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MINA

Behavioral Response to camera traps

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Preface:

This thesis completes my two-year master's degree in Ecology at the Faculty of Environmental Sciences and Natural Resource Management at Norwegian University of Life Sciences. Throughout this work, I gained valuable experience and knowledge and enjoyed the work.

I am grateful for all those who supported and guided me throughout the process. Especially to my professor Richard Bischof, who helped me immensely from the start to the finish. I will be forever grateful for your time, support, and effort for supervising me in my thesis especially for understanding me when I was not at my best.

I am thankful to my friends, and family for supporting me and always believing in me.

Ishwor Dhakal

16th June, 2025

Abstract:

In ecological studies, camera traps are gaining popularity due to their minimal invasiveness and ability to monitor multiple species simultaneously. However, animals can detect, and show behavioral responses to camera traps, potentially introducing data bias. Despite the wide use of camera traps, few studies have quantified the potential behavioral response of animals towards camera traps.

This study is aimed to examine the behavioral response of two medium and one small sized mammals: Red fox (Vulpes vulpes), European badger (Meles meles), and European pine marten (Maetes martes). The study uses data from SCANDCAM project in south eastern Norway. Behavioral indicators of detection, ear orientation and visual attention, and subsequent behavioral responses (approach, flight and observe) were assessed for all species across different flash types. The generalized mixed models revealed that while flash presence and type did not significantly affect detection behavior, species identity played a significant role in behavioral responses with the red fox exhibiting strongest reactions.

The findings from this study highlight the need for animal response to the camera traps to be taken in consideration during ecological and behavioral studies involving small to medium carnivores.

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1. Introduction

Camera traps are the cameras that operated remotely through active or passive sensors (Caravaggi et al., 2017). These cameras operate for a long period of time and capture images and videos when triggered by motion or heat sensors (McDonald et al., 2025). They are considered minimally invasive and reliable visual means of wildlife survey as they also reduce survey efforts (Rovero et al., 2013). Even though the cameras are considered non-invasive, recent studies show that animals can in fact detect and react to camera traps through different sensory cues (Houa et al., 2022; P. D. Meek et al., 2014; Rowcliffe et al., 2014). A number of studies have recognized animals' reaction to camera traps, which results in behavior alteration as a response(Glen et al., 2013). These responses should be accounted for, to strengthen precise interpretation and optimal utilization of camera traps in behavioral ecology.

The camera traps are established as a standard tool in ecological research and wildlife conservation for the visual data it provides, and this enables researchers to study multiple species simultaneously (O'Connor et al., 2017). The use of camera traps has widely increased in the recent decades throughout ecology and conservation research (Burton et al., 2015). Similarly, they are frequently used in wildlife surveys and monitoring activities and now are also being developed as an effective means for tracking biodiversity on a global scale (Wearn & Glover-Kapfer, 2019). Camera traps offer vast range of information significant to the conservation value of animals in question (Caravaggi et al., 2017).The data from camera traps can be utilized to capture population dynamics and various activity patterns (Iannino et al., 2024), abundance (Gilbert et al., 2021), and assess species diversity. In addition, they are useful to illustrate site occupancy of shy and elusive species (Houa et al., 2022), and for behavioral investigation (Villette et al., 2017). Moreover, camera trap surveys are more effective than traditional methods such as live trapping as they can detect more species with higher frequency (Wearn & Glover-Kapfer, 2019). With the growing advancement in technology, reduced equipment cost and their established versatility, the use of camera traps is expected to grow (Rovero et al., 2013).

Despite their growing importance in wildlife research for tracking species abundance and interspecific interactions, there are various gaps in terms of how these camera traps affect the behavior of animals in study (Caravaggi et al., 2020). These mechanical devices emit sound and light and carry human scent and have a noticeable presence where they are set (Caravaggi et al., 2020). The sound produced by the camera traps when they capture an image is audible to many animals as the frequency falls under their hearing range. Similarly, the light emitted, which include LED flash and infrared light is detectable to animals (P. D. Meek et al., 2014). Hence, animals do detect and respond to camera traps and tend to show behavioral responses like avoidance, attraction, and alterations in their activity pattern(P. Meek et al., 2016). These responses influence animals' course of action and how they navigate the environment(Houa et al., 2022). In recent studies with African apes, findings present strong behavioral responses to camera traps with increased inspection and visual attention. The reaction suggests that camera traps influence behavior, contributing to potential biases in ecological studies (Kalan et al., 2019). Many studies have quantified the behavioral responses of animals to camera traps; however, a significant number focus on large-bodied species, resulting in an inadequate evaluation of the reactions of medium and small-sized species to these devices (Cordier et al., 2022).Despite their high ecological significance and wide distribution, these species are underrepresented in behavioral studies involving camera traps (Cordier et al., 2022).

This study aims to investigate behavioral responses of two medium-sized and one small carnivore: the red fox (*Vulpes vulpes*), European badger (*Meles meles*), and European pine marten (*Martes martes*) to camera traps and how these responses differ across species and flash variations. The primary emphasis is to identify the indicators of camera traps detection and evaluate species specific responses to flash variations. Images of these species were analyzed to assess the response of these animals to camera traps. Instances where animals responded visually, smelled the camera, or displayed signs of acoustic response by orienting their ears towards it are recorded as apparent detection of the camera. The reactions of approaching the camera, observing the camera, or exhibiting flight response are documented after apparent detection. Additionally, a change in body angle is noted to evaluate shifts in the direction of movement in response to the camera trap. In line with the aim of the study, I outline the following objectives and predictions to guide this thesis.

1. **Objective 1 (O1):** To identify the behavioral indicators that suggest animals detect the presence of camera traps and whether there is a difference between species.

P1.1: Detection will be indicated by behavior such as smelling, observing and ear orientation toward the camera.

P1.2: Detection behavior will vary by species, with foxes and martens expected to show more visual cues than badgers due to their high reliance on vision.

2. **Objective 2 (O2):** To evaluate the response of animals to different flash types and to see if camera traps force a change in orientation.

    P2.1: The white LED flash is expected to result in a higher frequency of detection behavior compared to red infrared and invisible infrared flashes.

    P2.2: Camera traps encourage a greater change in direction for foxes and martens compared to badgers, as they are found to be more sensitive to novel stimuli.

2. Methods

This study is aimed to investigate species specific behavioral responses to camera traps among three species, Red fox, European Badger and European pine marten. The analysis is based on the existing photographic data from SCANDCAM project, a large-scale wildlife monitoring project coordinated by Norwegian Institute for Nature Research (NINA). While SCANDCAM project uses data from hundreds of camera traps placed around Norway to obtain valuable information about Lynx, wolves and wild boar (Iannino et al., 2024), this study focuses on sequences involving foxes, badgers and martens to assess their behavioral responses to camera traps.

