Flashing Large Mammals
Quantifying the effect of white LED flash on camera trapping detection rates

UiO : Department of Biosciences
University of Oslo

Torgeir Holmgard Valle

Method and materials

Study design

The Norwegian Institute of Nature Research (NINA) started with CTs to substitute snow track surveys of lynx family groups, after several years of varying snow season length in south eastern Norway (). The surveys are integrated in a coordinated Scandinavian science project on lynx, called Scandlynx.

I was given access to CTs used in the Scandlynx project, and chose the 60 sites closest to Oslo (for logistical reasons) which weren't already equipped with white LED light. Instead, these were equipped with either black or IR flash, but 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.
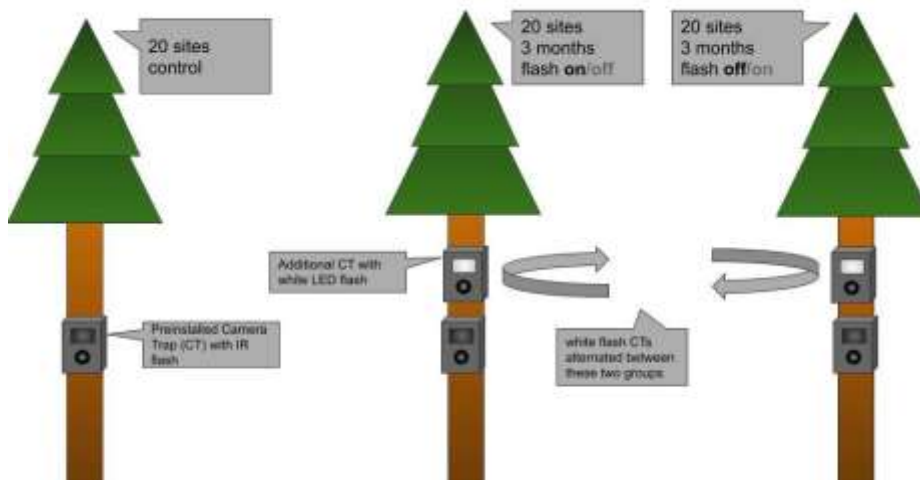
Experiment setup I chose 60 sites with preinstalled Infrared Camera Traps (IR CTs) for my study, and divided them into three groups, where the first group remained unchanged (control group), and the two other alternated on having additional white LED CTs present (treatment groups). Four sites were removed from the analysis due to large gaps in the data, etc.

I divided the sites randomly into three groups of 20 sites. Cameras in the first group remained unchanged as a control. The remaining two groups (hereby referred to as treatment groups) were equipped with an additional white LED camera (Reconyx PC850; hereby referred to as the LED CTs) in alternating 3 month-periods, as illustrated in figure.

I set up all LED CTs above the IR CTs already in place (installation examples in figure [fig:cam_ex_main]). At one site the IR camera had been installed so far above ground level that I chose to position the LED CT below the IR CT. The camera boxes containing the LED CTs remained at each site untill the end of the experiment. Note that the second treatment group had no extra boxes before the start of their first LED period in May 2019 (i.e. remained identical to the control group untill May).

I visited sites of the treatment groups at least once every three months in order to move the LED cameras. For logistical reasons I visited sites of the control group less often. However, as the 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 members of the NJFF.

When doing the analyses I needed periods of similar lengths to each other. Therefore, I divided the control group-cameras into four periods of similar lengths to that of the treatment group cameras (see figure [fig:timeseries]).

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), details in table [tab:cam_mod].

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,).

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. They were set to take 3 pictures per series, as fast as possible using *rapidfire*, and retrigger immediately using *no delay*.

The BROWNING™ cameras were also set to rapidfire, but to 8 photos per trigger, which made the memory cards more vulnerable to filling up before being collected. This happened in some areas with sheep and/or cattle, and sometimes due to triggering by vegetation.

Therefore, the BROWNING™ cameras tended to have more gaps of inoperable days. The true number of active camera days are confounded by the 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.

As seen in figure [fig:map], there was a correlation between latitude and camera type.

[fig:map]

Data processing

All SD cards were delivered to NINA for data processing. 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. Consequently, the rate of correctly identified species has gone up as the FRA sometimes detect animals that aren't easily noticed by human sorters (pers.comm. John Odden). The goal is to fully automate this identification 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).

The output I got as a result was a data frame containing a time stamp for every time the CTs were triggered, 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.

I defined one event as any one species passing with a buffer of 30 minutes untill next detection of the same species, in order to remove autocorrelation in observations, e.g from

ruminating individuals. Number of individuals and distance to CT were not taken into account.

My predictor variable of interest was a three level factor, where LED represented the periods with an additional white LED CT present, IR represented the periods *after* a white LED CT had been present, and Control represented all periods where a white LED CT had never been present. The different periods are visualised in figure [fig:timeseries].

