Mustelid Mugshots: a new camera-tube-lure system as monitoring tool for European polecats (*Mustela putorius*) in Sweden

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Preface:

For my family and Bjørn
- The last ones that will ever read my thesis, because of lack of English and being a dog -
and to get my master's degree.

Abstract

European polecat (*Mustela putorius*) populations are reported to be declining in a large part of its range. The species is listed in Annex V of the Habitat Directive, which requires periodical monitoring and reporting of its conservation and distribution trends. However, many countries lack monitoring data for polecats and suitable monitoring methods are missing. In Sweden, the only available data comes from 1) hunters that report their bags and 2) sightings. Robust methods are missing. Therefore, a method for systematic monitoring is needed to get updated data about the polecat distribution and population size.

In this study I tested a newly developed tube-lure system ("polecam") in four study sites in southern Sweden. I did this by placing 49 polecams during a period of two months in both spring (March-April) and fall (September-October) 2021. I related which landscape features influenced the detection probability: the distances from each polecam to the nearest buildings and main roads, the length of hedgerows in a 45m radius buffer around each polecam and a protective cover index (score 1-10) measured in the field. Furthermore I tested if the I^3S-software was able to semi-automatically identify polecats in the study sites and were able to photograph their facial masks. However, it was not possible to identify individuals with the software I^3S. My analyses of the landscape features showed, in contrast to my expectation, a high detection probability close to main roads, while other landscape features were not associated with the polecat detection. Further adaptions of the polecam and more studies about the landscape features, but also openness about alternative approaches is needed, to be able to develop a robust monitoring system.

Keywords: Mustela putorius; population status; monitoring; facial mask

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Abbreviations

GLM	Generalized Linear Model
GPS	Global Positioning System
I^3S-Contour	Interactive Individual Identification System
NMD	National Land Cover Database
Polecam	Tube-Lure System
QGIS	Geo-Information System Software

1. Introduction

Mustelids are important species and have complex impacts in population dynamics and natural systems (Korpela et al. 2014, Norrdahl and Korpimäki 2001, Brzeziński et al. 2019, Sievert et al. 2019). They occur in low densities and have a widespread distribution (Wright et al. 2022, Ferguson and Lariviére 2005).

Despite their widespread distribution, almost half of the mustelids are decreasing (Wright et al. 2022). Mustelids are very elusive and monitoring them, their space use and population dynamic is difficult (Gough and Rushton 2000, Randler et al. 2020, Wright et al. 2022, Ruiz-González 2007, Brzeziński et al. 2021, Baghli and Verhagen 2003). Cryptic, nocturnal and rare species usually require indirect approaches for studying their biology and habitat use (Zabala 2005, de Bondi et al. 2010), latter is important when developing new monitoring methods. To determine the distribution of a species presence/absence data is needed or individual capture-recapture to estimate densities (Manzo et al. 2011, Mattioli et al. 2018, Liu et al. 2010). For capture-recapture, individuals have to be identified (cited in Stier et al. 2015).

For monitoring several methods already exist like DNA analyses (Ruiz-González et al. 2007, Hansen and Jacobsen 1999), snow tracking (Burki et al. 2010, Stier et al. 2015), trapping (Burki et al. 2010, McDonald and Harris 1999, Stier et al. 2015), road kills or dead findings (Schwartz et al. 2020, Stier et al. 2015) and camera trapping (Randler et al. 2020, Mos and Hofmeester 2020, Stier et al. 2015). Although the most of these can only apply on a study area scale with a few individuals and short time spans, because of the high investment in time, required equipment and money (Berzins and Ruette 2014, Gough and Rushton 2000, de Bondi et al 2010).

Most data as an index of animal abundance and density are mostly from trapping and hunting, but hunting records can be misleading if the sampling effort is not controlled for (McDonald and Harris 2001, Imperio et al. 2010, Soininen et al. 2016). Hunting is affected by many factors and can change over time: including the decrease in interest in fur in general or due to changing market prices, regulations or weather (McDonald and Harris 2001). Conditions for hunting reports can vary between countries (Åhl et al. 2021) which makes comparison difficult.

In contrast to hunting and the methods that can only apply on small scales with a high investment, camera trapping can be more cost and time effective (de Bondi et al. 2010). Although camera traps do not always offer reliable species detections, therefore researchers often apply attractants, such as lures or glandular scents for a higher detection rate (Randler et al. 2020, Mills et al. 2019, Burki et al. 2010). Camera trapping is increasingly used as non-invasive tool for species inventories or species estimations (Randler et al. 2020, Mendoza et al. 2011). Several studies worked successfully with camera traps identifying individuals for their estimation of population sizes using their natural unique fur patterns (Mendoza et al. 2011, Trolle and Kéry 2003, Karanth and Nichols 1998). Some also included identification softwares to help with the big amounts of images (see Crouse et al. 2015, den Hartog & Reijns 2011).

The European polecat *Mustela putorius* (here further called polecat) has a widespread distribution in Europe, but undergoes a rapid decline in some parts of its range (Croose et al. 2018, Skumatov et al. 2016, Baghli and Verhagen 2003). The species is listed in Annex V of the Habitat Directive (42/93/EC), which requires periodical monitoring and reporting of its conservation and distribution trends (Russo and Loy 2020, Berzins and Ruette 2014). However, in some parts of Europe, trends could not be identified because data are insufficient (Croose et al. 2018, Skumatov et al. 2016, Mestre et al. 2007, Stier et al. 2015). According to Croose et al. (2018) the polecat was the most difficult to categorize of all small carnivore species during the Red List assessment.

The drivers of the suspected decline in polecat populations are still poorly understood (Russo and Loy 2020, Weber 1989). A review study from Wright et al. (2022) showed that they found less than 40 publications (in a time span from 1900 to June 2020) that identified threats for polecats. Threats can include changes in prey availability (Barrientos and Bolonio 2009, Berzins and Ruette 2014), low effective population sizes (Barrientos and Bolonio 2009), accidental and active poisoning/killing (Croose et al. 2018, Birks 1998, Elmeros et al. 2018), road kills (Barientos and Bolonio 2009, Berzins and Ruette 2014), but also hybridization with the domestic ferret (Costa et al. 2013), competition with the American mink (Barrientos 2015, Harrington and MacDonald 2008, Brzeziński 2021, Brzeziński 2010) and habitat alteration, like drainage of wetlands and reducing hedged farmland and therefore its connectivity (Barrientos and Bolonio 2009, Berzins and Ruette 2014, Trapp et al. 2019, Pelletier-Guittier et al. 2020, Dondina et al. 2016). Some of the factors affect the polecats directly by increasing mortality, some indirectly by reducing prey availability (Brzeziński et al. 2021). Not only the decline of the polecat, but also the decline of many other species got directly linked to habitat loss and fragmentation (Schumaker 1996). Habitat suitability and its alteration is thus an important factor determining the distribution and potential decline of polecats.

Polecats use a great variety of vegetation types and habitat structures and they can occur in riparian habitats, pastures, grassland and deciduous forests (see Zabala et al. 2005, Croose 2016, Baghli et al. 2005, Baghli et al. 2002, Mestre et al. 2007, Weber 1989, Weber 1988, Lodé 1994, Birks 1998, Virgós 2001). The habitat use of polecats depends on prey availability and protective cover, but it also changes seasonally (Baghli et al. 2005, Mestre et al 2007, Weber 1989, Lodé 1994) and can shift to human settlements in winter (Baghli et al. 2005, Baghli et al. 2002, Weber 1989).

Müller (2002) showed that polecats have a big variation of facial masks which are unique for every individual. The mask is characterized in a dark portion of the fur with a paler/white "half-moon" that contrasts above, around or on the side of the eyes. The "half-moon" varies in shape and can be connected, separated, mottled, paler/white or absent. The pattern around the nose, chin and cheek can also be paler/white and varies in dimension and shape (Russo and Loy 2020, Müller 2020, Blandford 1987, own sighting). The findings of Müller (2002) lead Russo and Roy (2020) to a study, to identify individuals with the help of the identification software I^3S with stuffed polecats from Italian museums.

As like for many other mustelids a robust monitoring for polecats is also lacking (Croose et al. 2018). In Sweden, the only available data for the population size of polecats comes from hunters that report their bags and sightings (Thurfjell and Tomasson 2017).

Due the required monitoring as an Annex V species and unknown population status of the polecat, it is necessary to develop a robust monitoring system to complement the present situation of unreliable methods (Croose et al. 2018, Hofmeester et al. 2019, Weber 1989, Stier et al. 2015).

In this thesis I present the "Polecam" concept as a new monitoring method for polecats. I tested if the concept based on Russo and Loy (2020) also works out in the field with wild polecats. For that I tested camera traps with a newly developed tube-lure system ("polecam") as a non-invasive method to monitor polecats in different possible habitats in southern Sweden. I did this by placing 49 polecams during a period of two months in both spring (March-April) and fall (September-October) 2021. I related which landscape features influenced the detection probability of the polecat. I expected that the polecat detection probability is influenced by different human factors like the distances to buildings and roads and the agricultural intensification. I expected that main roads have a negative influence on the polecat detection probability. I also expected that agricultural intensification has a negative influence on the detection probability (Zabala et al. 2005, Virgós 2001). Additionally, I expected a higher chance to detect polecats in locations with a high protective cover, as adaption to prey availability or to predation pressure (Weber 1988). Furthermore, I compared the two seasons, expecting that fall has a higher detection rate of polecats, due the presence of juveniles (cited in Blandford 1987).

Because it was a new method, I first tested if the polecam can be used to detect polecats and their facial masks in the field. I aimed to test if the photo-identification software I^3S (Interactive Individual Identification System) used by Russo and Loy

(2020) can also be used to identify wild individuals derived with the polecam. I used detection/non-detection data of polecats to estimate the relationship between habitat covariates and the detection probability of them.

To clarify my study, I formulated the following research questions:

1. Does the tube-lure-system work to detect polecats?
2. Which human factors affect the detection of polecats?

2.1 Does the distance to buildings in an area influences polecat detection?

- Is there a seasonal difference between spring and fall?

2.2 Does the distance to streets in an area influence the polecat detection?

- Is there a difference between the different types of roads?

H 2.2: Bigger roads have a negative influence on the polecat detection.

2.3 Does the agricultural intensity in an area influences polecat detection?

H 2.3: Intensified agriculture has a negative influence on the polecat detection.

3. Are there seasonal differences between spring and fall?

H 3: There is a higher density of polecats in fall than in spring.

4. How does protective cover influence polecat detection at single camera trap locations?

H 4: The polecat detection is higher in biotopes with high cover.

<u>Using I^3S as a new approach to identify individuals:</u>

5. Is it possible to take pictures of the facial mask for individual recognition?
6. Is it possible to recognize individual polecats in the field with the help of their facial mask in camera traps and the software I^3S?

