



Mustelid mugshots: photographing facial masks of European polecats (*Mustela putorius*) for individual recognition and density estimation using camera traps

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Abstract

Small carnivores play an important role in ecosystems, but their often hidden lifestyle makes them generally hard to observe. Camera-trapping methodology shows great promise as a standardized monitoring tool for small carnivores. The European polecat (*Mustela putorius*) is a species of conservation concern, listed on the Annex V of the EU Council's Directive on the conservation of natural habitats and of wild fauna and flora. Because of this, EU member states have to report the status of their polecat populations regularly. However, standardized methods to estimate the population size of polecat populations are currently lacking. We present a tube-based camera-trapping system, the Polecam, designed to obtain photographs of the facial masks of individual polecats. We tested the system in four study areas in southern Sweden during Spring and Autumn 2021. We obtained 52 observations of polecats, out of which we were able to identify 38 (73%) to individual. From these observations, we estimated area and season specific estimates of density for five season-area combinations using a multi-session spatial capture-recapture model. Density estimates ranged from 0.84 to 2.7 individuals/1000 ha, similar to the estimates from similar landscapes in other countries in Europe. We also obtained observations of six other species of small carnivores, suggesting that the Polecam could be used for multi-species monitoring, as well as density estimation of European polecats.

Keywords Mustelidae · Enclosed camera-trap system · Spatial capture-recapture · Small carnivore

Introduction

Small carnivores play an important role in ecosystems, forming a trophic level between producers, primary consumers and tertiary consumers (Marneweck et al. 2022). Despite the fact that some small carnivores have adapted to living in modern – human-dominated – landscapes (Bateman and

Fleming 2012), many species face conservation threats such as direct persecution, habitat loss, and reduced survival due to pollution and climate change (Marneweck et al. 2021). Compared to large carnivores, small carnivores show a larger diversity, occur at higher densities, and have shorter life spans, leading Marneweck et al. (2022) to suggest that small carnivores as perfect sentinels for monitoring effects of global change. However, due to their hidden lifestyle, small carnivores are generally hard to observe (Wright et al. 2022).

Traditionally, small carnivores are studied using a range of methods, such as snow tracking (Norrdahl and Korpimäki 1995), track plates (Zielinski and Schlexer 2009), scat surveys (Davison et al. 2002), and hunting bag statistics (Jachowski et al. 2021), with varying success, due to large differences in the effectiveness of methods among species and locations (Gompper et al. 2006). Recent technological advances, such as camera traps and environmental DNA (eDNA), have made the non-invasive monitoring of

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small carnivores more accessible (O'Mahony et al. 2017; Jachowski et al. [early view](#)). Although the use of eDNA, especially from scats, can result in high quality data on individual animals (Koelewijn et al. 2010), this technique is generally expensive to implement, and thus hard to use at large spatial scales (Kojola et al. 2018). In contrast, camera traps can be applied in a more cost efficient way (Wearn and Glover-Kapfer 2019), enabling the scaling up of monitoring programs (Steenweg et al. 2017). Furthermore, enclosed camera-trap systems have been successfully applied to detect a range of small carnivore species, including small mustelids (Soininen et al. 2015; Mos and Hofmeester 2020; Smaal and van Manen 2022; Jachowski et al. [in press](#)). However, camera trap applications generally focus on the identification of species, rather than individuals, making estimation of densities more difficult. Although recent statistical advances have made density estimation of unmarked animals possible (Gilbert et al. 2021), having individual identifications generally leads to more precise estimates. Thus, there is a need for methods that enable the identification of individuals, especially for species where monitoring of population numbers is important.

