Flashing Large Mammals

Does white LED flashes in camera traps affect detection rates of target species?

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Abstract

Keywords: Animal behaviour; camera trap shyness; monitoring bias; night-time photography

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1. Introduction

Estimating number of animals are central in population ecology, and census methods has always been under development in order to get accurate, reliable ways of conducting surveys (REF!). Counting mammals directly is often difficult, as many species are shy, elusive, and mainly nocturnal. Some methods involve walking one or several persons in a row, scaring up animals, and counting them as they flee. Still, any such method is prone to undercounting, due to low visibility in dense forests and lack of focus from observers after a while. There are other, indirect methods, like counting tracks or calls during the mating season, but these work best when the target species has a large density.

In northern areas, like Norway, counting animal tracks in snow has been a popular method. Snow track counts has the advantage of highly visible tracks, and a somewhat accurate dating of the tracks to the last snowfall, as old tracks vanish. However, lately the snow season in southern Norway has been variable, which makes snow track counts unpredictable and difficult to conduct at a consistent time of year (Odden 2015).

Therefore, the Norwegian Institute of Nature Research (NINA) has started to use camera traps (CTs) as a substitute method to monitor family groups of Eurasian lynx (*Lynx lynx*) in southereastern Norway (Odden 2015). The surveys are integrated in a coordinated Scandinavian science project on lynx, called Scandlynx.

CTs have been developing fast, and become quite affordable (Burton et al. 2015). They offer a consistent, standardised sampling method which also records date, hour and, in some instances, temperature. CTs normally use infra-red (IR) light to photo-capture animals, which is invisible to the human eye, but has been shown to be visible to several other mammals (Meek et al. 2014). However, the lack of sharpness and detail from IR photos limit the information we can retrieve from them, e.g. individual variation in coat patterns which can be used in capture-recapture models to accurately estimate population numbers.

The need for more detail has led to the usage of white light flashes. CTs with white light flash comes with either white xenon or white light-emitting diode (LED) technology, where xenon provides the sharpest photos, but has the disadvantage of requiring long cool downs after each photo (minimum of 22 seconds in Henrich et al. 2020).

Naturally, white light is highly visible to all land dwelling mammals, and will likely affect the animals to some extent (e.g. startle, stress) which in turn could bias the data we collect. Problems related to CT awareness and behavioural changes have already been discussed by many (Meek et al. 2014, Burton et al. 2015, Hofmeester et al. 2019). Beddari (2019) showed that grey wolfs (*Canis lupus*) in Norway tend to shy away from sites where a white LED CT was used, whilst the lynx seemed less bothered. Henrich (2020) studied roe deer (*Capreolus capreolus*) and red deer's (*Cervus elaphus*) responses to IR, black and white flash, but they used a xenon white flash, which has a long cool down, and hindered any meaningful comparisons of deer detection rates with the other flash types.

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

In this study, I will quantify how the usage of white LED flash affects the detection rate of the most common large mammal species in an area in Southern Norway. I have restricted the analysis to all wild species observed at least 50 independent times during my survey, which totaled nine species. Namely roe deer, red fox (*Vulpes vulpes*), badger (*Meles meles*), moose (*Alces alces*), red deer, red squirrel (*Sqiurus vulgaris*), hare (*Lepus timidus*), European pine marten (*Martes martes*) and lynx.

White LED CTs have similar recovery speeds to that of regular IR CTs, as both utilize LEDs as flashes, which makes them well fit for meaningful comparisons.

Hypotheses (H0): Usage of white LED flash will have no effect on the detection rate of any species.

(HA): 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.

2. Method and materials

2.1 Study area

The study area (59.36-60.45° N, 9.31-11.13° E) extends over much of the southeastern parts of Norway in municipalities Flå, Krødsherad, Sigdal, Ringerike, Modum, Hole, Lier, Øvre Eiker, Asker, Oslo, Enebakk, Indre Østfold, Våler, Råde, Moss, Frogn and Vestby in Oslo and Viken counties. 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 ℃, precipitation lies between 700-1500mm and growing season length lies between 170 - 190 days (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 (*Populous tremula*), alder (*Alnus incana*) and black alder (*Alnus glutinosa*).

2.2 Study design

I was given access to CTs used in the Scandlynx project, and chose 60 sites to get a substantial amount of data. For logistical reasons, I chose the sites closest to Oslo which weren't already equipped with white LED flashes. Instead, these CTs were equipped with infra-red flashes, and I will refer to them as the *IR CTs*.

The IR CTs had been installed on trees 1-3 m from wildlife, human or tractor paths, 30-160 cm above ground level, and their distance from houses or roads varied to a large extent. They were set up and handled by people from NINA and, at the sites further from Oslo, by local volunteers. 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.

I divided the sites randomly into three groups of 20 sites. The first group remained unchanged as a control, and the remaining two groups (hereby referred to as the *treatment groups*) were equipped with an additional white LED camera (hereby referred to as the *white LED CTs*) in alternating 3 month-periods, as illustrated in figure 2.2 on the facing page.

Periods when an additional white LED CT was present (and operational), I will refer to as *white LED periods*. Periods when the white LED was absent (or inactive), I will refer to as *IR periods*. All periods from the control group, I will refer to as *control periods*. Note that control periods also are periods with only IR CTs present, but differ from the IR periods in that there never was a white LED present at these sites.

I set up all white LED CTs above the IR CTs already in place (installation examples in figure 2.3). Using an electric drill, I mounted the CTs with metal cases that remained

Figure 2.1: Map of study area 60 sites in Southeastern Norway were included in the survey. Point colouration represents camera model, and white dots represent sites that had periods with an additional white LED camera trap (CT).

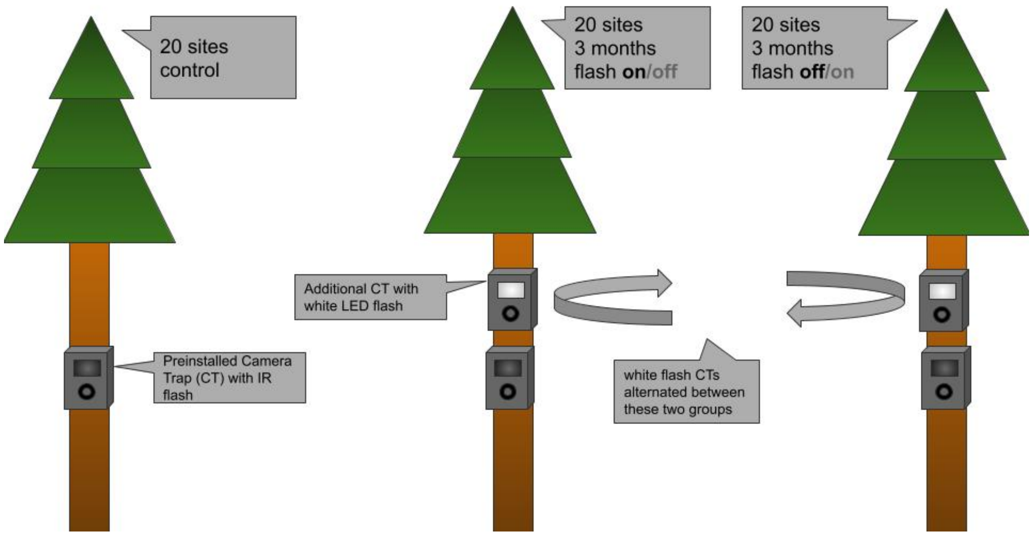


Figure 2.2: Experiment setup 60 sites with preinstalled Infrared Camera Traps (IR CTs) that was divided into three groups, where the first group remained unchanged (control group), and the two other alternated on having additional white LED CTs present or not (treatment groups).

locked between visits. I used short logs to adjust the angle of the white LED CTs, aligning them to match the corresponding IR CT's field of view. Vegetation obstructing the view of any camera was removed at setup, or when noticed during a later visitation (e.g. tall grass during summer). At one site the IR camera had been installed so far above ground level that I chose to position the white LED CT below the IR CT. The metal cases containing the white LED CTs remained at each site until the end of the survey. Note that the second treatment group had no additional metal case before the start of their first white LED period in May 2019.

I visited sites of the treatment groups at least once every three months in order to move the white LED cameras. For logistical reasons I visited sites of the control group less often. However, as all cameras were part of other, ongoing projects, they were occasionally visited by workers from NINA to retreive 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 local volunteers.

2.3 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). Model names are presented in table 2.1. As all Reconyx models were from the same series, they were practically identical in all aspects except for the type of flash. Differences in features and settings between the Reconyx an the Browning CTs are presented in table 2.2.

Cameras were operating 24 hours per day. All were set to take photos as quickly as possible with the *rapidfire* and *no delay* settings. However, the two brands differed slightly in their trigger recovery speed, as shown in table 2.2.

