-41 hectares [Baagøe og Jensen, 2007] and a home range of 16-81 hectares [Jeppesen, 1990]. The daily home range, however, varies between 1 and 27 hectares with an average of 8.5 hectares [Jeppesen, 1990]. A daily home range of this size will limit how far roe deer will walk to find a suitable fauna passage. Since roe deer are living in or near forests, passages should be in areas with small or large forests near the motorway. Due to the short distance that roe deer move daily, these types of fauna passages (see Table 9.3) need to be placed between fauna passages of type A and B and in areas near forest, may not be more than 1 kilometres apart (type A, B and C combined). This will minimize the barrier effect for roe deer and medium-sized mammals.

The fact that roe deer are highly territorial can be one of the reasons that they do not require as large fauna passages as the other deer species in Denmark. For smaller prey using the fauna passage, it is important that there are hiding places in the form of large rocks, tree trunks and stumps throughout the fauna passage. In addition, the fauna passages are made more efficient by ensuring natural lines from nearby nature to the fauna passage. At fauna bridges and landscape bridges, these lines should proceed throughout the passage and into a habitat on the other side of the passage. The location of hedges, trees, shrubs, hiding places and fencing (1.8 metres) for the fauna passage should be constructed according to Ujvári et al. [2011]. Since roe deer are less shy than other Danish deer species, these fauna passages may with advantage, unlike the type A and B fauna passages, be placed near urban areas and in areas of human activity.

Table 9.3: Requirements for fauna passages for roe deer and medium-sized mammals.

Type of fauna passages	Height (m)	Width (m)	Width of berms (m)	Openness/tunnel ratio
Fauna bridge (FB-C)	-	>20	-	>0.8
Landscaped bridge (dry) (LB-C(d))	>4	>20	-	-
Landscaped bridge (wet) (LB-C(w))	>4	>20 + watercourse	>10	-
Fauna tunnel (dry) (TU-C(d))	>4	>6	-	>0.75
Fauna tunnel (wet) (TU-C(w))	>4	>7 + watercourse	>3.5	>0.75

Small predators' fauna passages (Type D)

This type of fauna passage is made for medium-sized mammals such as fox and otter. There must be natural lines of the landscape (eg. hedges or streams) from a nearby habitat and to the opening of the tunnel. Throughout the passage, there should be hiding places in the form of large rocks, logs and stumps to make it more useful for smaller prey and thus usable for several species. The fence, which will go along and over the fauna passage, must be at least 1 metre high and buried in the ground. Since the smaller animals have a smaller home range than the larger animals, in surroundings with nature areas on either side of a major road there should be supplemented with this type of fauna passage so there is no more than 150-300 metres between fauna passages of the types A, B, C and D. This will minimize the barrier effect on small and medium-sized mammals. The recommendations for the dimensions of this type of fauna passage can be seen in Table 9.4.

Table 9.4: Requirements for medium-sized predators.

Type of fauna passages	Height (m)	Width (m)	Width of berms (m)	Openness/tunnel ratio
Fauna tunnel (dry) (TU-D(d))	>1	>1.5	-	>0.4
Fauna tunnel (wet) (TU-D(w))	>1	>3 + watercourse	>1.5	>0.4

Amphibian and reptile fauna passages (Type E)

This type of fauna passage is built for amphibians and reptiles. The dimensions of the fauna passages are the same for these animals; however, it is important to ensure that the substrate at the bottom is moist or dry depending on whether the fauna passage is expected to be used by upland reptiles or amphibians and reptiles that prefer moisture. In connection with the fauna passage, an amphibian fence should be placed along the road and to the fauna passage. In the middle of the opening, a transverse piece of fence that ensures that the animal stops and changes direction and thus does not pass by the entrance to the fauna passage may be placed with advantage. Location of fences, shelters and seating places on their way from the habitat to the fauna passage must be established according to Ujvári et al. [2011]. There are differences in how far the different species move from their breeding places, and therefore the distance and location of fauna passages depend on which species are likely to use the fauna passages. Since there not are found better recommendations for the design of this type of fauna passage than Ujvári et al. [2011], this recommendation has been used. See Table 6.6 on page 25 for more details about the design of these types of fauna passages.

10 Fauna passages for a possible motorway between Herning and Ringkøbing

Based on the recommendations in the previous chapter, there will in this section be discussed where fauna passages should be placed if a motorway between Herning and Ringkøbing were to be built.