2. Material and Methods

2.1 Study area

The study was carried out at four study sites in Skåne län (55° 59' 43.11" N, 13° 26' 30.38" E), which is the most southern county in Sweden (Figure 1). The county has a size of 10,939 square kilometers (Thurfjell 2011) with a population of 1,386,530 (December 2020) (Statistics Sweden 2021). The county is characterized by two different climates: a moist, warm continental climate and sea climate, with an annual temperature of 8.8°C and an annual mean precipitation of 650mm. The county is dominated by farmland with a mix of small-scale agriculture and extensive grazed pastures by cattle and partly horses. The main crops are wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), and oats (*Avena sativa* L.). Other landcover types are meadows and reed beds (*Phragmites australis* Cav.) (Thurfjell 2011) with forest patches. The forest patches are covered either by coniferous forests (mostly *Picea abies*) or deciduous forest dominated by beech (*Fagus sylvatica* L.) and oak (*Quercus robur* L.). Open water covers only a small percentage with shallow lakes that are surrounded by reed beds and a changing waterline during the year (Thurfjell 2011). The composition of the different landscape characteristics (agriculture, forest patches, …) vary in every study site.

The landscape is further characterized by the presence of many hedgerows and stonewalls as key features in the agricultural landscape (Figure 3). Most stonewalls are bare, but others are overgrown by vegetation (trees or shrubs). They are mostly situated between agricultural fields (Linnarson 2007, own sighting).

The study site in Baldringe (55°31'60" N, 13°49'60" E) lies 38m above sea level with a size of 25km². It is a mix between forest patches, farmland and several single houses.

The study site in Christinehof (55°43'4" N, 13°57'57" E) lies 119m above sea level with a size of 20km². The site is dominated by forest with a small mix of farmland and extensively grazed pastures by cattle and sheep with some wetlands and single houses at the border. Additionally, the castle Christinehof is located more in the center of the site.

The study site Högestad (55°30'0" N, 13°52'0" E) lies 31m above sea level with a size of 21km². The site is dominated by farmland with small forest patches, wetlands and a small village, including several single houses.

The study site Vitemölla (55°42'0" N, 14°12'0" E) lies 2m above sea level with a size of 20km². This site is the closest to the coast and mainly dominated by farmland with small forest patches, pastures with horses and cattle and several small villages, including several single houses.

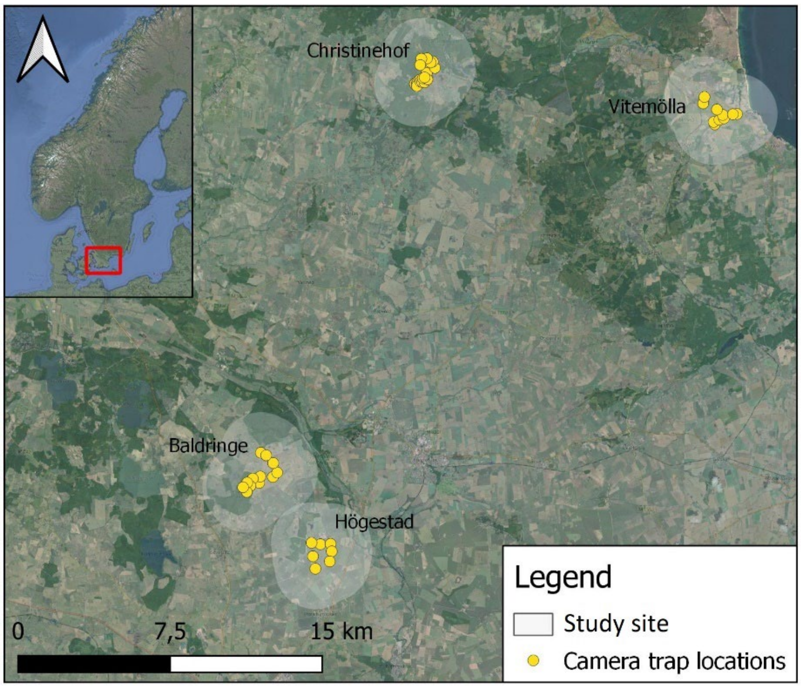

Figure 1. Overview of the four study sites in southern Sweden.

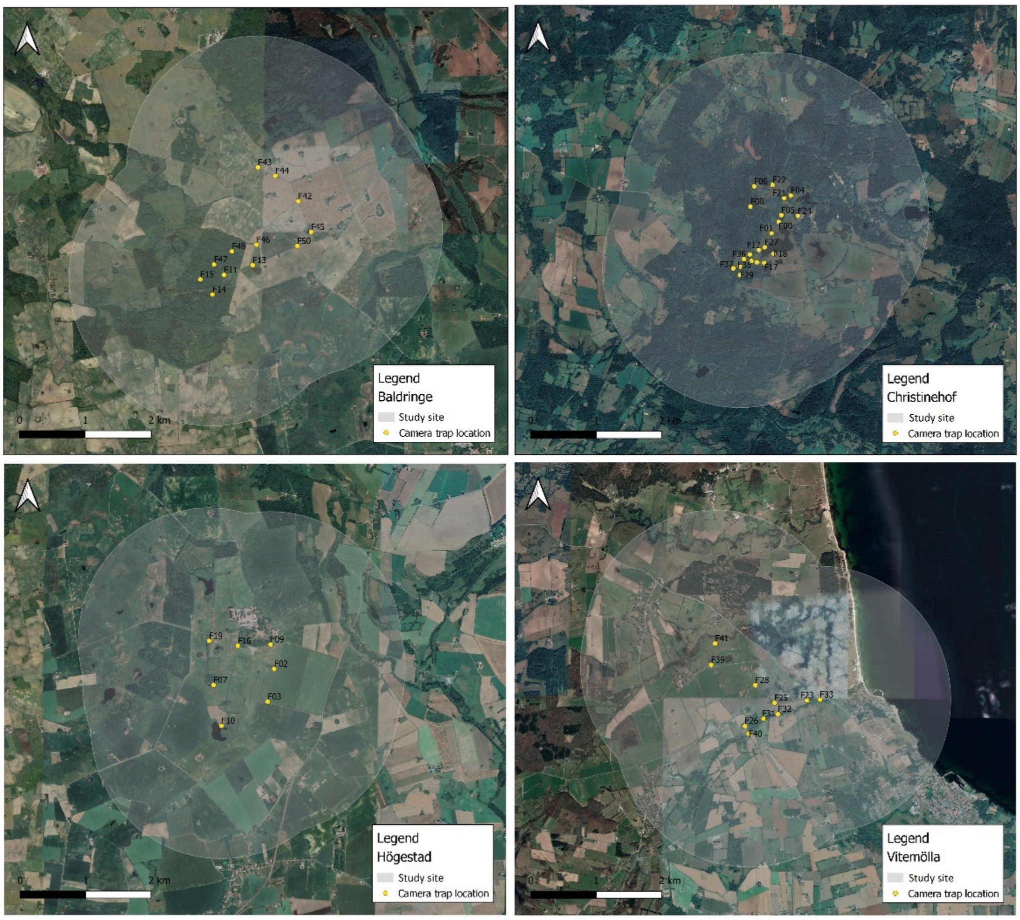

Figure 2. *Study sites with polecam locations. The open water in Vitemölla got excluded from my analyses.*

Figure 3. *Characteristical hedgerow in Skåne.*

2.2 Data sampling

2.2.1 Camera trapping

The study was performed during two sampling periods: one in spring from 16.03.2021 – 19.05.2021 and one in fall from 06.09.2021 – 24.11.2021 with 49 camera traps in each sampling period: 12 cameras in Baldringe, 20 in Christinehof, seven in Högestad and ten in Vitemölla (Figure 2).

I sampled the detection of polecats with camera traps (Browning Trail Camera, Model BTC 6HDPX) and a tube system (PVC drainpipe, length 48cm, with an inner diameter 10cm, a T-piece of 24cm, Figure 4) with canned sardines as lure (Sardinmästarens Sardiner– delikatessrökta i rapsolja). By combining a tube with a camera trap and a lure (further called polecam), I aimed to encourage the polecats to look in the camera to photograph their facial masks. To get a sharp image of the animals in the tube, I placed an additional + 2-dioptre lens (obtained from a set of regular reading glasses) in front of the camera.

The camera traps with the tube system and lure were put in suitable habitats where polecats are expected like field borders with stonewalls and bushes/trees as cover; deciduous forests, forest borders, areas close to water with a good cover, but also locations which were assumed to be less suitable habitats like coniferous forests or areas without good cover for them.

The can of sardines was only slightly opened to reduce the chance of animals taking the lure while allowing the fish smell to spread. For the avoidance of rodent encounter, the polecam was placed in a height, that it is difficult for a rodent to get into the tube.

Figure 4. The polecam - a tube-lure system with the camera on the right side of the tube and the lure on the left side. The grid above the lure lets the smell spread easier and increases the incidence of light inside, enhancing the quality of the daytime registrations (Mos 2019).

2.2.2 Qualitative and quantitative habitat assessment

As for mustelid species prey availability and protective cover is correlated to habitat use (see Baghli et al. 2005, Mestre et al 2007, Weber 1989, Weber 1988) I assessed the habitat around each polecam in a sampling plot with a radius of 2.5m quantitatively and qualitatively.

In the quantitative assessment I collected parameters like cover for the polecats and cover for food availability of rodents as its prey, as well as cover of fruit-bearing plants as a proxy for food availability for prey (Table 1).

The qualitative analysis classified the sampling plots on a scale of 1 to 10, where 1 is bad and 10 is a good quality according to its cover for polecats (Figures 5 and 6), cover of fruit-bearing plants and availability and quality of shelter for the polecats (based on Department of Environment and Heritage Protection 2017, Johnson 2005).

Table 1. Documented parameters for quantitative and qualitative habitat assessment.

Documented Parameters	
Quantitative parameters	Qualitative parameters
Cover (%)	**Scoring: 1 (bad) to 10 (good)**
Bare ground	Combined protection cover of the plot
Grass	Combined cover of food-bearing plants
Trees	Quality and availability of shelter
Shrubs	
Water	
Woody plants	
Wood piles	
Food-bearing plants	
Other	
Presence/Absence	
Stone heaps	

Figure 5. *Example for a bad protective cover, with no vegetation cover to hide for polecats.*

Figure 6. *Example for a good protective cover, with a high vegetation cover to hide for polecats.*

2.2.3 I^{3}S – semi-automated recognition of individual polecats

To be able to estimate densities of species it is necessary to capture-recapture individuals, which requires identification of individuals (cited in Stier et al. 2015). With the help of ^{I3}S Contour I tested if it is possible to identify individual polecats via their facial masks.