The largest functional difference between the two brands was in the number of photos taken per trigger.

(a) Browning IR installed on fallen tree.

(b) Reconyx IR installed with snow cap.

(c) Reconyx IR 160 cm above the ground. Therefore, I positioned the wLED underneath.

(d) Additional CT boxes remained during IR periods.

Figure 2.3: Examples of camera setups The preinstalled IR cameras varied in the way they were set up. Lower cameras had Infra-Red flash, upper cameras had white LED flash.

While Reconyx CTs were set to take 3 photos per trigger, the Browning CTs were set to 8 photos per trigger. In turn, Browning CTs tended to fill their memory cards faster in areas with sheep or cattle, and due to triggering by vegetation. Consequently, they tended to have less active days than the Reconyx, as CTs stop taking pictures when their memory cards are full. Adding insult to injury, the Browning CTs weren't set to take time lapse photos, confounding the number of active days. To approach the true number of active CT 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. On the other hand, Reconyx cameras were set to take one time lapse photo per day, making it easy to verify which days they were operational.

Table 2.1: Camera models included in the survey

Brand	Model name	Flash type
Browning	Spec Ops: Extreme	No-glow IR
	HC500 Semi-Covert IR	Red-glow IR
Reconyx	HC600 High-Output Covert IR	No-glow IR
(HyperFire	PC800 Professional Semi-Covert IR	Red-glow IR
Series)	PC900 Professional Covert IR	No-glow IR
	PC850 Professional White Flash LED	White LED

Table 2.2: Camera settings and features Overview of the number of cameras and camera settings for the two brands, Browning and Reconyx. One model of Browning and five models of Reconyx cameras were used (see Table 2.1). Camera specifications are gathered from product reviews (www.trailcampro.com).

	Browning	Reconyx
Number of cameras	34(?)	26(?)
Trigger speed	0.43 s	0.28 s
Recovery speed	0.8 s	0.9 s
Photos per trigger	8	3
Detection angle	45.5°	42°
Field of view	40.6°	42°
Quiet period	No delay	No delay
Trigger interval	*rapidfire*	*rapidfire*
Time lapse	No	Yes

As seen in figure 2.1, there was a correlation between latitude and camera type.

2.4 Data processing

All SD cards were delivered to NINA for data processing. Firstly, a facial recognition algorithm (FRA) was used to identify species on all pictures. Afterwards, a human sorter reviews the software's output, confirming all the correct identifications and rectifying the wrong ones. Consequently, the rate of correctly identified species has increased as the FRA sometimes detect animals that aren't easily noticed by human sorters (John Odden pers. comm.). NINA's goal is for the FRA to automatically and reliably delete pictures of humans, which has been requested from The Norwegian Data Protection Authority (Datatilsynet) for CT usage in parks and other densely crowded areas (John Odden pers. comm.).

The white LED CTs were considered as external flashes, and so, only the pictures from the preinstalled IR CTs were sorted for species identification. NINA provided me with a data frame containing time stamps for every triggering of each IR CT, including all metadata from the CTs, coupled with predicted species (FRA output, with a confidence number), verified species (by human sorters), number of animals and distance from camera. Thus, if a moose ruminated in front of a camera for 30 minutes, the data frame would include several detections in sequence. In order to remove autocorrelation in the observations, I defined an event to be any sighting of a species that occurred more than 20 minutes after the previous sighting of the same species. Number of individuals was not taken into account. My predictor variable of interest was the three different types of periods, namely IR, white LED and Control periods.

I extracted metadata from all pictures taken by the white LED CTs and used that to define the duration of each white LED period. If a site's white LED CT stopped working (eg. due to full SD card or empty batteries) before the day I came to relocate it, that site would have already entered its next IR period. This happened a few times, which can be seen as the times a light blue period starts outside of the shaded areas in figure 2.4. If an IR CT stopped working during a white LED period, that period represented a GAP even if the white LED CT still functioned. Nonetheless, the site, and it's inhabitant animals, would all the same be exposed to the white flash up until the start of the following IR period. I never experienced that both the IR and white LED CTs of a site had stopped working at the same time.

When modelling the detection rates, periods of similar lengths were required. White LED and IR periods were clearly defined, but control periods lacked a common definition for period splits, as I visited control sites less frequently than the treatment sites. Therefore, I divided the control sites into four periods of similar lengths to that of the IR- and white LED-periods (see figure 2.4).

In total, 4 sites were removed before the analysis due to technical faults, or alike. 1 CT was removed from the control group, as it turned out to be a white LED camera. 3 CTs were removed from the treatment groups, because of large or frequent gaps due to technical errors, and at one site, ineffective placement of the additional white LED camera.

2.5 Statistical analysis

To test for effects of the white LED flash I used the R programming language (R Core Team 2021), in the RStudio IDE (RStudio Team 2020), adopting large parts of the tidyverse (Wickham et al. 2019) and the easystats (Makowski et al. 2020) frameworks along the way. Complete citation of R packages used are presented in appendix 4.5.

GLMM

To test H1 I looked for differences in detection rate per day, using Generalised Linear Mixed Models (GLMM) with the glmer function from the R package lme4 (Bates et al. 2020). I fitted separate models for each species to avoid overly complicated models. Locations that had 0 observations of the modelled species were filtered out before the modelling, but for all locations that had observed the species, all periods were included. The dependent variable was count data (number of observations), and I therefore assumed the error term followed a Poisson distribution ($X \sim Pois(\lambda)$).

I included location ID and week of the year as random effects to account for consistent differences between camera sites and seasonal changes during the year of study. 95% Confidence Intervals (CIs) and p-values were computed using the Wald approximation. I used standardized parameters (mean = 0, SD = 1) to enable comparison of effect sizes.

The main term of interest was time since deployment (continuous) interacting with type of flash period (categorical; formula: n.obs $\sim$ time.deploy $*$ flash). For the sites that

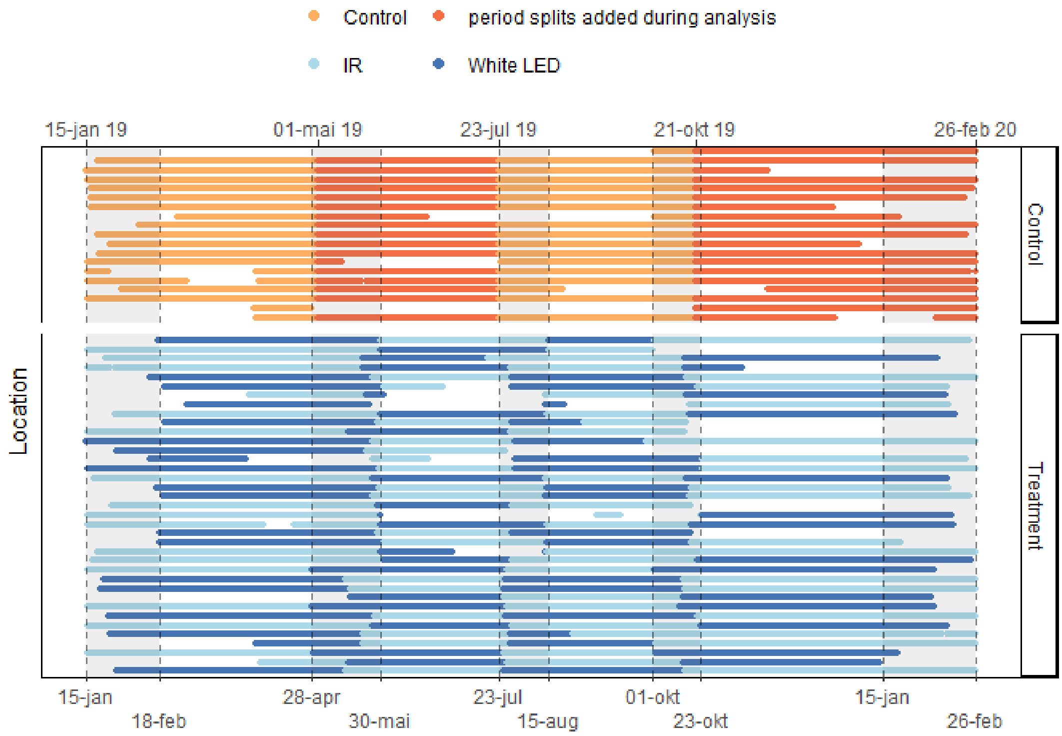


Figure 2.4: An overview of active camera days for each camera throughout the whole study period. Colours indicate the different periods for each site. White spaces indicate gaps where the IR CTs were inactive. Control camera periods were defined in similar lengths to that of the treatment group during analysis. As a result, the first day of control periods are often set at dates far from when I actually visited a site. Shaded areas represent my field work periods.