The European or western polecat (*Mustela putorius* – from here on referred to as polecat) is a species of conservation concern, with suspected population declines over large parts of its range (Croose et al. 2018). It is listed on Annex V of the EU Council's Directive on the conservation of natural habitats and of wild fauna and flora (EU Habitats Directive – 42/93/EC). Due to this listing, every EU membership state needs to periodically report on the status of the polecat population in their country. However, targeted monitoring of polecats is lacking in most European countries, likely because to date there are no effective monitoring methods for this species (Croose et al. 2018). The monitoring that does occur is mainly focussed on polecat distribution based on sightings or hunting bag/trapping statistics (Croose 2016; Thurfjell and Tomasson 2017), but trends in hunting/trapping records can be misleading as sampling effort is often not controlled for (McDonald and Harris 1999). One exception to the general lack of targeted monitoring of polecats is a recent effort in the Netherlands, that implements camera traps with a can of sardines as lure to monitoring polecat distribution at a national scale (La Haye et al. 2017). As most countries are lacking targeted monitoring of polecats, there is a need for a standardized monitoring method to monitor the size of polecat populations, and camera traps may be a suitable tool. Müller (2002) suggested that polecat individuals can potentially be identified based on their facial masks. Russo and Loy (2020) then applied this method on photographs of museum specimens in combination with a matching algorithm suggesting that photographs of facial masks could be used for monitoring polecats.

In this study, our aim was to develop a methodology to get facial photographs of polecats to identify individuals in a field setting. We describe a camera-trap based method – the Polecam – a camera trap system in a tube with a lure. We tested this set-up in a small-scale study in four study areas in southern Sweden during two seasons (Spring and Autumn) in 2021, and applied a multi-session spatial capture-recapture model (Royle et al. 2014) to the obtained observations of individual polecats to derive density estimates for the study areas for the seasons when we observed polecats in each area.

Description of the Polecam

In order to obtain photographs of facial masks of polecats, the animals have to be drawn close to the camera trap and be encouraged to look straight into the camera. Furthermore, one would ideally be able to place the system in micro-habitats that polecats often visit, e.g., among stonewalls and under dense vegetation. We decided to place the camera trap inside a tube with a reservoir where lure could be applied. Based on the materials that were easily accessible in Sweden, we made the tube system from a PVC drainpipe with a length of 48 cm and an inner diameter of 10 cm, and a T-piece of 24 cm (Fig. 1). We chose a tube diameter of 10 cm to potentially include a hair trap in the tube if a first test would show that the polecats would stick their heads inside the tube. To allow light into the tube and make it easier for the smell of the lure to spread, we cut a hole in the top of the T-piece over which we attached a raster so animals would not be able to use it as a second entrance. The bottom of the T-piece was big enough to house a lure, e.g., a can of sardines. Furthermore, the T-piece allowed us to place the Polecam slightly higher above the ground, potentially minimizing small rodents entering the tube. The camera trap was attached at the other side of the tube. In order to obtain sharp images at a distance of approximately 50–60 cm, we attached a +2-dioptre lens, originating from a pair of reading glasses, in front of the camera trap lens.

Field test: detecting polecats

To test the functionality of the Polecam, we performed a field test as a proof-of-concept in four study areas in the county of Skåne the southernmost county in Sweden (Fig. 2). We selected Skåne as the county to test the Polecam because it has the highest hunting bag statistic for polecats in Sweden (Swedish Association for Hunting and Wildlife Management; <https://www.viltdata.se>) and largely consists of suitable polecat habitat (Osinga et al. 2023). The four study areas, Baldringe, Christinehof, Högstad and Vittemölla, were all property of 'Högstad & Christinehof' a