On Figure 10.1, Figure 10.2, Figure 10.3 and Figure 10.4, the locations of fauna passages in connection with a motorway between Ringkøbing and Herning can be seen. There are 63 fauna passages on a 44-kilometre stretch. There are five fauna passages of types A and five of type B. On the route there are river valleys and gravel pits where it is deemed possible to place landscape bridges. Since there are areas with lakes or wetlands that are fragmented by the motorway, there are not placed extra fauna passages of type E for amphibians and reptiles. However, there may be local knowledge of migration routes for these animal groups, which should be investigated. Several places have been supplemented with fauna passages of type D, as there are nature areas close to the motorway or on both sides. This will allow smaller animals' greater opportunity to cross the motorway safely.

Which animals there are road killed is announced by Morten Elmeros. He also stated that Aarhus University has developed a equation to calculate the risk of running into an animal on a given route. On the road that runs parallel to a motorway between Ringkøbing and Herning, is the risk of running into roe deer greatest between fauna passage 2 and 11 and between fauna passage 20 to 22. It can be advantageous to put up fence between fauna passages in these two lines to guide the animals to the fauna passages.

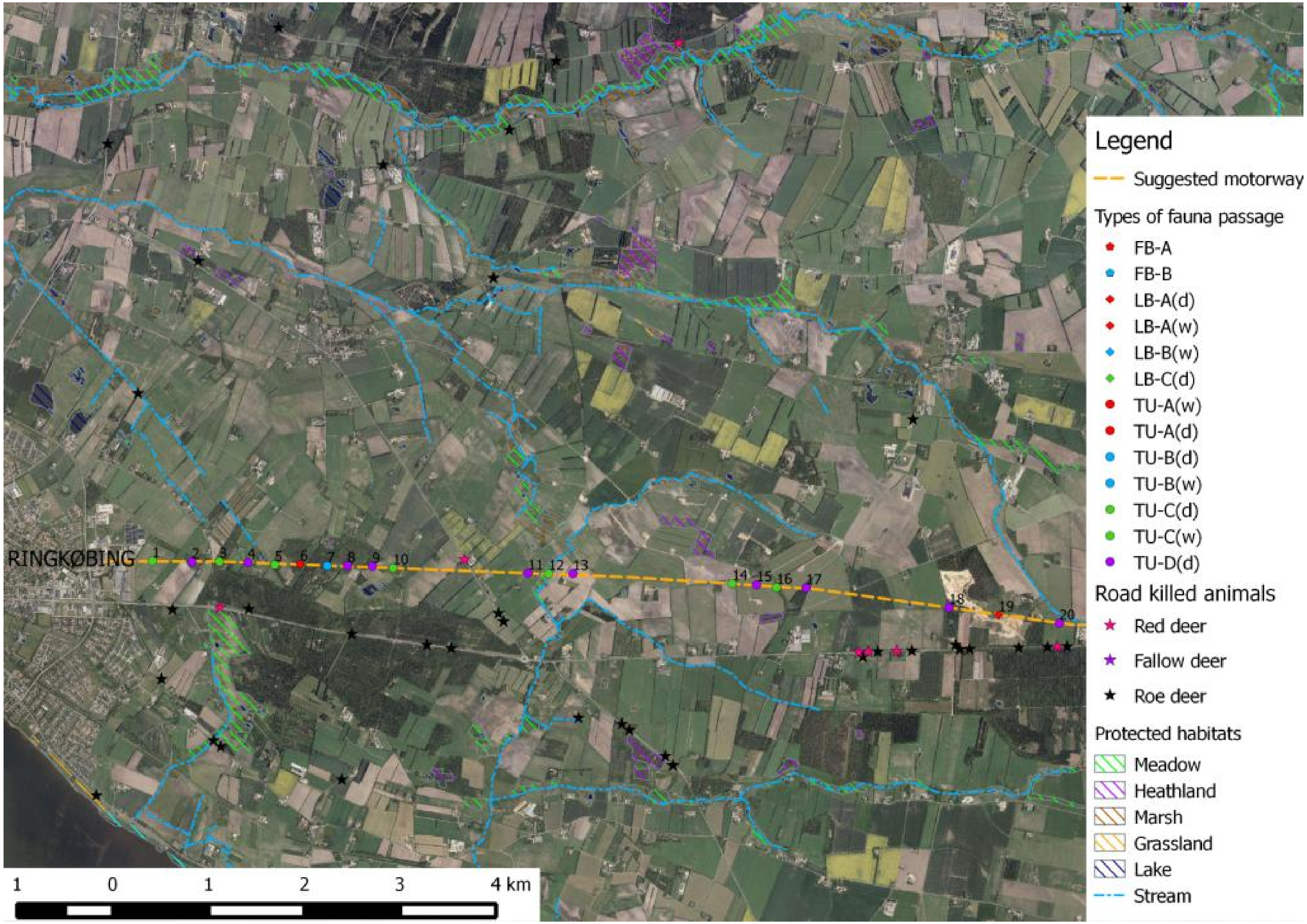

Figure 10.1: Location of fauna passages at a possible motorway between Ringkøbing and Herning. Fauna passages are located based on guidelines given in the previous chapter.

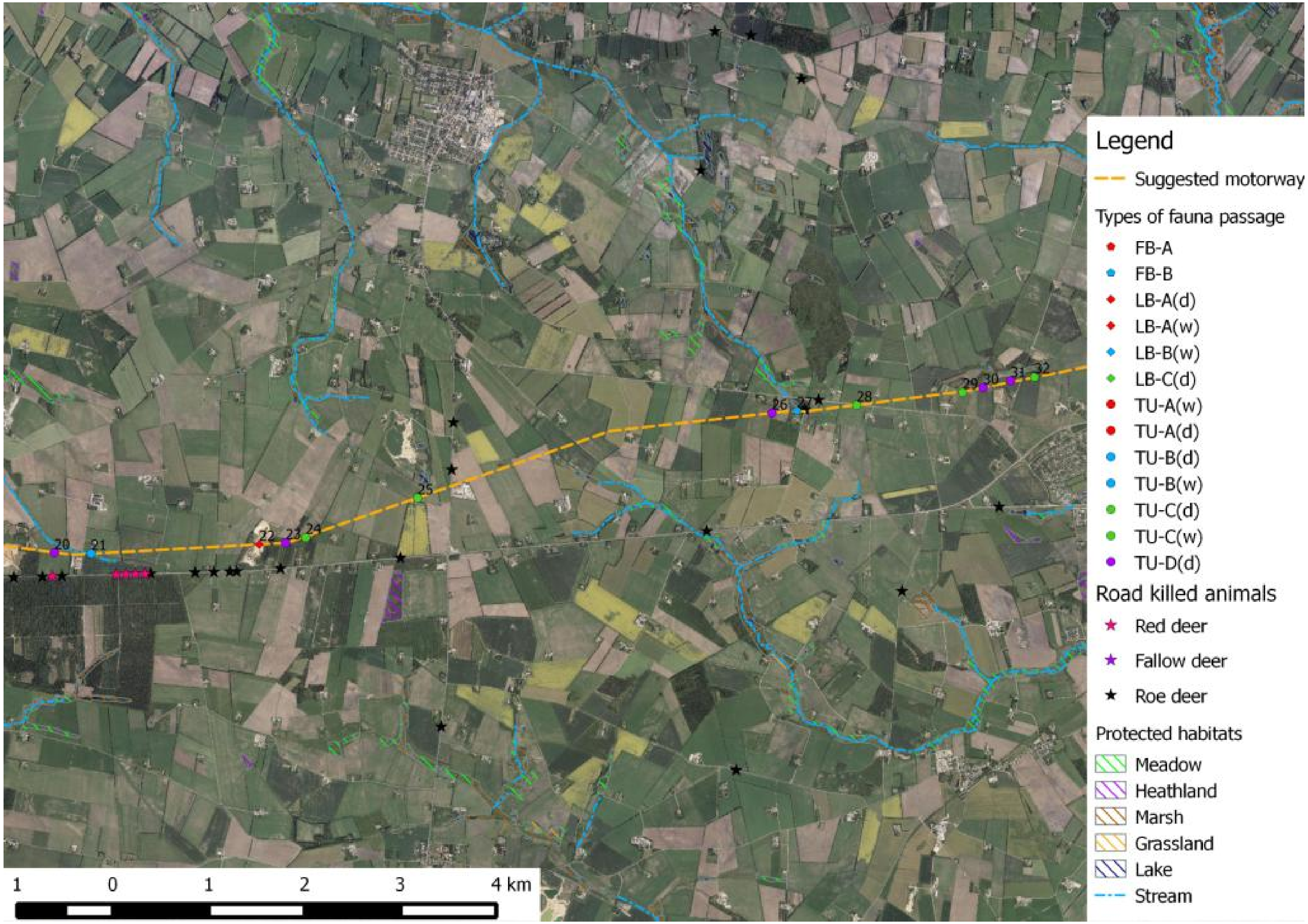

Figure 10.2: Location of fauna passages at a possible motorway between Ringkøbing and Herning. Fauna passages are located based on guidelines given in the previous chapter.

