An examination into the use of the fauna passages, installed under the train tracks, by medium to small vertebrates

A report submitted as the examined component of the Project Module SXE390

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ABSTRACT

Train tracks are a major barrier for the movement of wildlife and lead to habitat fragmentation. One mitigation approach is the addition of ecoducts (this term is used to cover a range of fauna passage types) when renovating. A literature review revealed that most studies on ecoducts focuses on large mammals or amphibians, and traffic accidents on roads. To fill this knowledge gap, this study focusses on the use of ecoducts under train tracks by small to medium sized mammals.

Three wildlife surveillance (trail) cameras were placed out at two ecoducts and one eco-bridge (designed for animal usage) along the Roslagsbana train track in the Täby municipality (Sweden), which were within a few kilometres of each other and easily accessible. The aim being to capture data on wildlife traffic through these ecoducts.

Initially, following recommendations from earlier studies, the cameras were configured to take a picture every 30 seconds. However, as this failed to capture many transits the configuration was changed to motion detection resulting in a lot more transit data capture. An analysis of the data showed there was no significant difference between the sites and that the number of daily transits recorded is in line with other studies, of 1-2 per day. In addition, images were captured of an otter, an endangered species in Sweden, and these sighting can be added to the existing sighting database, Artportalen.

Despite being recommended in construction guidelines no pre-study was carried out before the ecoducts were introduced so it is not possible to come to any conclusions about the success of this mitigation technique. However, the data gathered can be used to help estimate current population levels and can be combined with a larger study on animal populations in the surrounding areas to help evaluate the habitat degradation as a whole.

(299 of 300 words)

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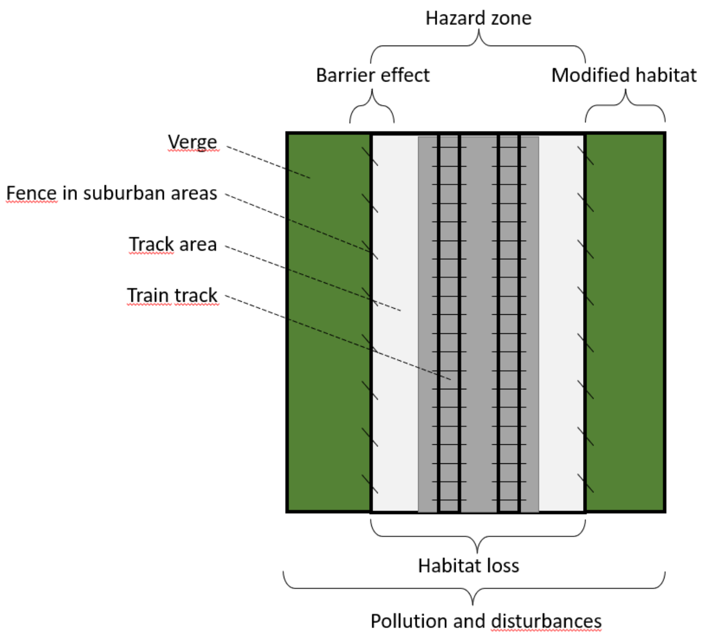
INTRODUCTION

Modern traffic infrastructure is a leading cause of of habitat fragmentation (Trafikverket, 2005), and "the breaking apart of continuous habitat" (Bennet and Saunders, 2010) is itself a leading cause of the decline in biodiversity. This fragmentation turns the forests that covered nearly the whole of Sweden into a set of smaller forest "islands" broken apart by roads and train tracks. The theory of island biogeography (Dyson, 2022) tells us that these smaller areas cannot support large populations and the roads and tracks form barriers which stop "colonisers" arriving to refresh the gene pool; having negative effects on genetic diversity, and several studies bear this out (Holdegger & DiGuilio, 2010). Although, these barriers also lead to an increase in 'edges', which can be very suitable for some species: "There is strong evidence that railway verges offer new habitats for generalist species and for opportunistic individuals" (Barrientos and Borda-de-Água, 2017).

Roads and train tracks are barriers not just to finding a mate but also to finding food and shelter and get in the way of migration routes (Dyson, 2021). Some species cannot negotiate the tracks, others are scared away by the noise ((Barrientos and Borda-de-Água, 2017) and many of those that can traverse the barrier may fall victim to collisions with vehicles (Helldin & Petrovan), all of these effects are depicted in figure 1, below. These issues have led to the idea that corridors should be created to connect these habitat fragments and for traffic infrastructure this has meant the introduction of ecoducts: bridges or tunnels crossing the roads and tracks, as standard practice during construction and renovation (note that throughout this report the term ecoducts will be used to cover all types of passages designed for wildlife traffic). The ecoducts' design is based around animal size, the amount of light and the surface type (see figure 19 in the appendix for examples of different types of ecoducts).

Figure 1 Traffic zones and effects on wildlife, adapted from Trafikverket (2015)



Although there are instructions and guidelines (Trafikverket, 2015) for the building of ecoducts, including an evaluation of the local wildlife in order to ascertain the types of ecoducts required and suitable placement, there seems to be little work carried out to confirm that they are used as intended and even less work done on whether this has helped mitigate the effects of habitat fragmentation, a number of researchers have identified this lack (including Helldin & Olsson, 2010).

There have been several studies (in Sweden, as well as internationally) on the use by large mammals, such as elk and deer, of large ecoducts and culverts (for instance Seiler and Olsson, 2009), but mainly with a focus on reducing collisions. There have also been several papers focussing on amphibian's use of ecoducts (Helldin and Petrovan, 2019 and Pomeranzi, 2017) however there seems to have been little evaluation of the use of ecoducts and culverts by small mammals, the majority have focussed on one species (such as Clevenger et al, 2001). However, the construction company Vinci released a report on a large scale, 5-year project monitoring of ecoducts crossing French motorways (Fagart et al, 2016). This paper focussed mainly on the process and methods of monitoring different types of ecoducts, making recommendations for best practice, although a large amount of data on the amount of animal traffic was included in the report the authors themselves state that evaluation of the mitigation effects was left for another research project.

The aim of this investigation was to monitor the animal traffic through 3 ecoducts placed under the Roslagsbana train tracks in the Täby municipality over a number of weeks in order to assess whether they are used and by which species. This was done using trail cameras, a tool becoming more popular as size, price and complexity of use have all come down. The initial aim was to compare the animal traffic between the different sites and nearby culverts but due to the low levels of traffic encountered this was modified to just comparing the sites. Then to try and relate these traffic levels to those reported in other papers. As with other reports this paper will not cover the wider implications for habitat fragmentation but focusses instead on providing data for use in future investigations which at least covers one of the areas identified by Helldin and Olsson: that there is a lack of data from Sweden that can be used to compare with other countries.