I^{3}S Contour v3.0 is one application of the I^{3}S family (Reijns 2020). I^{3}S is an Interactive Individual Identification System. Originally created for marine wildlife identification, now it is also used in a wide variation for other species. The use of I^{3}S – Contour in this study is based on the study of Müller (2002) that showed big variation of facial masks which are unique for every polecat. The uniqueness makes it possible to identify individuals. The possibility of individual recognition lead Rosso et al. (2020) to a study with stuffed polecats from museums comparing the unique facial mask patterns through pictures and I^{3}S. I used I^{3}S with wild captured pictures of polecats.

I^{3}S assists in identifying animals with a semi-automatic tracking algorithm (den Hartog & Reijns 2011). The algorithm helps to follow the contour of an animal – here in this case the facial mask of the polecat. The I^{3}S overlays the to comparable contours of the animals in the database and looks for match quality. The less space in-between the contours mean a higher match probability – shown in a ranked list with the most relevant results (Russo et al. 2020, Reijns 2020, den Hartog & Reijns 2011).

The image of the polecat should be taken ideally perpendicular to the line of sight and not more than 30 degrees of that line (den Hartog & Reins 2011). To create the contour in I^{3}S, two outlines of the facial masks were followed – starting from the outer side of the mask and ending at the nose tip of the individual (Figure 7) (see also Russo et al. 2020). The outlines were automatically captured through I^{3}S Contour (Russo et al. 2020, den Hartog & Reijns 2011). The start and end point were set by me as the operator (Russo et al. 2020). The processed pictures with the contours were then compared with all the pictures of the final database through the semi-automatic algorithm and a matching list probability (see also Russo et al. 2020, den Hartog and Reijns 2011).

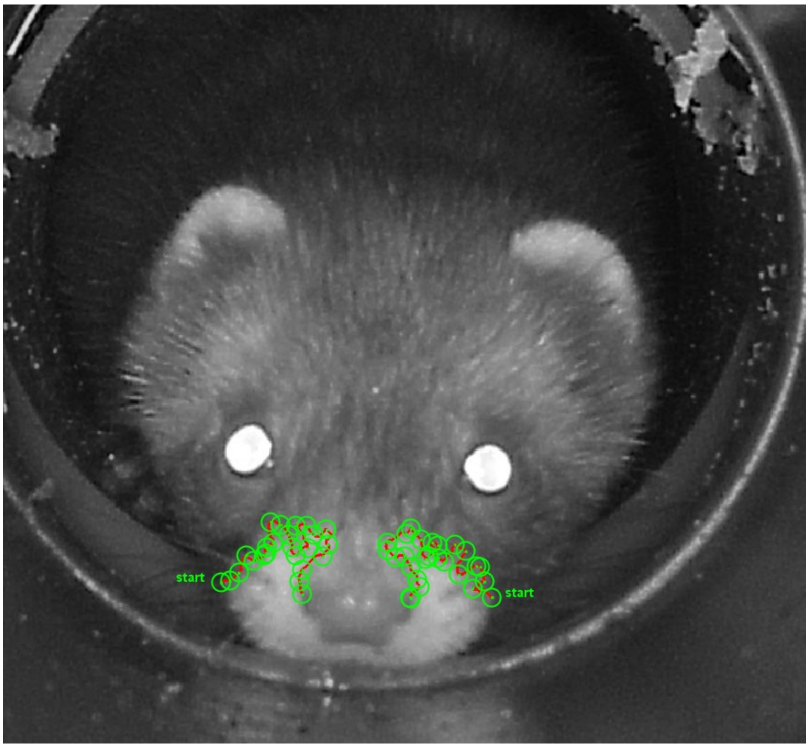

Figure 7. *Example of the start points of each contour and the semi-automatic contour identification of the facial mask of a wild captured polecat.*

I sorted the total amount of polecat pictures from spring and fall in four categories. One category for pictures, which could not be used, because they were too blurry, dark or only a part of the polecat was visible and therefore the identification of the individual not possible. Another category contains pictures, which show the front of the polecat and the mask completely or at least partly visible from the front. The other categories were separated in left and right, where the polecat only was visible from one side of the head. Left and right were defined in the point of view facing the camera directly, when our left is their left and our right is their right.

To make sure that the system worked I started a testing phase with two identical pictures of the same individual and compared them after I created the outlines of the facial masks individually for each test-picture. After the first testing phase I ran through three rounds of comparison with the original pictures. First, I compared only the spring pictures, then I included spring and fall pictures in one database. As not all the pictures of the polecats were perfectly captured from the front, I also included the pictures which only showed one side of the polecat. To get the highest match probability I tried different ways to compare the pictures.

First, I used all pictures with both sides of the facial masks clearly visible and compared those (further called “front”). With both sides for comparison there is a better chance to get a higher match, but some facial masks were only captures from either the left (further called “left”) or the right (further called “right”) side. To be able to also include these pictures in the study I started a second run and created a new database. I took the “front” pictures only taking the contour of the left side of the facial mask and compared them with the “left” photos. For the third run I took the “front” pictures only taking the contour of the right side of the mask and compared them with the “right” pictures.

For the fourth and final run I changed the contrast for all pictures in *Microsoft Fotos 2021* (Microsoft Cooperation 2020) to make the contours of the facial mask more visible and hence comparison easier. The contrast level was switched to the maximum. I started the same procedure (run 1 to 3) with the new contrast.

After each possible match I compared the rank list in I^3S according to its match numbers. If the rank list number is lower, the match probability is higher (den Hartog & Reijns 2011). Additionally, I compared the histogram for every possible match and each polecat facial mask of the rank list manually, regardless if the I^3S showed a high match probability or not to detect possible errors. For each possible match I controlled the location of the captured pictures in QGIS. I excluded the matches when the polecat pictures got captured in a completely different study site as I did not expect individuals to be able to travel among study sites. I only included the pictures of the same study sites. Exception were Högestad and Baldringe, because they were directly neighbouring study sites.

2.2.4 Extraction of landscape features

Determination research area and creation of buffer zones
For the landscape analyses I used QGIS 3.16.11-Hannover (QGIS 2021). All data were transformed in the same Coordinate Reference System EPSG: 3006 SWEREF99 TM, based on the National Land Cover Database (NMD, Issue 1.0, 2020-08-26, Nilsson et al. 2020, Olsson et al. 2020).

To determine the research area sizes I uploaded the polecam locations from the GPS in QGIS and set a 2km buffer around each polecam using the QGIS Geoprocessing tool *Buffer*.
Since the home range of polecats can vary greatly in size between 0.085-1.608km² (see Baghli and Verhagen 2004, Lodé 1996, Brzeziński 1992, Weber 1989b) I chose the 2km buffer around each polecam according to the average travel distance of 2.29km per night for males and females (Baghli and Verhagen 2004).

To get the individual study sites (Baldringe, Christinehof, Högestad, Vitemölla) I merged the buffer zones from each site with the QGIS Geoprocessing tool *Dissolve*.

Distance measurements of variables

To measure the closest distances of the variables (distance to buildings, forest edge, roads (small, big), stonewall, water, field edge) I used *Measure Line tool* manually and wrote the results down in an Excel file (Microsoft 365) for my further analyses. As base for my measurements, I used a combination of the data of the Landcover Database and the ortho-photographs map from Google Satellite from QGIS *QuickMapServices*. For the distance to the different kind of roads I used the Open Street Map in QGIS (OSM Standard 2021). It was not always possible to identify the real size of the roads in the Open Street Map, so I simplified the procedure using two categories of roads: smaller roads (county roads and other local roads) colored in white and yellow in Open Street Map; and big roads (national roads) colored in orange.

White colored roads are small roads towards houses or connecting villages. They are numbered from 100 upwards. They can be paved or also be gravel roads.

Yellow colored roads are Swedish county roads or public roads maintained by the Swedish Trafikverket. They are numbered from 100 upwards.

Orange colored roads are the national roads and numbered from 1 to 99. These roads are usually of high quality.

The definition of roads is according to the standard level of Open Street Map (https://www.openstreetmap.org) and the Swedish Trafikverket (Swedish Transport Administration, https://www.trafikverket.se).

The distances to big roads had a big variation with a range from 88m to 6410m, with a mean of 3496m. In Vitemölla the big roads are the closest to the camera trap locations (range from 88m to 1033m, with mean 454m) and in Christinehof the big roads were furthest away (range from 5616m to 6410m, with mean 6046m) (Table 2). The distances to buildings were quite divers and had a range from 42m to 1107m, with a mean of 561m.

Table 2. *Distance measurements of roads in the four different study sites Baldringe, Christinehof, Högestad and Vitemölla. Scale is in meters.*

Distance Measurements Roads in Meters

		Baldringe	Christinehof	Högestad	Vitemölla
	Min	30	6	107	29
Small Road	Mean	420	451	429	122
	Max	726	965	952	359
	Min	2424	5616	850	88
Big Road	Mean	3242	6064	1335	454
	Max	4100	6410	1955	1033

2.2.5 Reclassification of landscape

Landcover

For the spatial pattern analyses I used the National Land Cover Database (NMD) of Sweden (Issue 1.0, 2020-08-26, Nilsson et al. 2020, Olsson et al. 2020). NMD is a land cover map over the whole country and has 25 thematic classes in three hierarchical levels. The map is in a raster format (GeoTiff) with 10m pixel resolution and a minimum mapping unit of 0.001ha (Olsson et al. 2020).

To be able to do analyses with the raster data I first clipped the whole NMD in the smaller areas of my buffer zones of each of my study sites. For that I used the Extraction tool *Clip Raster by Mask Layer* in QGIS. The input layer was the landcover layer and the mask layer the buffer of each study site. As the output layer was a two-coloured black and white layer the style of the land cover layer got copied (*copy style*) to get the original colour distribution back. The next step was reclassifying the table of each study area. For this I used the *Processing toolbox → Raster analysis → Reclassify by table.* I classified three values in the table: Forest, crop and no data. I chose the values for the forest (values 111 to 128) and crop (arable land; value 3) according to the NMD list of codes and attributes (see Olsson et al. 2020) and classified it manually in QGIS. The output of no data value was chosen to be 0 and the range boundaries *min <= value <= max* to include all the values that are needed (Table 3).

Table 3. Reclassification of agriculture and forest in study sites. Value=1 got excluded from the reclassification process. Value=2 (forest or crop values) got included. Values according to the NMD list of codes and attributes of Olsson et al. 2020.

Reclassification Agriculture			Reclassification Forest		
Minimum	Maximum	Value	Minimum	Maximum	Value
1	2	1	0	110	1
3	3	2	111	128	2
4	999	1	129	999	1
Value 1: excluded in classification			Value 1: excluded in classification		
Value 2: included in classification			Value 2: included in classification		

Fragstats

With the reclassified areas and the help of Fragstats I analysed the landscape features that might influence the polecat detections in the study sites.