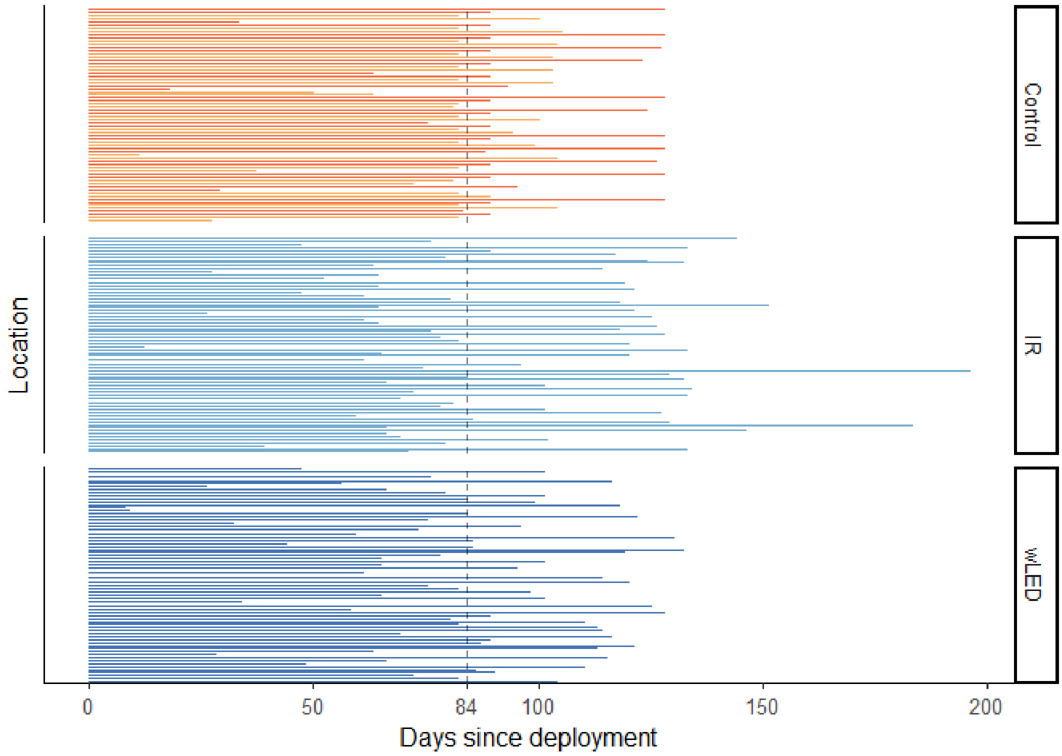


Figure 2.5: Period lengths for each camera. Vertical line represents the median IR period length, which was shorter than the median of the other groups. Data superseding the median were trimmed away for the GLMM.

were equipped with an additional white LED camera, time since deployment starts from the day I visited the camera, and set up/took down the white LED. The control group's "day 0" of time since deployment were set at points reflecting the onset of field work each time, in order to obtain periods of similar lengths to that of the white LED-locations.

I trimmed the period lengths down to a reduced maximum length, based on the median length of the IR and white LED periods, to enhance meaningful comparison. Thus, any period exceeding the shortest median length, was trimmed down, as visualized in figure 2.5. Finally, due to large eigenvalues in the fixed effects, the model failed to converge, and an error message prompted me to rescale variables. Therefore I divided the time since deployment-variable by ten, which solved the convergence issue. Consequently, the time axis is shown in days/10, which means that 8 corresponds to 80 days.

If there were any effect of the white LED, the IR period should show a regression to the norm, ie. counteracting the trend during the white LED periods. Thus, if the white LED had a negative slope along the time axis, the IR should have a positive slope. Further, the detection rate at the start of each period, should correspond somewhat to the detection rate at the end of the previous period. Still, that pattern could be skewed to some extent due to my visitation of each location at the start of all IR and white LED periods.

Equivalence test

I used the standard significance level of $\alpha = .05$, and performed an equivalence test on my model outputs, using the function equivalence_test from the R package parameters (Lüdecke et al. 2021). In an equivalence test, model parameters are tested against a Region of Practical Equivalence (ROPE) as opposed to merely one single mean value which is done in a standard Null Hypothesis Significance Test (NHST). Thus, rather than saying that a parameter's effect was significantly different (or not) from 0, the *effect size* is also considered. If the parameter estimate and confidence interval (CI) lies outside the ROPE, the effect is significantly and practically different from 0, and the null hypothesis is rejected. However, if the CI is inside the ROPE, H0 is accepted, no matter if a NHST would have deemed it significantly different, because the difference is so small that there is practically no effect.

Inside the function equivalence_test I used the Two One-Sided Tests (TOST) rule, where the CI is set to $1 - 2 \times \alpha$. In my case that gave a CI of 0.90. For models from count data, the residual variance is often used to define the ROPE range. However, the description of the rope_range function from the package bayestestR (R-bayestestR) states this threshold as "rather experimental" and that the range is probably often similar to the default [-0.1, 0.1] of a standardized parameter. Hence, I used the default ROPE range which corresponds to a negligible effect size according to Cohen, 1988.

3. Results

The type of CT flash had an overall minor effect on detection rates. In general, the control periods (which never had white flashes) had a somewhat lower detection rate than the IR and white LED periods.

There were a total of ≈ 18000 camera trapping days, which was unevenly distributed between the different periods and period types.

I will present detailed results of all the nine mammalian species included in my analyses in order from most to least number of events, as shown in figure 3.3. Each species is presented with a figure showing activity across time of day, a photo taken with a white LED CT of the species, an equivalence test, and a plot of the marginal means of the fixed effects in the GLMM model, showing the detection rates of all three types of periods (Control, IR and white LED) along a time axis.

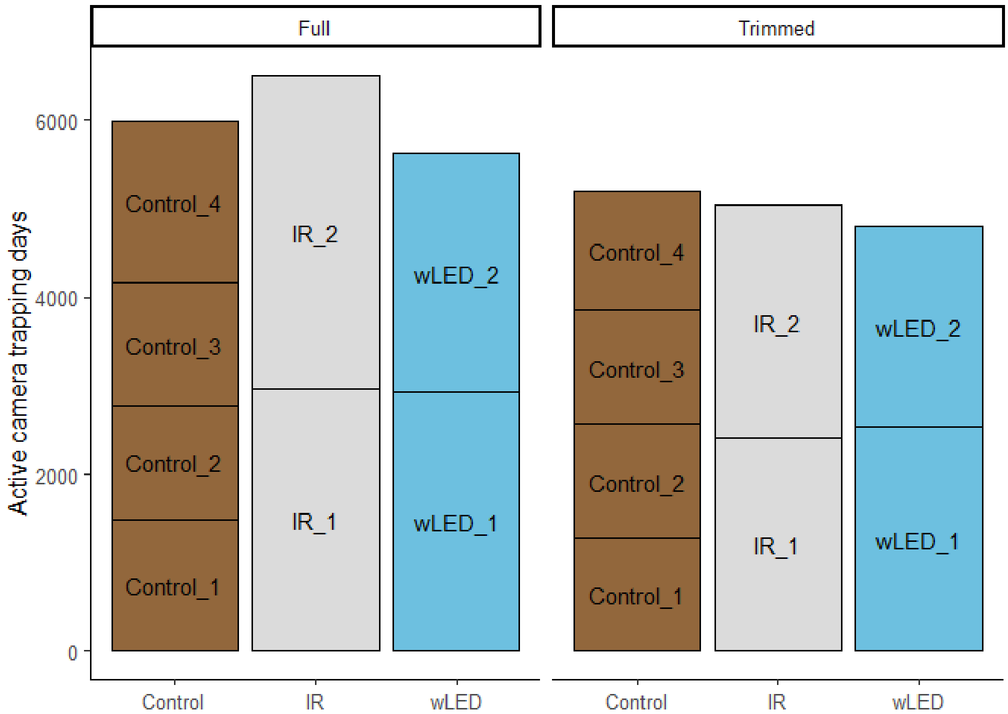


Figure 3.1: Caption1

The main effect of LED was positive for most species, although none responded significantly (table 3.1).

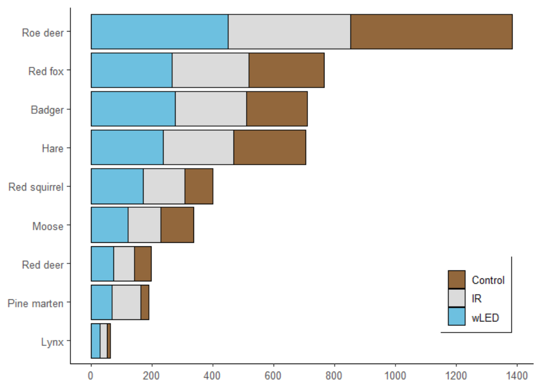


Figure 3.2: Raw count and number of events per species

Figure 3.3: Camera trapping days and number of events per species

Table 3.1: Results of Poisson mixed effects models on detection rate of species at 56 different locations in southeastern Norway, with three different treatment levels interacting with time since deployment (Time); periods from sites unchanged through the the whole study period (Intercept), periods with only IR camera (IR), periods with an additional white LED camera (wLED). Random effects are location ID and week of year.