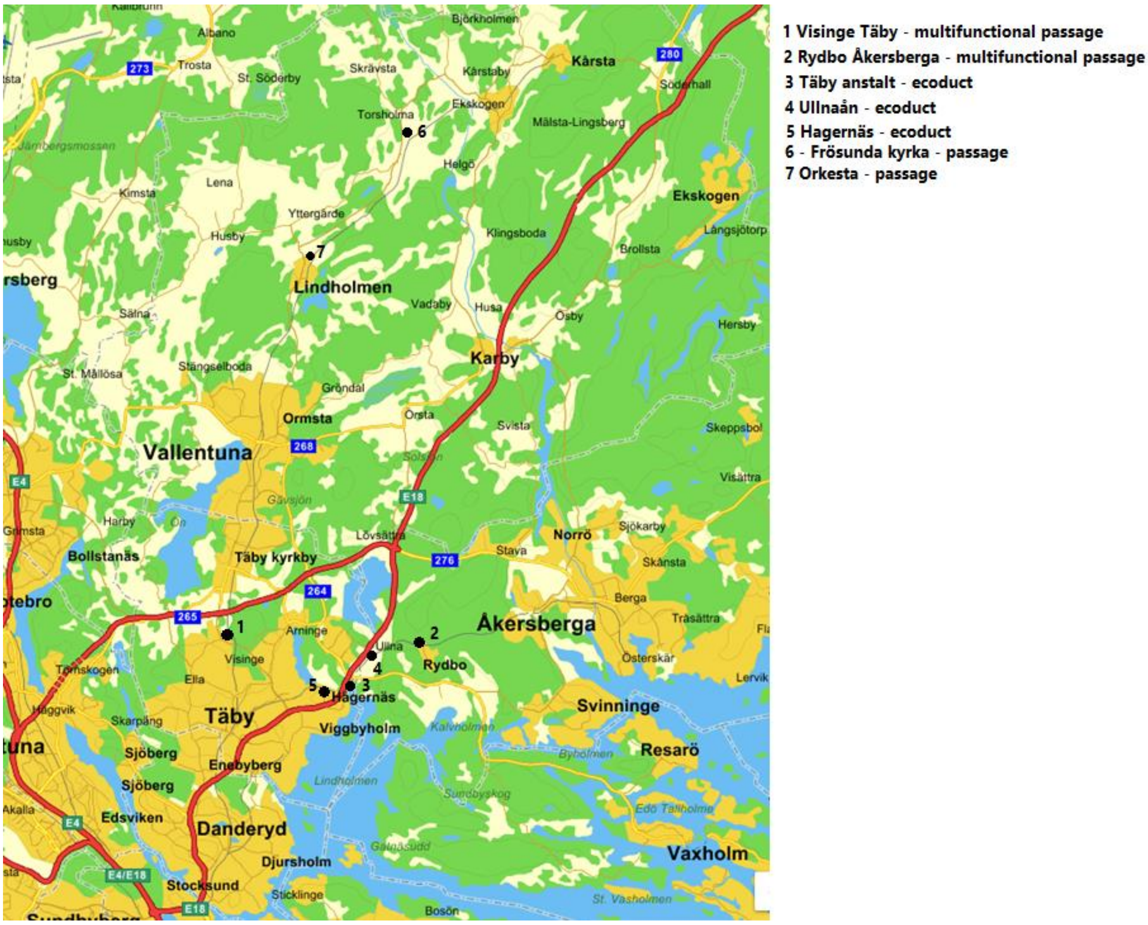
MATERIALS AND METHODS

Sites

The Roslagsbana train track was recently renovated and the number of tracks doubled from one to two to allow an increase in commuter train traffic. As part of the renovation the drainage under the tracks was improved and ecoducts introduced in line with Trafikverket's (Swedish transport authority) policy on minimising damage to the environment (Banverket, 2004).

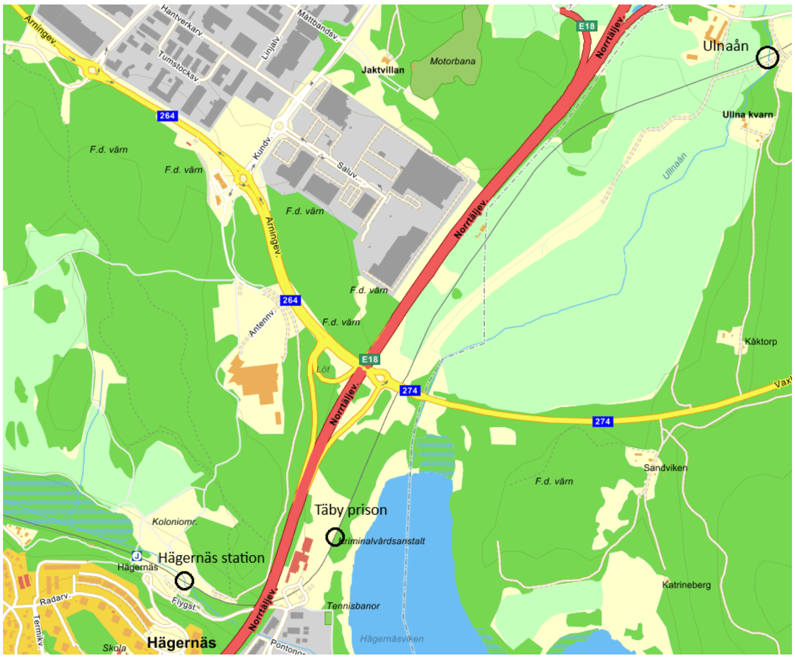
Seven potential sites were initially identified along the track: 3 ecoducts, 2 multifunctional passages, and 2 water passages/bridges (see map in figure 2).

Figure 2 Map showing location of potential sites



The multifunctional passages (Jägerbrand, 2020) were rejected because they were much larger (in terms of dimensions not length) than envisaged for this study and as it would entail extra permissions due to the chance of capturing the faces of members of the public. The water passages were rejected because they were further away increasing logistical difficulties. The ecoducts (one is actually an "ecobridge" intended for animal passage), are relatively close together (within 2km, see figure 3), but above all they were the ones recommended for study by an ecologist from Trafikverket and where that person could provide support.

Figure 3 Map showing location of the 3 selected sites zoomed in



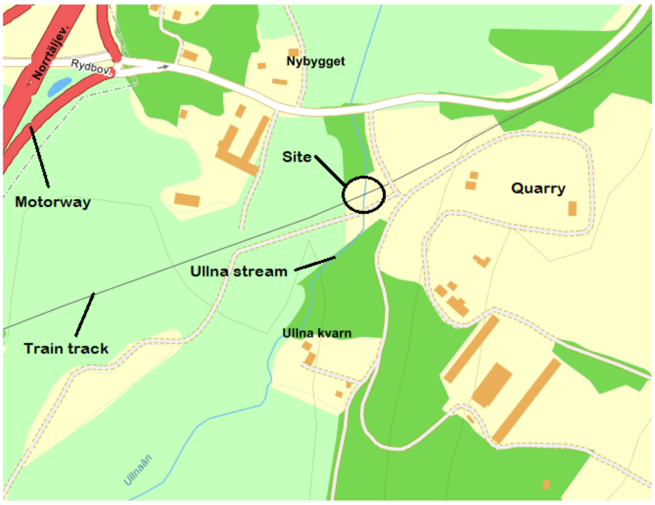
The initial plan was to set up 2 cameras; one to cover the passage and the other to cover a nearby culvert and then to move the cameras between sites. However, due to difficulties with securing a camera at Täby and there not being a culvert at Hägernäs this was modified to one camera at each site covering as much of the passages and surrounding area as possible; the three cameras were out at the same time, experiencing the same weather seasonal effects as wildlife wake up from the winter (the thaw set in in early April in 2022).