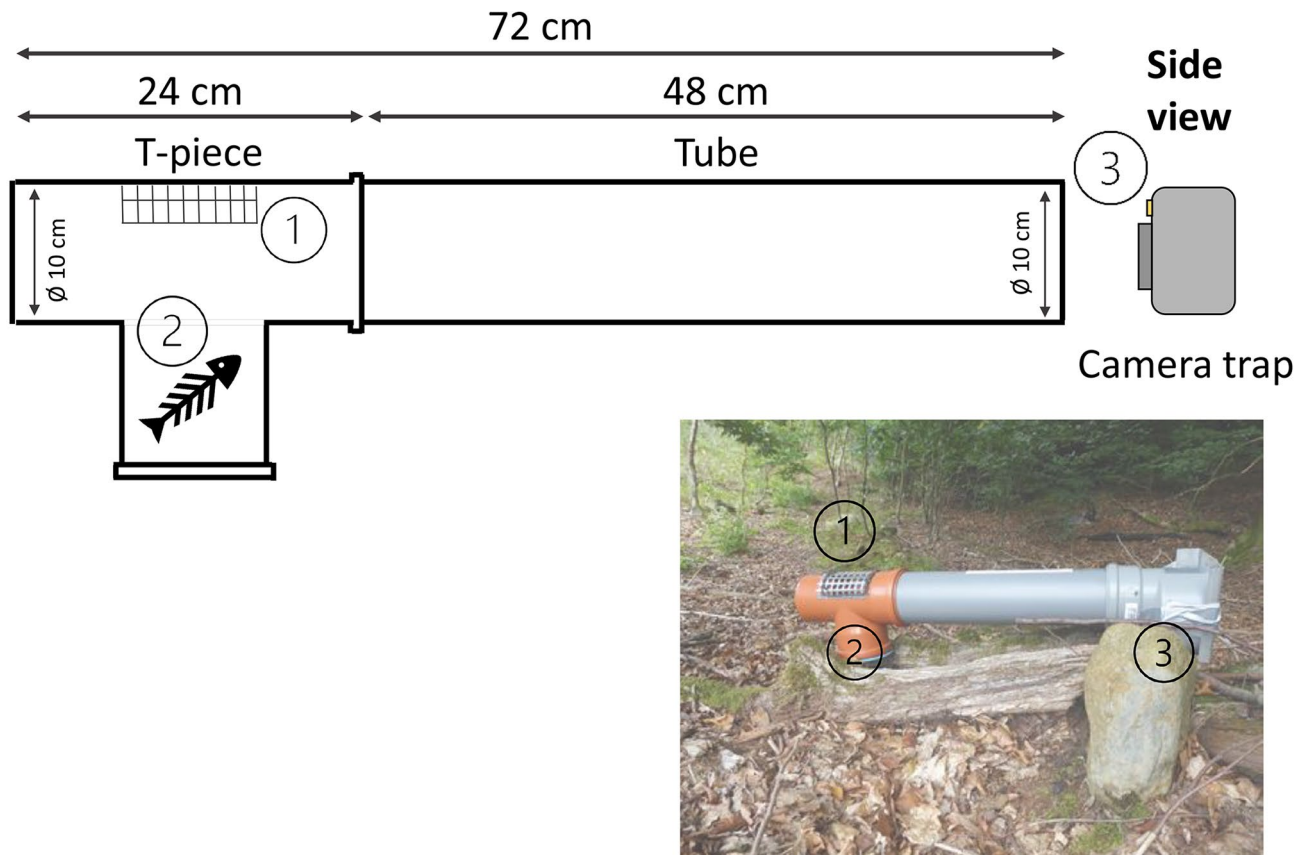


Fig. 1 Design description of the Polecam and an example in the field. The raster in the T-piece allows light to come into the tube (1), allowing for colour images during the day, and makes it easier for the smell

of the lure to spread, while the bottom of the T-piece is big enough to house a can of sardines as lure (2). The camera trap is placed on the other side of the tube (3)

large private estate focussing on agriculture and forestry, as well as hunting (Fig. 2). The areas consisted of a combination of mixed forest and open habitats, partially extensively grazed with livestock, with many stonewalls, hedgerows and other linear elements often used by polecats (Blandford 1987). Baldringe (55°31'60" N, 13°49'60" E) has a size of approximately 25 km², with a mixture of forest patches, farmland and several single houses. Christinehof (55°43'4" N, 13°57'57" E) has a size of approximately 20 km² and is dominated by forest with a small mix of farmland and extensively grazed pastures by cattle and sheep with several wetlands and single houses at the border. Högestad (55°30'0" N, 13°52'0" E) has a size of approximately 21 km² and is dominated by farmland with small forest patches, wetlands and a small village, including several single houses. Vitemölla (55°42'0" N, 14°12'0" E) has a size of approximately 20 km², and is mainly dominated by farmland with small forest patches, pastures with horses and cattle and several small villages, including several single houses.