Fragstats (McGarigal 2012) is a spatial pattern analysis program for quantifying the structure of landscapes. The landscape subject to analyse is user-defined and can represent any spatial phenomenon (McGarigal 2015, McGarigal and Marks 1995). Fragstats quantifies the spatial heterogeneity of the landscape and represents it either in a categorical map (landscape mosaic) or as a continuous surface (landscape gradient) (McGarigal 2015, McGarigal and Marks 1995). The software computes several statistics for each patch, class (patch type) in the landscape and for the landscape metrics as a whole (McGarigal 2015, McGarigal and Marks 1995). Only one strategy (patch, class or landscape) is allowed per run with several options to choose for the analyses. My main setting for general options is the 4 cell neighbouring rule. The 4-cell rule considers only the four adjacent cells that share a side with the focal cell for determining patch membership. The distance- and area-based metrics computed in Fragstats are reported in meters and hectares (McGarigal 2015, McGarigal and Marks 1995).

Measuring agricultural intensification

In each study site I calculated the average size of agricultural fields, average size of forest and total length of hedgerows/stonewalls as a measure of agricultural intensification and forest patchiness. Goal was to determine if the agricultural intensification has an influence on the polecat detection and if there is a connectivity between the different forest patches with the hedgerows. Connectivity is defined as the degree to which a landscape allows or prevents an organism to move among patches (Tischendorf and Fahrig 2003) and is a fundamental concept in ecology (Moilanen and Nieminen 2002). First, I did the measurements and the calculations in a bigger scale – using the 2km buffer of the four study sites. For the second step, I did the measurements and calculations in a smaller scale around each polecam location. For the smaller scale I used a 45m buffer around every polecam. I chose the 45m radius to avoid overlapping buffer zones and making the results redundant. The procedures of the bigger and smaller scale are the same.

As basis for my hedgerow/stonewall measurements I used a combination of the data of the Swedish Landcover Database (Nilsson et al. 2020, Olsson et al. 2020) and ortho-photographs from Google Satellite provided by QGIS *QuickMapServices*. The additional map from Google Satellite was needed, because the Landcover Database did not have inserted all hedgerows in their map.

I used the same *reclassification by table* procedure to classify the agriculture for the 45m buffer zone as explained in the section before.

For the calculation of the average size of the agricultural fields I used the class metrics. Class indices represent the spatial distribution and pattern within a landscape of a single patch type (McGarigal 2015, McGarigal and Marks 1995).

Most of the class indices can be interpreted as fragmentation indices, because they measure the configuration of a particular patch type (McGarigal 2015, McGarigal and Marks 1995). To calculate the mean size of the agricultural fields I chose the option *Mean* in the class metrics. Base of the data was the agricultural reclassified dataset of QGIS.

Additionally, for my further calculations of my study sites I was measuring the length of the hedgerows in each of the four 2km buffer zones of my study sites manually with the *Measure Line tool* in QGIS. To be able to summarize the measured hedgerows I created a *New Shapefile Layer* for each study area and measured all hedgerows I saw with the Geometry type *Line*. All measurements got collected in the attribute table of each study site. In the end I used the *open field calculator* and the geometry tool *$length* in the attribute tables for the total length of the hedgerows of each site. Output of the length is meters. To use the length of my hedgerows for my calculations I calculated the running meter per ha as line index for my further analyses.

The composition of the mean agriculture sizes in the study sites was divers. Areas with a mean average size of Baldringe with 28.69ha, Christinehof 3.9ha, Högestad 31.29ha and Vitemölla 6.9ha were computed. Also, the total length of hedgerows/stonewalls in these areas showed variation: Baldringe 22860m, Christinehof 18,960m, Högestad 24,580m and 46,040m (Table 4). Narrowing it down to the 45m buffers (a 45m buffer consists of 0.6ha) 61% of the buffer zones had no agriculture and only 38% had agriculture landscape features. In the buffer zones with agriculture the intensity varied between 0.00ha to 0.55ha, with a mean of 0.09ha. The hedgerows varied between a length from 0m to 131m, with a mean of 18m. Although also here the majority of 78% of the buffers had no hedgerow features and only 22% of the buffer zones included hedgerows.

Table 4.: *Measurements of mean agriculture (ha), length of hedgerows and (m) the calculated line index (m/ha). Calculated in the four study sites (2km buffer).*

Study area	Mean Agriculture (ha)	Hedgerow Length (m)	Line Index (m/ha)
Baldringe	28.69	22860	9.31
Christinehof	3.9	18960	9.20
Högestad	31.29	24580	11.55
Vitemölla	6.9	46040	20.54

3. Statistical analyses

To analyse the effect of landscape variables on polecat detections I used a generalized linear model (GLM) with binomial distribution in R - version 4.1.2 (R Core Team 2021). I selected nine ecological meaningful variables a priori for my further analysis (Table 6).

I used the detection or non-detection of polecats at a polecam location as dependent variable, all the ecological meaningful variables were treated as independent variables: distance to nearest small and big roads, distance to nearest buildings, agricultural mean size (ha) in the 45m buffer, length of hedgerows as a line index (m/ha) in the 45m buffer, cover of grass in 2.5m plot, woody plants cover in 2.5m plot, stone heap presence/absence in 2.5m plot and protective cover as score out of a viewpoint of the polecat in 2.5m plot. Additionally, I included the four study sites Baldringe, Christinehof, Högestad and Vitemölla as a fix factor. I excluded the mean forest size (ha) beforehand, due correlation with the mean agriculture size (ha) (Pearson rank correlation, $t = -3.92$, $df = 47$, p-value < 0.001, correlation -0.49). Additionally due the too small dataset in spring I only used the fall data for my statistical analysis.

Prior to the analysis I computed a Pearson rank correlation test to evaluate collinearities between my variables and created a correlation matrix with the *sjPlot* package (Lüdecke 2021).

The Pearson rank correlation describes the relationship between two variables. It can range from a value -1.0 (negative relationship) to + 1.0 (positive relationship). If there is no relationship between the two variables the value is zero (Goodwin and Leech 2010). When the correlation coefficient was higher than 0.39, I retained only one variable for my final GLM. I kept generally the one variable, that was more meaningful from the ecological point of view. The value in the brackets is the p-value (Table 5).

For my final analysis I kept the variables nearest distance to big roads, nearest distance to buildings, line index (45m buffer), score cover (2.5m plot) and the study sites.

Due to the different units of my data, I standardized each covariate by subtracting the mean and dividing by one standard deviation for easier comparison among regression coefficients.

Table 5. Pearson rank correlation. The value closer to (+/-) 1 shows a high correlation between two variables. The value closer to 0 shows a low correlation. The value in the brackets is the p-value of the correlation.

	DistanceStreetSmall	DistanceStreetBig	DistanceBuilding	agriculture_mean_ha	line_index	GrassCover	WPlantsCover	StoneHeap	ScoreCover
DistanceStreetSmall		0.315 (.027)	0.444 (.001)	-0.045 (.760)	-0.177 (.225)	0.207 (.153)	-0.119 (.414)	-0.161 (.270)	-0.008 (.956)
DistanceStreetBig	0.315 (.027)		0.319 (.025)	-0.273 (.058)	-0.038 (.795)	-0.012 (.935)	-0.108 (.461)	-0.238 (.100)	-0.056 (.702)
DistanceBuilding	0.444 (.001)	0.319 (.025)		-0.378 (.007)	-0.337 (.018)	0.089 (.545)	-0.413 (.003)	-0.399 (.005)	-0.409 (.004)
agriculture_mean_ha	-0.045 (.760)	-0.273 (.058)	-0.378 (.007)		0.506 (<.001)	-0.139 (.342)	0.445 (.001)	0.644 (<.001)	0.416 (.003)
line_index	-0.177 (.225)	-0.038 (.795)	-0.337 (.018)	0.506 (<.001)		-0.077 (.599)	0.315 (.027)	0.395 (.005)	0.266 (.064)
GrassCover	0.207 (.153)	-0.012 (.935)	0.089 (.545)	-0.139 (.342)	-0.077 (.599)		-0.280 (.051)	-0.187 (.199)	0.050 (.733)
WPlantsCover	-0.119 (.414)	-0.108 (.461)	-0.413 (.003)	0.445 (.001)	0.315 (.027)	-0.280 (.051)		0.196 (.177)	0.390 (.006)
StoneHeap	-0.161 (.270)	-0.238 (.100)	-0.399 (.005)	0.644 (<.001)	0.395 (.005)	-0.187 (.199)	0.196 (.177)		0.349 (.014)
ScoreCover	-0.008 (.956)	-0.056 (.702)	-0.409 (.004)	0.416 (.003)	0.266 (.064)	0.050 (.733)	0.390 (.006)	0.349 (.014)	

Computed correlation used pearson-method with listwise-deletion.

Table 6. *Ecological meaningful variables for statistical analysis. Variable marked with * got included in the final statistical analysis with GLM binomial, additionally to the study sites as fix factor.*

Ecological Meaningful Variables					
Variable	Unit	Code	Description	Scale	Source
Agriculture Mean Size	ha	agriculture_mean_ha	mean area of agriculture	45m buffer	computed with Fragstats
Distance Building*	meter	DistanceBuilding	distance of edge of buildings to camera trap		computed with QGIS
Distance Road Big*	meter	DistanceStreetBig	distance of center big road to camera trap		computed with QGIS
Distance Road Small	meter	DistanceStreetSmall	distance of center small road to camera trap		computed with QGIS
Grass Cover	percentage	GrassCover	percentage of grass cover in sampling plot	sampling plot (2.5m)	fieldwork
Line Index*	m/ha	line_index	total length of hedgerows	45m buffer	computed with QGIS
Stone Heap	1/0	StoneHeap	presence or absence of stone heaps	sampling plot (2.5m)	fieldwork
Protective Cover*	1-10	ScoreCover	protection cover from polecat view, scored from 1 (bad) to 10 (good)	sampling plot (2.5m)	fieldwork
Woody Plants Cover	percentage	WPlantsCover	percentage of woody plants cover	sampling plot (2.5m)	fieldwork

4. Results

4.1 Does the polecam work to detect polecats?

The polecam does work out to detect polecats (Figure 8). In spring 15 of the 49 camera traps failed – the cameras got lose and due to the wrong angle photographed the ground. The 34 working cameras captured polecats in three polecam locations with four detections (Table 7 and Figure 9).

In fall one of the 49 camera traps failed completely and one drowned towards the end of the fieldwork. At 19 polecam locations polecats were detected (Table 7 and Figure 10) with a total of 47 polecat detections. Although the camera trapping was focused on polecats other species and Mustelidae got also captured in the polecams like American mink (*Neovison vison),* European otter (*Lutra lutra*), Pine marten (*Martes martes*), Stoat (*Mustela erminea*), European badger (*Meles meles*) and Red fox (*Vulpes vulpes*).