The three sites are described in more detail below:

Ullnaån

This site is next to a gravel quarry and the road is heavily trafficked by trucks going to and from the quarry during working hours but little other car traffic. There is a bridge taking the trains over the road and the stream (called Ullnaån in Swedish) goes under the track about 20 metres away from the road (See figure 4).

Figure 4 Map showing placing of site at Ullnaån
(SWEREF99 TM (north, east) 6595973, 678871)



When the culvert was renovated the Trafikverket ecologist suggested 2 ecoducts be included (one on each side of the main culvert) at the same time, as it would entail relatively little extra costs. The culvert comes out in a small collection area and then there is a second culvert going under the service road, before returning to a free-flowing stream (See figure 5). The ecoducts are 60cm in diameter.

Figure 5 Picture of the ecoducts alongside the culvert at Ullnaån

The camera is placed a little to the left of the above picture (figure 5), at an angle so that all three, two ecoducts and culvert, are captured (see figure 6).

Figure 6 Picture of the camera position at Ullnaån

Täby Prison

This site is on the other side of the train track from a low security prison, the ecoduct was placed there at the request of the county council to make sure there was a connection between the green areas, see map in figure 7, although there is no similar connection between the two sides of the motorway. The marshy area alongside the water has been identified by the council as an area of natural interest (Collins 2011) and the green area on the other side of the motorway is a nature reserve.

Figure 7 Map showing placing of site at Täby prison
(SWEREF99 TM (north, east) 6594535, 677689)

There is a gravel access road alongside the train track that is very well used by the locals for walks, and a marshy area on the other side of this road (see figure 8).

Figure 8 Picture of the position of the ecoduct at Täby prison

For this reason it was decided (on the advice of the Trafikverket ecologist and later confirmed by Fagart et al, 2016) that the camera actually be placed inside the tunnel (hanging from the roof, see figure 9). The other side of the road would be very noticeable to people who may disturb the camera and also much harder to pick up signs of small animals at a 5m distance. This ecoduct is also 60cm in diameter.

Figure 9 Picture of the ecoduct outside Täby prison, with culvert to the left

Figure 10 Picture of the camera positioned inside the ecoduct

The cable is to a large external battery and the chain is to reduce the risk of theft (see figure 10). The gravel was already placed inside the ecoducts on construction and was added to cover up the cable and chain as much as possible.

Hägernäs station

This site neighbours a nature reserve to the northeast and west as well as a large allotment area directly to the north (see map in figure 11).

Figure 11 Map showing placing of site at Hägernäs station
(SWEREF99 TM (north, east) 6594372, 677257)

When renovating the tracks at Hägernäs station it was decided to replace the bridge under the tracks with another design incorporating “shelves” at the side allowing passage for animals (see figure 12), following the guidelines referred to above.

Figure 12 Picture of the ecoduct at Hägernäs station

The camera is placed on the opposite side of the tracks, in this picture, and angled to capture both sides of the bridge (see figure 13).

Figure 13 Picture of the camera position at Hägernäs station

Camera configuration and data analysis

The cameras used are Pro-Optics PRO 3.4G (see figure 14) and were initially configured to take a picture once every 30 seconds (following recommendation made by Pomeranzi, 2017, Jumeau et al, 2017, and Fagart et al, 2016, who all explained that motion detection triggers did not capture small animals or amphibians well). After approximately one month the configuration was changed to motion detector (see Analysis section). The 32GB memory card was retrieved and batteries recharged every 4-5 days. Each camera was chained to a fixed place, in order to reduce the risk of removal, and then covered by stones and/or tarpaulin for added protection and discretion, as all the sites are used by the public.

Figure 14 Trail camera, Pro-Optics PRO 3.4G

The cameras have a lens width of 51' so a cardboard triangle was formed to help with aiming the camera as it is not possible to see the picture once the camera is closed.

On retrieval the pictures were analysed. For the first month, when a picture was being recorded every 30 seconds, it was necessary to check which pictures may have captured an image of wildlife. This was done using a (written for this project and not commercial) command line program that compares the changes in pixels between one picture and the preceding one. The program then copies the pictures with a big enough difference (this value is configurable and experimentation showed that 3-6% difference was suitable, depending on the site) to a separate file for manual checking. This saved a large amount of time as 1 day of monitoring leads to approximately 2000 pictures per camera and the filter reduced the number of pictures that had to be checked manually by 50-60%. When an image with an animal was found the following details were recorded: date, time, weather, species. The iNaturalist app was used as help with species identification where necessary.

The second month the cameras were operating with motion detector but each image still had to be checked manually for species identification as there were a large number of false positives. The camera took 3 consecutive pictures and this usually made it possible to assess the direction of travel of the animal. After a month the cameras were gathered in and the data analysed. The filter program was not used in this case as the filtering method was not useful in this situation.

Results

Camera configuration

Initially, from 27th April to 20th May 2022, all the cameras were configured for time lapse (a picture every 30 seconds) as more suitable for capturing any slow-moving animals such as amphibians and small mammals (see above). The length of passage at Täby prison and Hägernäs (15-20m), and width of the passage covered at Hägernäs (5-10m) both seemed long enough to be able to capture any faster moving animals.

Table 1 Number of transits captured per site with initial camera configuration
27th April to 20th May 2022

Animal	Site Hägernäs	Ullnaån	Täby Prison	Total
Badger *(M. meles)*			1	1
Fox *(V. vulpes)*	1			1
Otter *(L. lutra)*		1		1
Roe deer *(C. capreolus)*	3			3
Unknown	1			1
Total	5	1	1	7

Table 1 shows that over this period extremely few transits were recorded. However, some animal traffic was captured outside the passages (For instance, amphibians were detected coming up from the water at Hägernäs, see appendix, image too small to identify species). Due to this lack of traffic a short experiment (20th May to 2nd June, 2022) was carried out at Täby Prison to see how much animal traffic was passing in front of the tunnel, to review the possibility that they were simply choosing not to use the tunnel. This involved switching the camera to point outwards and changing to motion detection. This revealed that that there was plenty of wildlife in the area (see appendix, table 6). At the same time the camera at Ullnaån was also switched to motion detector, which resulted in more data being captured at this site (see below). The camera at Hägernäs was temporarily removed during this period to address battery issues.