We performed our field test during two seasons to test which of these two seasons would be optimal for polecat monitoring. The first test was performed in Spring, from 16

March to 19 May 2021. We selected this period as it coincides with the mating season for polecats, during which polecats show an increased activity (Blandford 1987). The second test was performed in Autumn, from 6 September to 25 November 2021. We selected this period as it coincides with the time that juveniles start dispersing and population densities are at their highest, resulting in a second activity peak (Blandford 1987). In both seasons, we deployed 49 Polecams fitted with a Browning Trail Camera (Model BTC 6HDPX) and a can of sardines (Sardinmästarens Sardinier) as lure. We slightly opened the can of sardines so the animals could smell the fish and oil but not reach the sardines. Camera traps were set to 'Trail' mode and to take eight pictures when triggered, at medium picture size (8 MP). We set a capture delay of 1 min to minimize the number of triggers due to unwanted visits of small rodents. Furthermore, we set motion detection to 'Long' and used the 'Smart IR' function for getting good quality images at night.

We placed Polecams in microhabitats where we expected polecats to occur, at field borders with stonewalls and bushes/trees as cover; along fallen trees in deciduous forests, and forest borders; and in the riparian zone along



Fig. 2 Maps of the four study areas. Map on the left shows Sweden as divided into counties, with the county of Skåne (light blue) and the location of the study areas (box) highlighted. Each study area map shows the locations of the Polecams (dots) as well as major forest areas

(dark green) and water (light blue). The scale gives the scale of the study area maps. Background map data copyrighted OpenStreetMap contributors and available from <https://www.openstreetmap.org>

streams and ponds. In order to ensure that each individual polecat would have more than one Polecam in their home range, enabling recaptures of the same individual at multiple Polecams, we placed Polecams on average every 300 m along linear features (distances between Polecams ranged between 45 m and 750 m, based on availability of suitable locations). This was based on home-range size estimates of 0.5–1 km² for female polecats (Blandford 1987; Baghli and Verhagen 2004) and resulted in 12 locations in Baldringe, 20 locations in Christinehof, seven locations in Högestad and ten locations in Vitemölla (Fig. 2). Of the, in total, 49 used Polecams for each season, three Polecams failed to work properly, one at Christinehof and one at Högestad in Spring, and one at Christinehof in Autumn. This resulted in a total trapping effort of 47 Polecams and 2831 trap nights

in Spring, and 48 Polecams and 3670 trap nights in Autumn (Table 1).

After retrieval of the Polecams, we uploaded all images to a server running Trapper (Bubnicki et al. 2016) to classify the images. Trapper is an open source, Django based web application to manage camera-trapping projects. We classified observations that were more than five minutes apart as separate observations. We obtained four polecat observations at three locations (one at Baldringe and two at Högestad) in Spring, and 48 polecat observations at nineteen locations (six at Baldringe, 12 at Christinehof, and 1 at Vitemölla) in Autumn (Table 1). This resulted in an average trapping rate of 0.14 observations per 100 trap nights in Spring, and 1.3 observations per 100 trap nights in Autumn. Apart from polecats, we obtained observations of other small carnivores: red fox (*Vulpes vulpes*), Eurasian badger

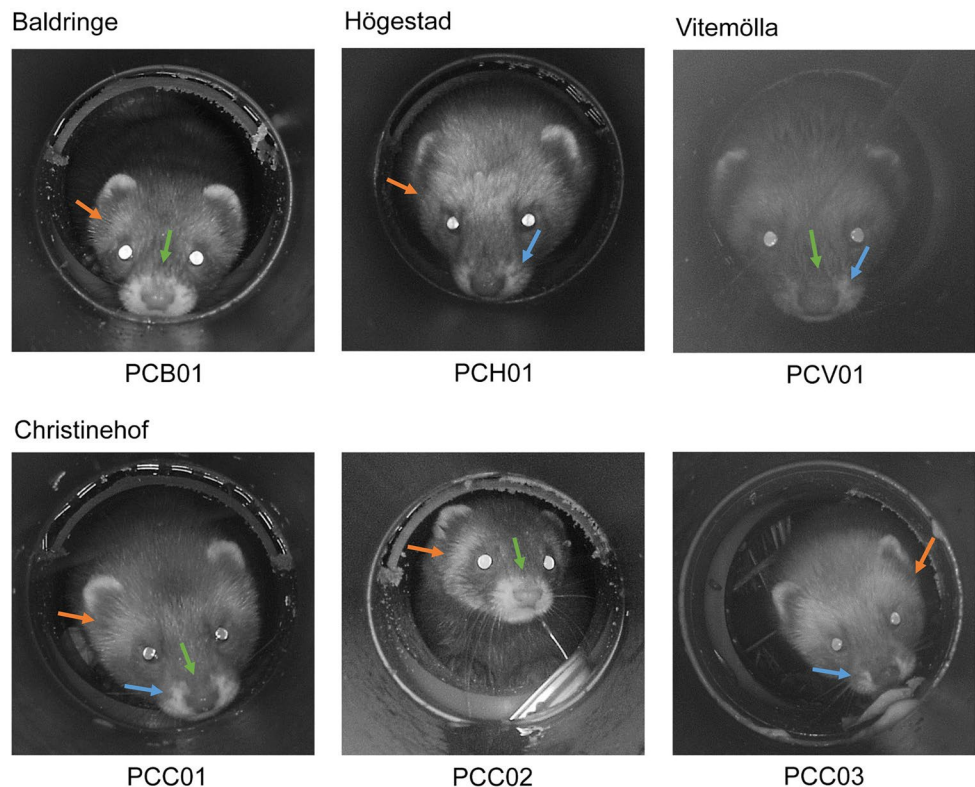
Table 1 Effort, number of polecat observations, and density estimates per study site and season