Species	Parameter	Coefficient	SE	95% CI	z	p	SGPV
Roe deer	Intercept	-2.85	0.38	(-3.58, -2.11)	-7.57	< .001	0.00
	Time	-0.05	0.02	(-0.09, -0.01)	-2.24	0.025	1.00
	IR	-0.26	0.44	(-1.12, 0.60)	-0.59	0.557	0.14
	wLED	-0.13	0.44	(-0.99, 0.73)	-0.30	0.761	0.14
	Time * IR	0.02	0.03	(-0.04, 0.08)	0.71	0.476	1.00
	Time * wLED	3.37e-03	0.03	(-0.05, 0.06)	0.12	0.901	1.00
Red fox	Intercept	-3.44	0.26	(-3.94, -2.94)	-13.40	< .001	0.00
	Time	-5.47e-04	0.03	(-0.06, 0.05)	-0.02	0.985	1.00
	IR	0.03	0.32	(-0.59, 0.65)	0.09	0.926	0.19
	wLED	0.18	0.31	(-0.44, 0.79)	0.56	0.574	0.19
	Time * IR	-2.41e-03	0.04	(-0.08, 0.07)	-0.06	0.949	1.00
	Time * wLED	-0.01	0.04	(-0.08, 0.06)	-0.30	0.763	1.00
Badger	Intercept	-4.49	0.37	(-5.22, -3.76)	-12.12	< .001	0.00
	Time	0.06	0.03	(0.00, 0.13)	1.85	0.064	0.82
	IR	0.17	0.39	(-0.59, 0.93)	0.44	0.657	0.16
	wLED	0.24	0.38	(-0.51, 0.99)	0.64	0.523	0.16
	Time * IR	0.01	0.04	(-0.07, 0.09)	0.27	0.784	1.00
	Time * wLED	4.35e-03	0.04	(-0.07, 0.08)	0.11	0.914	1.00
Hare	Intercept	-3.91	0.36	(-4.61, -3.21)	-10.94	< .001	0.00
	Time	0.04	0.03	(-0.03, 0.10)	1.12	0.263	1.00
	IR	0.38	0.42	(-0.44, 1.21)	0.91	0.363	0.14
	wLED	0.25	0.42	(-0.58, 1.08)	0.59	0.555	0.14
	Time * IR	-0.05	0.04	(-0.13, 0.03)	-1.26	0.209	0.88
	Time * wLED	1.27e-03	0.04	(-0.08, 0.08)	0.03	0.975	1.00
Red squirrel	Intercept	-5.42	0.52	(-6.43, -4.41)	-10.49	< .001	0.00
	Time	0.08	0.05	(-0.02, 0.18)	1.61	0.108	0.61
	IR	0.82	0.60	(-0.36, 2.00)	1.36	0.174	0.10
	wLED	0.50	0.61	(-0.69, 1.69)	0.82	0.410	0.10
	Time * IR	-0.18	0.06	(-0.30, -0.05)	-2.79	0.005	0.13
	Time * wLED	-0.02	0.06	(-0.14, 0.11)	-0.26	0.796	0.91
Moose	Intercept	-4.15	0.30	(-4.75, -3.56)	-13.75	< .001	0.00
	Time	6.30e-03	0.05	(-0.08, 0.10)	0.14	0.890	1.00
	IR	-0.08	0.35	(-0.77, 0.60)	-0.23	0.814	0.17
	wLED	0.30	0.34	(-0.36, 0.97)	0.89	0.373	0.18
	Time * IR	0.05	0.06	(-0.06, 0.17)	0.86	0.389	0.75
	Time * wLED	-6.98e-03	0.06	(-0.12, 0.10)	-0.12	0.902	1.00
Red deer	Intercept	-3.89	0.41	(-4.69, -3.09)	-9.55	< .001	0.00
	Time	-0.09	0.06	(-0.21, 0.02)	-1.63	0.104	0.53
	IR	-9.87e-03	0.50	(-0.99, 0.97)	-0.02	0.984	0.12
	wLED	-0.69	0.53	(-1.72, 0.35)	-1.30	0.192	0.12
	Time * IR	0.06	0.08	(-0.09, 0.21)	0.81	0.421	0.65
	Time * wLED	0.23	0.08	(0.08, 0.38)	2.96	0.003	0.00
Pine Marten	Intercept	-5.95	0.54	(-7.02, -4.89)	-10.95	< .001	0.00
	Time	0.09	0.09	(-0.09, 0.28)	0.97	0.331	0.52
	IR	1.69	0.58	(0.55, 2.82)	2.92	0.004	0.00
	wLED	0.76	0.61	(-0.43, 1.95)	1.25	0.210	0.10
	Time * IR	-0.11	0.11	(-0.32, 0.09)	-1.07	0.286	0.46
	Time * wLED	0.03	0.11	(-0.18, 0.24)	0.30	0.768	0.56
Lynx	Intercept	-4.82	0.58	(-5.96, -3.67)	-8.24	< .001	0.00
	Time	-0.22	0.14	(-0.49, 0.05)	-1.58	0.113	0.24
	IR	-0.20	0.72	(-1.61, 1.21)	-0.28	0.781	0.08
	wLED	0.15	0.72	(-1.26, 1.55)	0.20	0.839	0.08
	Time * IR	0.25	0.16	(-0.07, 0.57)	1.53	0.127	0.22
	Time * wLED	0.26	0.16	(-0.06, 0.58)	1.59	0.112	0.20

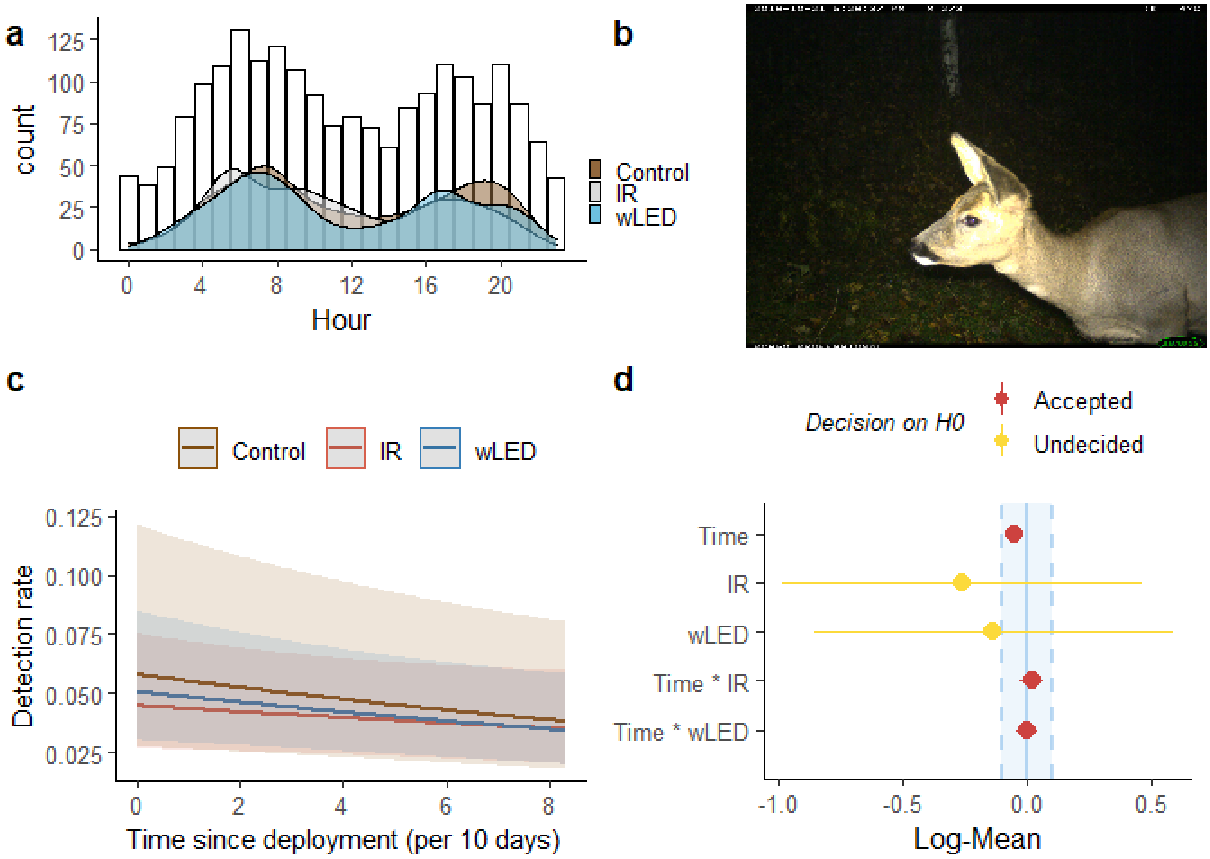


Figure 3.4: Roe deer a) The predicted detection rate of roe deer for each level of the flash-variable. Confidence intervals (CI) represented by dotted lines.
b) Model parameters presented in an equivalence test. ROPE is set to ±0.1 Log-Mean, $CI = 1 - 2 \times \alpha$.
c) Bars represent the raw count of total roe deer detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a roe deer. The deer passed the camera repeatedly and often stopped in front of the flashing light