After this experiment it was decided that even if transits by small animals would be missed (but they were not being recorded anyway) that the configuration on all three cameras would be changed to motion detector, and the camera at Täby Prison switched back to pointing inwards. This resulted in a much larger number of transits being recorded as shown in the table 2 below. Note that the camera at Täby Prison was stolen so that no images were available after 22nd June.

Table 2 Total number of transits captured per site with second camera configuration (motion detector)
3rd June – 3rd July 2022

	Site			
Animal	Hägernäs	Ullnaån	Täby Prison	**Total**
Badger *(M. meles)*		16	21	37
Cat *(Felis)*		1		1
Fox *(V. vulpes)*	11	12	4	27
Otter *(L. lutra)*		5		5
Mink *(Neovison vison)*		12		12
Roe deer *(C. capreolus)*	12			12
Weasel *(Mustela erminea)*		3		3
Unknown	1	6	3	10
Total	24	55	28	107

* Not possible to see if the mink is European or American

(Note that the values for Ullnaån include the transits recorded 29th May to 2nd June and no images were available at Täby Prison after the 22nd June)

Where identification was unsure but highly likely it was included in the species count rather than counted as "Unknown". In addition, it was not always obvious whether a transit had taken place; this was a judgement call based on the position of the animal in the three consecutive pictures taken when the detector was triggered (see appendix for a brief discussion on this issue). Below (figure 15) are some examples of images captured.

Figure 15 Sample of images captured at the different sites
a. A roe deer (C. capreolus) at Hägernäs b. An otter (L. lutra) at Ullnaån c. A badger (M. meles) at Täby Prison

(a) 

(b) 

(c) 

(Note that the camera was hung upside down in the tunnel at Täby Prison so the images have been rotated).

Animal traffic

An examination of the timeline (see figure 20 in the appendix) for all data captured clearly shows that the number of transits captured increased when the camera configuration was changed to motion detector. Some of the capture failure can be attributed to technical problems such as battery failure, the SD card being filled up, or the camera being knocked over. However, there is a week (prior to the theft) at Täby Prison where no transits were captured and which cannot be explained by technical issues. It appears that animals failed to use the passage at all during this time and there is no obvious explanation for this, it could be simply that the badgers have been moved on or run over on the motorway.

There are 13 days where all the cameras were configured the same way and were not experiencing technical issues. These days are shown in table 8 in the appendix and form the basis for a statistical analysis using the single factor ANOVA test to compare the daily traffic at the three sites. The results are presented in table 3 below.

Table 3 Results of single factor ANOVA analysis comparing number of transits per day

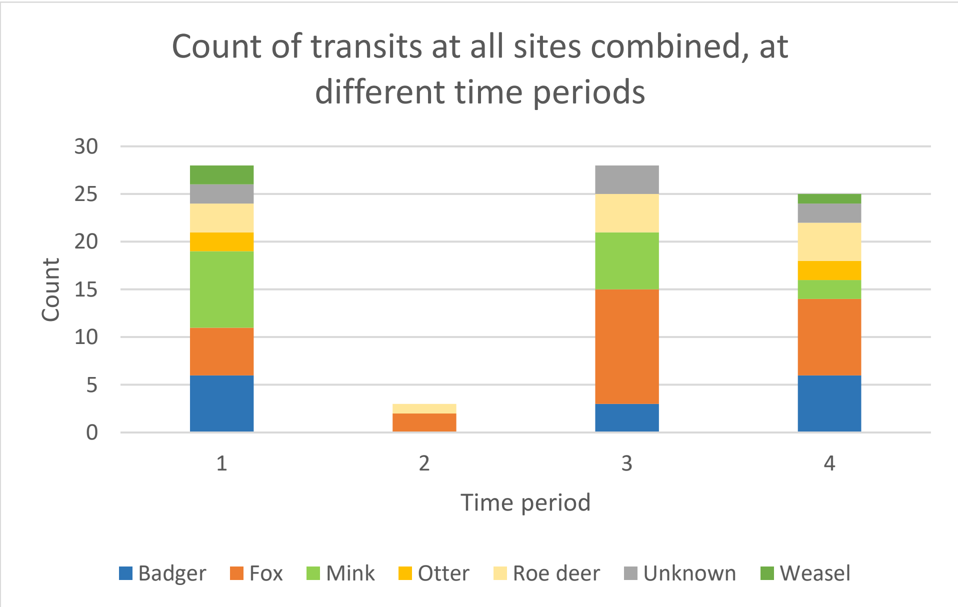
SUMMARY				
Groups	*Count*	*Sum of traffic*	*Average*	*Variance*
Hägernäs	13	18	1.384615	1.423077
Ullnaån	13	31	2.384615	2.25641
Täby Prison	13	20	1.538462	4.602564

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.538462	2	3.769231	1.365325	0.2682	3.259446
Within Groups	99.38462	36	2.760684			
Total	106.9231	38				

This shows that although there was a difference in the number of transits captured at each site as the P value is above 0.05 there is no statistical significant difference between the sites in terms of number of transits per day.

A simple analysis of the data shows that, in figure 16 below, very few transits are recorded between 6am and 12noon. Otters seem to prefer the late evening and early morning, whereas foxes appear to travel throughout the day. (See figures 21 and 22 in the appendix for more details).

Figure 16: The total number of transits at all sites combined across four time periods of the day 1: midnight to 6am, 2: 6am to noon, 3: noon to 6pm, 4: 6pm to midnight



It was not possible to ascertain if it was the same animal being captured in each image, so the direction of travel was checked (see table 4 below). As the number of transits in each direction was roughly equal this seems to indicate that there were only a couple of animals making the journey back and forth, at least for the badger and fox. There does not appear to be any patterns where the animals were tending to move in one direction in one time period and in the other direction in another time period. The different directions of travel seemed to be evenly spread across the different time periods.

Table 4 Direction of transits per site, a. Hägernäs b. Ullnaån c. Täby Prison
(Unknown species not included)

(a) Hägernäs

Species	Direction left	right
Fox *(V. vulpes)*	6	5
Roe deer *(C. capreolus)*	5	7
Total	**11**	**12**

(b) Ullnaån

Species	Direction In	Out
Badger *(M. meles)*	7	8
Fox *(V. vulpes)*	5	6
Mink *(Neovison vison)*	7	4
Otter *(L. lutra)*	2	3
Total	**21**	**21**

(c) Täby Prison

Species	Direction from prison	to prison
Badger *(M. meles)*	8	12
Fox *(V. vulpes)*	3	1
Total	**11**	**13**

Discussion

Technical Issues

After the start of this project a report was found (Fagert et al, 2016), on transits through fauna passages under motorways in France, which reflect much the same experiences gained in this project. Cameras configured to take pictures every 30 seconds produce a huge number of images that must be filtered and verified (only 1% of the images had an animal in it and only 1% of those showed a transit). There is a program available for this (Motion Meerkat) but as it has not been updated in 5 years it was not used. The simple program developed to help reduce the number of pictures to be checked could be improved by compressing images to reduce noise or even using AI techniques and thereby reduce the number of images that need to be checked manually even more.