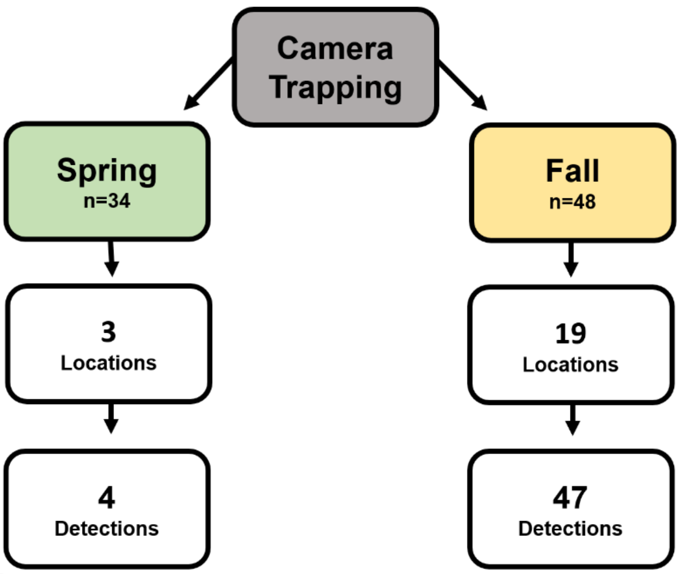

Figure 8. *Results of camera trapping in spring and fall, n is the amount of the functioning polecams.*

Table 7. *Details of detections and working polecams in the four study sites.*

Study site	Polecams total	Working Polecams		Detections	
		Spring	Fall	Spring	Fall
Baldringe	12	9	12	1	16
Christinehof	20	13	19	0	30
Högestad	7	4	7	3	0
Vitemölla	10	8	10	0	1
Total	49	34	48	4	47

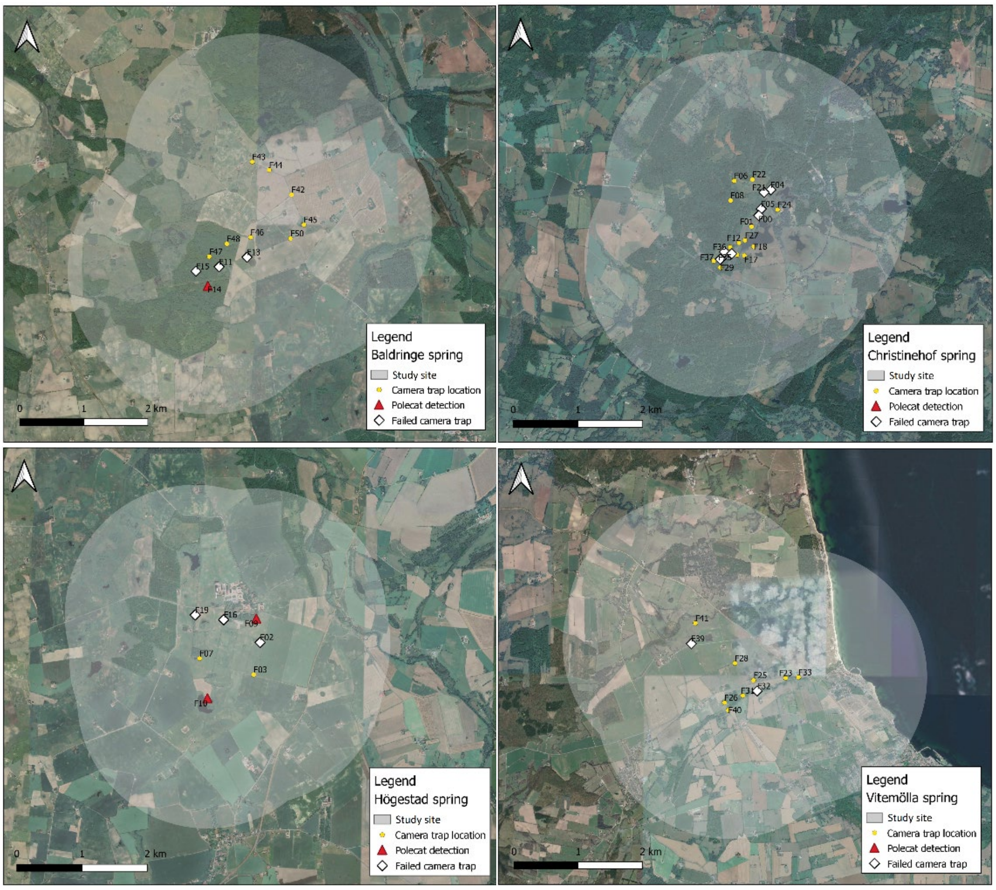

Figure 9: Polecat detections and failed polecams in the four study sites in spring.

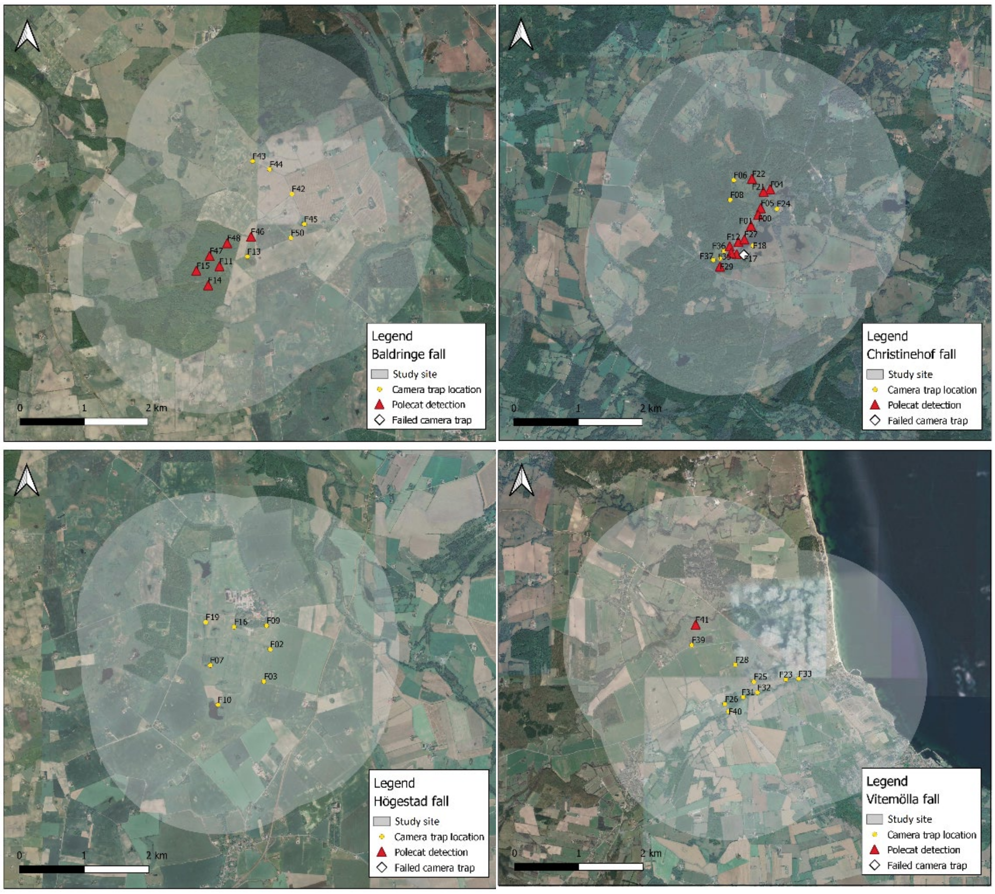

Figure 10. *Polecat detections and failed polecams in the four study sites in fall.*

4.1 Which factors influence the detection probability of polecats?

Seasonal differences between spring and fall

In spring the cameras captured polecats in three polecam locations with four detections. In fall the cameras captured polecats in 19 polecam locations with a total of 47 detections. The result show that there is a higher density of polecats in fall than in spring (Chi-squared-test, χ^2= 36.25, df = 1, p-value < 0.001). Although, due the small dataset in spring I could not include the spring data for my analysis.

Distance Measurements

For my final analyses I kept the variables nearest distance to big roads and buildings, line index, score cover and the four study sites as fix factor.

The GLM binomial contained 48 observations of the fall data, with detection/non-detection as depending variable with a Model Fit $\chi^2(7)$ = 32.36 and pseudo R^2=0.66 (Cragg Uhler). The results of the GLM binomial showed no evidence that the distance to buildings have an influence on polecat detection probability (Table 8 and Figure 11).

It was not possible to analyse the seasonal differences between spring and fall for the distance to buildings due the too small dataset in spring.

I found moderate evidence that the polecat detection probability decreased with distance to big roads (Table 8 and Figure 12).

Table 8. *Results of the GLM binomial. (Intercept) is the study site Baldringe.*

	Est.	**S.E.**	**z val**	**p**
(Intercept)	-1.39	1.44	-0.97	0.33
Distance Road Big	-14.18	6.85	-2.07	0.04
Distance Building	0.62	0.81	0.76	0.45
Line Index	0.29	0.81	0.35	0.73
Score Cover	0.10	0.49	0.21	0.84
Study Site Christinehof	17.35	8.26	2.10	0.04
Study Site Högestad	-32.86	3203.81	-0.01	0.99
Study Site Vitemölla	-19.74	8.77	-2.25	0.02

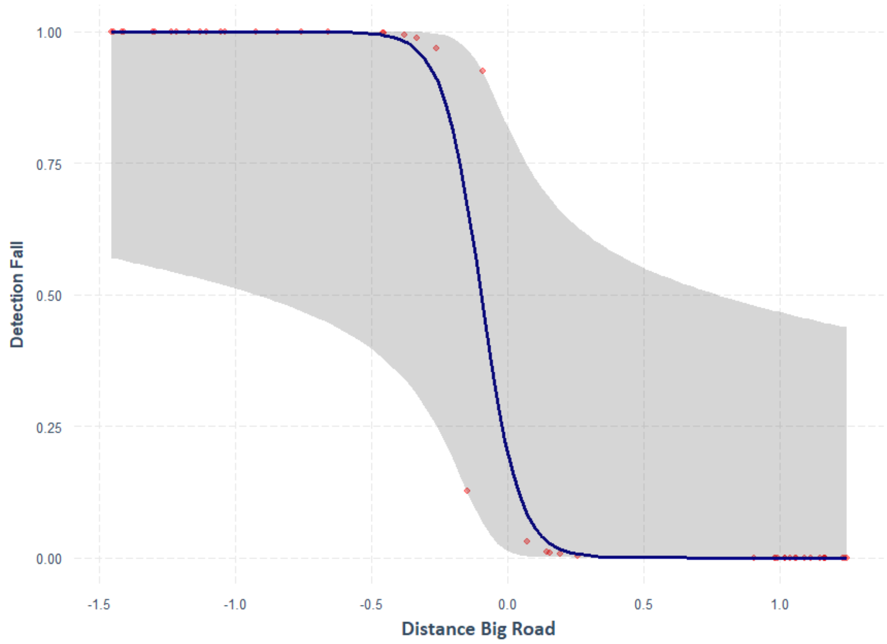

Figure 11. *Partial residual plot of the relationship between the distance to the nearest big road and polecat detection probability in fall. The solid line indicates the model estimate with the 95% confidence interval in grey. The red points are the partial residuals.*