Location	Season	Polecams ¹	Total trap nights	polecat observations ²	observed individuals	Density estimate (ind. / 1000 ha)
Baldringe	Spring	12 / 12	724	1 / 1	1	1.1 (0.13 to 10.1)
	Autumn	12 / 12	876	12 / 16	1	0.84 (0.098 to 7.2)
Christinehof	Spring	19 / 20	1099	0 / 0	0	-
	Autumn	19 / 20	1482	21 / 31	3	2.7 (0.61 to 11.7)
Högstad	Spring	6 / 7	378	3 / 3	1	1.6 (0.17 to 15.8)
	Autumn	7 / 7	539	0 / 0	0	-
Vitemölla	Spring	10 / 10	630	0 / 0	0	-
	Autumn	10 / 10	773	1 / 1	1	0.96 (0.11 to 8.4)

¹ The number of Polecams given is “the number that effectively worked” / “the number deployed”

² The number of polecat observations given is “the number of identifiable observations” / “the total number of observations”

Fig. 3 Individual polecats observed in the different study areas. We identified one individual in each of the study areas Baldringe (PCB01), Högstad (PCH01), and Vitemölla (PCV01), while we identified three individuals at Christinehof. We mainly used three characteristics to identify individuals: **1**) the amount of white above the nose (green arrows), **2**) the shape and size of the white on the sides of the nose, that often showed individual patterns (blue arrows) and **3**) the size and contrast of the “half-moon” pattern above the eyes (orange arrows). The arrows highlight some (but not all) of the used characteristics per individual



(*Meles meles*), Eurasian otter (*Lutra lutra*), European pine marten (*Martes martes*), American mink (*Neovison vison*), and stoat (*Mustela erminea*; Figure S1).

Feasibility test: identifying individuals and estimating density

After an initial classification to species level, we further classified polecat observations to the individual level. Although polecats have a clear facial marking that is different between individuals and can thus be used for individual recognition, this facial marking is not always clearly visible on all images. Furthermore, the angle at which polecats were photographed differed among observations and images within observations. We initially tried to use the I³S contour

software (<https://reijns.com/i3s/>) to identify individuals, as suggested by Russo and Loy (2020). However, the software identified different images from the same series (and thus the same polecat) as different individuals, while it grouped images from polecats from different study areas (that were spaced such that individual polecats would not occur in more than one area) as the same individual, likely as a result of this large variation in photography angles. We therefore resorted to manual identification. This identification was performed by three authors (TH, NE, and HT), taking a conservative approach where we only included identifications for observations where all three agreed on the individual identification. This meant that images where characteristics were not clearly visible according to all three authors were not included with individual identification. We did this to

avoid splitting errors that might inflate density estimates (Johansson et al. 2020). Out of the 52 polecat observations, 38 (73%) could be identified to individual. In these observations, the polecats looked straight into the camera (Fig. 3) or were photographed in an angle where the main characteristics of their facial mask were still visible. We identified one individual in each study area, except at Christinehof, where we identified three individuals (Fig. 3). The individual that was present at Baldringe in both seasons was likely the same individual.