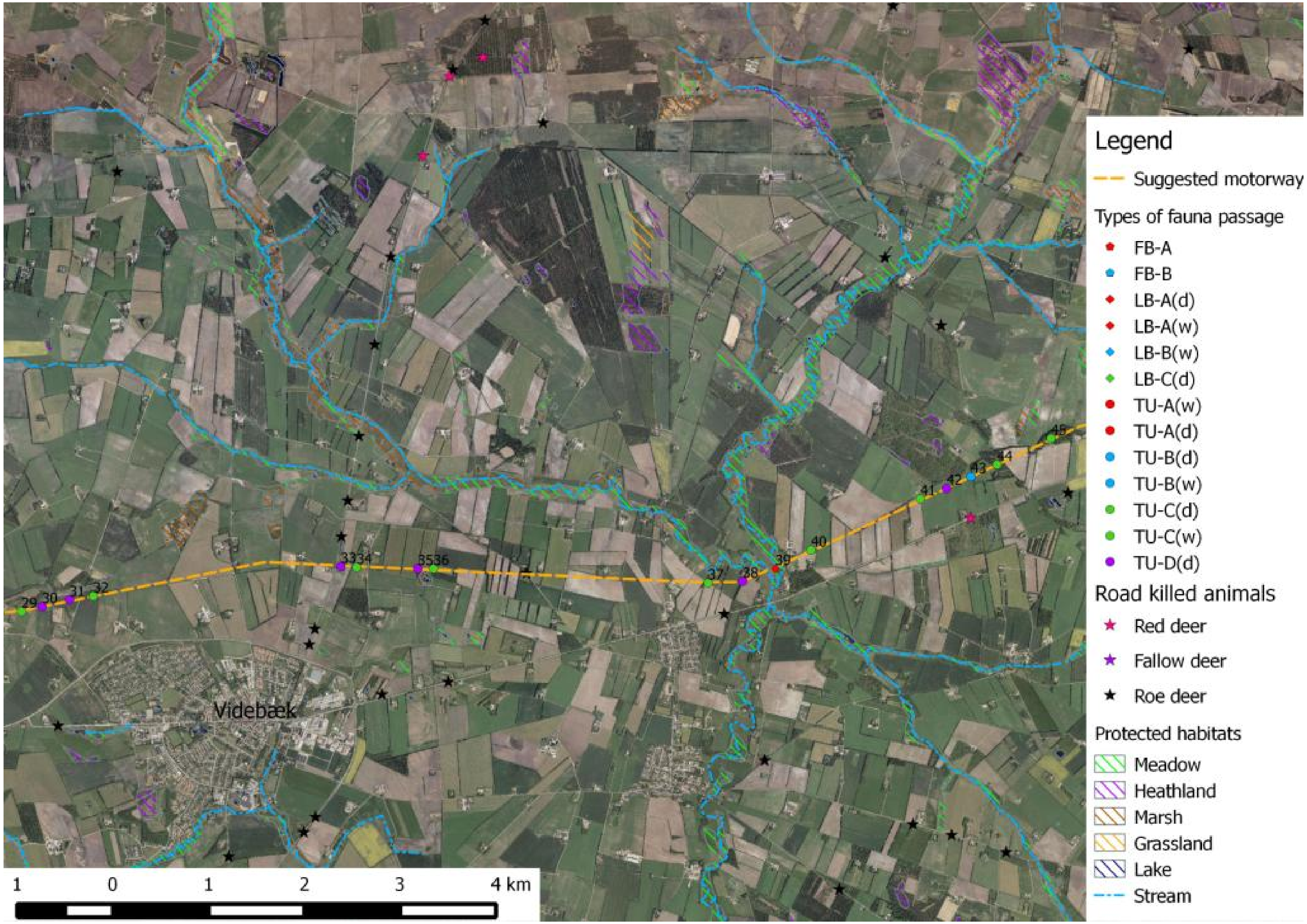

Figure 10.3: Location of fauna passages at a possible motorway between Ringkøbing and Herning. Fauna passages are located based on guidelines given in the previous chapter.