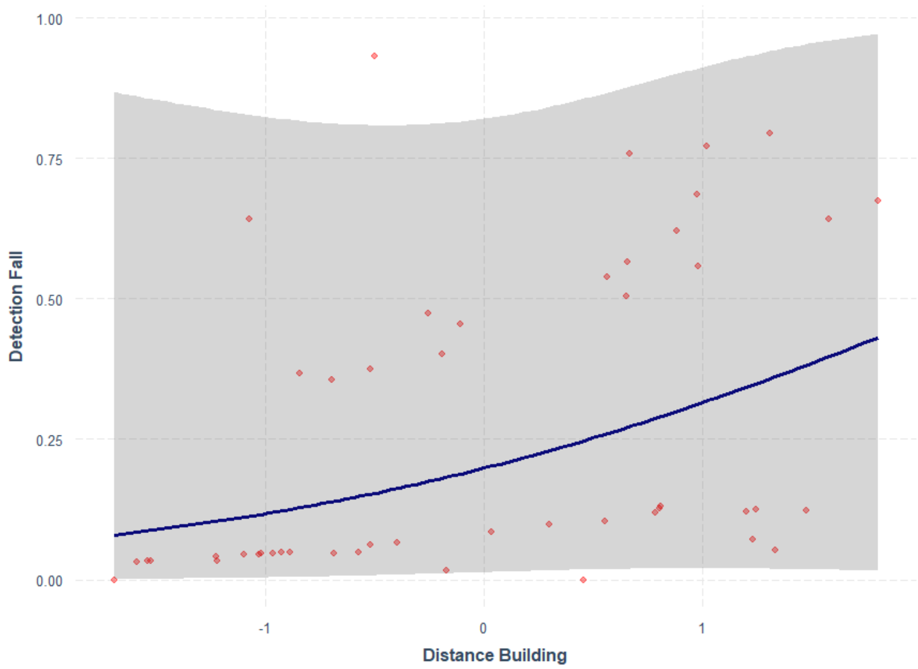

Figure 12. *Partial residual plot of the relationship between the distance to the nearest building and polecat detection probability. The solid line indicates the model estimate with the 95% confidence interval in grey. The red points are the partial residuals.*

Agrictultural intensification

I found no evidence the that agricultural intensification is associated with polecat detection probability (Table 8 and Figure 13).

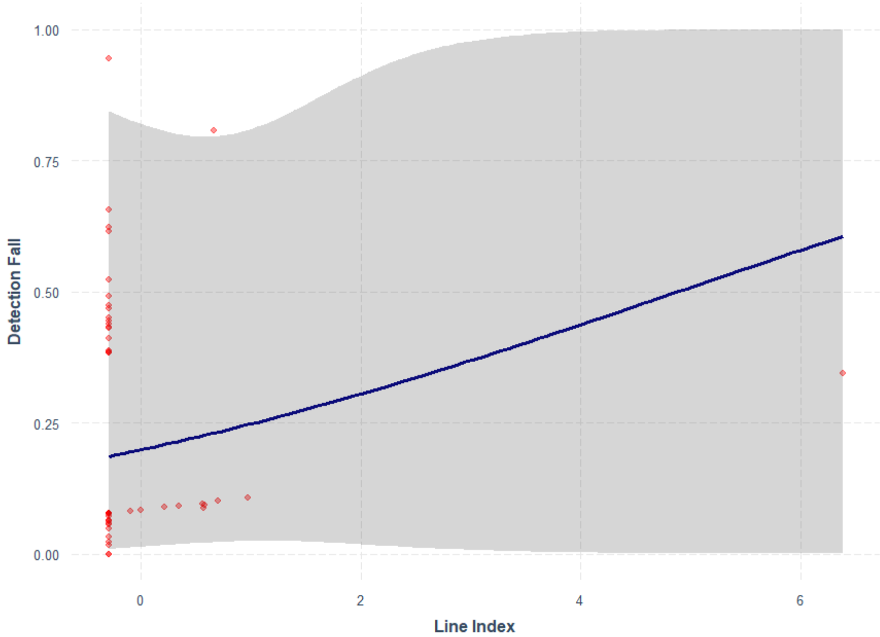

Figure 13. *Partial residual plot of the relationship between agricultural intensification and polecat detection probability. The solid line indicates the model estimate with the 95% confidence interval in grey. The red points are the partial residuals.*

Study sites

The probability of detecting polecats was higher in Christinehof than in the other study sites. The probability of detecting polecats was lower in Vitemölla than in the other sites (Table 8 and 9, Figure 14). The computed Tukey's post-hoc test shows the difference among all four study sites (Table 9).

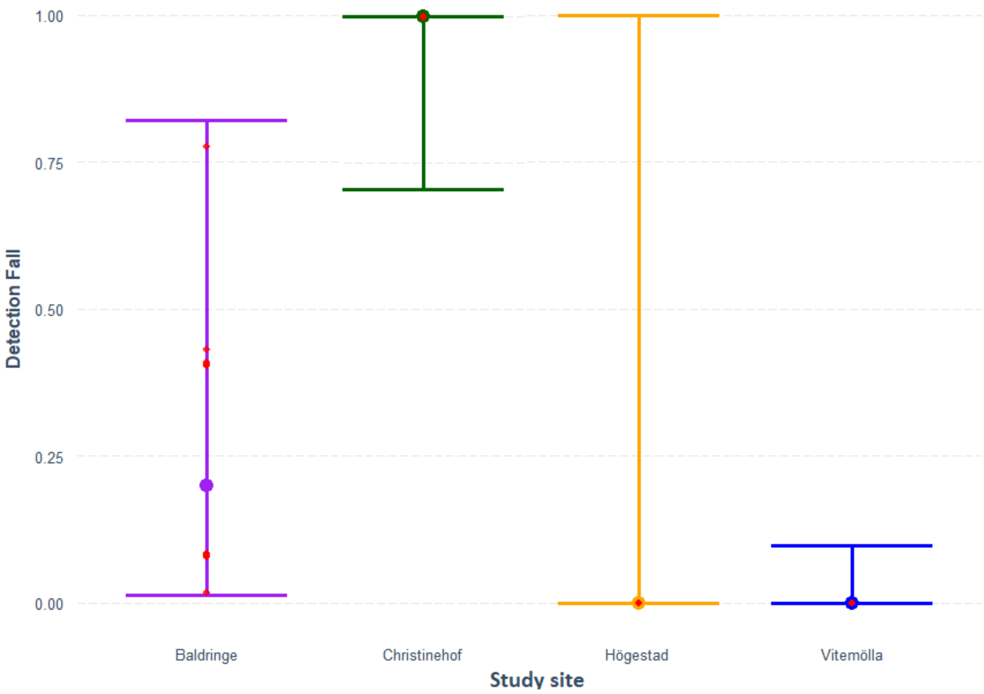

Figure 14. *Comparing the four study sites shows the different evidence of influences to the polecat detections. The probability of detecting polecats was higher in Christinehof than in the other study sites. The probability of detecting polecats was lower in Vitemölla than in the other sites*

Table 9.Tukey's post hoc test.

Contrast	Estimate	SE	Df	z.ratio	p-value
Baldringe-Christinehof	-14.9	6.12	Inf	-2.439	0.07
Baldringe-Högestad	29.1	2064.92	Inf	0.014	1.00
Baldringe-Vitemölla	16.9	6.00	Inf	2.823	0.02
Christinehof-Högestad	44.0	2064.94	Inf	0.021	1.00
Christinehof-Vitemölla	31.8	11.83	Inf	2.691	0.04
Högestad-Vitemölla	-12.2	2064.92	Inf	-0.006	1.00

Protective cover

Looking closer to the protection cover of the single 2.5m radius around each polecam, it showed that 47% of the sampling plots had a good, 16% a moderate and 27% a bad protective cover. Of the 19 polecams that detected polecats in fall, six were in bad, four in moderate and nine in good protective cover.

I found no evidence that the cover around the polecams had an influence on the polecat detection probability (Table 8 and Figure 15).

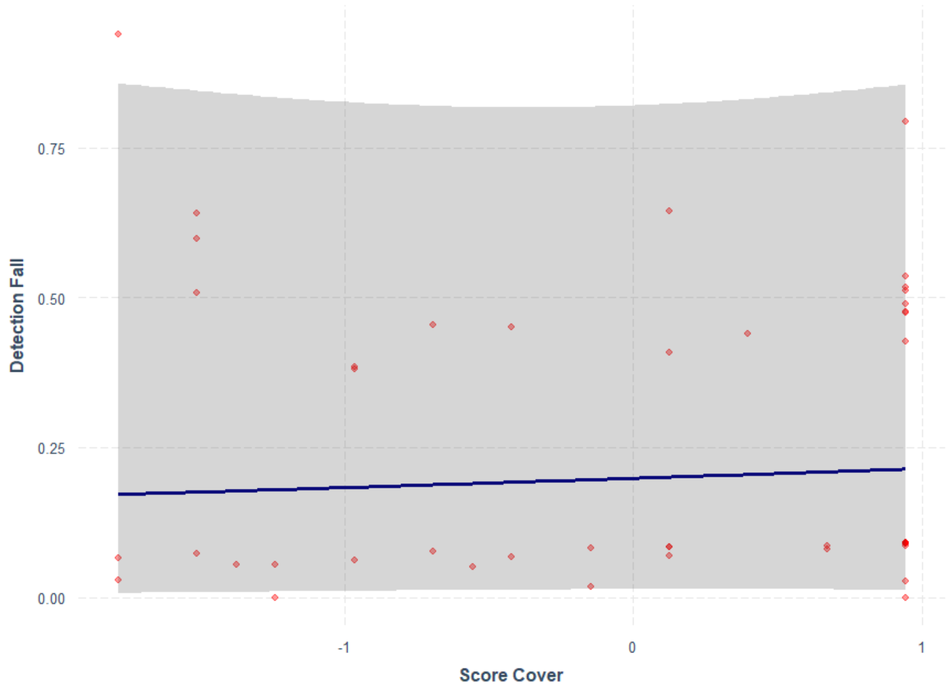

Figure 15. *Partial residual plot of the relationship between protective cover and polecat detection probability. The solid line indicates the model estimate with the 95% confidence interval in grey. The red points are the partial residuals.*

4.2 Facial mask comparison with I^3S

In spring three of the four pictures met my requirements and could be included to work with the software I^3S. One picture did not fulfill the requirements and got excluded, because the camera did not capture the full head of the polecat.