4 sites were removed before the analysis due to technical faults, etc. 1 CT from the control group, as it turned out to be a white LED camera.3 CTs from the treatment groups, because of large or frequent gaps due to technical errors, and ineffective placement of the additional white LED camera.
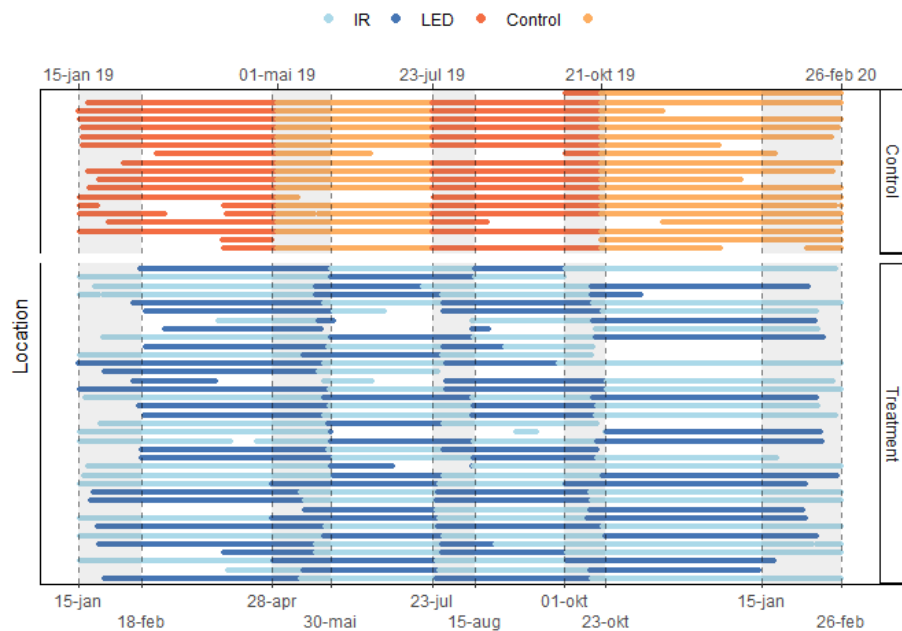
Active camera days Colours indicate the different periods for each camera. White spaces indicate gaps where the IR CTs were inactive. Control camera periods were defined in similar lengths to that of the treatment group during analysis. As a result, "day 0" of Control-cameras are often set at dates far from an actual visitation day. Shaded areas represent my field work periods. [fig:timeseries]

Statistical analysis

To test for effects of the white LED flash I used the R programming language (), in the RStudio IDE (), adopting large parts of the tidyverse () and the easystats () frameworks along the way. Complete citation of R packages used are presented in appendix [app:sessinfo].
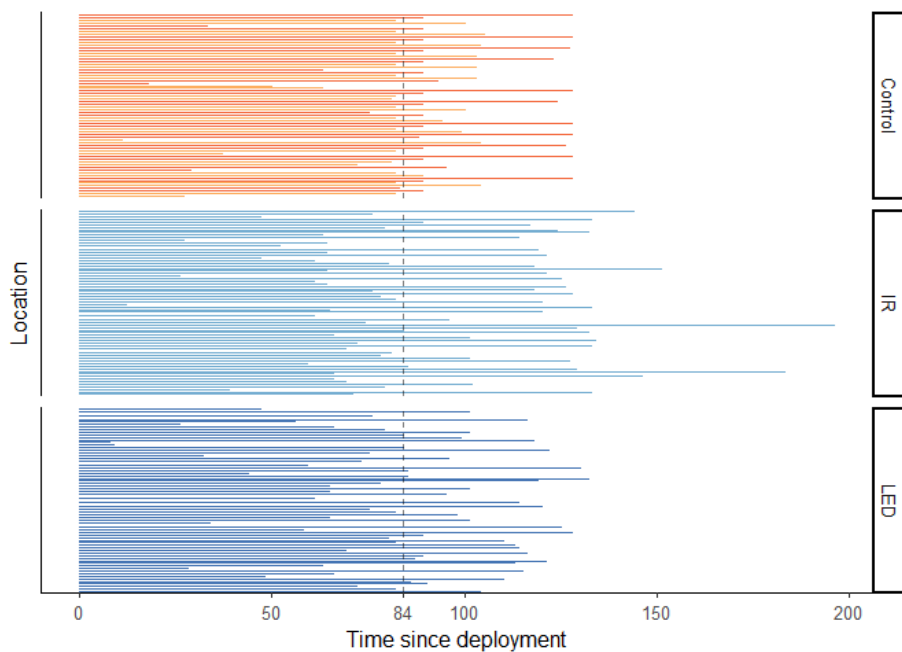
GLMM

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 (). I fitted separate models for each species to avoid overly complicated models. 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 in days interacting with flash type (formula: n.obs $\sim$ time.deploy $*$ flash). The flash type-variable corresponds to white LED present/absent or control group. For the sites that 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 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 [fig:median_period]. 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 error. Consequently, the time axis is shown in days/10, which means that 7.5 corresponds to 75 days.