The motion detector trigger produced fewer images to check but there was a very large number of false positives that had to be sorted out at Hägernäs and Ullnaån due to grass blowing across the lens (although this was reduced by removing nearby grasses), rain, and shadow (99% of those images were false positives but 27% of the images containing an animal were of a transit).

One issue not covered in other reports is how difficult it is to aim cameras correctly and how to change SD cards and batteries without disturbing the area, especially at Täby prison where the camera was in the tunnel. (Although it was confirmed by Fagert et al (2016) that inside the tunnel was indeed the best placement). Especially bearing in mind that discretion is required where members of the public are likely to notice and interfere with the equipment. However, the price and functionality of cameras is constantly improving so less investment is at risk when setting up this kind of monitoring system than previously.

These trail cameras were sufficient to record images of medium sized mammals but failed to record any significant images of amphibians or small mammals, even when recording every 30 seconds. There were a few images with these smaller animals in but the species could not be identified, as can be seen in the example in figure 17.

Figure 17 Hägernäs, Amphibian travelling up from water, unidentified species

Of the small mammals only one rodent (species unknown and not using the passage) was recorded at Ullnaån however more smaller animals must be in the area as a couple of times a mink was recorded with a small mammal in its mouth (see figure 18). This may be because the motion detector is not fast or sensitive enough to capture them, in which case a different camera type needs to be used to study these animals. But it is also possible that small mammals are avoiding these fauna passages as they are used by their predators.

Figure 18 Ullnaån, Mink (Neovison vison) with small mammal in mouth

Traffic evaluation

It was surprising how few transits were recorded for the initial configuration (time lapse). As it was assumed passage length would compensate for the time lag; or at least a larger proportion of transits would be captured. This seems to have been an incorrect assumption as ten times more transits were recorded with the second configuration (motion detector). But this is also related to how few transits there are in these fauna passages (see below). Of course, more transits may have been captured with 15second intervals and definitely with video but then more sophisticated methods of image analysis would be required than was available in this project.

The following table shows the average number of transits per day recorded in this report and in other similar reports.

Table 5 Summary of number of transits recorded over time from this and other similar projects

Source reference	Passage type	Number transits	Animal type
This report	Type III and VIII Small hydraulic passage and tunnel	1.4 – 2.4 per day	Small to medium mammals
Ascensão & Mira (2007)	Type I Culvert	2.2 per day	Small to medium mammals
Pomezanski (2017)	Type II Amphibian tunnel	12-16 per day	57% small mammals 43% amphibians
Westberg & Ellvin (2021)	Type IV – V Large passages	2-17 per day	majority foxes
Gagnon et al (2011)	Type V Large mammals	5-7 per day	Medium to large mammals
Amber et al (2021)	Type VIII Small tunnel	• shrew 4 per day, • deer mice 3 per day • vole 6 per day • jumping mice 2 per day	Small mammals
Fagert et el (2016)	Type VIII Small tunnel	1-2 per day	Mammals
Popp & Hamr (2018)	Crossing tracks	1-2 per day	Small to large mammals

(Note the passage type definitions used are from Fagert et al, 2016 and shown in figure 19 in the appendix).

Multiple sources (Gagnon et al, 2011, and Fagert et al, 2016) report that wildlife takes time to find and become accustomed to the fauna passages built for them. The passages evaluated in this report have been in place for over three years so this should not be an issue, although there was some disturbance when setting up and maintaining the cameras. This supports the belief that the numbers recorded for this project are comparable to the other reports. The exception here is the report from Pomezanski which recorded much higher traffic levels. However, this is probably because of the location of the ecoducts in that study; which were intended “to maintain connectivity between a provincially significant wetland complex and an isolated wetland area” (Pomezanski, 2017), rather than connections in, or on the outskirts of, a suburban area underneath train tracks.

The ANOVA test showed that there was no statistical difference between the sites in terms of the amount of traffic per day either, although there is some difference in the species encountered. For instance, it was not unexpected that roe deer were only recorded at Hägernäs where the bridge was high enough to allow their movement (it is not unusual to see roe deer close to the suburbs in Stockholm as so many woods neighbour the urbanised areas). At Hägernäs it is possible that the roe deer are moving to and from the nature reserves (see map in figure 11). Although there is a large amount of built-up area one side this is also the only safe crossing over the tracks large enough for roe deer in this immediate area. Further up track, where there are no fences, leads to even more built up areas, and further down track is blocked by fences and the motorway.

It was also expected to see foxes and badgers at all three sites, Trafikverket (2005) regard foxes and badgers as having the same passage requirements. Foxes are common in suburban areas and badgers common in the outskirts. However, badgers were missing at Hägernäs, possibly the allotments surrounded by fencing and the stream make it an unattractive route for badgers. Alternatively, that they have no need to move across the tracks, there is nothing of interest closer to the housing when there is plenty of natural space a little further north. Whereas in Ullnaån and Täby prison there is possibly a requirement to move between both sides of the tracks in order to forage. At Täby Prison these foxes and badgers may have their den/burrow on one side of the tracks, in the nature reserve and forage in the other in the small woodland (see map in figure 7) next to the prison, or vice versa.

As noted above, it was not possible to identify individuals, but it seems likely that there were only a couple of individual badgers (and as badgers tend to be in clans this would be reasonable) and foxes (who also live in families) moving back and forth along the passages. The typical home ranges are 5-12km for a fox, an otter 7-14km, and a mink ranges up to 15km of a river. (Animalia, 2021). With such large ranges for these animals, it might explain why traffic numbers at one specific spot are quite low when there is no specific reason to draw them there.

That the otter(s) and mink(s) were only found at Ullnaån is equally no surprise as this is the only place where there is a culvert with water at the bottom. Fagert et al (2016) stated that otters are hard to detect due to their insulated fur; that does not seem to have been a problem here but there is no way of corroborating whether any transits were missed without using an additional detection method such as track pits or a camera running video. (Note that track pits might be hard to place and maintain where the area in front of the camera is not flat or wide, as is the case for Hägernäs and Ullnaån).

The mink is probably *Neovison vison,* an invasive species brought in via mink farming (Persson et al, 2012) in the 1800s and now thriving throughout Sweden. The otter is a very happy sighting as it is a threatened species in Sweden (SLU, 2022); the populations crashed in the 1970’s although they seem to be now recovering somewhat. Unfortunately, no beavers were recorded at Ullnaån although there was evidence (a felled tree) that they had been active in the area recently, it is possible they have moved on.