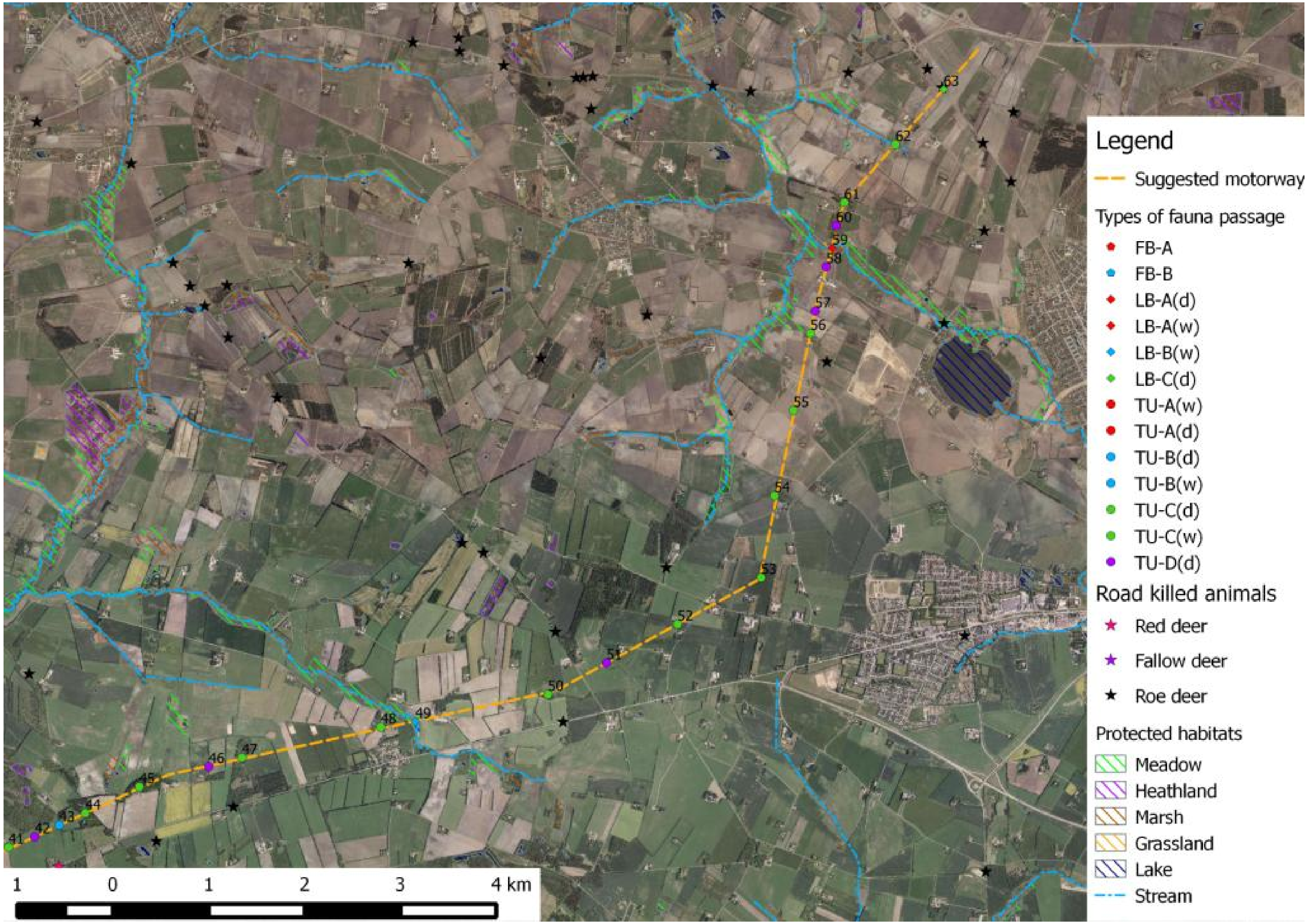

Figure 10.4: Location of fauna passages at a possible motorway between Ringkøbing and Herning. Fauna passages are located based on guidelines given in the previous chapter.