*Figure *. An overview of the operational ~~P~~period lengths of each camera. Vertical line represents the median IR period length, which was shorter than the median of the other groups. Data superceding the median were trimmed away for the GLMM. [fig:median_period]*

Equivalence test

I used the standard significance level of $\alpha = .05$~~., Iand I~~performed an equivalence test on my model outputs, using the function equivalence_test from the R package parameters (). In an equivalence test, model parameters are tested against a Region of Practical Equivalence (ROPE) as opposed to merely one single mean value, thus accounting for the *effect size* of each parameter. If the parameters estimate and CI falls outside the ROPE, their null hypothesis is rejected. However, if the CI is inside the ROPE, H0 is accepted, no matter if a standard Null Hypothesis Significance Test (NHST) would have deemed it significant.

Inside the function equivalence-test I used the Two One-Sided Tests (TOST) rule, where the confidence interval (CI) is set to $1 - 2 \times \alpha$. In my case that gave a narrow 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 () 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 (*https://easystats.github.io/bayestestR/reference/rope_range.html*, accessed 11.3.2021). Hence, I used the default ROPE range, which corresponds to a negligible effect size according to Cohen (~~,~~1988).

Merknad [AM1]: ? kutt?

Merknad [AM2]: Ref?

Merknad [AM3]:

Merknad [AM4]: Du bruker CI ovenfor, skal def ved første bruk

Merknad [AM5]: 90%
Det er vel ikke narrow
Vanlig er 95%

Merknad [AM6]: Ref?

Results

~~GLMM~~

All species

As the control-group (Intercept in table [tab:param]) stayed unchanged through the whole study period, and was visited less than the other cameras, I expected there to be no trend over time (i.e. time.deploy ≈ 0 in table [tab:param]). Any fluctuations in detection rates due to weekly (and ultimately seasonal) changes should be controlled for by the random effect-term for week of the year, leaving the control group as a representation of the baseline detection rate. This held true for all the species in my analysis.

In general, the control-group with standard cameras had somewhat lower detection rates than the cameras with LED or IR ~~two treatment~~ groups for all species (see table [tab:param])~~. However, for most species, the slopes of IR and LED are completely covered by the Control-group's confidence interval (CI), meaning that~~, but the differences ~~are~~ were non-significant.

If there were any effect of the LED, the IR period should show a regression to the norm, ie. counteracting the effect of the LED. Thus, if the LED had a negative slope along the time axis, the IR should have a positive slope. Further, their respective main effects (ie. when time since deployment = 0) should correspond somewhat to the other factor's simple effect of when time since deployment is at maximum value (84 days). Still, as time since deployment = 0 corresponds to the day of my visitation, my presence could skew that pattern to some extent.

The main effect of LED was positive for most species, although none responded significantly (table [tab:param]).