We ran a single multi-session spatial capture recapture (SCR) model to estimate population density of polecats for the study areas and seasons where we captured at least one identifiable polecat. We used a multi-session model as it allowed us to estimate parameters based on data from multiple sessions (in our case study areas and seasons) so we could use all available information to inform the model while estimating a season and location specific density (Royle et al. 2014). This meant that we could test if the baseline encounter probability (p_0) differed between seasons, while estimating a single value for the parameter describing how detection probability decreases with distance from an individual's activity centre, σ . We did this, as we wanted to use as much information as possible to estimate σ , as we expected a limited number of polecats in each of the study areas. We therefore fitted one model to our data, including session as a covariate on density, and season as a covariate on p_0 .

We fitted the multi-session SCR model using the *oSCR* package (Sutherland et al. 2019) as implemented in R (version 4.3.1; R Core Team 2023). We created a state space for each study area with cells of 100 m² over an area including all Polecam locations and a buffer of two times the mean maximum distance moved as estimated from all recaptures using the *make.ssDF* function from the *oSCR* package. When fitting the model, we used the default settings from the *oSCR* package.

Individual polecats were observed between one to fourteen times (mean = 5.4 ± 4.9 SD), and four out of seven observed polecats were captured in more than one location. The time between first and last capture of those polecats that were captured more than once ranged from seven to 70 days (mean = 39 days ± 20 SD). The mean maximum distance moved of the observed polecats was 1.0 km, resulting in a state space buffer of 2 km. The baseline encounter probability (p_0) in Spring was slightly lower (0.014, 95% CI: 0.0025 to 0.072) compared to Autumn (0.026, 95% CI: 0.012 to 0.054) but with largely overlapping confidence intervals. The estimate of σ , describing how detection probability decreased with distance from an individual's activity centre, was 0.58 km (95% CI: 0.33 to 1.03 km), suggesting that our state space buffer of 2 km was appropriate. Estimates of

polecat density ranged from 0.84 to 2.7 individuals/1000 ha (Table 1). The estimated realized density maps indicate that polecats did not occur in the whole study area in Baldringe (Autumn), while densities were estimated to be higher outside of the Polecam locations for Baldringe (Spring), Christinehof (Autumn), and Vitemölla (Autumn; Figure S2).

Discussion

Polecats are a species of conservation concern, but standardized monitoring methods for this species are generally lacking. Here, we set out to develop and test a camera trap system – the Polecam – aimed at photographing the facial mask of polecats for individual identification. We successfully tested the system in a small-scale study in four areas during two seasons, identified six individuals and obtained density estimates for five area and season combinations. The lure, a can of sardines that was minimally opened, functioned well to attract polecats to look into the tube of the Polecam, and attracted a range of non-target small carnivore species. Previous studies found that using lure generally increases detections of small carnivores on camera traps (Mills et al. 2019; Holinda et al. 2020). A similar tube-based camera-trap system, the Struikrover®, also uses a can of sardines as bait and has been shown to be effective in detecting small mustelids and other small mammals (Smaal and van Manen 2022). The recaptures of the same individuals at multiple locations and over time suggest that the lure functioned in attracting animals to the Polecams multiple times despite the lack of a reward. However, the large variation among individuals in the number of captures and time between first and last capture suggest that there were differences in response to the lure and Polecam among individuals. This might be a consequence of differences in boldness (increasing p_0) and differences in ranging behaviour (increasing σ), which likely differ between the sexes as trapping rates are generally higher for male polecats (Brzeziński et al. 2021). Further development enabling the identification of the sex of captured polecats and studies with higher numbers of captures enabling the modelling of different detection probabilities among individuals would be needed to disentangle such individual and sex differences in responses. However, given our success in capturing multiple individuals, the Polecam seems to be successful in detecting polecats in a way that allows individual identification with minimal disturbance.