In addition, no rats were seen at all although it is reputed that there are more rats than people in the greater Stockholm area (Gunér, 2022). This could be due to them moving too fast to be captured by the cameras. It would be of interest to try and identify more suitable camera techniques to capture the rodent and smaller mammal traffic in these areas.

The transit time patterns largely reflect those expected, that all the medium sized mammals are most active in the later afternoon evening to early morning (Ogurtsov et al, 2018), although there were slightly more transits in the third period (noon – 6pm) than expected compared to Ogurtsov’s data. All three sites would be experiencing peak people traffic from 6am to 8pm and this would the most obvious reason for reduced animal traffic. Although there were more people around the Täby prison area (well used walk) than Ullnaån (close to a gravel quarry but nothing else) they still had the same time patterns. Indicating that the time of day is more important than people traffic when it comes to animal traffic. No statistical test was applied to this data as it was felt there were insufficient data to compare time periods for different species at the different sites.

The drawback of this type of study (as noted by Helldin et al, 2010) is that it only tells us that the passages are being used and little else. Though, combining this with knowledge of typical territory size and family numbers means a rough estimate may be made of the populations. However, this tells us nothing about whether the fauna passages have reduced the problem of habitat fragmentation as we cannot compare to any data from before the passages were put in place. The more rigorous pre-studies recommended by Lesbarreres & Fahrig (2012) and van der Grift et al (2013) and others, is still not being carried. The ecoducts in this report were built by Trafikverket in accordance with the guidelines that were last updated in 2015 (Trafikverket, 2015), and include recommendations for a pre-study. However, at none of the sites was any evaluation done before hand. This limits the conclusions that can be drawn from this type of study.

Ideally this work should be extended to cover a larger amount of time such as a few years, to see if any seasonal patterns emerge or changes in traffic levels across years. This data may also be useful as a basis for evaluating population levels using techniques such as the Formozov-Malyshev-Pereleshin formula which relates track counts to population size (Keeping and Pelletier, 2014) or the time-to-event and space-to-event models used by Loonam et al (2014) to estimate population size.

Summary

This report demonstrates, again, that ecoducts are indeed used by medium-sized mammals and provides some data that allows comparisons to be made with other studies thereby helping build up the knowledge bank. The data gathered is in line with earlier studies indicating that there is nothing very different in this geographical area. It was fortunate that an otter was captured digitally should other ecologists wish to review possible population sizes, as it is a threatened species. The main recommendation from this work echoes earlier papers that pre-studies should be carried out on wildlife transits of the railway track before the next round of renovations to allow for comparison. In addition, that this method should be used more extensively to estimate local population levels.

(4888 of 5000 words)

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(Note that Banverket was a separate authority at the time of the reports writing and has since been absorbed into the larger Trafikverket authotrity. Large parts of this report are available in English from: https://handbookwildlifetraffic.info/ch-7-fauna-passages-and-other-solutions/7-3-reducing-the-barrier-effect-underpasses/)

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Camera specification

Available at https://www.pro-optics.se/)

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Appendices

Definitions:

- A transit is defined as movement through the tunnel or under the bridge and not movement next door or in front of the passage.
- The category “Unknown” covers images where only a paw or back or other such glimpse was recorded so not possible to identify.
- The direction of travel could often be seen from the 3 consecutive picture as shown in the following sequence, where the fox at Hägernäs seems to be travelling from right to left ie towards the ecobridge:

But in the next series of pictures it only seems very likely that the mink is heading into the ecoduct at Ullnaån as it has disappeared in the last image.

Figure 19 Different types of fauna passages, reproduced from Fagert et al (2016)

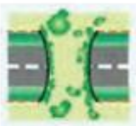
Descriptive image	Description of the structure type
	**Type I:** Culvert or scupper.
	**Type II:** Amphibian tunnels.
	**Type III:** Small combined hydraulic passages. **a:** Small hydraulic structure with submersible dry land. **b:** Hydraulic structure with narrow dry land. **c:** Medium-sized hydraulic structure with dry land 1.5m above. **d:** Large hydraulic structure that can be used by large and small animals. **e:** Dry pipe located near the hydraulic structure.
	**Type IV:** Small forest or agricultural passage.
	**Type V:** Underpass for large animals.
	**Type VI:** Wildlife overpass, green bridge, plant-covered bridge.
	**Type VII:** Viaduct as an underpass.
	**Type VIII:** Ecological corridor (tunnel).

Figure 20: Transits at all sites, across time, also showing where issues hindered the collection of images