3.1 Roe deer

Roe deer was the most common species detected by the CTs, with a total number of 1709 events. The species was detected at all times of day, with marked peaks of activity during the twilight hours. Looking at the density curves in figure 3.4c, the overall activity pattern was consistent between the three types of periods (control, IR and white LED). The detection rates were also similar, as demonstrated in figure 3.4a.

The GLMM explaining variation in detection rate had a substantial explanatory power (conditional R2 = 0.45), but the part related to the fixed effects alone (marginal R2) was just 0.002. In other words, most of the explained variation in detection rate was due to seasonal changes and variation between the different camera sites captured in the random terms. In a standard null hypothesis significance test (NHST) no parameters were significant.

The equivalence test in figure 3.4b accepted the validity of H0 (that there were no effect) for the effect along the time axis in all three types of periods. However, the detection rate varied a lot in all periods, which hindered a decision on the main effect of IR and white LED periods.

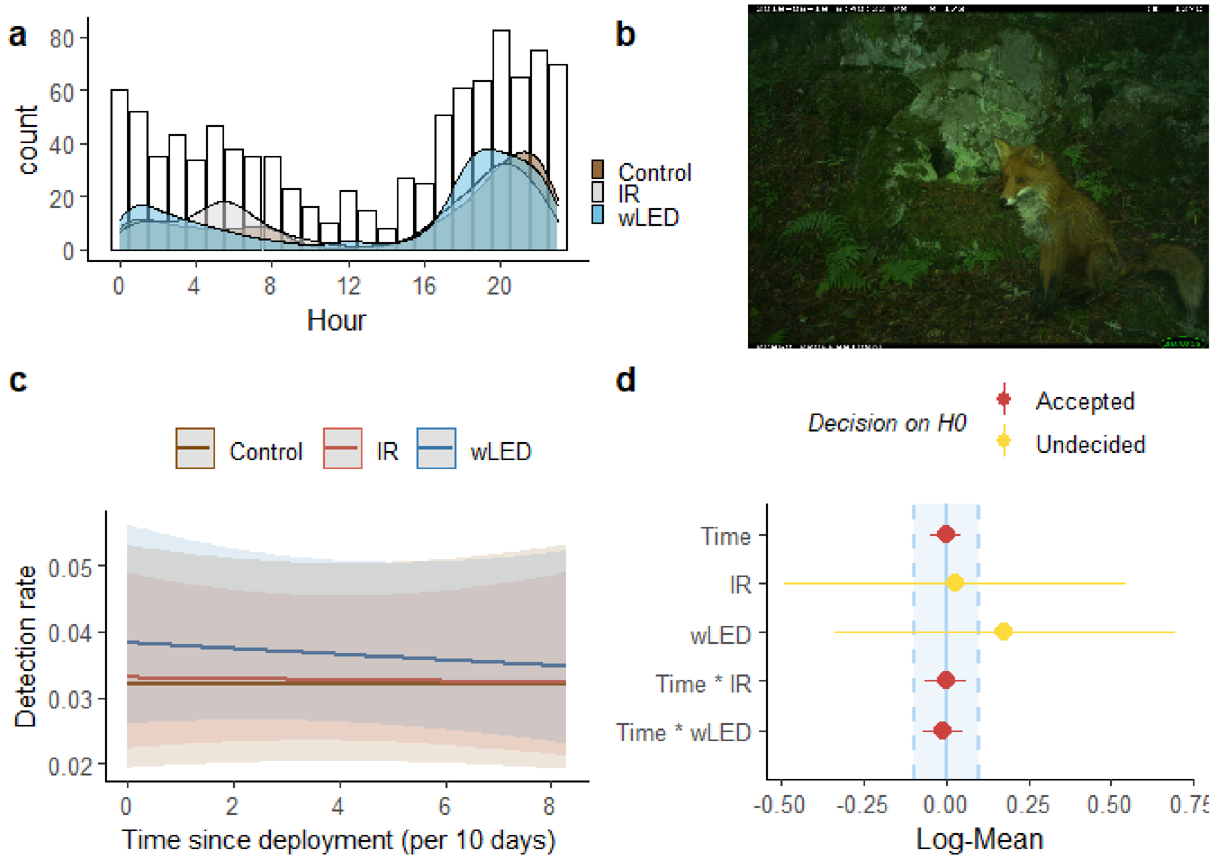
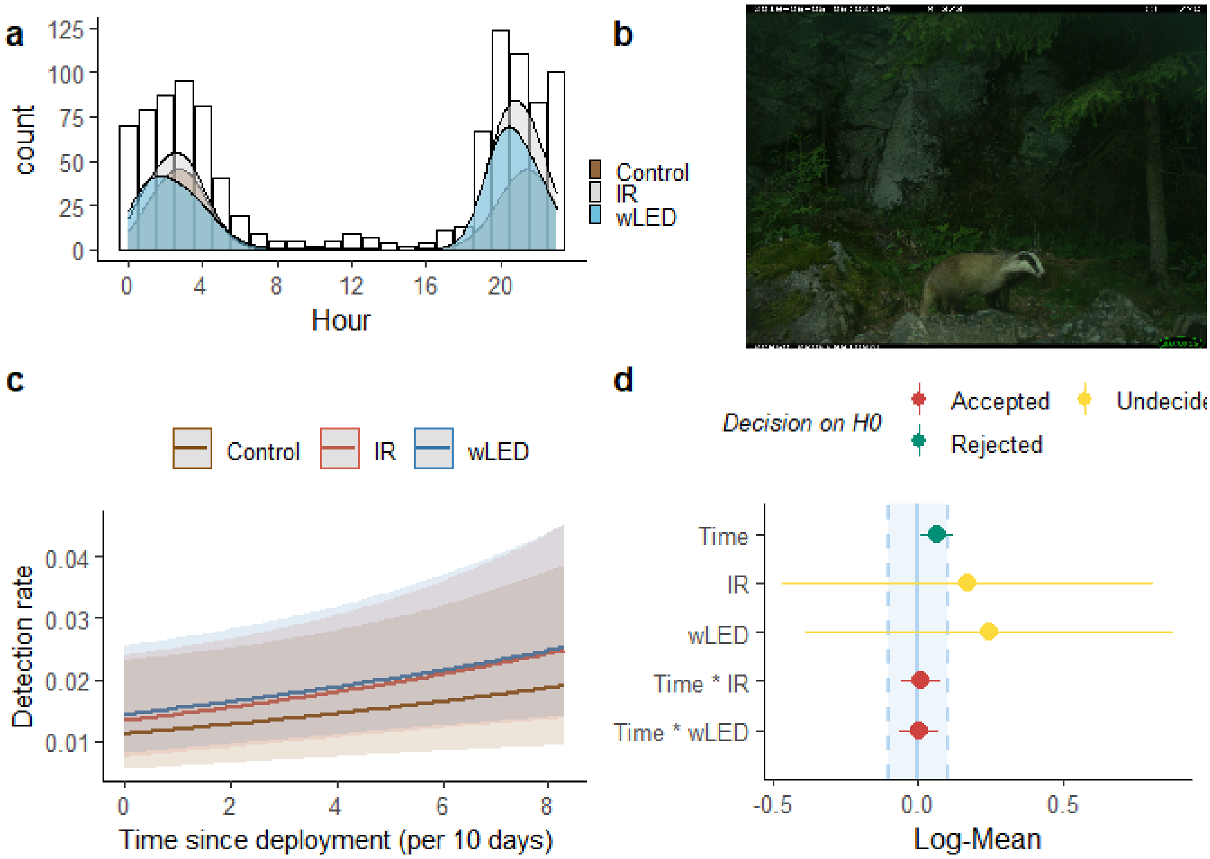


Figure 3.5: Red fox a) The predicted detection rate of red foxes for each level of the flash-variable. Confidence intervals (CI) represented by dotted lines.
b) Model parameters presented in an equivalence test. ROPE is set to ±0.1 Log-Mean, $CI = 1 - 2 \times \alpha$.
c) Bars represent the raw count of total fox detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a red fox. The fox stopped in front of the flashing camera and waited for a following individual before they continued.