Species	Parameter	Coefficient	SE	95% CI	z	p
Roe deer	(Intercept)	-3.47	0.43	(-4.31, -2.62)	-8.06	< .001
	TimeDeploy	-0.05	0.02	(-0.09, -0.01)	-2.22	0.026
	IR	0.08	0.51	(-0.92, 1.08)	0.16	0.875
	LED	0.20	0.51	(-0.79, 1.20)	0.40	0.688
	TimeDeploy * IR	0.02	0.03	(-0.04, 0.08)	0.69	0.489
	TimeDeploy * LED	2.86e-03	0.03	(-0.05, 0.06)	0.11	0.916
Red fox	(Intercept)	-3.44	0.26	(-3.94, -2.94)	-13.40	< .001
	TimeDeploy	-5.47e-04	0.03	(-0.06, 0.05)	-0.02	0.985
	IR	0.03	0.32	(-0.59, 0.65)	0.09	0.926
	LED	0.18	0.31	(-0.44, 0.79)	0.56	0.574
	TimeDeploy * IR	-2.41e-03	0.04	(-0.08, 0.07)	-0.06	0.949
	TimeDeploy * LED	-0.01	0.04	(-0.08, 0.06)	-0.30	0.763
Badger	(Intercept)	-4.79	0.39	(-5.56, -4.02)	-12.15	< .001
	TimeDeploy	0.07	0.03	(0.00, 0.13)	1.90	0.058
	IR	0.27	0.42	(-0.55, 1.09)	0.64	0.523
	LED	0.34	0.42	(-0.48, 1.15)	0.81	0.421
	TimeDeploy * IR	7.08e-03	0.04	(-0.07, 0.09)	0.17	0.865
	TimeDeploy * LED	3.93e-03	0.04	(-0.07, 0.08)	0.10	0.922
Moose	(Intercept)	-4.75	0.38	(-5.49, -4.01)	-12.58	< .001
	TimeDeploy	9.66e-03	0.05	(-0.08, 0.10)	0.21	0.830
	IR	-0.04	0.44	(-0.90, 0.82)	-0.09	0.927
	LED	0.34	0.43	(-0.51, 1.19)	0.78	0.434
	TimeDeploy * IR	0.05	0.06	(-0.07, 0.16)	0.78	0.433
	TimeDeploy * LED	-0.01	0.06	(-0.12, 0.10)	-0.19	0.849
Red deer	(Intercept)	-5.99	0.71	(-7.39, -4.59)	-8.38	< .001
	TimeDeploy	-0.10	0.06	(-0.21, 0.02)	-1.56	0.119
	IR	0.07	0.81	(-1.51, 1.65)	0.09	0.930
	LED	-0.60	0.82	(-2.21, 1.02)	-0.72	0.469
	TimeDeploy * IR	0.06	0.08	(-0.09, 0.22)	0.80	0.424
	TimeDeploy * LED	0.23	0.08	(0.07, 0.39)	2.81	0.005
Lynx	(Intercept)	-6.38	0.71	(-7.77, -5.00)	-9.03	< .001
	TimeDeploy	-0.21	0.14	(-0.48, 0.06)	-1.52	0.128
	IR	-0.49	0.83	(-2.11, 1.14)	-0.59	0.558
	LED	-0.14	0.83	(-1.76, 1.48)	-0.17	0.867
	TimeDeploy * IR	0.24	0.16	(-0.08, 0.56)	1.48	0.140
	TimeDeploy * LED	0.25	0.16	(-0.07, 0.57)	1.54	0.124
Hare	(Intercept)	-4.29	0.43	(-5.13, -3.45)	-10.05	< .001
	TimeDeploy	0.04	0.03	(-0.03, 0.10)	1.13	0.258
	IR	0.24	0.50	(-0.75, 1.23)	0.47	0.636
	LED	0.11	0.51	(-0.89, 1.10)	0.21	0.835
	TimeDeploy * IR	-0.05	0.04	(-0.13, 0.03)	-1.28	0.199
	TimeDeploy * LED	8.95e-04	0.04	(-0.08, 0.08)	0.02	0.983
European Pine Marten	(Intercept)	-6.38	0.57	(-7.50, -5.27)	-11.20	< .001
	TimeDeploy	0.10	0.09	(-0.09, 0.28)	1.01	0.314
	IR	1.67	0.61	(0.47, 2.87)	2.73	0.006
	LED	0.76	0.64	(-0.49, 2.01)	1.20	0.232
	TimeDeploy * IR	-0.11	0.11	(-0.32, 0.09)	-1.08	0.280
	TimeDeploy * LED	0.02	0.11	(-0.19, 0.24)	0.22	0.828
Red squirrel	(Intercept)	-5.72	6.21e-04	(-5.72, -5.72)	-9211.38	< .001
	TimeDeploy	0.08	6.21e-04	(0.08, 0.08)	132.04	< .001
	IR	0.83	6.21e-04	(0.83, 0.83)	1334.43	< .001
	LED	0.51	6.21e-04	(0.51, 0.51)	818.92	< .001
	TimeDeploy * IR	-0.18	6.21e-04	(-0.18, -0.18)	-286.42	< .001
	TimeDeploy * LED	-0.02	6.21e-04	(-0.02, -0.02)	-26.66	< .001

Table 2.1: Model parameters
Results of generalised linear mixed effect models on detection rate of species at 56 different locations in south-eastern Norway, with three different treatment levels; periods from sites unchanged through the the whole study period (Intercept), period with only IR camera (IR) and period with additional white LED camera (LED). Random effects are location ID and week of year. 95% Confidence Intervals and p-values were computed using the Wald approximation.

Roe deer
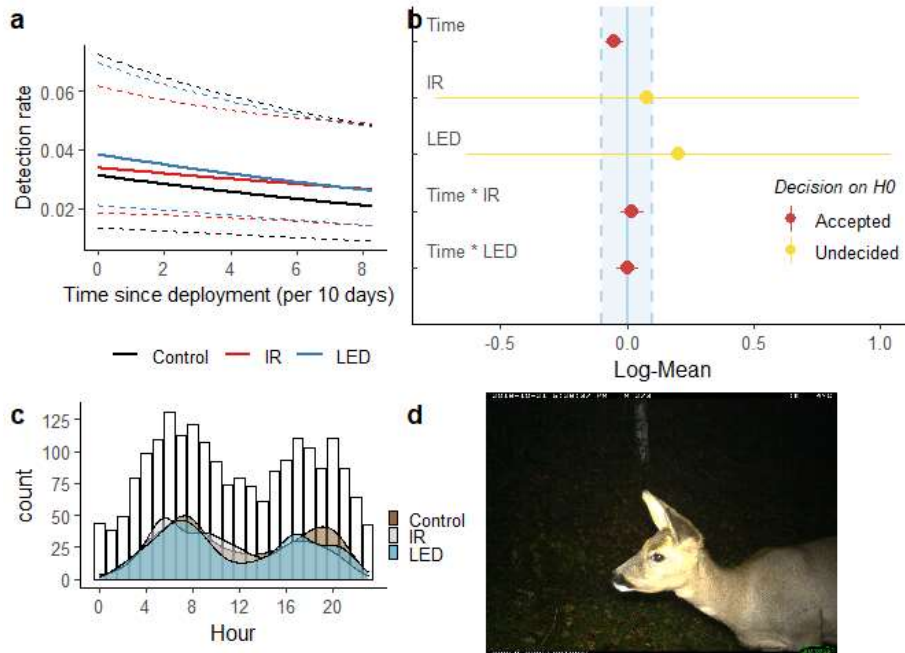
Roe deer a) The predicted detection rate of roe deer for each level of the flash-variable. Confidence intervals (CI) represented by dotted lines.
b) Model parameters presented in an equivalence test. ROPE is set to ± 0.1 Log-Mean, $CI = 1 - 2 \times \alpha$.
c) Bars represent the raw count of total roe 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

For roe deer, the model explaining variation in detection rate has a substantial explanatory power (conditional R2 = 0.45), but the part related to the fixed effects alone (marginal R2) is just 0.002. In other words, most of the explained variation in detection rate is due to seasonal changes and variation between the different camera sites captured in the random terms.