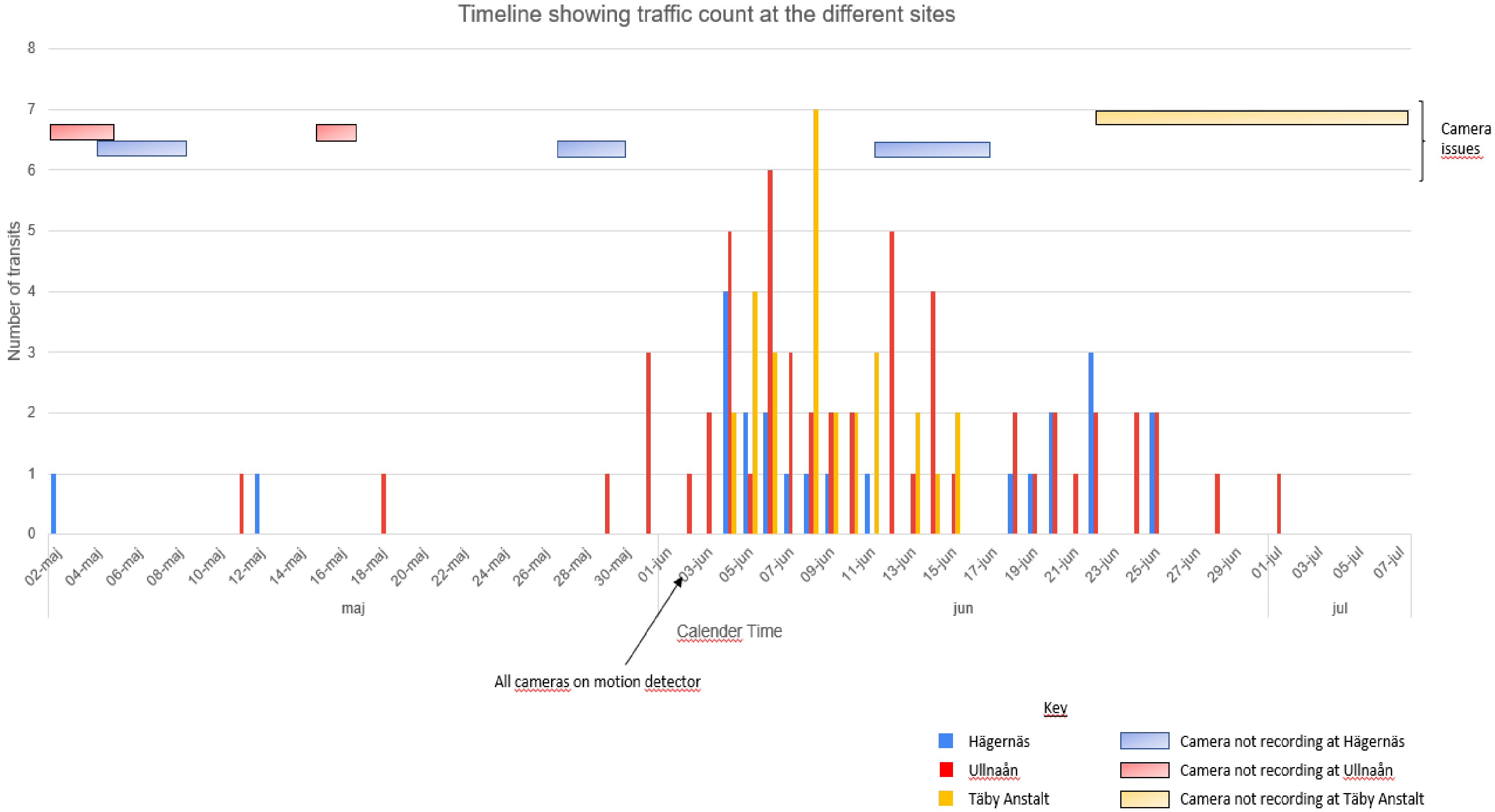


Table 6 Summary of animal passes by recorded at Täby prison (20th-24th May and 29th May- 2nd June 2022), recording outside the passage

Animal	Badger	Fox	Hare	Roe deer	Unknown
count	9	25	1	15	8

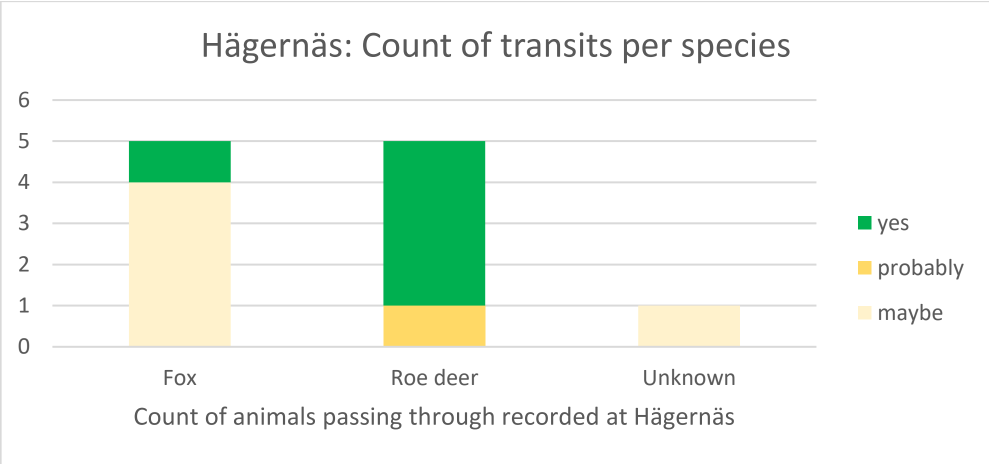
Table 7 Summary of all animal counts recorded at Hägernäs (29th April – 20th May 2022), including the fox and roe deer transits, prior to configuration change

Animal	Image Count	Individuals
Unknown	16	5
Bee	1	1
Bird unknown species	2	2
Blackbird	23	5
Blue/Great tit	29	7
Crow	50	8
Fox	1	1
Amphibian	80	5
Magpie	15	6
Mallards	184	41
Roe deer	5	3
Thrush	3	2
Wagtail	180	51

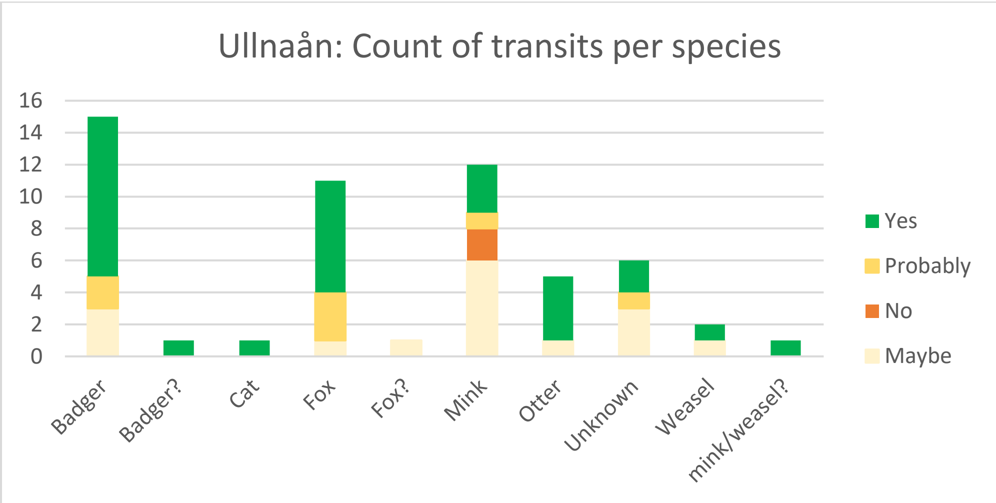
Table 8 Number of transits captured per site for days where all cameras working and configured in the same way, used for statistical analysis

Date	Hägernäs	Ullnaån	Anstalt
3 June	0	2	0
4 June	4	5	2
5 June	2	1	4
6 June	2	6	3
7 June	1	3	0
8 June	1	2	7
9 June	1	2	2
10 June	0	2	2
18 June	1	2	0
19 June	1	1	0
20 June	2	2	0
21 June	0	1	0
22 June	3	2	0

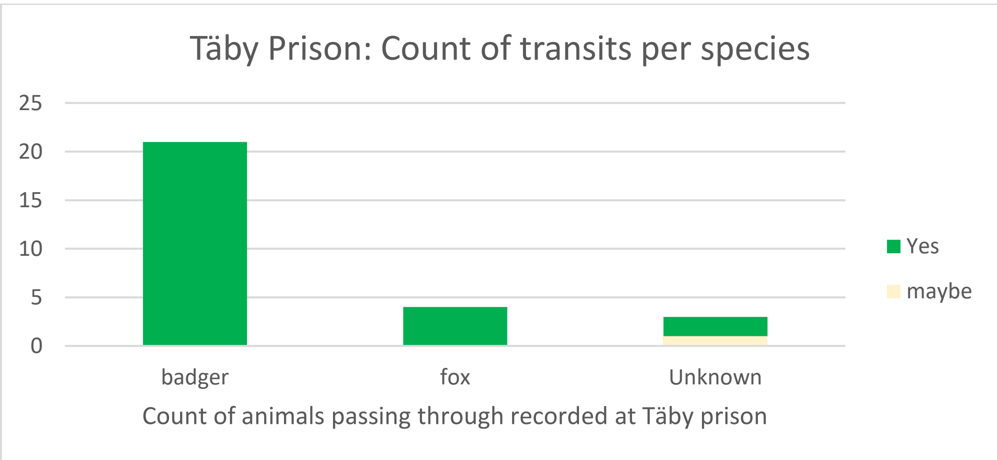
Figure 21 Counts of transits that show both the uncertain species identification and the certainty of the passage. (a. Hägernäs b. Ullnaån c. Täby Prison)



