

Contents

1 Abstract	1
2 Dedication	2
3 Acknowledgements	3
4 Introduction	5
5 Method and materials	6
5.1 Study species	6
5.2 Study area	6
5.3 Study design	7
5.4 Data Collection	9
5.5 Data processing	9
5.6 Statistical analysis	10
6 Results	12
6.0.1 Number of pictures taken or whatnot	12
6.1 Overlap analysis	12
6.2 Box plots	13
6.3 Time to event analysis	13
7 Discussion	15
7.1 Overlap analysis	15
8 Conclusion	16

Chapter 4

Introduction

How does the usage of white LED flash affect our data?

Litt om estimeringsmetoder og problemer - og at det er særlig vanskelig for nattaktive og sky arter. Litt om bruk av kamerafeller og metodikk som er i enorm utvikling. Binde opp til NINA arbeid og samarbeid i Skandinavia

Capture Recapture models only available for naturally marked species (e.g. tigers *Panthera tigris*, leopards *Panthera pardus*). "Nevertheless, the majority of wildlife species are not easily individually identifiable from photos, rendering CR approaches difficult and leading to widespread interest in alternate analytical approaches for 'unmarked' species" Burton et al. 2015

Camera traps give us the opportunity to monitor in a quantifiable, somewhat standardised way, that is almost non-invasive. Normally the cameras have been using infrared light to flash animals during the night, as this was believed to be invisible to the animals (although - unfortunately for us - it is not). However, the lack of sharpness and detail in these photos limit the information we can retrieve from them (e.g. individual variation in coloration), which has brought us to the usage of white LED flashes. Naturally, the white LED flash is highly visible for any surface dwelling mammal, which begs the question to what extent it impacts the animals. Or rather, to which *additional* extent it impacts the animals, and therefore, how it affects our data. Animal sightings by camera traps can be used to measure species density, and any deviation from the norm in probability of sighting, will skew the precision of the estimate. Beddari 2019 showed that wolfs (*Canis lupus*) tend to shy away from camera traps using white LED flash, whilst the lynx (*Lynx lynx*) is less bothered, compared to the usage of infrared flashes. The wolfs were more shy and aware of all cameras in general, attributed to their higher sense of smell, which is a reminder that each species will perceive the camera presence different, and thus behave differently as a response to the stimuli.

Ledestjerne In this study, I will attempt to quantify how the usage of white LED flash affects the detection rate of *the most common large mammal species in the area* and whether this effect correlates with other factors as urbanisation.

* Hypothesis 0: Usage of white LED flash will have no effect on the detection rate of any species.

* Hypothesis 1: Usage of white LED flash will stress one or more species in general, and therefore lower the detection rate of the stressed species. The effect will likely vary in extent between species.

* Hypothesis 2: The effect of the white LED will correlate with urbanisation-factors, as individuals that live closer to urban areas are habituated to Artificial Light At Night (ALAN), and thus will have a weaker response to the white LED

Chapter 5

Method and materials

5.1 Study species

The species I'll focus on in this thesis are the species that most frequently was observed (>50 events), excluding farmed animals (e.g. cattle), humans and dogs, and grouped categories of animals (e.g. birds). Given that the decisions on cameras placement (height and angle) were made with photo capturing lynx() in mind, I have also excluded smaller species from the analysis. This includes three species, squirrel(), hare() and European pine marten(*Martes martes*). Though they showed up frequently on many locations, there are inevitably some cameras that are too biased towards larger animals, resulting in an inconsistency of their detection rates. In turn, it is difficult to distinguish whether the species was affected by the white LED or not, as they could have triggered the camera, but already escaped the frame.



In the end, the species I have used in my analyses are roe deer(), red fox(), badger(*Meles meles*), moose(), red deer(*Cervus elaphus*) and lynx.

5.2 Study area

The study area (59.36-60.47° N, 9.43-10.91° E) extends over much of the southeastern parts of Norway in counties Flå, Krødsherad, Sigdal, Ringerike, Modum, Hole, Lier, Øvre Eiker, Asker, Oslo, Enebakk, Indre Østfold, Våler, Råde, Moss, Frogn and Vestby. The climate has a continental character due to rain shadows of the mountain ridges from the west.

The mean annual temperatures ranges from 2-6°C and precipitation lies between 700-1500mm (Moen 1999). Topography is predominantly flat towards the south, and more rugged and elevated towards the north. The landscape is a mosaic of forest and agricultural areas, divided with a wide network of gravel roads. The area is situated in the southern boreal and the boreonemoral zones.

Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) make up the dominating boreal coniferous forests, with frequent presence of silver birch (*Betula pendula*) and downy birch (*Betula pubescens*), then aspen (*Populus tremula*), alder (*Alnus incana*) and black alder (*Alnus glutinosa*).

Growing season length 170 - 190 days (Moen, 1999, map 6, s.21) Snow cover length

Most cameras were set in forest areas, usually by a tractor path or human trail, sometimes by animal paths. Their distance from houses or roads varied to a large extent, and some areas were logged (ved Vansjø) and even greatly changed under development of new infrastructure (toglinje på nordligste kamera 1255)

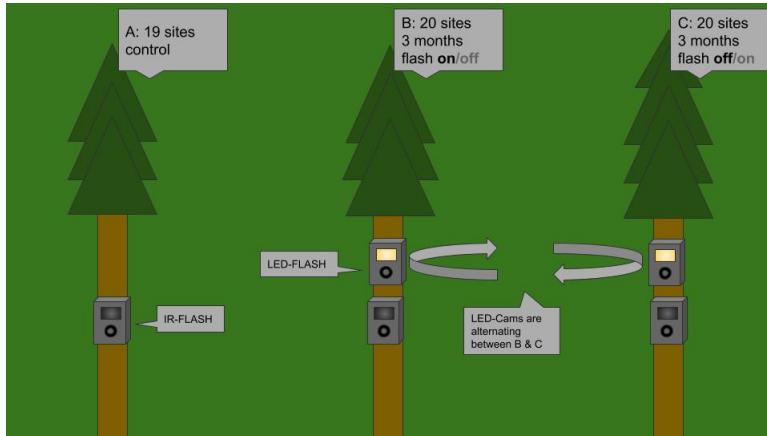


Figure 5.1: Experiment setup

5.3 Study design

For the study I chose 60 already established camera sites with infrared light (Reconyx and Browning models), in order to have a reference of capture frequencies. The cameras had been installed on trees 1-3 meters from human or tractor paths, 40-120 cm above ground level, with the original aim to photo capture lynx (Odden 2015). I divided the sites randomly into three groups of 20 cameras. Cameras in group A remained unchanged, whilst group B and C were equipped with an additional white LED camera (Reconyx PC850) in alternating 3 month-periods, as shown in figure 5.1.

The preinstalled cameras were set up and handled by people from the Norwegian Institute of Nature Research (NINA) and — at the sites further from Oslo — by members of the Norwegian Hunters and Fishers Society (NJFF). The installation of the cameras did not follow a strict protocol, nor were their locations chosen randomly. The overall placement was systematic as decided by NINA, then there was a deliberately-biased placement of the CTs put up in areas where the individual handler deemed it most likely to photograph lynx, and hence, based on a combination of site accessibility and expectations of animal occurrence.

As shown in figure 5.1, I set up all white LED cameras above the cameras already in place. However, at the particular site shown in figure 5.2c on the following page the infrared camera had been installed so far above ground level that I chose to position the white LED camera below the camera already in place. For the periods without white flash treatment, I moved the cameras to their next site. However, the boxes installed on the trees remained (see figure 5.2d). First, I equipped Group B with white LED in a 3 week period from January - February 2019. The boxes remained until the end of the experiment. Group C, on the other hand, had no extra boxes before the start of the second period in May 2019 (i.e. remained identical to the control group A until May).

I visited sites of group B and C at least once every three months in order to move the LED cameras. For convenience I visited sites of group A less often. However, as the cameras were part of other, ongoing projects, they were occasionally visited by other workers from NINA to retrieve the Secure Digital memory cards (hereby SD Cards) for data. This was mostly the case for sites close to, and south of, Oslo, or rather, the cameras not normally operated by members of the NJFF.