The main effect of the white LED periods were non-significantly positive compared to the control-group (Intercept). The same is true for the IR periods, although to a slightly lower extent. However, along the time since deployment-axis (time.deploy * flash [LED]) there was a negative effect, to the extent that after two months the mean detection rate sank below that of the IR periods (see figure [fig:raadyr]a). Nevertheless, the confidence

intervals (CI) of both white LED and IR periods almost completely overlap, and hence, are not significantly different.

When a parameter is within the ROPE in an equivalence test, it signifies that the difference from the Log-mean, and the variance of the parameter, is low enough that we can accept H0, rather than just fail to reject it.

According to this test, white LED is different enough that we cannot conclude on it's main effect, but it's trend over time (Time * LED) is practically equivalent to H0. In other words, the equivalence test suggests that there is no significant difference in the long run, but there might be an increase in detections right after the day of deployment. However, the increase could also result from inhereting a slightly higher detection rate from the IR periods *if* there truly is a negative effect of the white LED over long periods of time.

Red fox
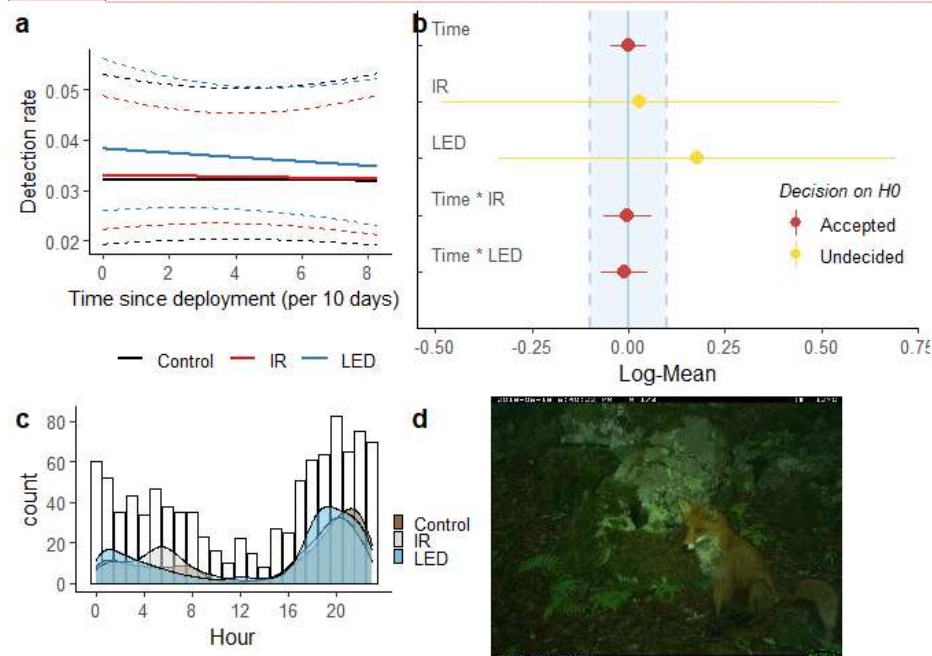
~~Red fox~~ *Figure *. a) The predicted detection rate of red foxes for each level of the flash-variable (*give levels*) for time since deployment. Lines are predicted values and ~~with C~~confidence intervals (CI) represented by dotted lines.*
b) Model parameters presented in an equivalence test. ROPE 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.

For red fox, the model explaining variation in detection rate has a moderate explanatory power (conditional R2 = 0.19), and the part related to the fixed effects alone (marginal R2) is just 0.001.