3.2 Red fox

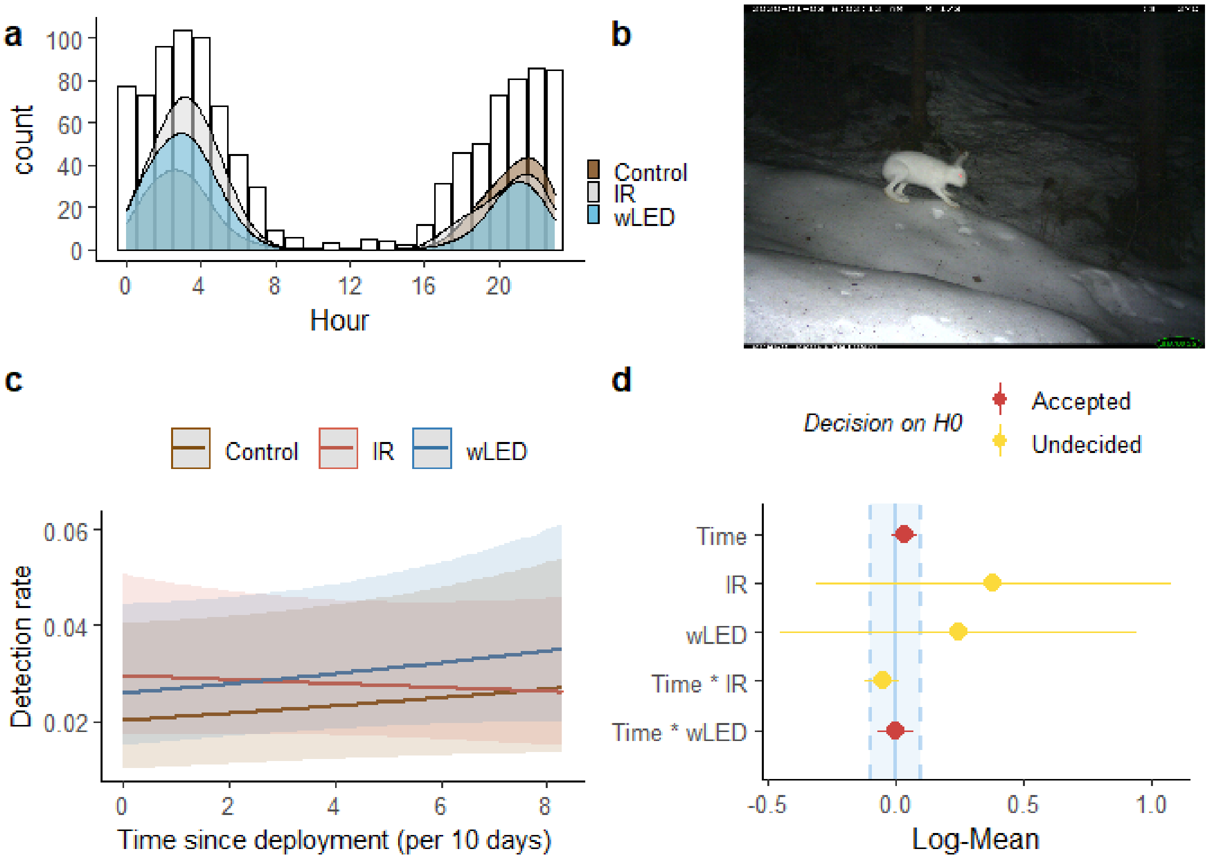
The red fox was the second most common species with 913 events. The red fox was also active during the whole day, but with a more pronounced peak in the late evening continuing until the break of day, as visualised in figure 3.5c. The overall pattern was similar between each group (Control, IR, white LED), and the overall effect of white LED was minor.

The GLMM explaining variation in detection rate of red fox had a substantial explanatory power (conditional R2 = 0.19), but the part related to the fixed effects alone (marginal R2) was just 0.001. In other words, most of the explained variation in detection rate was due to seasonal changes and variation between the different camera sites captured in the random terms. No parameters were significant in a standard NHST, and considering the equivalence test in figure 3.5b, the effect of time was practically equivalent for all types of periods. However, the large variation in the main effect of IR and white LED hinders any decision on H0.