(a)

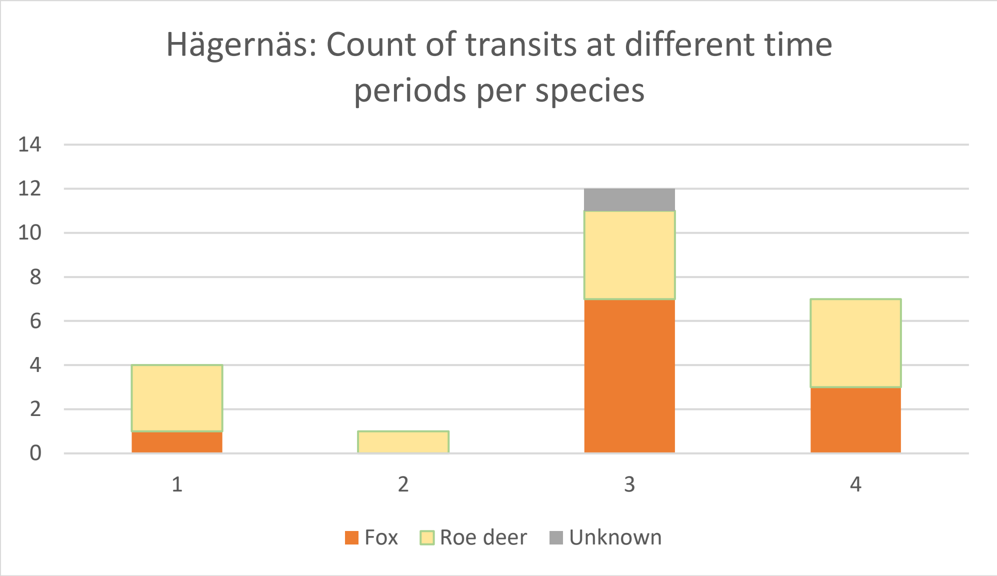


(b)

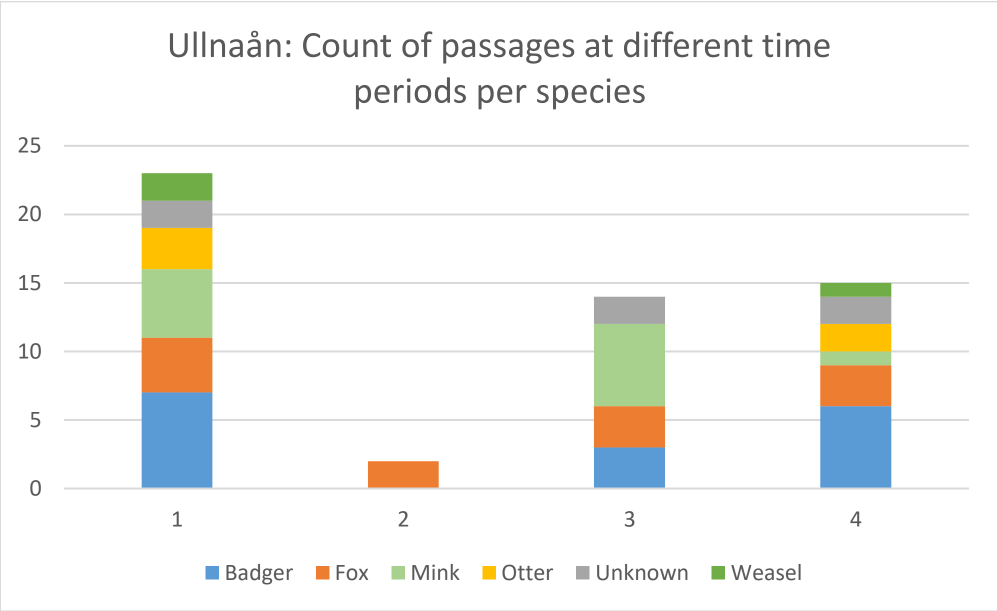


(c)

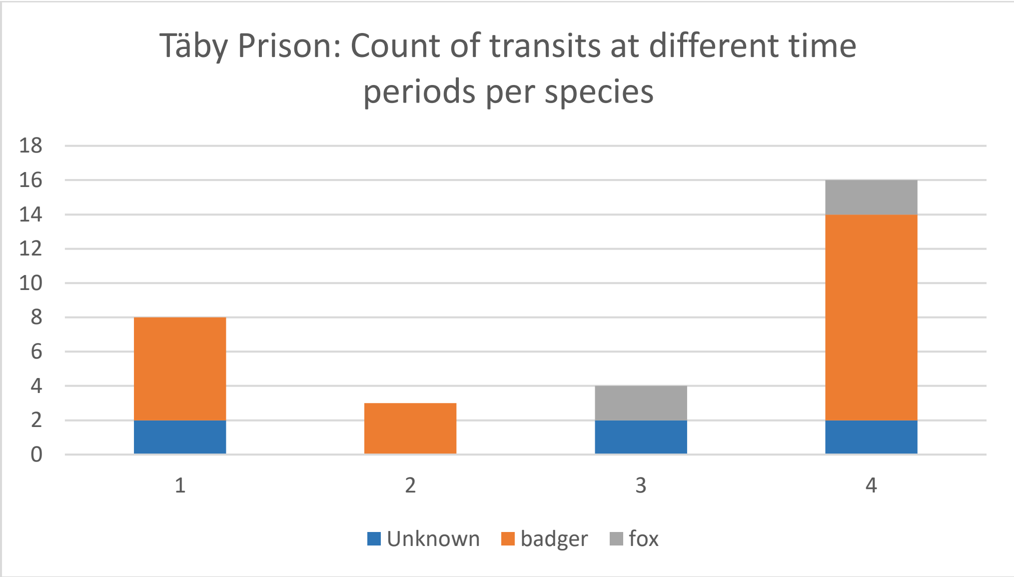
Figure 22 Counts of transits at different times of the day for different species, 1: midnight to 6am, 2: 6am to noon, 3: noon to 6pm, 4: 6pm to midnight. (a. Hägernäs b. Ullnaån c. Täby Prison)



(a)



(b)


Täby Prison: Count of transits at different time periods per species
18
16
14
12
10
8
6
4
2
0
1
2
3
4
Unknown
badger
fox
(c)