11 Discussion

Most of the planned fauna passages on the route between Funder and Låsby were not yet built. Therefore estimates were made from information provided by the Danish Road Directorate. The number and types of fauna passages on this route may end up being different, and thus the results might be different after construction has been finished.

Several of the landscaped fauna passages were missing hedges to guide animals to fauna passages. Moreover, hiding places for small animals were missing in several of them. Therefore, the effectiveness of these passages might be lower than if hedgerows between fauna passages and nearby natural areas had been established. It remains yet to be seen if these conditions will be improved on fauna passages between Funder and Låsby as these are not yet finished. However, there are several landscape bridges which provide a better connection between habitats as well as several fauna passages located in wooded areas where animals can hide among the trees, which makes it safer for them to wander to the fauna passages.

There are large differences in the types of fauna passages constructed between Ikast and Funder compared to the fauna passages that have been planned between Funder and Låsby. There is approximately 1.4 fauna passage per kilometre on both lines (see Table 11.1), but there is a difference between the types of the constructed fauna passages. Between Ikast and Funder, six of the fauna passages are too small to be classified according to Ujvári et al. [2011], whereas this is not the case for any of the passages between Funder and Låsby. This may be due to guidelines on fauna passages published in 2011; while the first part of the motorway was built, no such guidelines existed. There is a higher rate of fauna passages for red deer and roe deer between Funder and Låsby than between Ikast and Funder, which is also the case with TU5 fauna passages. Since the population size of deer in the area is not known, it cannot be assessed whether there should be a larger fauna passage per kilometre like the one recommended by Ujvári et al. [2011] in areas with many deer. The same applies to passages for badgers. The term "many" is relative and it will therefore always be a matter of opinion whether there is a need for a large fauna passage each kilometre. The reason for the large number of TU5 fauna passages is due to the fact that all the fauna tunnels that are listed with a width of 1.5 metres must be treated as a type TU5, since the requirement for TU3 is a width larger than 1.5 metres. However, there may be changes once the passages will be constructed, and therefore the number of TU3 fauna passages may rise. However, it seems as if the release of the guidelines for fauna passages has resulted in a better management of fauna passages.

Table 11.1: Numbers of fauna passages and different types of fauna passages per kilometre. Distance 1 is between Ikast and Funder, distance 2 is between Funder and Låsby. Fauna passages for group 2 are TU2, LB2 and FB2. Fauna passages for group 1 are TU1, LB1 and FB1.

Distance	**Numbers per kilometre**	**Unit**
1	1.37	Fauna passages/km
2	1.39	Fauna passages/km
1	0.26	TU5/km
2	0.61	TU5/km
1	0.11	TU3/km
2	0.04	TU3/km
1	0.11	For group 2/km
2	0.21	For group 2/km
1	0.16	For group 1/km
2	0.25	For group 1/km

Several of the fauna passages that were constructed could be improved by planting hedgerows at the entrance, which aids animals in being guided to the fauna passage. Moreover, in several of the fauna passages stumps, rocks or other hiding areas for smaller animals could be placed. In fauna passage 2 there were no horizontal berms and therefore this passage could be improved by placing berms on the inner side of the bridge. Since the final result of fauna passages between Funder and Låsby is not yet known, it is not known whether there will be hedgerows or other natural lines that can lead fauna to the fauna passage and on the other side of the motorway.

Studies from Austria (Woess et al. [2002]) resulted in a different way to classify fauna passages. This is based on the importance of migration routes. There are also more specific guidelines on how many fauna passages need to be built and how far the distance between the large fauna passages should be. From the sizes that the fauna passages are classified by, there are fewer that can be classified than compared to Danish guidelines. However, the fauna passages do meet the requirements concerning the distance between them. Since the average distance between the fauna passages of type A, B and C must be 10 kilometres and is 3.7 kilometres, it has been estimated, based on Woess et al. [2002], that there is a sufficient number of larger fauna passages. However, nature and the way nature is cultivated in relation to agriculture, constructions and nature reserves differs from Denmark to Austria, and therefore this may also be the reason for the different requirements. Moreover, this recommended distance given by Woess et al. [2002] is of a general nature, whereas the Danish recommendations do not have any recommendations on the frequency of large fauna passages in areas with few deer. Thus, contradictory to Austrian guidelines, no recommendations to build fauna passages for larger animals in these areas exist.