2.1 Study Area

The study is conducted with camera traps deployed in south-eastern Norway, particularly in former Viken county. This area is characterized by diverse ecosystems, including forests, mosaic of agricultural fields, and semi urban areas. The terrain in the area is varied, including rolling hills, valleys and several water bodies that contribute to the rich biodiversity.

Figure 1: Study area south eastern Norway with camera locations
Source: Generated using Norgeskart (Kartverket, 2025)

The forests are primarily composed of Norway spruce (*Picea abies*) and Scot pine (*Pinus sylvestris*), interspread with deciduous species such as Birch (*Betula spp*.), aspen (*Populus tremula*), and rowan (*Sorbus aucuparia*). The understory vegetation includes a variety of shrubs, mosses and lichens which provide ample cover and foraging opportunities for wildlife. The forests are home to a wild array of wild species. The common mammals found in the region are moose (*Alces alces*), Roe Deer (*Capreolus capreolus*),Red Fox, European Badger, and European pine marten. Other mammals include Eurasian lynx (*Lynx lynx*), Eurasian Beaver (Castor *fiber)* and small rodents. The mean annual temperature in Akershus ranges 5 to 7 degree Celsius and it receives mean annual rainfall of 78.43mm (Meteorologisk Institutt, 2025). These ecoligoal characteristics make the region suitable for year round camera trap deployment and support stable population of mesocarnivores suitable for behavioral studies.

2.2 Study species

European badger inhibits a wide range of habitats and their distribution ranges across a large part of Europe. Its ability to exploit a wide range of habitat has made it a common and widespread species in Europe (Torretta et al., 2024). European badger is an opportunistic feeder and consumes a wide range of food based on availability. They are predominantly nocturnal and prey on smaller species(Chiatante et al., 2017).

Red fox is one of the most widely distributed carnivores globally, and its native range covers most parts of the northern hemisphere (Wooster et al., 2019). Because of it’s ecological adaptability, red fox can adapt to a wide range of habitats ranging from lush forests to snow covered areas. They are one of the most important predators in a number of ecosystems, due to their influence on ecosystems through predation and adaptability (Soe et al., 2017).

The European pine marten occupies most parts of Europe, spreading from the Mediterranean basin to western Siberia and it is considered a forest specialist particularly living in “vast, undisturbed stands of older mixed forest” (Bartolommei et al., 2016). Martens have a flexible feeding range which helps them to adapt a wide range of habitat, and the population has shown an increase since the 1980s (Twining et al., 2019).

2.3Camera trap configuration and data source

The study uses camera trap data from the archive of SCANDCAM project (**https://viltkamera.nina.no/**), a long-term wildlife monitoring initiative of NINA. The project deploys an extensive network of camera traps all over Norway throughout the year primarily to monitor large carnivores such as lynx, wolves and wild boar focusing on their distribution and development over time. For the purpose of this study, photographic data from 182 different locations between 2018 and 2023 were used.

The camera trap deployment within the SCANDCAM project follows a standardized spatial design, where the landscape is divided into grid cells of approximately 50 sq. kms. In each grid, the camera trap is set strategically to maximize the probability of detection of Lynx population(Iannino et al., 2024). The cameras are set in locations chosen in collaboration with local knowledgeable partners, in cart roads, paths in steep slopes, forest roads, and game trails while excluding continuous mountain areas and densely populated areas (NINA, 2025).

At each location, the camera traps are mounted in the trees at an approximate height of 70 cms, angled at right angle to the expected direction of animal movement and approximately 2 metres away from the road.

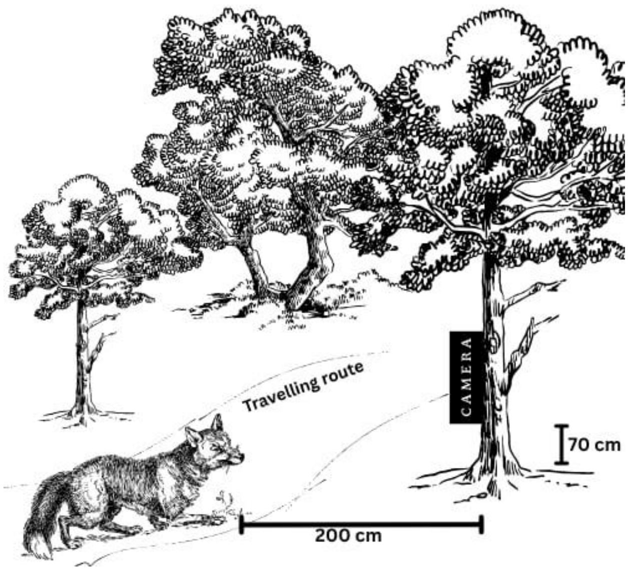

Figure 2: Camera trap setup.

In this study, data were obtained from 182 locations equipped with different models of Reconyx (Reconyx HC500 HC600, PC850, PC900 and HF2 pro,Holmen, Wisconsin, USA). These cameras use passive infrared sensors that captured picture and video of animal after detecting movement or heat when an animal passes in front of the camera(P. D. Meek et al., 2014b; Rovero et al., 2013). The cameras followed SCANDCAM's standard settings, with motion sensitivity set to high and the trigger speed set to rapid fire. With this setup, there is no lag between consecutive triggers, enabling the camera to take burst of three shots per trigger event at a maximum rate of two images per second(Lissner Beddari, 2019).

Each camera was set to its highest available image quality and all devices had a field view of 42°, providing a standarized visual farame across deployments. There were five models of camera traps used in this study, and they emitted three types of flash: White LED, red glow infrared and no glow infrared.

Camera model	Flash type
Reconyx PC800	Red glow IR
Reconyx PC850	White glow LED
Reconyx HC600	No glow IR
Reconyx HC500	Red glow IR
Reconyx PC900	No glow IR

Table 1: Camera models used in the study and their flash types.

2.4 Image processing and behavioral assessment.

The behavior assessment for all the photos was done by a single observer (myself), to ensure consistency in interpretation. The photos with multiple individuals of the focal species were also excluded, as the animals might respond differently to camera traps when they are in groups (Kalan et al., 2019).

Before the photos were assessed for their behavioral responses, the timeseries id provided by NINA, date, time, camera model and the type of flash, species and if the flash was activated were recorded for each photo. Additionally, the animal's activity and the type of movement at the time of detection were also recorded.