We obtained density estimates of 0.84 to 2.7 individuals/1000 ha. These are within a similar range as densities of found by Weber (1988) in similar landscapes to our study areas in Switzerland (1.1 and 4.4 individuals/1000 ha), while they are lower than the densities obtained by Brzeziński et

al. (2010) in a more extensively used and more productive area in Poland (9 individuals per 10 km shoreline). Thus, we think that our density estimates are realistic. Our study areas were relatively small, and we occasionally only photographed a single polecat at the edge of the study area, suggesting that future efforts should focus on larger study areas. This might also have resulted in less accurate estimates, as several polecats were only observed once at the edge of the trapping grid. This also increased the effect of our choice of state space on the density estimates. An increase in the number of individuals captured and spatial extent of the study would thus be ideal. This would potentially also allow for the inclusion of habitat covariates in the model, enabling inference on the relationship between polecat density and different habitat covariates. We did not opt for such an approach in this study, as we did not have *a priori* information on where polecats occurred in our study areas and thus wanted to spread our chances of deploying Polecams in areas with polecat presence. Furthermore, we performed our field test more as a proof-of-concept to test if we were able to capture polecats and identify individuals. Now that we were successful with this, we think it would make sense to scale up the test to get a density estimate for a larger area.

We were able to identify 73% of the polecat observations to the individual level. Not all polecats looked into the Polecam long enough to obtain a photograph that allowed individual recognition. This has likely resulted in an underestimation of p_0 as we discarded observations of likely known individuals, which might have resulted in overestimates of density (Johansson et al. 2020). Unfortunately, we were not able to replicate the success of Russo and Loy (2020) in applying the I³S software to identify polecats in a field setting. One potential addition to the Polecam is to include a device for capturing hair from animals that look into the tube, similar to hair tubes (Croose et al. 2023). This would immediately allow for the identification of sex and verification of individual identifications based on genetic methods (Costa et al. 2012). It would, however, also increase the cost of implementation, as Polecams would need to be checked regularly to remove hair samples, and there would be additional costs for the genetic analyses. Alternatively, deep learning algorithms developed for human face recognition could be adapted to aid the identification of polecats, similar to the application BearID developed to identify brown bears (*Ursus arctos*) from their faces (Clapham et al. 2020).

Here, we present a novel camera-trap-based method to determine the population density of polecats. As monitoring of polecats, and especially the estimation of population densities, is currently limited, despite the species listed on the Annex V of the EU Habitat directive, such a monitoring method is highly needed. Although we recognise that our density estimates have large uncertainty, these are already a

step in the right direction as other camera-trap methods so far have not enabled individual recognition of polecat individuals. A larger test of the applicability of the Polecam at a larger spatial scale would still be needed to test its usability for monitoring purposes. We thus recommend others to test the usability of the Polecam under different scenarios, including in locations with vastly different landscapes than our study sites, and in situations with higher and lower polecat densities. The Polecams did not only obtain photographs of polecats, but were successful in detecting six other species of small carnivores (Figure S1). This suggests that the Polecam can be used for multi-species monitoring of a range of small carnivores, including other species of conservation concern (e.g., Eurasian otter), and an invasive exotic species (American mink).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s13364-024-00751-4>.

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Author contributions Tim R. Hofmeester: Conceptualization (equal), Data curation (lead), Formal analysis (lead), Investigation (supporting), Methodology (equal), Project administration (equal), Supervision (lead), Visualization (lead), Writing – original draft (lead), Writing – review & editing (lead). Nadine Erath: Data curation (supporting), Investigation (lead), Writing – review & editing (supporting). Jeroen Mos: Conceptualization (equal), Methodology (equal), Writing – review & editing (supporting). Henrik Thurffjell: Conceptualization (equal), Funding acquisition (lead), Investigation (supporting), Methodology (equal), Project administration (equal), Supervision (supporting), Writing – review & editing (supporting).

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Data availability All data used in this paper are available on GitHub: <https://github.com/Tim-Hofmeester/polecam>. An archived version of this repository can be found on Zenodo: <https://doi.org/10.5281/zenodo.11258877>.

Code Availability All code used in this paper are available on GitHub: <https://github.com/Tim-Hofmeester/polecam>. An archived version of this repository can be found on Zenodo: <https://doi.org/10.5281/zenodo.11258877>.

Declarations

Ethical approval Not applicable.

Consent for publication Not applicable.

Consent to participate Not applicable.

Conflict of interest The authors declare no conflict of interest.

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