The main effect of the white LED periods were non-significantly positive (flash[LED] in table [tab:param]) compared to the IR- and control-periods (flash[IR]; Intercept)-. However, along the time since deployment-axis (time.deploy * flash [LED]) there was a negative effect, to the extent that after two months the mean detection rate sank below that of the IR periods (see figure [fig:raadyr]a). Nevertheless, CI of both white LED and IR periods almost completely overlap, and hence, are not significantly different.
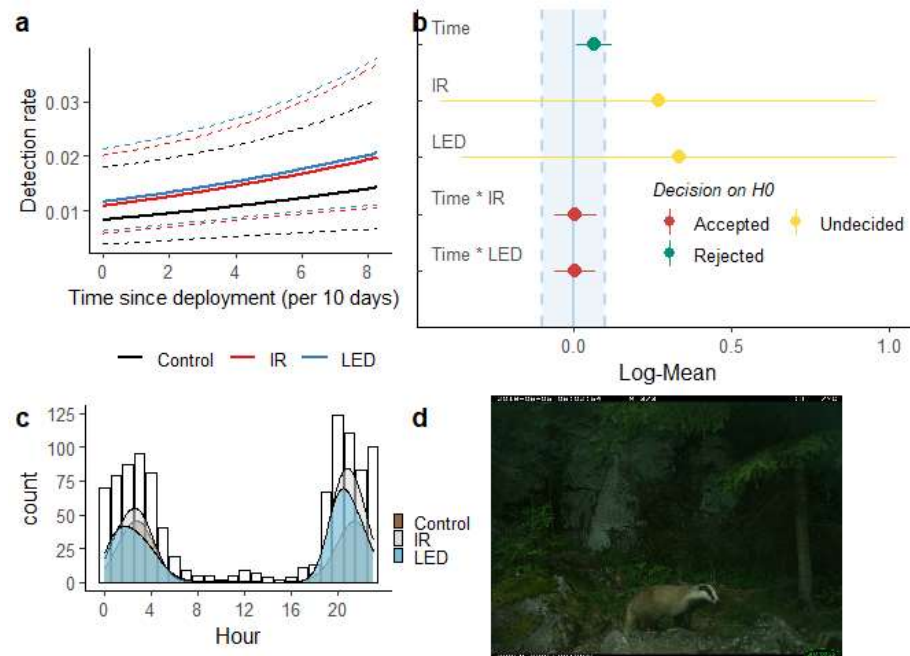
Badger

Badger a) The predicted detection rate of badgers for each level of the flash-variable. Confidence intervals (CI) represented by dotted lines.
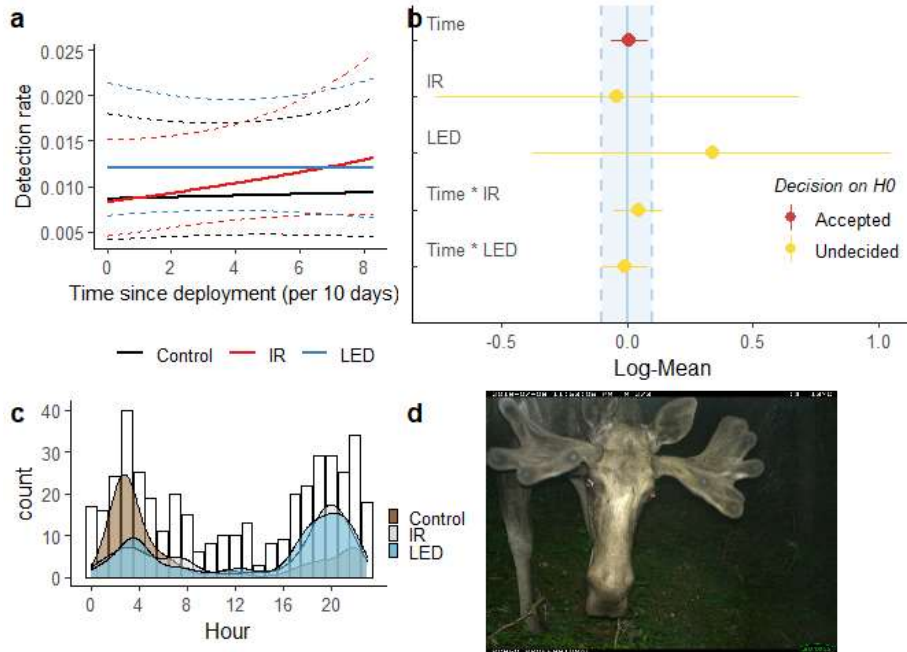*b) Model parameters presented in an equivalence test. ROPE is set to ±0.1 Log-Mean, $CI = 1 - 2 \times \alpha$.*
c) Bars represent the raw count of total badger detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a badger. DESCRIPT

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) iwas just 0.006.
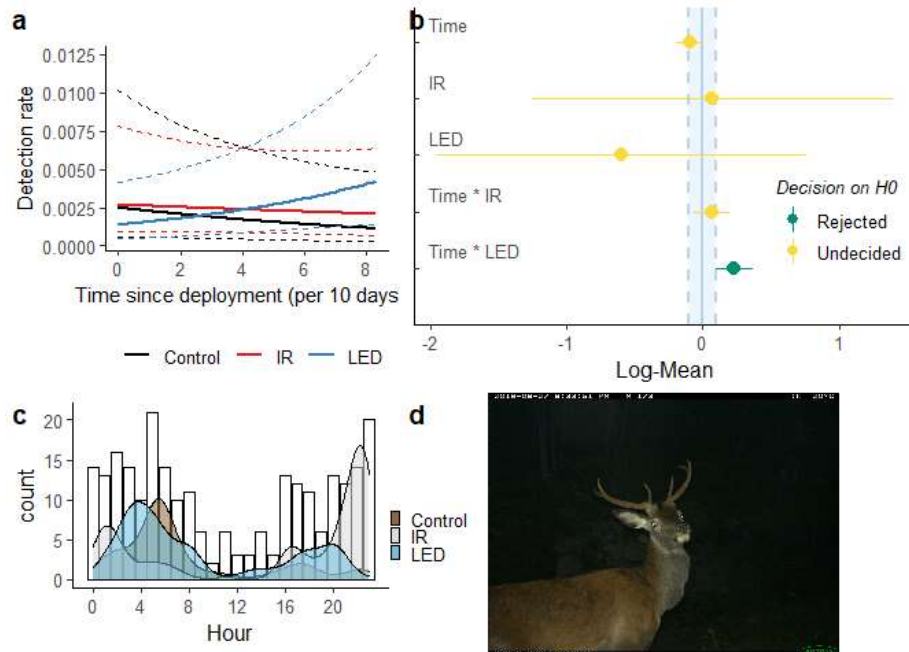
Moose