I followed the ethogram developed by Biddari Lissner (2019), to see if camera trap causes a change in the behavior of fox, badger, and marten. The ethogram is based on observed behaviours in the dataset and helped classify different types of activity. The animal is considered to have apparently detected the camera (apparent detection), if it was staring at the camera (visual detection) or it's ears pointing to the camera (acoustic detection). Following the animal's detection of the camera traps, the behavioral responses that animals show is recorded, whether it is approach, observe/inspect, or flight response. The behavioral responses are recorded in the cases where the animals sniffed or squinted their eyes. To see if there is a change in direction of movement of animal, the body angle, and head angle of the animal in response to the camera is also recorded. The body angle is recorded in respect to the camera facing North regardless of the orientation it is set on the field.

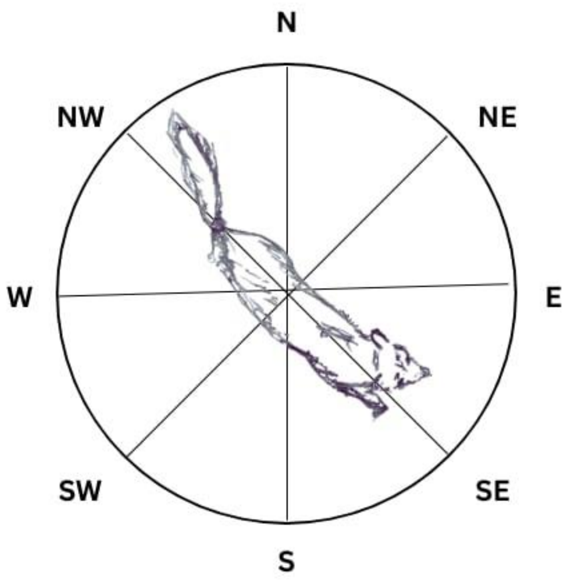

Figure 3: Picture illustrating the use of cardinal and intercardinal directions to record body and head angle relative to the camera. The camera is considered facing north. Here, the head and body angle of animal are recorded as SE (South East).

Figure 4: Sample photos of body angles recorded using compass for each direction, the camera lens is facing north.

The information thus was recorded and categorized as following:

Movement type: What type of movement the animal is showing. Still, walking, jumping, or running.

Eyes to the camera: If the animal is looking at the camera. Recorded as True if the animal is looking at the camera and False if it is not. Recorded as NA if the head is not visible.

Ears to the camera: Recorded as 1 if one ear is pointed or attentive towards the camera, and 2 when two ears are pointed and attentive towards the camera and 0 if no ears are pointed towards the camera.

Behavioral response to the camera: After the animal showed the signs of apparent detection towards the camera, the behavioral response is recorded. The behavioral responses recorded are as follows;

- Observe/ Inspect: When the animal stares at the camera apparently observing it.
- Approach: When the animal moves towards the camera after apparently detecting it.
- Flight: When the animal shows flight response after apparently detecting the camera.

Figure 5: Three different behavioral responses of animals after apparent detection: observe, flight, and approach.

Body angle relative to the camera: An imaginary line was drawn along the anteroposterior axis of the animal's body, pointing the direction of the animals body. This was recorded using the compass with the camera lens facing North.

Head angle to the camera: Following the same technique as the body angle, the head angle of the animal in relation to the camera trap was recorded. This was categorized as body angle relative to the camera trap.

Olfactory sensing of the camera: If the animal is observed to sniff in the direction of camera, this was recorded as true else false. In case the animal is smelling the camera, the behavioral response is categorized as observe.

Physical contact with the camera: Physical contact with the camera is recorded as True if there are obvious signs of the animal touching the camera. In case it was recorded as True, the behavioral response is recorded as observe.

Squinting: Recorded as true if the animal closed its eyes partly or fully while facing the camera and the flash is deployed.

2.5 Statistical Analysis:

The statistical analyses for this study were done in R (R Core Team, 2024), a statistical computing environment. After image assessment, the behavioral response was quantified as the change in behavior before and after apparent detection of the camera. The level of significance was set to $\alpha=0.05$.

The analysis in this study consists of regression analysis. The predictor variables used in the analysis are flash type, flash, and species. The response variables were apparent detection, behavioral responses and change in direction. The data used in the analysis are aggregated by timeseries id. Whenever an animal passes in front of the camera, the camera takes a burst of pictures, and each detection event is provided with a timeseries id. In the analyses in this study, the detection events are aggregated by timeseries id to avoid over estimation of responses.

<u>Apparent detection with flash availability</u>

To assess whether the presence of active flash affected the probability of apparent detection (Prediction 2.1), a Generalized Liner Mixed Effect Model (GLMM) was fitted using the glmer function from R package lme4. The response variable was apparent detection (binomial), and the model was fitted with a binomial error distribution. The predictor variables were flash (presence or absence), and species as fixed effects. Location id was included as a random effect to account for repeated observations at the same camera trap location.

<u>Apparent detection with flash type:</u>

To access whether flash type made a significant effect in the apparent detection of cameras (Prediction 1.2), a generalised mixed model (GLMM) was fitted using glmer function from the R package lme4. The response variable apparent detection was binary (1= detection observed, 0= not observed), and the predictor variables were flash type (white LED, no glow IR and red glow IR). Location id was included as a random effect. The cases where the flash was not activated were marked as no flash in flash type.

<u>Behavioral responses flight and approach</u>

To check whether flash types and species influenced the likelihood of behavioral responses flight and approach (Prediction 1.1), generalized liner mixed model (GLMM) with binomial error distribution and a logit link function was used and the analysis was conducted using the gmler function from the lme4 package. The behavioral responses: flight and approach were aggregated with timeseries id to treat a response within a single detection sequence, as single event. The binary outcome variable was then modelled as the response variable, and flash type and species were taken as predictor variables, with location id as the random effect. The predicted probabilities and 95 percent confidence interval were calculated using ggpredict () function, and the results were visualized through ggplot2.

<u>Movement type and apparent detection</u>

To examine whether there is significant association between movement type and apparent detection (Prediction 2.2), a generalized linear mixed model (GLMM), with binomial error distribution and a logit link function was used and the analysis was conducted using gmler function from the lme4 package in R. Movement type and species were included as predictor variables and location id was taken as random effect.

<u>Change in body orientation:</u>

To evaluate whether camera traps caused rapid change in direction (Prediction 2.2), a Generalized Linear Mixed Model (GLMM) was used. A rapid change in direction was defined as a shift of more than 90 degrees in the animal's body angle within a same detection event (within same timeseries). The body angle was recorded in cardinal directions and converted into degrees, from which the difference in the maximum and minimum angles per visit were used to compute the angle change. The binary response variable was assigned a value of 1 if the change in body angle exceeded 90 degrees, and 0 otherwise. The model was fitted with gmler package function from lme4 package in R,using rapid change in direction as response variable and species and flash type as fixed effects. Location id was used as random effect to account for repeated observations at the same site.