(a) Browning infrared,
installed on a fallen tree



(b) Reconyx infrared,
installed with a snow cap



(c) Reconyx infrared above,
installed 160 cm above ground level



(d) Browning infrared,
white LED flash has just been removed

Figure 5.2: The preinstalled cameras varied in the way they were set up. Lower cameras with infrared, upper cameras with white LED (except in example c)

Table 5.1: Camera models

Producent	Model name	Flash type	Trigger speed	N
Reconyx HyperFire Series	HC500 Semi-Covert IR	IR	0.2s	?
	HC600 High-Output Covert IR	Black	0.2s	?
	PC800 Professional Semi-Covert IR	IR	0.2s	?
	PC900 Professional Covert IR	Black	0.2s	?
Browning	PC850 Professional White Flash LED	White	0.2s	20
	Spec Ops: Extreme	IR	0.7s	24

5.4 Data Collection

Five different models of RECONYX™ (address: 3828 Creekside Ln, Ste 2, Holmen, WI 54636, USA, www.reconyx.com) cameras were used, and one model of BROWNING™ (address: One Browning Place, Morgan, UT 84050, USA, www.browningtrailcameras.com) 5.1.

Reconyx-cameras have been reported of having an average trigger speed of 0.2 seconds, whereas the Browning model was reported an average of 0.7 seconds (Trigger speed shootout, Trailcampro 2014).

Cameras were operating 24 hours per day. The RECONYX™ cameras were set to take one time lapse photo per day in order to verify that the cameras had been operational. The cameras were programmed to have highest possible sensitivity, as described in Odden 2015. They were set to take 3 pictures per series, as fast as possible using *rapidfire*, and retrigger immediately using *no delay*. At the start of the study, I adjusted the BROWNING™ camera settings from 3 to 8 photos per trigger, in order to gather more data on behavioural responses to the white LED flash stimuli. However, behavioural  responses are beyond the scope of this study.

Unfortunately, with such data heavy settings, memory cards are more vulnerable to filling up before being collected, in areas with sheep and cattle, or when cameras get triggered by grass or branches blowing in the wind. Therefore, the BROWNING™ cameras, which also happen to be the northernmost cameras, tended to have more gaps of inoperable days.

Whenever I noticed vegetation blocking the view of the camera, or excessively triggering it, I removed the vegetation.

5.5 Data processing

All SD cards were delivered to NINA for data collection. Firstly, a facial recognition algorithm (FRA) is used to sort all the pictures. Afterwards, a human sorter checks the softwares' output, confirming all the correct decisions (i.e. species detections) and correcting all the wrong ones. The goal is to fully automate this process, which is a request from The Norwegian Data Protection Authority (DPA) in relation to usage of cameras in densely crowded areas (e.g. parks). As per the four eyes principle, the detection rate of photographed species has gone up as a result of the FRA (pers.comm. John Odden).

The output I got as a result, was a data frame containing a time stamp for every shutter activity, including all meta data from the camera, coupled with predicted species (FRA output, with a confidence number), verified species (by human sorters), number of animals and distance from camera. The time stamps from the white flash cameras were used to verify whether an animal was in fact flashed or not, which I then used as my main predictor in the modelling.

I defined one event as any 1 species passing with a buffer time of 5 min before or after

The true number of active camera days are confounded by the inconvenient lack of time lapse photos from the Browning cameras. To approach the true number of active days, I assumed all Browning cameras to be functional every day, unless the camera was inactive when I visited it. In that case, I considered the camera inactive since the day of its last photo.

5.6 Statistical analysis

To test for effects of the white LED flash I used the R programming language (R Core Team 2020), in the RStudio IDE (RStudio Team 2020), adopting large parts of the tidyverse framework along the way (Wickham et al. 2019). Session info in appendix ??.

Multiple hypothesis testing

When testing multiple groups for significance, the false positive rate will inevitably go up. By chance, if I tested 20 groups where the H_0 were true, an $\alpha = 0.05$ ($= \frac{1}{20}$) would deem at least one of the groups to be significantly different, thus rejecting the H_0 on false terms (ie. committing a type 1 error). Therefore, when testing six species, I should demand stronger evidence to reject the null hypothesis. The Bonferroni correction (Holm 1979) is straight forward, multiplying each p-value by the number of comparisons, or in other words dividing the α by the number of comparisons. This highly diminishes the chance of committing type 1 errors, but unfortunately increases the chance of type 2 errors (failing to reject a false null hypothesis) Shaffer 1995. In my case, using the Bonferroni correction would result in:

$$\alpha = \frac{0.05}{6 \text{ species}} = 0.0083 \text{ per species} \quad \text{💡}$$