Moose a) The predicted detection rate of moose 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 detections per hour of the day, and density curves show the overall pattern for each group

d) LED-CT photograph of a Moose. DESCRIPT

Red deer

a

Detection rate vs Time since deployment (per 10 days)

Control — IR — LED

b Time, IR, LED, Time * IR, Time * LED

Decision on H0
- Rejected
- Undecided

Log-Mean

c count vs Hour
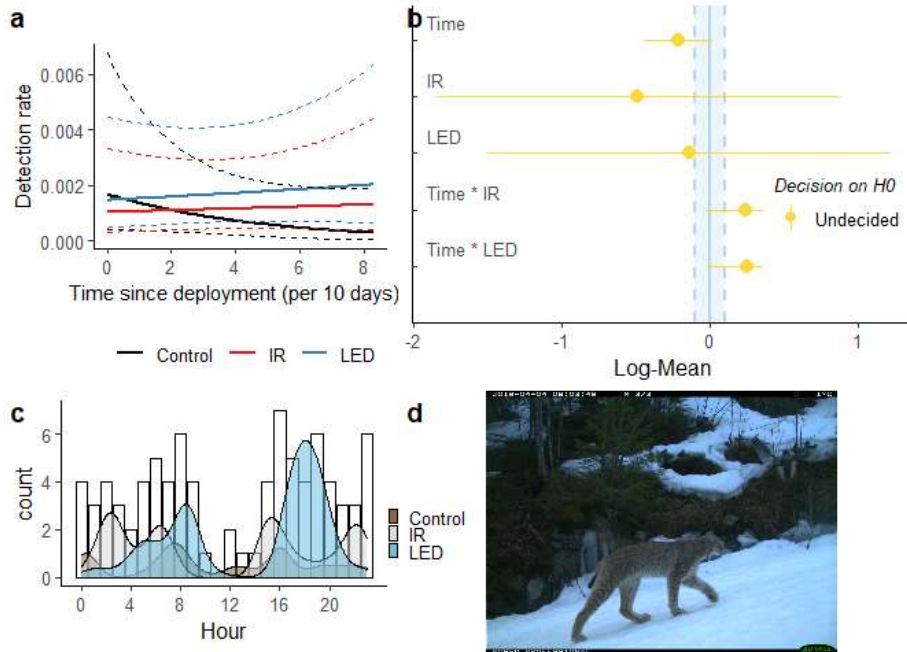
- Control
- IR
- LED

d

Red deer a) The predicted detection rate of red 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 × α.
c) Bars represent the raw count of total Red deer detections per hour of the day, and density curves show the overall pattern for each group.
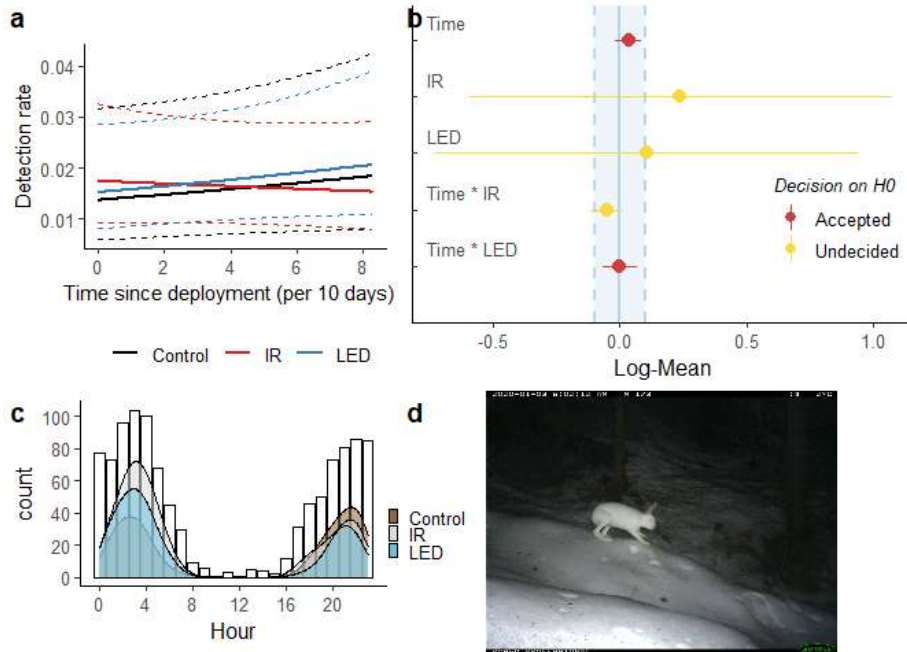*d) LED-CT photograph of a red deer. DESCRIPT*