3. Results

The dataset consists of camera trap photo data from 572 unique detection events. Each event is defined by a unique Timeseries.id, representing a burst of images linked with a single animal passage. I used the camera trap pictures between 2018 to 2023 across 182 different locations (location.id) using different camera models and flash types (White LED, Red Glow IR, and No Glow IR) for the analysis. The most frequently recorded species was badger, followed by foxes and martens as represented in Figure 6.

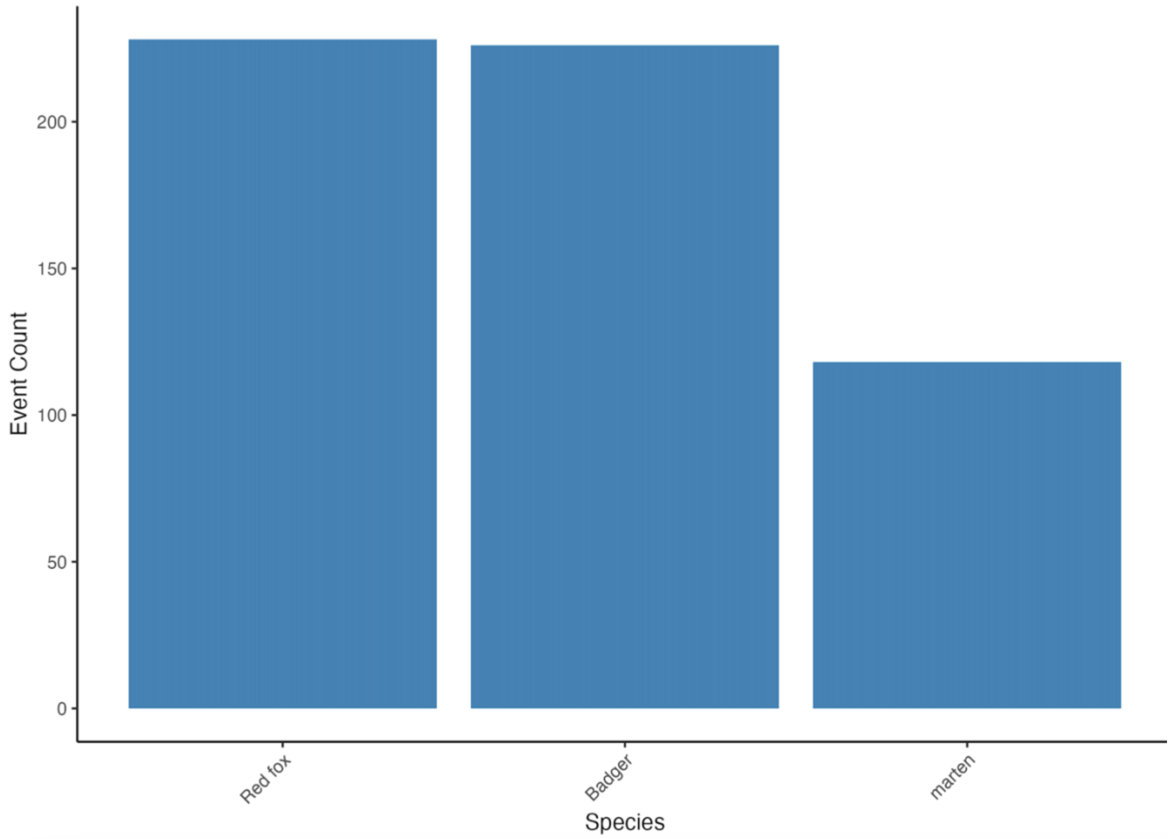

Figure 6 Number of unique detection events by species: red fox, badger, and marten. The species are on the x- axis and the number of events is on the y-axis.

3.1 Apparent detection with flash/no flash

The GLMM result as shown in Table 1, showed that the presence of flash did not have a significant effect on the likelihood of apparent detection (Estimate = –0.99, SE = 0.76, p = 0.19). Likewise, there were no significant differences in apparent detection between species when compared to badgers. There was a marginally significant interaction between flash and marten (Estimate = 1.62, SE = 0.90, p = 0.072), suggesting that martens may be more likely to show signs of detecting the camera when flash is used. But this trend did not reach the conventional threshold for statistical significance. The interaction between flash and red fox was also not significant (Estimate = 1.09, SE = 0.84, p = 0.19). Taken together, these results suggest no strong overall effect of flash or species alone, but hint at possible species-specific sensitivity to flash, particularly in martens. The probability of apparent detection in Red fox, however, was much higher (0.7) as compared to Badger and Marten as depicted in Figure 4.

*Table 2Results from GLMM (apparent_detection ~ flash * species + (1 | location.id). The effect on apparent detection with presence or absence of flash with species. The numbers specify the estimate, standard error, z-value, and p-value.*

Term	Estimate	SE	z	p
(Intercept)	-0.52	0.74	-0.71	0.48
flashTRUE	-0.99	0.76	-1.31	0.19
Marten	-0.6	0.83	-0.72	0.47
Red fox	1.08	0.8	1.35	0.18
flashTRUE: Marten	1.62	0.9	1.8	0.072
flashTRUE: Red fox	1.09	0.84	1.3	0.19

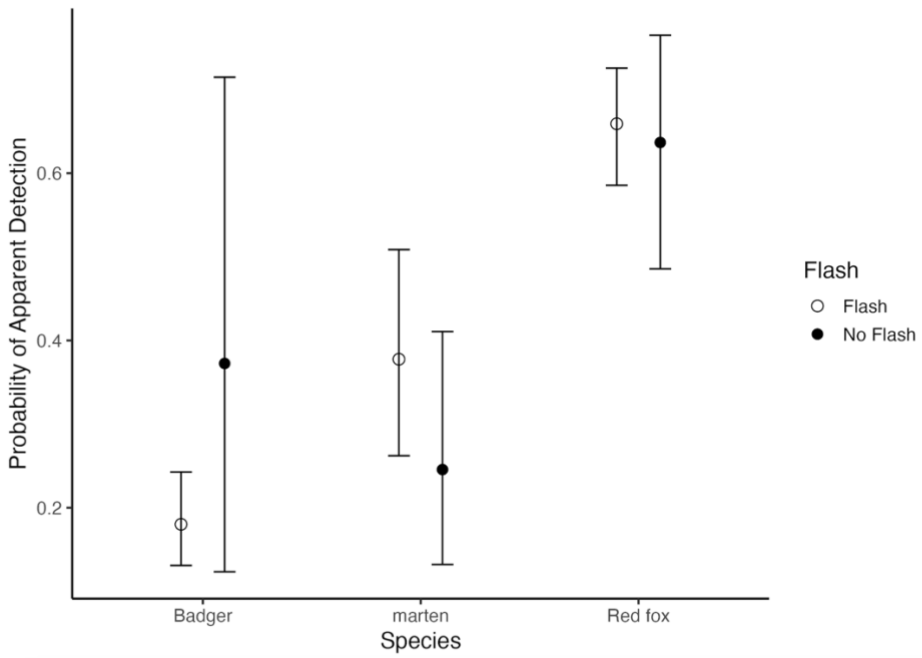

*Figure 7: Predicted probability of apparent detection with presence or absence of flash among species. Predicted probability of apparent detection by species and presence or absence of flash from GLMM (apparent_detection ~ flash * species + (1 | location.id). Filled symbols represent No flash and open symbols represent Flash. Species is on the x-axis. Probability of apparent detection is on the y-axis. The vertical lines mark the 95% CI.*