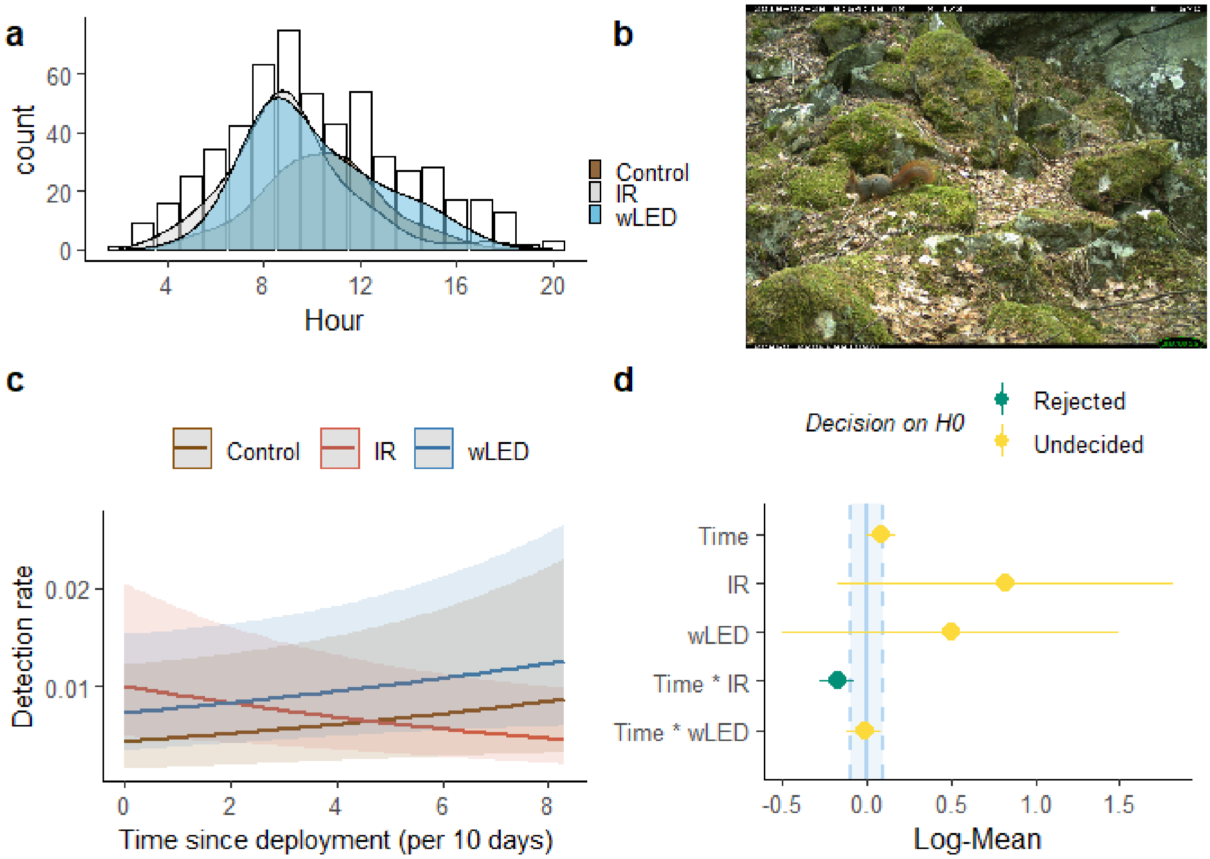


3.3 Badger

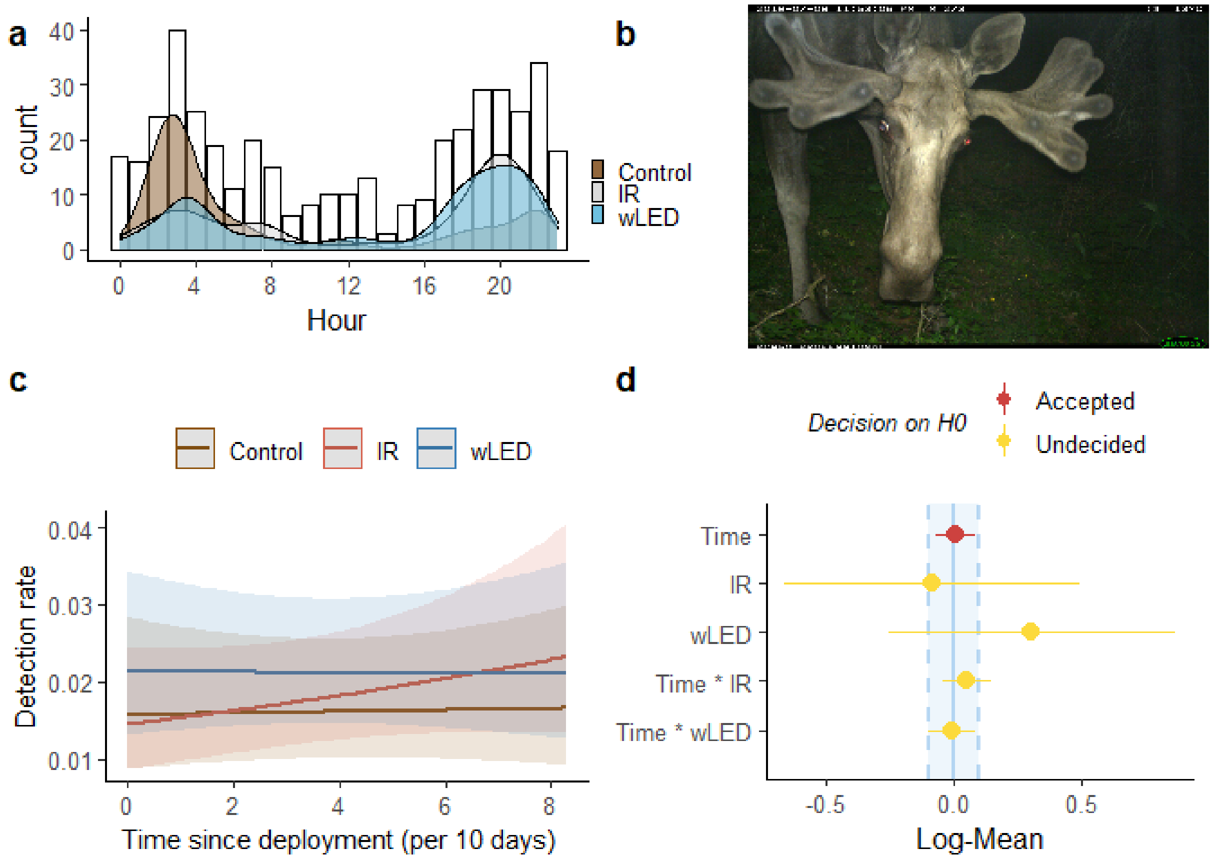
For badger, the model explaining variation in detection rate has a substantial explanatory power (conditional R2 = 0.42), but the part related to the fixed effects alone (marginal R2) is just 0.006.


a
100
80
60
40
20
0
count
0
4
8
12
16
20
Hour
Control
IR
wLED
b
c
Control
IR
wLED
0.06
0.04
0.02
Detection rate
0
2
4
6
8
Time since deployment (per 10 days)
d
Decision on H0
Accepted
Undecided
Time
IR
wLED
Time * IR
Time * wLED
-0.5
0.0
0.5
1.0
Log-Mean

3.4 Hare



3.5 Red squirrel


a
count
Hour
Control
IR
wLED
b
c
Control
IR
wLED
Detection rate
Time since deployment (per 10 days)
d
Decision on H0
Accepted
Undecided
Time
IR
wLED
Time * IR
Time * wLED
Log-Mean