Lynx

Lynx a) The predicted detection rate of lynx 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 lynx detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a lynx. DESCRIPT
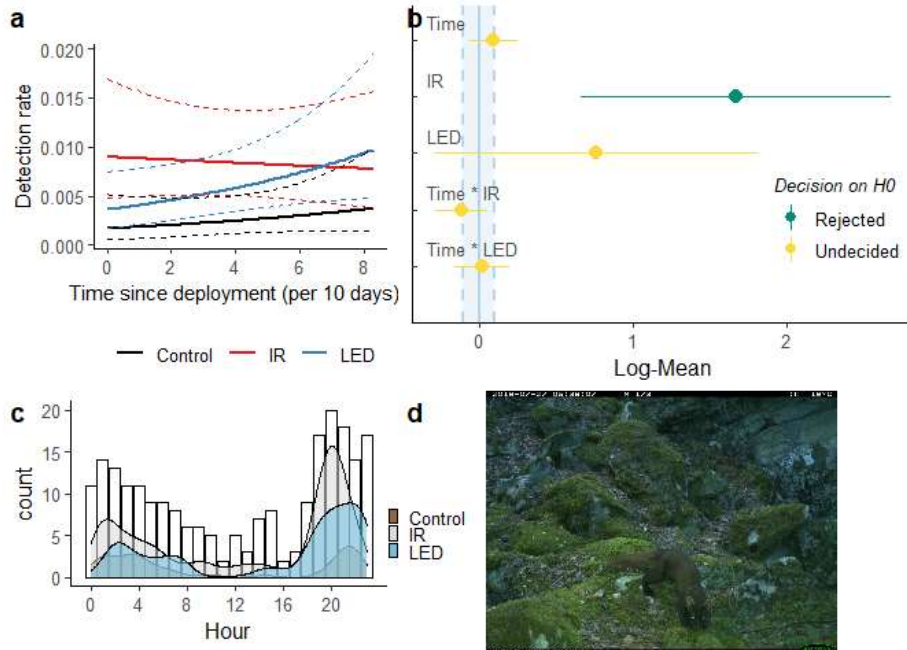
Hare

a

b

c

d

Hare a) The predicted detection rate of hares 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 hare detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a hare. DESCRIPT

Pine marten

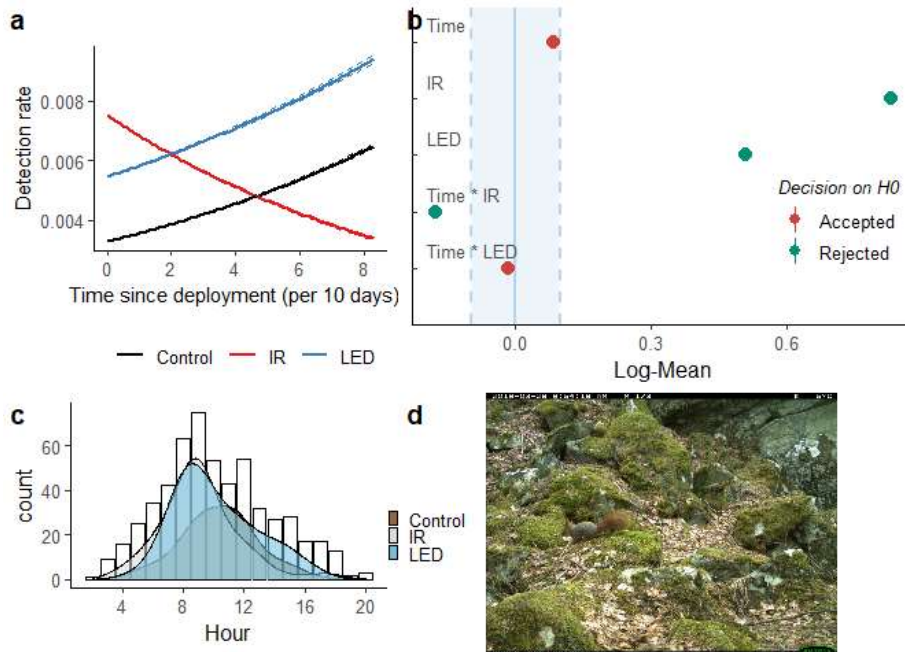**a**

b

c

d

Pine marten a) The predicted detection rate of pine martens 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 pine marten detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a pine marten. DESCRIPT

Red squirrel

Red squirrel a) The predicted detection rate of squirrels 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 squirrel detections per hour of the day, and density curves show the overall pattern for each group.
d) LED-CT photograph of a squirrel. DESCRIPT

The model for red squirrel failed to converge, and therefore the p-values should be disregarded.

Still, it is interesting to see the IR and LED-slopes crossing each other. Looking at the density plot, one would not expect that most squirrels were flashed by the white LED particularly often, as most detections are during the day.

Merknad [AM20]: Bør ikke plot opp fra denne modellen.
Høre med Inger Maren om hvorfor?