A less conservative method is the sequentially rejective Bonferroni test (Holm 1979), often called Holm method, which is a modification of the Bonferroni correction. Here, the most significant test is given the Bonferroni correction (α/n tests). Then, the second most significant test gets an $\alpha/n - 1$, or, a slightly larger alpha. Continuing until the least significant test gets an $\alpha/1$ (i.e. retains the original $\alpha = .05$). In my case, using the Holm method results in:

$$\frac{\alpha}{6}, \frac{\alpha}{6-1}, \dots, \frac{\alpha}{1}$$

Hypothesis 1

To test H_1 I looked for differences in mean detection rate per day, using Generalised Linear Mixed Models (GLMM) with the R package lme4 (Bates et al. 2015). White LED present/absent was the predictor, while location ID and month was used as random factors, to control for underlying differences between sites, and seasonal changes. 💡

In addition, I used a Cox proportional hazards regression model (CPH model) (Cox, 1972), as a time to event analysis. Also called Survival analysis, the model compares groups' risk of experiencing an event (the *hazard ratio* between the groups), and was first developed for use in medicinal studies (e.g. cancer risk studies).

I used the CPH model to elaborate on the effect of the white LED by checking whether *confirmed* events of a flashed species affected the time until said species' redetection. The coxme function from the coxme package (Therneau 2020a) was used to include random effect arguments. 💡

Hypothesis 2

If the H_0 was rejected for a species, I tested the H_2 . To do that, I performed a new Cox PH, without the random effects, and looked for an interaction between the flashed-variable, and a spatial covariate for distance to nearest ALAN (data from FK). This time, I used the coxph function from R package Survival (Therneau 2020b).

P-tests and assumptions

For the GLMM, I used a XX as p-test For the Cox model, I used the Wald test as the significance test, with xyz distribution over df degrees of freedom. osvosv.

The XX was used to check assumptions for GLMM

The Schoenfeld test was used to check for the survival model's assumption of proportional hazards.

Bibliography

- Burton, A. Cole et al. (2015). "Wildlife camera trapping: A review and recommendations for linking surveys to ecological processes". In: *Journal of Applied Ecology* 52.3, pp. 675–685. ISSN: 13652664. DOI: 10.1111/1365-2664.12432.
- Beddari, Benedicte Lissner (2019). "Behavioral responses to camera traps : a study on two large carnivores in Norway". In: *Master of Sciences in Natural resource Management*, p. 52. URL: <https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2608534>.
- Moen, Asbjørn (1999). *National Atlas of Norway: Vegetation*. Ed. by Arvid Lilletethun. Hønefoss: Norwegian Mapping Authority, p. 209. ISBN: 82-7945-000-9 Vegetation. URL: https://www.nb.no/items/URN:NBN:no-nb%7B%5C_%7Ddigibok%7B%5C_%7D2010011503011.
- Odden, John (2015). *Bruk av viltkamera i overvåking av gaupe - et pilotstudie i tre områder på Østlandet - NINA Rapport 1216*. Tech. rep. Oslo, Norway, p. 54. URL: <https://brage.nina.no/nina-xmlui/handle/11250/2368722>.
- Trailcampro (2014). *Trigger speed shootout*. URL: <https://www.trailcampro.com/pages/trigger-speed-shootout-archive> (visited on 15/01/2021).
- R Core Team (2020). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Vienna, Austria. URL: <https://www.r-project.org/>.
- RStudio Team (2020). *RStudio: Integrated Development Environment for R*. RStudio, PBC. Boston, MA. URL: <http://www.rstudio.com/>.
- Wickham, Hadley et al. (2019). "Welcome to the {tidyverse}". In: *Journal of Open Source Software* 4.43, p. 1686. DOI: 10.21105/joss.01686.
- Holm, Sture (1979). "A Simple Sequentially Rejective Multiple Test Procedure". In: *Scandinavian Journal of Statistics* 6.2, pp. 65–70.
- Shaffer, Juliet Popper (1995). "Multiple hypothesis testing". In: *Annual Review of Psychology* 46, pp. 561–584. DOI: 10.1146/annurev.ps.46.020195.003021.
- Bates, Douglas et al. (2015). "Fitting Linear Mixed-Effects Models Using {lme4}". In: *Journal of Statistical Software* 67.1, pp. 1–48. DOI: 10.18637/jss.v067.i01.
- Therneau, Terry M (2020a). *coxme: Mixed Effects Cox Models*. URL: <https://cran.r-project.org/package=coxme>.
- (2020b). *A Package for Survival Analysis in R*. URL: <https://cran.r-project.org/package=survival>.