In fall 28 of the 47 pictures met the requirements to work with facial recognition. 19 pictures were excluded: nine photos were too blurry/unsharp, five had the wrong angle, two pictures were crooked so only a small part of the polecat was visible, on two pictures the facial mask was hidden and one photo showed a deformed snout and facial mask of a polecat, because it tried to steal the lure (Figure 16-18).

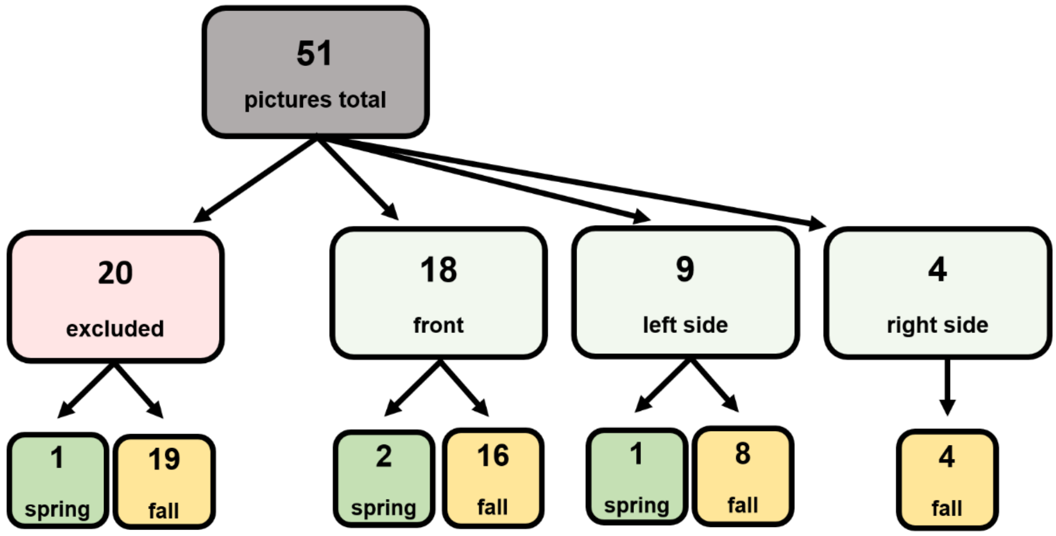

Figure 16. Overview of the captured pictures for individual recognition in both seasons.

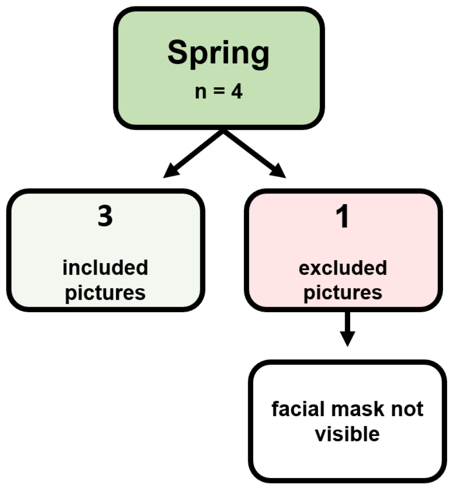

Figure 17. Overview of the captured pictures for individual recognition in spring.

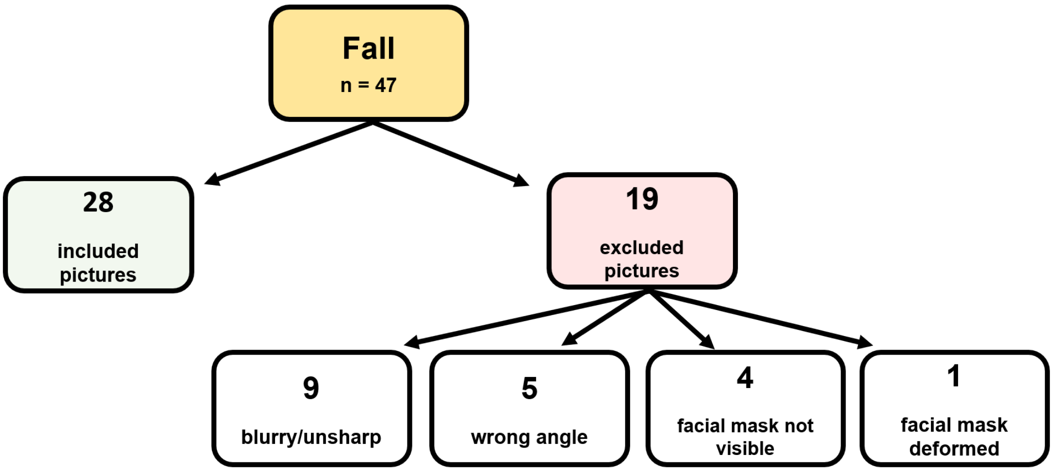

Figure 18. Overview of the captured pictures for individual recognition in fall.

Facial identification with I^3S-Contour

Before using the help of I^3S for the classification I compared the facial masks of the polecats manually by eye. I started like mentioned in the section before with 51 pictures. 20 pictures got excluded beforehand, because they did not fit my requirements. 14 pictures did not have matching facial masks, 12 pictures matched and five pictures were difficult to tell.

In the next step I worked with the help of I^3S. I compared every single facial mask with the other masks in the database. Even though I tried three different ways to compare the facial masks (front, left side and right side) and again with a higher contrast the results in I^3S were not clear. The software suggested high matches for individuals that were far away in different study sites, while often suggested low matches for pictures that were taken at the same polecam (Figure 19). Additionally, when I used facial mask "A" as base and compared it with the rest of the data with the other masks, in the first run, facial mask "B" was shown in Rank 1. Then using mask "B" as a base comparing with the rest of the masks, "A" was not as expected in Rank 1, but often appeared in different higher Ranks. Summarizing the results (Figure 19) show that there was no clear relationship between the Rank number from the software and the group in which the picture fell.

2

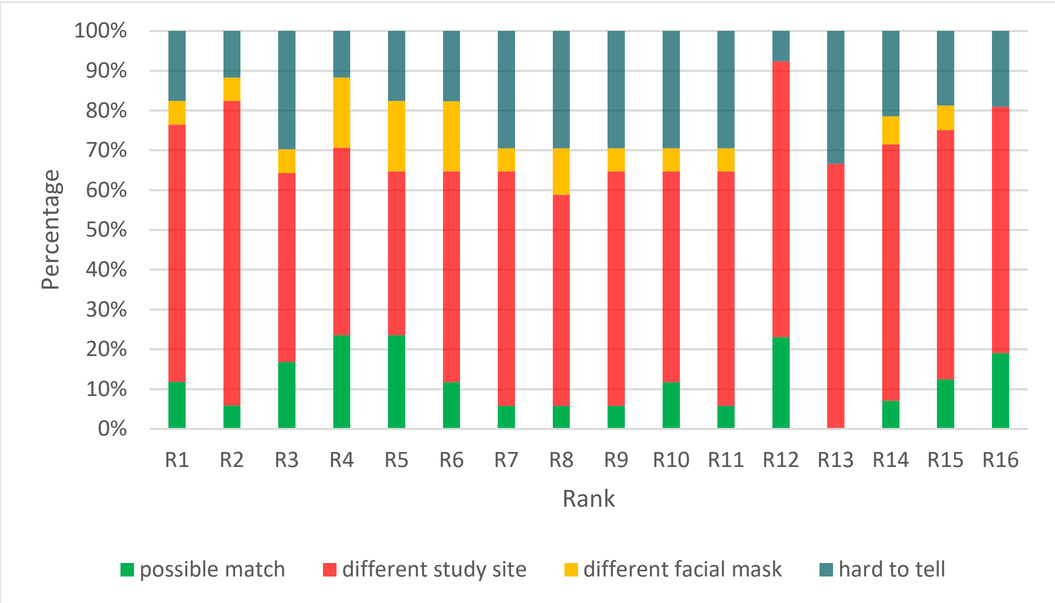

Figure 19. *Comparison the facial mask with the help of I^3S- Contour. For every facial mask 16 other facial masks of the database got suggested for comparison. A lower Rank number means a higher match probability.The summary does not show a clear relationship between the Rank number from the software and the group in which the picture fell.*

5. Discussion

Using the newly developed polecam I was able to show that it is possible to detect polecats and take pictures of their facial masks. Despite the usage I^3S software for individual recognition further adaptions are needed (explained further below). The data analysis indicates that polecat detection probability decreases with the distance to big roads. On the other side other landscape features did not show any clear relationship with polecat detection. The covariates that I measured did not explain the variation in the detection probability, except for the factor study sites, which might be linked to differences in polecat density among sites. I found a difference of the detections between spring and fall, with more detections in fall.

5.1 Camera trapping

The camera traps in spring had an enormous amount of vegetation and rodent pictures. To avoid large numbers of false triggers it is necessary to make sure, that rodents can't encounter the traps (Mos 2019) and that the front of the tube is mostly free from moving vegetation (Apps and McNutt 2018). The latter is more complicated with the polecat's preference of high protection cover (see Zabala et al. 2005, Baghli et al. 2005, Mestre et al 2007, Weber 1989). Additionally, several polecams got used by spiders as haven, which lead the lenses and sensors to be completely covered in spider webs. This could also have been a reason for the reduction of picture quality.

15 camera traps in spring could not be used, because the camera shifted and photographed the ground. A proper fixation of the cameras in the tubes is mandatory to maintain an equal chance of detection probability so the different seasons can be better compared.

I found a difference of the detections between spring and fall, with more detections in fall, which supported my hypothesis of a higher amount of polecats in fall than in spring. The higher density is likely explained by the dispersal of juveniles (cited in Blandford 1987).

5.2 Landscape analyses

Doing landscape analyses of European polecats brought some challenges considering the practical and theoretical approaches. Mustelidae have a great range of variations according to their morphology, behavior and ecology. Many factors, biotic and abiotic, also influence the distribution of a species in a landscape in different scales (Gough and Rushton 2000, Brzeziński et al. 2021). It is not possible to quantify all components in a GIS, because some are unknown and others are difficult to measure. The high variation in my results showed that probably other factors have a higher influence on polecat detections than my variables (the distance to nearest streets and nearest buildings, agricultural intensification and protective cover). The main factor determining polecat detections is polecat density, which might have differed among study site and could be one explanation of the high variation in my results. It also could be possible, that my covariates were in the wrong scale to have an explainable influence on my results: the polecams within the sites did not differ much in the distance to nearest buildings, neither did the hedgerows. The only covariate that might have explained within site variation was score cover – and there results showed that these had no influence on the detection probability.