3.2 Apparent detection with flash types

The GLMMs revealed that flash types did not have a significant main effect on detection probability. The interactions between flash type and species were not statistically significant, suggesting that the flash types did not alter the apparent detection probability in any of the species. However, the interaction between fox and white LED was close to significance, indicating a trend towards reduced detection of red foxes under white LED flash.

*Table 3:Output from GLMM GLMM (behavioral_response ~ flash_type * species + (1 | location.id). The effect of apparent detection between species and flash types, Red glow IR, white LED and no glow IR. The numbers specify the estimate, standard error, z-value, and p-value.*

Term	Estimate	SE	z	p
(Intercept**)**	-1.55	0.25	-6.27	3.7e-10
flash_typeRed glow IR	-0.13	0.68	-0.2	0.85
flash_typeWhite LED	0.33	0.4	0.81	0.42
Marten	0.73	0.38	1.92	0.055
Red fox	2.35	0.31	7.57	3.8e-14
flash_typeRed glow IR:Marten	1.17	1	1.17	0.24
flash_typeWhite LED:Marten	-0.35	0.64	-0.55	0.58
flash_typeRed glow IR:Red fox	0.03	0.86	0.03	0.98
flash_typeWhite LED:Red fox	-0.91	0.52	-1.76	0.078

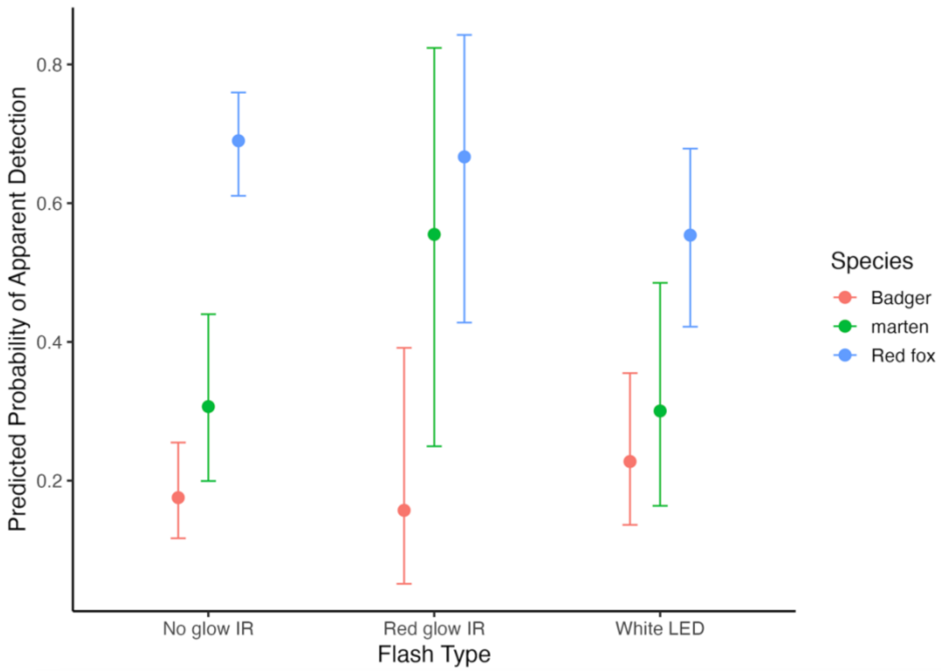

*Figure 8:Predicted probability of apparent detection by species and flash type from GLMM (behavioral_response ~ flash_type * species + (1 | location.id). Red represents badger, green represents marten and blue represents red fox. The flash types, no glow IR, Red glow IR and white LED is on the x-axis. Probability of apparent detection is on the y-axis. The vertical lines mark the 95% CI.*

3.3 Behavioral responses flight and approach

The effect of flash type did not have a significant influence in behavioral response of animals. Nome of red glow IR (E= 0.11, SE= 0.34, z=0.33, p-value= 0.74) or white LED (E= -0.23, SE= 0.23, z= -1.01, p-value= 0.31), significantly altered the probability of a reactive response after an apparent detection. Meanwhile, a significant effect of species in the reactive response was observed. Red foxes exhibited a significantly higher probability of reacting compared to badgers (estimate= 2.17, SE= 0.23, z value= 9.27, p-value < 0.001), and martens also exhibited significantly higher probability of reacting (estimate= 0.59, SE= 0.28, z= 2.15, p-value = 0.03. The findings suggest that species identity, plays a significant role in how animals react behaviourally to camera traps.

*Table 4: Output from GLMM (behavioral_response ~ flash_type * species + (1 | location.id)., The effect of behavioral responses approach and flight with flash types: red glow IR, White LED, and no glow IR. The numbers specify the estimate, standard error, z-value, and p-value.*

Term	Estimate	SE	z	p
(Intercept)	-1.53	0.2	-7.67	1.7e-14
Red glow IR	0.11	0.34	0.33	0.74
White LED	-0.23	0.23	-1.01	0.31
Marten	0.59	0.28	2.15	0.032
Red fox	2.17	0.23	9.27	1.9e-20