A thesis from California (Cavallaro et al. [2005]) suggested to classify fauna passages according to the size of the animals that are meant to use the passage in question. However, this does not take into account that certain species are shyer than others. Besides size, the guidelines presented by Cavallaro et al. [2005] also make demands on the distance between small fauna passages. If their classification is applied on the fauna passages analysed in this report, the number of fauna passages that could be classified is nearly the same as when applying the Danish method. However, the distance between fauna passages for upland reptiles does not meet the requirements, as was the case for fauna passages for small mammals. In addition, the requirements for fauna passages for large mammals were not nearly as large as those given by Danish and Austrian guidelines. The minimum height for wildlife passages for large animals is 1.83 metres according to Cavallaro et al. [2005], which can cause problems in areas with larger deer species. In addition, the requirements for the area of the opening of fauna passages of type FSM (fauna passages for small mammals) and FAR (fauna passages for amphibians and reptiles) were very small, which means that most small fauna passages end up in the category for fauna passages for upland reptiles (FUR). It is estimated that these passages may well be used by small mammals, since the requirements are otherwise very similar. If a fauna passage with dimensions corresponding to FUR is moist, upland reptiles will not use it. However, it would be expected that reptiles and amphibians will use it as they prefer the moist environment.

Several fauna passages between Ikast and Funder were designed in a way which made it impossible to classify them and thus there is very little likelihood that any animals will use these. Moreover, there were several streams that did not have fauna passages, and thus there were no crossing facilities for the animals that are associated with these streams. From Ikast to Bording there was an animal fence on both sides of the motorway, and thus the barrier effect is larger than if there had been no fence. To avoid an increased barrier effect, it is important that the fence only are placed where there is good fauna passages as the animals are lead to. If there is fencing further, the possibility for genetic exchange with populations on the other side of the motorway will decrease. In areas with high probability of run into animals, can there for example be built good fauna passages with fencing to guide the animals to the passengers.

There is only designed one fauna passage for larger mammals. At larger fauna passages placed after Bording, shelter and hiding places for smaller animals have been constructed, and thus passages on this route are more considerate of these animals than on the stretch between Ikast and Bording. On the stretch between Funder and Låsby there are several major fauna passages and the larger mammals have been taken more into account on this stretch than between Ikast and Funder. However, there are places with §3 protected nature reserves in which fauna passages would benefit the local fauna.

The frequency of large fauna passages seems at first glance to be sufficient, however, it would be advantageous to construct several fauna passages for small animals as well, since these animals do not wander as far as larger animals. Therefore they need the fauna passages to be closer. There is a dire need of more knowledge about what distance the various fauna passages should cover. By having more specific guidelines for placement of fauna passages, such as a guide to the minimum number of each type of fauna passage and a guide to how often they should occur in areas with a given population size, they would possibly be better managed.

In order to improve guidelines aimed at placing fauna passages most advantageously, this lack of knowledge about how far different species will wander when trying to find a suitable passage needs to be remedied. For example, there is only limited knowledge of how far roe deer will wander to find a fauna passage, and thus it is difficult to put a precise measurement of the distance between fauna passages for roe deer. The same is true for most species. When using a lot of money on the construction of fauna passages, the location of them should be good as effective in preventing the barrier effect as possible. Therefore, it is advantageous to investigate in different species response pattern on a motorway. For example, a GPS could be placed on several individuals close to various motorways in order to see how they react to the barrier presented by the motorway.

12 Conclusion

When motorways are built, a fragmentation of the landscape occurs with the motorway acting as a barrier for both flora and fauna. This often has major consequences for several species as dispersal potential and gene flow is reduced by fragmentation and the barrier effect. Some habitats may become so small that the associated species become extinct in the area. By building fauna passages with the correct dimensions and at optimal locations, the barrier effect and thereby also the number of road-killed animals is reduced.

In this thesis, current knowledge on fragmentation, barrier effect and fauna passages are described and afterwards applied on a concrete Danish example. Based on the motorway between Ikast and Låsby, it has been assessed whether the fauna passages were optimally sized and located and whether more could be constructed with advantage.

Ikast to Funder
Many fauna passages on the stretch between Ikast and Funder were missing natural lines of the landscape such as hedgerows to lead the fauna to the fauna passage.

Between Ikast and Funder, several major fauna passages could have been placed advantageously as there were few passages for red deer, and they were all after Bording. Several of the fauna passages between Ikast and Bording were also lacking hiding places for small animals.