It is essential to identify the factors that are considered to have the biggest influence on the distribution and create a simplified representation of it in a GIS model (Gough and Rushton 2000). Measurements of intensification or connectivity can get approaced in different ways. For my analyses I used the line index of hedgerows for the agricultural intensification. Although the analyses did not include fallow lands and swamp areas which can be also an important part to describe the intensification or vice versa the heterogeneity of a landscape. Swamps and fallow lands are also important habitat elements for the polecat (see Baghli et al. 2005, Mestre et al. 2007, Zabala et al. 2005, Virgós 2001).

Hedgerows are an essential key element in intensified agricultural landscapes and play an important role in landscape connectivity and therefore a key component for a successful dispersal of wildlife or also as habitat (Trapp et al. 2019, Dondina et al. 2016, Pelletier-Guittier et al. 2020). Their use is strongly species-specific and influenced by the internal characteristics (Dondina et al. 2016). The impact of hedges and their characteristics (width and internal) to the polecat detections could be an interesting study of its own.

In the context of the line index for connectivity it might be suggested to compute the connectivity also with other indices like Patch Cohesion Index. This index measures the physical connectedness of the corresponding patch type (McGarigal 2015, McGarigal and Marks 1995) and would according to Schumaker (1996) be an index which is robust to details, artifacts and parameterization.

5.2.1 Distance measurements

The distance to buildings showed no evidence of an influence on polecat detection probability. A possible reason could be that the data sampling took place in time periods where polecats are less dependent on human settlements (see Baghli et al. 2005, Baghli et al. 2002, Weber 1989). Other results might appear when another study takes place in the winter season as well.

Contrary to my hypothesized association that a small distance to bigger roads has a negative influence on polecat detection probability, the results suggest that with a higher distance to bigger roads the probability to polecat detections sink.

However, a more plausible explanation is that the distances between polecams and big roads where too big and went partly beyond over the daily travel distance of a polecat (Baghli and Verhagen 2004, Brzeziński 1992). Especially in the study site Christinehof I measured the highest distances from big streets to the camera traps – in comparison with other studies (e.g., Baghli and Verhagen 2004, Brzeziński 1992) it is questionable if the big roads have a direct influence on the polecat detection in my study area. Looking at the the polecam detections in QGIS it showed the most detections were in forest areas or close to forest edges. In the study site Baldringe the forest was closer to a big road than the agriculture area with no detections. Also, the one detection in Vitemölla was closer to a big road, although in an unsuitable habitat in the middle of a cattle pasture withouth cover. Therefore, it could be possible that the higher detection probability closer to big roads could be influenced by other variables with a higher importance for polecats or by coincidence. Thus, the results should be interpreted carefully.

Additionally, it was difficult to determine the actual sizes of roads in the study area. In Sweden a big road, like a national road can sometimes also have the same characteristics like a smaller road according to speed limit and size. Not only the size of the road could have an important influence on the polecat detection, but also its traffic frequency. For further studies it might be interesting to look not only on the distance to big roads, but all road types and the density of the road network in the study area.

Equally the protective cover and the agriculture intensification show no evidence of an influence on polecat detection probability. My data does neither support my hypothesized association that intensified agriculture has a negative influence on the polecat detection probability, nor that the polecat is present in biotopes with high cover. Although several studies (see Zabala et al. 2005, Baghli et al. 2005, Mestre et al 2007, Weber 1989) show that the habitat use of polecats depend on protection cover and the agriculture intensification has an influence on polecats' ecology and distribution/abundance (Virgós 2001, Zabala et al. 2005). That leads me to the suggestion that other factors might have a higher influence on the polecat detection probability in Skåne. There are already models approaching the spatial distribution of Mustelids, although they differ in complexity. Estimation of prey abundance influence the habitat use of polecats (Gough and Rushton 2000, Baghli et al. 2005, Mestre et al. 2007, Weber 1989) and could be an important variable for the analysis. Although collecting data about prey availability is difficult, because of their high time and space dynamic (Gough and Rushthon 2000). The study of Mestre et al. (2007) showed that the ecological variables with the highest influence for polecats were main water course length, number of scrubland patches, Shannon Wiener Landscape diversity index and number of water surface patches. Albeit Mestre's study took place in southern Portugal, which has a different landscape composition than southern Sweden.

5.2.2 Study sites

To focus attention on the different study sites that show different evidence for the polecat detection probability: Christinehof with high evidence of positive association of polecat detection probability and Vitemölla with high evidence of negative association. Tukey's post-hoc test showed an infinite value of degrees of freedom, caused by the zero detections in the study site Högestad. Due the zero detections in Högestad the estimate of that study site could not get detected.

Looking closer at the two study sites, Christinehof and Vitemölla, it shows that they differ greatly in their landscape composition (see also Methods and Material: study area) and amount of polecams. Christinehof is located, compared to Vitemölla, quite remote and has a higher proportion of forest in the study area (mean 0.87ha). In contrast Vitemölla's mean forest proportion is 0.15ha. Although Christinehof has lower length of hedgerows I used for the line index: Christinehof 18,960m and Vitemölla 46,040m. The mean agricultural size does not differ highly in the analysis (Christinehof 3.9ha and Vitemölla 6.9ha), although Vitemölla's small mean agricultural size is not reflecting the actual amount of agricultural size in the site, caused by the high number of patches in the Swedish Landcover Map (Christinehof 94 patches, Vitemölla 138 patches). For a good interpretation of the agriculture intensification, it is important to look at the combination of the number of patches and the mean agriculture size (McGarigal and Marks 1995).

It sticks out that many detections are in forest areas or at forest edges and hedgerows between open fiels had no detections. Although interpretation of this observation should be handled cautiously. The camera traps got arranged in one line, sometimes in small distances (Christinehof about 90m distances), which makes it easy for one individuum to trigger multiple cameras by just passing by and creates a bias. Nonetheless it might be worth trying if the forest has an influence on polecat detection.

It must be highlighted that the number of polecams in Christinehof were twice as high as in Vitemölla – which could also have an influence on the polecat detection. Since the polecams were partly located in closer distances the detection rate could be influenced by one single individual in a short time. However, this study was a pilot study, therefore the selection of the polecam locations were not completely randomized. The polecam locations got individually selected for a higher detection chance in suitable habitats and not sutitable habitats for comparison.

One interesting aspect in Vitemölla was that, although there were polecams in suitable habitats, like a riverine system in a forest patch, the only detection of a polecat was in a cattle pasture with no cover in exposed location. Looking closer into the camera detections for other species I noticed that in four of the six camera traps in suitable riparian habitat Eurasian otter (*Lutra lutra*) and American mink (*Neovison vison*) were detected. According to some studies (see Harrington and MacDonald 2008, Harrington et al 2009, Barrientos 2015, Brzeziński 2021) the occurrence of mink and otter could also have influenced the polecat detection in that area due to interspecific competition.

5.3 Facial mask comparison with I^3S

The failed comparison with I^3S can have several causes, starting with the optimal conditions to take the pictures (see also den Hartog & Reijns 2011). Unfortunately, in nature it is almost impossible to fulfill these optimal conditions (Russo et al. 2020) and the pictures are influenced by many environmental factors.

Den Hartog & Reijns (2011) mentioned that the software assumes linearity of the animals. Although the facial mask of a polecat underlies deformation shown as movement of facial expression (licking their snout, trying to steal the lure,…) which makes proper comparison difficult (own sighting).

Besides of the influence of the polecat itself it is also important to keep in mind that the field study had other circumstances than the study of Russo et al. (2020) with stuffed polecats from the museum. The camera traps in the field often have an insufficient image quality for individual recognition (Randler et al. 2020), the cameras in my study took black and white pictures, which made it sometimes hard to distinguish if the color is part of the contour of the facial mask or influenced by the light of the camera or the surrounding. It also happened that it was not possible to follow the contour, because the pictures were too blurry from the beginning or latest when you tried to zoom in for more details. A better quality and resolution of pictures increase the comparison probability. This could be achieved by adapting the distance of the camera to the photographed individual by changing the length of the tube-system. Another option for a possible higher facial mask capture might using videos instead of pictures – although also here the resolution must be good enough.

Comparing the pictures manually (without the help of I^3S) by eye I found a higher flexibility using all parts of the facial masks and the whole appearance of the polecat. I^3S is limited by only focusing on the pattern around the snout of the polecat, although the facial mask of a polecat has more unique features like the "half moon" around the eyes (Russo and Loy 2020, Müller 2020, Blandford 1987, own sighting) or other anomalies like scars etc. that could also be used for comparison. However, it is important to keep in mind that I^3S is a semi-automatic tool which is used to support the identification of individuals, but the user still has to manually decide if the pattern match or not.

If another study is planned to use I^3S, a combination of DNA analyses and camera trapping with facial recognition would complement the system. DNA analyses will give the security if the individual recognition really works. Although DNA analyses can be cost-intensive and need more management to control the traps (de Bondi et al. 2010). For long term studies it could be worth seeing, if the facial masks of juveniles change in comparison to adulthood, to keep a reliable database from juveniles to adults. These results could also influence the capture-recapture-analyses and bring more light in the biology of the European polecat.

6. Conclusion

In this study I could present that it is possible to detect polecats with the new developed polecam system and take pictures of their facial masks in the field. Furthermore, it is partly possible to identify individuals manually by eye, but it is not easy. Additionally to the polecats also other mustelids and other species got detected.

The usage of the I^3S-Contour software showed that the comparison of individuals in the wild is difficult and further adaptions for the picture quality are needed. Using DNA samples to support the comparisons is an important complement to the system. DNA analyses allow us to be 100% certain about possible matches of individuals and would help to improve the system.

My landscape analyses could not show that my chosen variables had an important influence on the polecat detection probability in Skåne. Other variables or my variables in a bigger scale might have a higher influence. That leads towards the importance about openness for all approaches, also going from human-centered views more towards mustelid-perspectives (Gough and Rushton 2000) in future work. A change of perspective could help to find new factors which influence the polecat's habitat choices and leads to a better understanding of the species.

Overall, I think the polecam is promising tool for a non-invasive way to detect polecats, and other mustelids.

For future work it can be auspicious including citizen science to compare the efficiency between human and software identification of facial masks and use that knowledge for further improvements of the identification software.

Doing individual recognition of polecats is not easy and my study showed that there is still improvement needed, but it is worth to keep going to be able to develop a robust monitoring system for determining their population status in the long term.

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