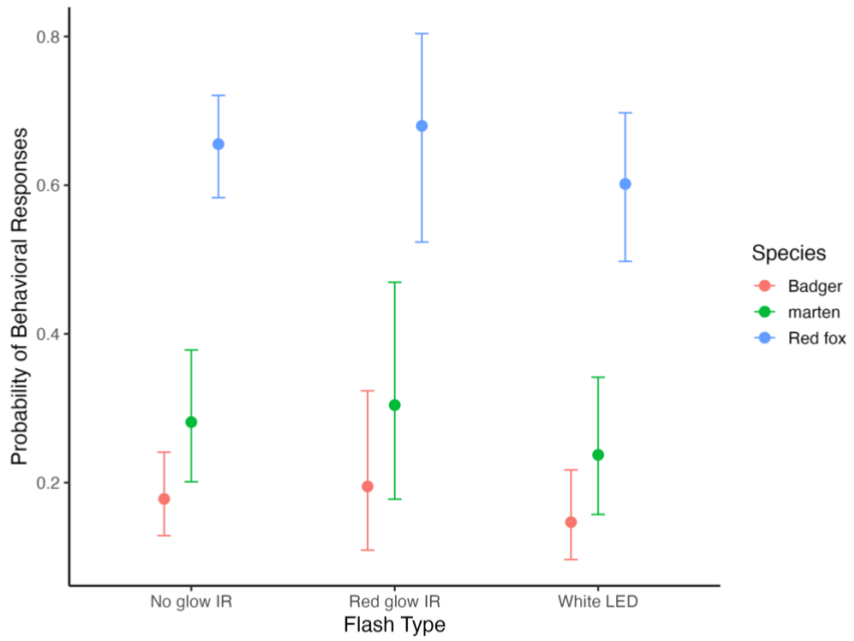

*Figure 9: Predicted probability of behavioral response by species and flash type from GLMM (behavioral_response ~ flash_type * species + (1 | location.id). Red represents badger, green represents marten and blue represents red fox. The flash types, no glow IR, Red glow IR and white LED is on the x-axis. Probability of behavioral response is on the y-axis. The vertical lines mark the 95% CI.*

3.4 Movement type and apparent detection

Movement type was not found to significantly influence the likelihood of apparent detection. When compared to individuals exhibiting undefined movement (reference category), animals that were running (estimate = -0.84, p = 0.25), walking (estimate = -0.67, p = 0.26), or still (estimate = 0.70, p = 0.24) did not show any statistically meaningful differences in their probability of being classified as an apparent detection. Red foxes were much more likely to display apparent detection behavior compared to badgers (estimate = 2.24, SE = 0.26, z = 8.75, p < 0.001). In contrast, martens did not differ significantly from badgers in their likelihood of apparent detection (estimate = 0.44, SE = 0.33, z = 1.35, p = 0.18).

*Table 5: Output from GLMM (apparent_detection ~ movement_type * species + (1 | location.id)., The effect of apparent detection with type of movement. The numbers specify the estimate, standard error, z-value, and p-value.*

Term	Estimate	SE	z	p
(Intercept)	-1.17	0.61	-1.91	0.056
Running	-0.84	0.74	-1.14	0.25
Still	0.7	0.59	1.18	0.24
Walking	-0.67	0.59	-1.13	0.26
Marten	0.44	0.33	1.35	0.18
Red fox	2.24	0.26	8.75	2.2e-18

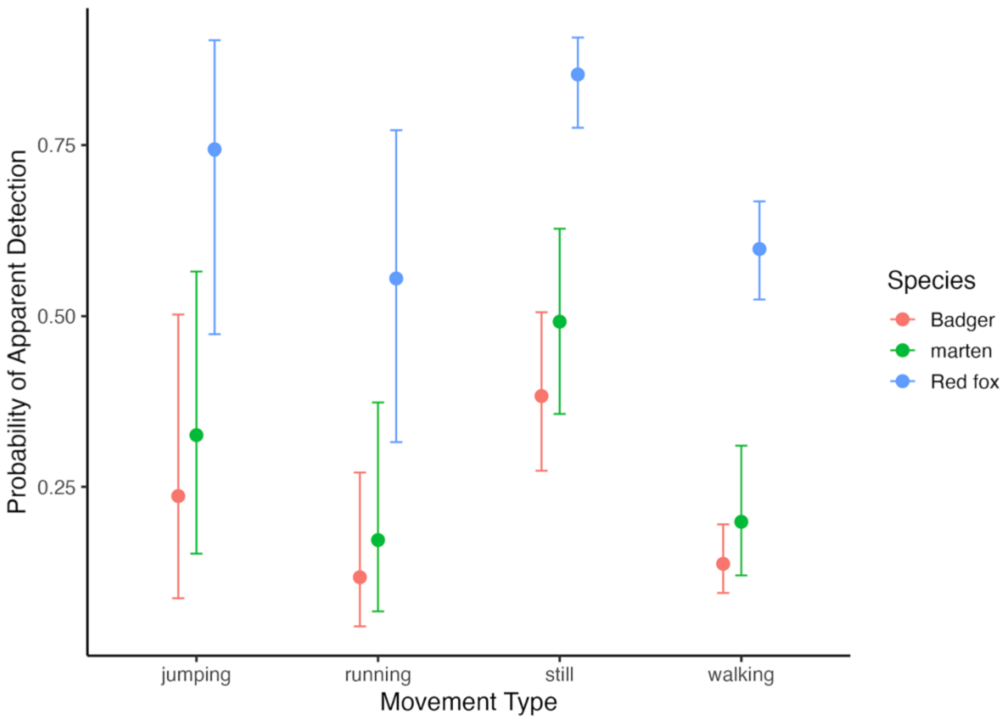

*Figure 10: Probability of apparent detection by species and movement type from GLMM (apparent_detection ~ movement_type * species + (1 | location.id). Red represents Badger, green represents marten and blue represents red fox. Different movement types, jumping, running, still and walking is on the x-axis. Probability of apparent detection is on the y-axis. The vertical lines mark the 95% CI.*

3.5 Rapid change in direction

None of the fixed effects or interaction terms were statistically significant (p >0.05), indicating that none of species' identity or flash type, independently, or in combination had a significant influence in the probability of rapid change in direction. Compared to no flash, red glow IR (p= 0.789), and white LED (p= 0.942) flash did not significantly alter the direction of movement. Similarly, compared to badgers, red foxes (p= 0.852), and martens (p = 0.868), did not differ significantly in their response.

*Table 6: Output of GLMM (drastic_rotation ~ flash_type * species + (1 | location.id). The effect of rapid change in direction with flash type and species. The numbers specify the estimate, standard error, z-value, and p-value.*

Term	Estimate	SE	z_value	p_value
(Intercept)	-1.92	0.3	-6.31	2.88e-10
Red glow IR	0.1	0.69	0.15	0.883
White LED	-0.24	0.49	-0.5	0.62
Marten	-0.1	0.47	-0.22	0.829
Red fox	-0.19	0.37	-0.51	0.613
Red glow IR: Marten	0.16	1.12	0.14	0.89
White LED:Marten	0.09	0.84	0.11	0.91
Red glow IR:Red fox	-0.1	1.05	-0.1	0.923
White LED:Red fox	0.51	0.67	0.77	0.442