Between Ikast and Boarding there are several places where there can advantageously be placed fauna passages. This is principally by piped streams, but also places where there are protected lakes on both sides of the motorway.

Funder to Låsby
As all fauna passages between Funder and Låsby not yet were built, it cannot be assessed if they all are placed at the most optimal position in the landscape. However, the fauna passages found are well located in relation to the protected nature reserves. Apart from the challenge presented by streams, there are only few places with protected nature reserves on both sides of the motorway where further fauna passages can be placed with advantage.

Between Funder and Låsby there were several major fauna passages, and thus the barrier effect of the larger mammals is smaller on this stretch than between Ikast and Funder.

Recommendations for construction of fauna passages
Based on studies undertaken during this report, it ended with recommendations for four types of fauna passages. To ensure the animals will use these wildlife passages there may be placed fence leading to the fauna passage if the passage is good. The use of fences should be limited to places where there is high risk of road-kill otherwise it will increase

the barrier effect further as the animals are prevented from crossing the motorway.

- Type A: This type is for large mammals such as red deer and wolves.
  - Fauna bridges must be at least 50 metres wide and have an openness ratio of at least 0.8.
  - Landscape Bridges must be at least six metres high, have a width of at least 20 metres + possible watercourse and berms of at least 20 metres on each side of the watercourse.
  - Fauna tunnels must be at least six metres tall and have a tunnel ratio of at least 1.5. Is it a dry tunnel the width must be at least 12 metres while in cases where a watercourse runs through, it must have berms of at least 7 metres on each side of the watercourse.

- Type B: is for deer and medium-sized mammals such as badgers and hare.
  - Fauna bridges must be at least 30 metres wide and have an openness ratio of at least 0.8
  - Landscape Bridges must have a minimum height of 4 metres, in addition, requirements are similar to Type A passages.
  - By fauna tunnels, the minimum height must be 4 metres and additional requirements are the same as for Type A passages.

- Type C: is for roe deer and medium-sized mammals such as badgers and here.
  - Fauna bridges must be at least 20 metres wide and have an openness ratio of at least 0.8
  - Landscape Bridges must have a minimum height of 4 metres, in addition, requirements are similar to Type A passages.
  - Fauna tunnels must be at least four metres tall and have a tunnel ratio of at least 0.75. Is it a dry tunnel must the width be at least six meters while in cases where a watercourse runs through, it must have berms on at least 3.5 metres on each side.

- Type D: is for medium-sized predatory mammals such as badgers and foxes. This type is only available as fauna tunnels.
  - Fauna tunnels must be at least one metre high and have a tunnel ratio of at least 0.4. Is it a dry tunnel the width must be at least 1.5 metres while in cases where a watercourse runs through, it must have berms of at least 1.5 metres on each side.

Herning to Ringkøbing

The recommendations mentioned above are used to indicate what type of fauna passages which should be constructed if the motorway is extended between Herning and Ringkøbing and where they should be located.

The number of fauna passages per kilometre of motorway between Herning and Ringkøbing ended up being about the same as there are in connection with the motorway between Ikast and Funder and between Funder and Låsby. However, there are differences in the types of fauna passages. Since there was a lack of knowledge of the requirements of amphibians and reptiles and since there were no obvious areas where these animals need to cross the motorway, there was no need to supplement with this type of fauna passage.

Wanted knowledge

In order to get a better understanding of how fauna passages for various species have to be placed, it should be researched how these species respond to a motorway and how far they will walk in order to find a fauna passage.

Moreover, population size in areas along a road would help to provide a picture of how great the need is to place fauna passages. Aarhus University has the knowledge of where different animals are road killed from 2003 to 2012. Based on their data, they have developed a equation to calculate where on a given route is most likely to run into an animal. This equation can also be used in the planning of new roads. This makes it possible to take into account where the need for location of fauna passages is greatest.

Although the location of fauna passages can be improved, there is improvement over time on the stretch between Ikast and Låsby. On the stretch Ikast - Boarding there is animal fence on both sides of the motorway and several fauna passages do not live up to the instruction that apply nowadays. Between Boarding and Funder, there is only animal fence on few parts of the distance and there are several major fauna passages, which are also better placed in the landscape. Based on what is planned between Funder and Låsby there are even more large fauna passages and animal fence also seems to only come for short stretches.

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