3.6 Moose

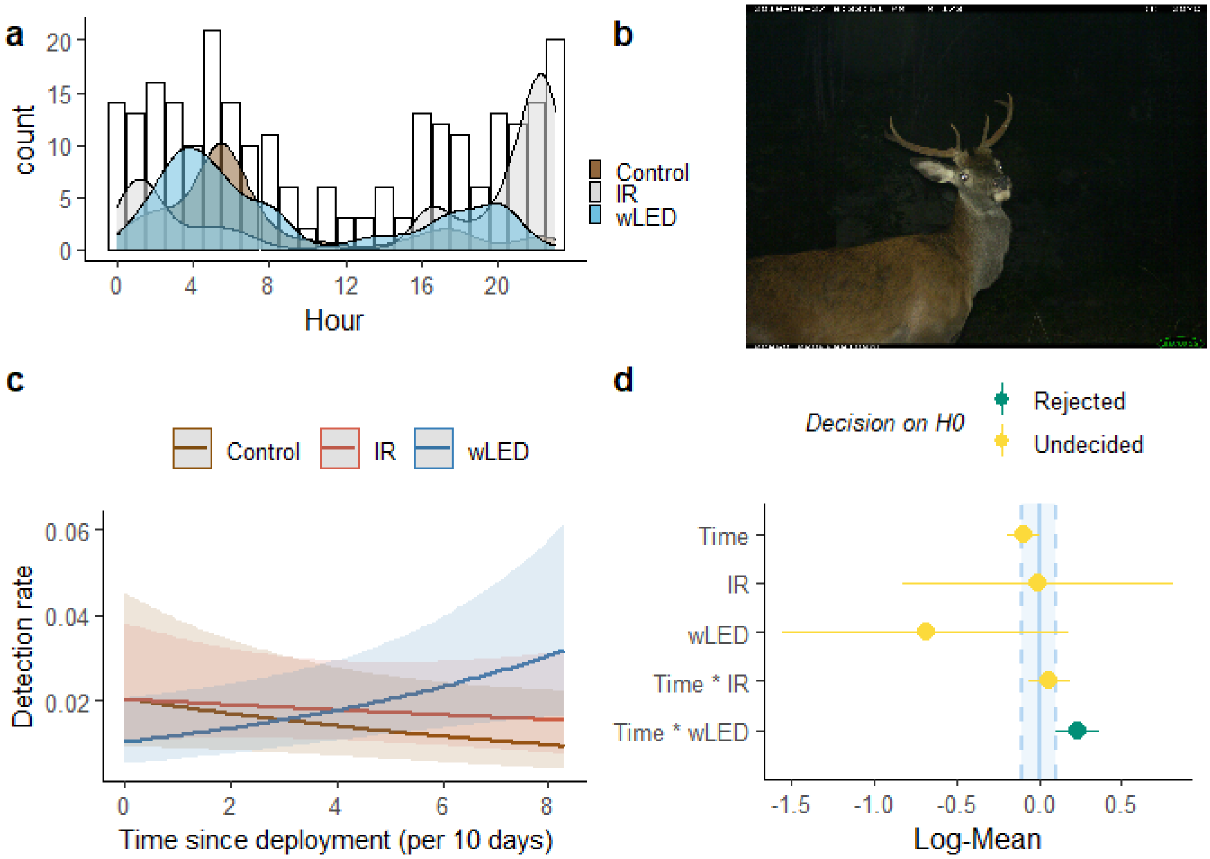


Figure 3.6: Red deer

3.7 Red deer

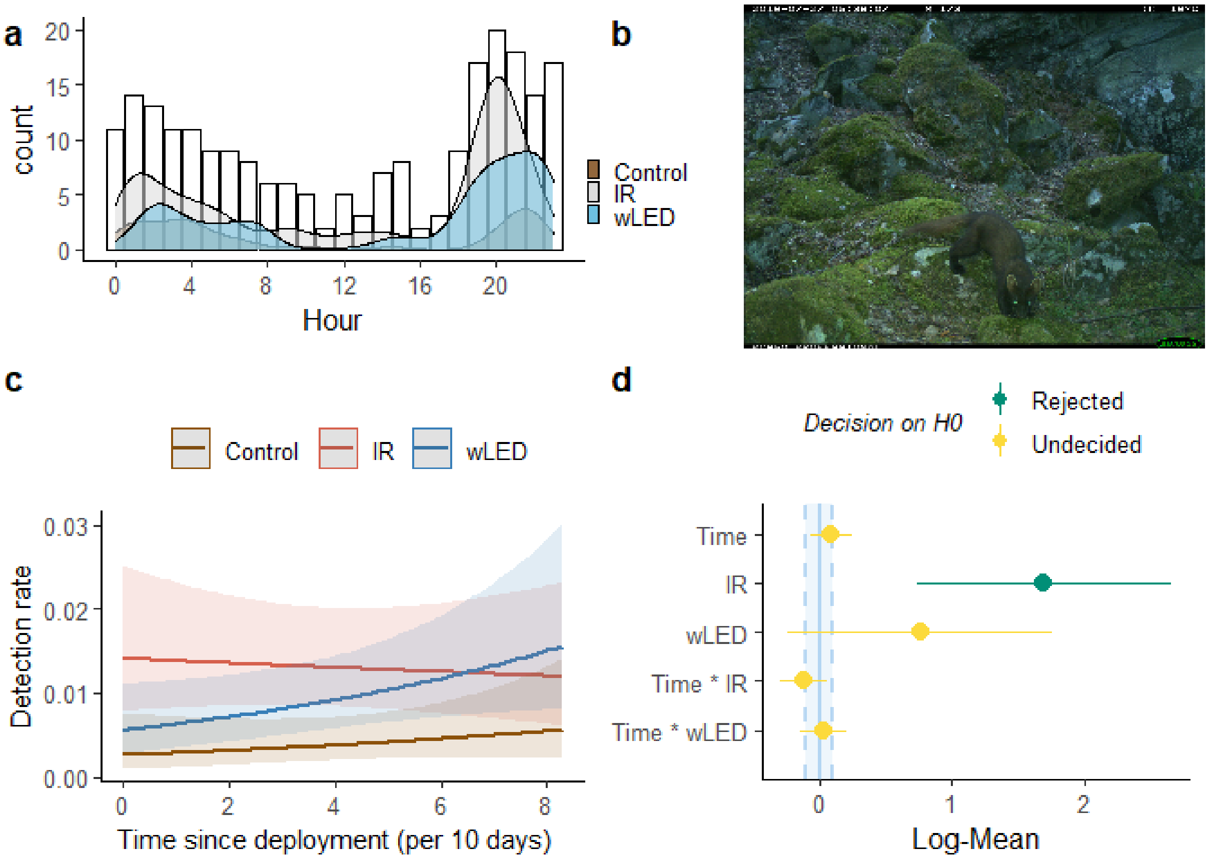


Figure 3.7: Pine marten

3.8 Pine marten

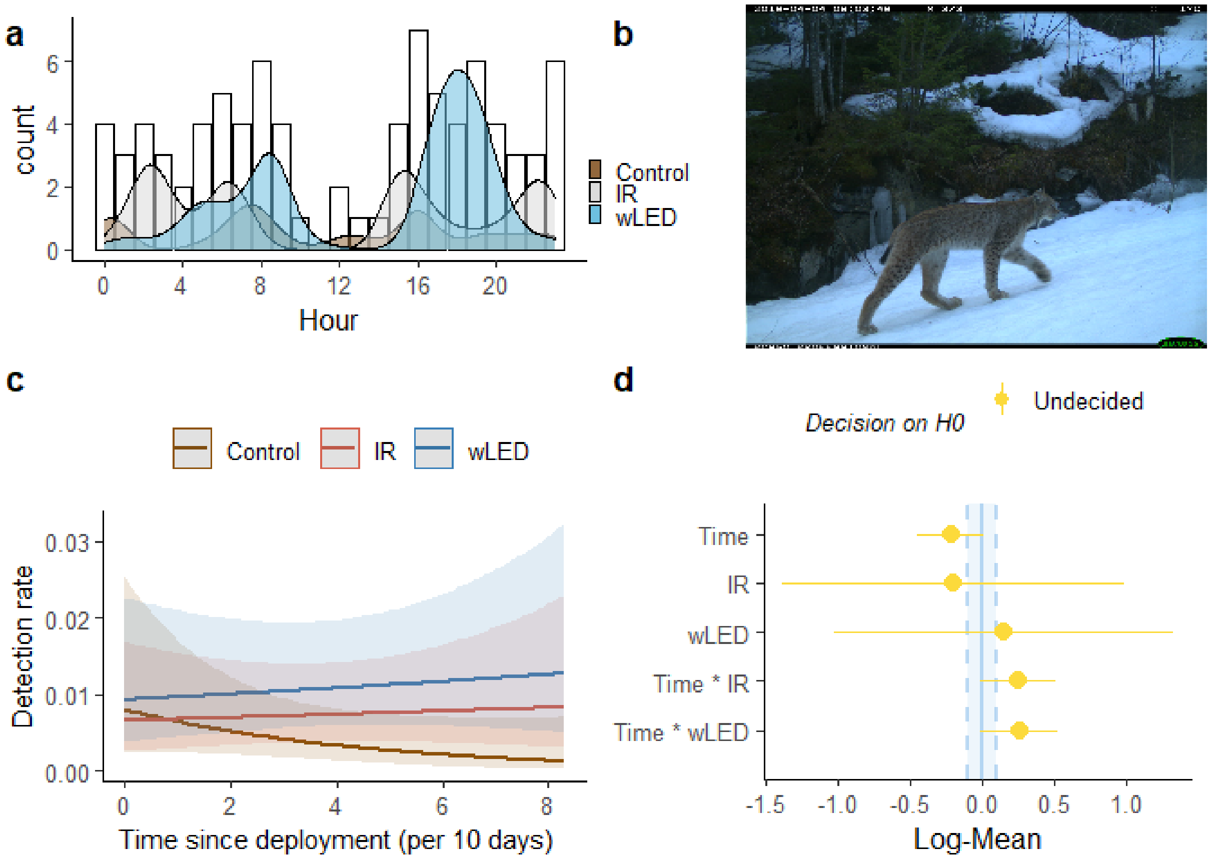


Figure 3.8: Lynx

3.9 Lynx

4. Discussion

In the example of Scandlynx, CTs have been introduced as a more reliable survey method than snow track counts of the Eurasian lynx in Norway. The CTs bring in a lot of useful information about the lynx, but it is also triggered by the rest of the mammal species in the area. Thus they provide a lot of information of other species as well, which would be a shame to throw away.

4.1 Overall activity pattern of the mammal community

As I have shown in the density plots from my raw data, I am able to record the daily activity pattern of these other mammal species, and (all/most/some/none) matched the activity-patterns that I expected out from reading about their known activity patterns. Only the red squirrel showed a diurnal pattern. Roe deer and pine marten were active throughout the day, but both had their peaks in the twilight hours.

4.2 The effect of CT flashes on large carnivores

The decisions on setup of the IR CTs were solely based on maximizing the chances of detecting lynx, and on gathering as much information about individual lynx as possible. My aim has been to see if the decision on whether or not to use a white LED flash affects the detection rates of other species. Beddari (2019) showed that grey wolfs shy away from sites equipped with white LED CTs. They scared away from the site immediately, and were (only redetected in TK instances / never redetected). For lynx the story was different. One lynx was recorded sleeping in front of a white LED CT, and the white LEDs didn't seem to affect the chance of redetection. Henrich et al. (2020) investigated the detection rates of roe deer and red deer in the Bavarian Forest National Park and the Northern Black Forest in Germany, but were unable to conclude on the effect of white light as they used a xenon white flash, that had a cool down of at least 22 seconds after each photo was taken.

I used white LED . . .

4.3 Activity pattern of cervids using CTs

Considering the results for roe deer, although the density figures can't tell me if each photo was taken before or after sunrise/sunset, there seems to have been a significant portion taken during the twilight. Thus, it has been dark enough that the white LED has been triggered. However, there were little activity during the middle of the night, when the light stimuli would have been at its strongest. Consequently, most photos were taken when the flash stimuli wasn't at its strongest. The overall pattern stayed the same for all periods, which at least tells us that any effect of the flash seems to have been small.

Looking at equivalence test of roe deer in figure [fig:raadyr]b, the main effect of the IR and white LED periods have a wide CI, which makes us unable to conclude on the groups' true effect sizes. IR is estimated to be within the Region of Practical Equivalence (ROPE), and LED is estimated to be outside, but the large variation still present in the data prevents a conclusion. Considering the time variable, and its interactions, all are within the ROPE, and the test tells us to accept its practical equivalence to H0, namely that there is no effect. Still, when interpreting a continuous variable as this, it is worth considering its scale. I scaled my time variable to represent 10 day intervals, in order for the model to converge. That means the estimated effect of time since deployment is ten times larger than it would have been if it remained as 1 day intervals. Conversely, had I scaled it to represent the whole span of 84 days, the estimated effect and confidence interval would have been 8.4 times larger than what it is now (0.4), and so would it's confidence interval. The equivalence test would be undecided on the effect of time since deployment.

4.4 Methodological considerations

hello hello

CT setup

Seeing as many experiments are set up with a period length much shorter than mine, it seems reasonable to aim for a time unit which would translate well to these more common lengths. Henrich et al. (2020) set up cameras for periods of 20 days, and could therefore not have detected any effects on a time scale of 84 days.

Study design

Nevertheless, the control-group is what I am using as a reference point to what is normal. What I am interested in investigating is whether, and to what extent, the LED group deviates from the control group. As mentioned, the main effect is non-significantly negative compared to both the control and the IR. The same is true along the time axis. Both the slope for IR and white LED are practically equivalent to the slope for control.

Estimation issues

Let's talk about estimation issues

4.5 Model performance

Using the performance package i checked various assumptions, and all held up Overdispersion, zero-inflation and singularity all held up in every model.

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