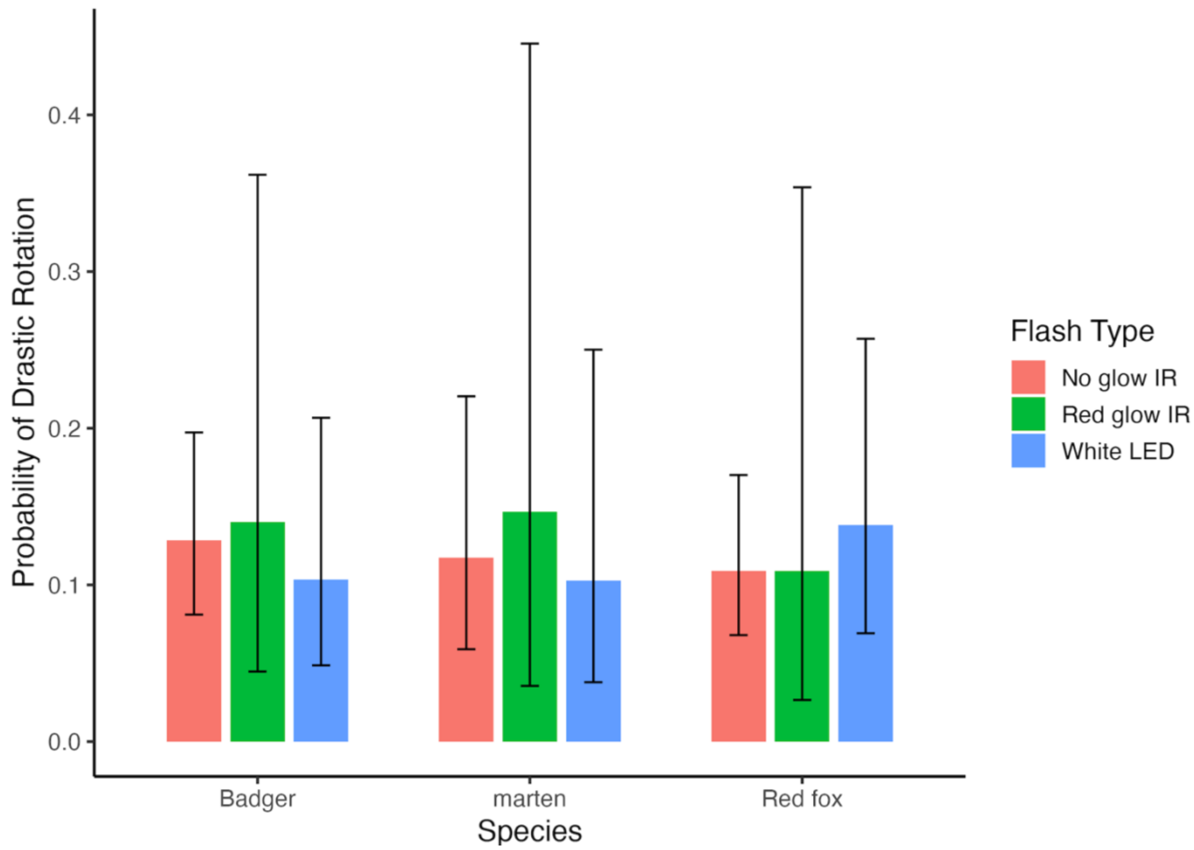

*Figure 11:Predicted probability of drastic rotation by species and flash type from GLMM (drastic_rotation ~ flash_type * species + (1 | location.id). Red represents No glow IR flash type, green represents Red glow IR and blue represents white LED flash types. The species, badgers, marten and red fox is on the x-axis. Probability of drastic rotation is on the y-axis. The vertical lines mark the 95% CI.*

4. Discussions

The findings of the study demonstrate that camera traps, although commonly considered non-invasive, have some level of invasiveness when deployed, and elicit detectable behavioral responses from animals. All the three target species, red fox, badger, and European marten showed signs of apparent detection and behavioral response to the presence of camera traps. These responses, although minimum in some cases imply that camera traps play some role in behavioral response of the animals. Furthermore, the nature and intensity of the reactions were found to be species- specific, which supports the need for consideration of behavioral responses when conducting ecological studies using camera traps.

4.1 Apparent detection and Species

The results from my analysis showed significant differences in the probability of apparent detection between species, Red fox, Martens and badgers. Red fox showed higher probability of apparent detection with presence or absence of flash, flash types, and movement type as compared to martens and badgers which is consistent with the findings of the study on Red foxes (Wooster et al., 2019) that they have a curious nature and are more reactive to their environments and stimuli. Furthermore, Red foxes showed higher probability of apparent detection while they were still as compared to other activity such as jumping, running, and walking.

4.2 Apparent detection and Flash

The results from my analysis revealed that the presence of camera flash had no significant effect on the possibility of apparent detection across all three species. Although marginal, the interaction between martens and flash presence demonstrated a degree of significance, which indicates potential species-specific response to the stimulus. This observation aligns with the prediction that the response to certain flash in camera traps is species-specific(Glen et al., 2013).

However the metrics used for apparent detection in this study, that are based on eye contact with the camera and ears pointing towards the camera may not fully capture the animal's initial awareness of the camera. Studies have shown that animals can respond to camera traps through subtle cues such as scent trails left during installation sometimes without displaying behavioral changes (Caravaggi et al., 2020; P. Meek et al., 2016; P. D. Meek et al., 2014a). Additionally, the lack of species level difference could be the result of habituation in familiar environment and familiarity with anthropogenic objects to avoid costly responses to harmless stimuli (Blumstein, 2016).

4.3 Apparent detection and flash type

The results from GLMMs showed that flash type did not have statistically significant effect on the probability of detection. Although the response was minimal, all three species in the study reacted to all flash types, especially red fox which had a near significant interaction with flash types. This aligns with the study done by (Ladd et al., 2023a), which found that there was no significant change in detection rate between the two flash types: White LED flash and IR flash.

4.4 Behavioral responses approach and flight

Analysis indicated that behavioral response; flight or approach following apparent detection was not significantly affected by flash type. However, there was a clear difference in response between the species. Red foxes exhibited significantly higher probability of responding compared to badgers, and martens also showed increased odds of flight or approach behavior. The absence of behavioral response with red glow IR and white LED flash aligns with prior studies indicating the visual stimulus of camera flashes may be insufficient to trigger a pronounced behavioral change (Ladd et al., 2023a; P. Meek et al., 2016). However, the presence of significant species-level differences observed in this study highlights that the interspecific variation is more pronounced to elicit behavioral response than flash technology. Given their ability for high visual acuity and explanatory foraging behavior, red foxes may be more sensitive to environmental cues like camera traps, and show increased behavioral responses (Wooster et al., 2019).

4.5 Movement type and apparent detection

The absence of a notable correlation between movement type and apparent detection indicates that behavioral states such as walking, running, or remaining still, do not significantly affect whether animals (apparently) detect camera traps. This discovery is rather contradictory since it can be anticipated that stationary or slow-moving animals would have greater opportunities to notice and react to a camera equipment. However, it corresponds with previous findings that detection in camera trap research is not exclusively determined by movement, speed, or style, but rather affected by a combination of sensory cues and individual attention(Rowcliffe et al., 2014). Apparent detection as defined in this study, relies on explicit visual or auditory responses, and may therefore overlook more subtle detection events occurring during movement.

Furthermore, species identity emerged as a significant factor as red foxes showed a higher likelihood of apparent detection compared to badgers. This supports the prediction that the species with more visually exploratory behavior, such as red foxes, are more likely to exhibit noticeable reactions to novel stimuli like camera traps(Glen et al., 2013). However, Martens did not differ with badgers significantly which may reflect their different sensory priorities. When comparing behavioral data across species in camera trap studies, these interspecific variances highlight the need for caution, especially when apparent detection metrics are employed.

4.6 Rapid change in direction

This study aimed to see whether species identity or flash type had an influence in rapid changes in body direction, with the change in body angle of more than 90 degree as an indicator of reactive behavior. The results were consistent with other findings from my study indicating flash type did not significantly influence change in direction, however, unlike other outcomes, species identity also did not affect directional change. The probability of animals changing direction remained consistently low in all flash conditions, suggesting limited behavioral disruption by flash. The lack of observed change in direction may be attributed to the camera placement strategy explained in earlier sections of this study. As the camera were aligned with the animals' natural travel routes, the animals might have visually acknowledged the camera by observation but continued in their path without deviating. Consequently, even when detection occurred, change in direction might not have been recorded. This interpretation is further supported by the likelihood of animals showing detection behavior through subtle responses like pausing, or slight body orientation (Ladd et al., 2023)The results should be interpreted with caution given the limitations of the data set. The relatively small sample sizes with specific flash type combinations might have reduced the statistical power to detect subtle behavioral responses.

These findings challenge earlier studies that visual capability of animals in detecting camera traps is significantly influenced by the type of flash employed (Glen et al., 2013). However, emerging evidence suggest that cats and foxes might rely on auditory cues more than visual cues when detecting camera traps. Meek et al., (2016) observed that red foxes displayed behavioral responses to camera without visually engaging with the camera, implying that sounds emitted by the camera might act as primary detection trigger.

The low influence of all flash types in the change in direction supports that infrared and visible flash cameras to be continued to use in the movement and behavioral studies of medium sized carnivores. While flash induced directional change appears to be minimal in this context, including more detailed behavioral data and ensuring balanced sampling across camera settings will improve future evaluations.

4.7 Implications

The findings from this study have important methodological, ecological and conservation related implications for the use of camera traps in behavior studies on medium to small sized mammals. A key insight is the potential for unaccounted behavioral data to create a bias in the data collected through camera traps, as highlighted in the study(Lissner Beddari, 2019). One of the main challenges of these kinds of behavioral studies is quantifying the biases introduced by specific reactions following apparent detection, or by the mere presence of the camera. The assumption of similar detectability across species, which has been applied in occupancy models, may not be true for the behavioral studies involving camera traps (O'Connor et al., 2017). For example, foxes in this study showed a higher behavioral response than badgers and martens, indicating unequal detection probability across species.

The findings highlight the significance of considering the specific characteristics of speies when analyzing camera trap data for behavioral and ecological studies(Larrucea et al., 2007). If behavioral responses like attraction and avoidance to camera traps differ between species, then analyses assuming homogenous detectability can lead to skewed estimates of abundance and activity pattern (Green et al., 2023; Hofmeester et al., 2019; O'Brien, 2011). Hofmeester et al., (2019), stressed the need for conceptual frameworks to account for detection biases, failing to which undermines cross-species comparisons and behavioral inferences. This study further emphasizes that flash type selection alone should not be used as a determinant of a camera trap's suitability for behavioral analyses. Instead, the results align with Ladd et al., (2023), who demonstrated that white flash may elicit more observable reactions, but they do not significantly alter detection behavior in Eld's deer, and there was no significant difference in the detection rate between different flash types. Therefore, incorporating species specific responses, research environment, and methodological constraints is crucial for precise interpretation and optimal utilization of camera traps in behavioral ecology.

4.8 Limitations and suggestions for further studies

The behavioral responses were scored by a single observer to ensure consistency. However, manual assessment is subjective and may result in the misclassification of subtle behavioral responses. Observer error is a recognized challenge in behavior studies, and it can lead to potential mistakes in important behavioral data (Burghardt et al., 2012).

One of the key limitations of this study is comparatively limited sample size, especially when the data are categorized by species and flash type. Limited number of detections per event reduced the statistical power of the analyses, hence increasing the probability of Type II error, which leads in failure to identify existing responses (Fluck et al., 2024).This also partly explains why no significant differences were found in some of the variables, such as change in direction and response to flash. In behavior ecology, small sample size can lead to biased and inaccurate estimates potentially undermining the reliability of ecological conclusions(Fluck et al., 2024). A larger dataset would have allowed for better stratification across species, flash types, and responses thereby enabling more robust inferences.

Moreover, with camera traps, responses can only be recorded when the animal is inside the field view of the camera, and responses before and after the animal enters the field view of the camera might have been missed (Ladd et al., 2023). The study used still images for interpretation of responses, which may limit the ability to record responses occurring between image intervals. Incorporating video footage would enhance the temporal resolution of observations and may be helpful in extended behavioral research(Green et al., 2023).

For further studies on this topic, I recommend using a larger, more balanced sample size to improve statistical power and account for intra-specific variability. The use of video footage to support still images may help to observe the responses that take place during image intervals. To reduce the observer's bias in recording behavior responses, the assessment of responses might benefit by incorporating blinded assessments or multiple observers. Wherever feasible, integrating anthropogenic cues might help better understand animal behavior and increase the credibility of camera trap studies.

5. Conclusion

Camera traps are widely used for behavioral ecology studies. Most studies assume that camera traps are non-invasive or minimally invasive. However, a research gap persists in the behavioral responses they may elicit, especially in medium and small sized mammals. These responses may cause data bias, if not accounted for. While recent studies have focused on non-invasiveness of camera traps, they are primarily focused on large mammals.

This study tried to quantify the behavioral responses of two medium sized carnivores and a small sized carnivore to camera traps, primarily focusing on apparent detection and change in direction of movement. Flash types did not play a significant role in apparent detection, but species identify had a significant role in behavioral responses such as flight or approach, particularly in red foxes. The low frequency of rapid change in direction for all flash types and species, likely reflects the methodological limitations of small sample size, camera placement and use of still frame data.

The findings from the study highlights the need to consider behavioral response of animals when interpreting camera trap data, especially when drawing ecological conclusions like population dynamics, movement, and detection patterns.

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