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METHODS PAPER

Effectiveness of a commercial lure to attract red fox

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Abstract

In camera trap studies, attractants may be used to increase detection probabilities of wildlife, which may help to improve estimates of abundance and occupancy. Using a semi-experimental approach, we investigated if a commercial, strawberry scented lure increased detection probability and visiting time duration in red fox *Vulpes vulpes*, and the potential reasons for variation in these parameters. In September 2020, within the Stelvio National Park, central Italian Alps, 32 camera sites were randomly assigned to 4 different treatments: 8 to commercial lure, the target of our investigation; 8 to orange aroma, to test for the "curiosity" effect; 8 to cat kibble, to test for the "likability" effect; 8 to camera trap only, the control test. Detection probability and duration of visiting time were estimated using hurdle negative binomial regression models. Daily detection probability was significantly higher with lure (0.078), orange aroma (0.086), kibble (0.075) than with camera trap only (0.031); in the first day after treatment, the time an animal spent in front of the cameras significantly increased with orange aroma (16.61 s) and kibble (33.78 s) compared to lure (9.97 s) and camera trap only (0.38 s). Our results support the use of lures to improve detection probability and visit duration in red fox, but we could not disentangle the drivers of increased parameter estimates. When consumable costs are considered, the use of the commercial strawberry scented lure does not appear justified for both detection probability and visit duration, and cheaper alternatives may be preferable.

Keywords Camera traps · Detection probability · Lures · Visiting time · *Vulpes vulpes*

Introduction

Camera traps are increasingly used as non-invasive tools for ecological research (O'Connell et al. 2010; Steenweg et al. 2017; Magle et al. 2019) and are especially useful for monitoring rare or elusive species (Burton et al. 2015). For example, camera traps make it possible to investigate the distribution, abundance, and behavior of a wide range of animals, especially mammals (O'Connell et al. 2010; Burton et al. 2015; MacKenzie et al. 2017). To obtain such information, camera traps typically require a sufficient sample of detections of the target species. However, cameras have a relatively small detection zone, which leads to limited spatial coverage in relation to the home range size of target species, with potentially negative consequences for studies dealing with wide-ranging, rare, or elusive taxa (Burton et al. 2015).

In studies addressing presence and distribution of wildlife, it is common for individuals to go undetected, which may lead to an insufficient number of detections, thereby causing inaccurate estimates of abundance or occupancy patterns (MacKenzie et al. 2006; Pease et al. 2016). To overcome these issues, thus increasing detection probabilities, attractants such as scented lure or baits have been used (Long et al. 2012). Attractants can be defined as any substance, material, device, or technique that can be used to attract a target species and optimize sampling effort (Schlexer 2008). Attractants can be classified as: (*i*) baits, which allude to the feeding and consumption instincts of the target species and involve the use of a food reward such as a carcass or raw meat (Glen and Dickman 2003; du Preez et al. 2014); (*ii*) lures (including scented, visual, and auditory lures), which attract animals by stimulating their reproduction, foraging, or marking behavior; (*iii*) natural attractants, which rely on characteristics naturally present in the environment to attract individuals (Schlexer 2008). Scented lures are the most

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widely used attractants for carnivores, including perfumes, plant extracts, and the odor of other predators (Schmidt and Kowalczyk 2006; Schlexer 2008; Banks et al. 2016). Nevertheless, the specific effects of attractants on camera trap detections are poorly studied (Ferreras et al. 2018).

The aim of this study was twofold: (*i*) to investigate if the use of a commercial, strawberry scented lure can increase detection probability and visiting time duration in red fox *Vulpes vulpes*; (*ii*) to investigate the potential reasons for changes in both parameters associated to the use of scented lure, assuming that fox would be attracted either because intrigued by an unknown smell ("curiosity" effect) or because of association with a potential source of food ("likability" effect). Foxes are known to positively react to olfactory cues, and attraction to lures such as plant essences or scent of other carnivores has been reported (e.g., Wikenros et al. 2017; Ferreras et al. 2018; Tourani et al. 2020). Consequently, we would expect that foxes be attracted by novel and heterogeneous odors, and that the attraction be consistent across the commercial lure and the smells associated with a potential source of food, or with unknown origin. If so, we anticipated that detection probability and visiting time duration would significantly increase with the use of the commercial lure, as compared to sites with no lure (Ferreras et al. 2018; Tourani et al. 2020); no specific hypothesis was formulated with respect to potential drivers of attractiveness, but the driving effect (either "curiosity" or "likability") should have similar parameter estimates to the commercial lure, while the non-driving effect should have similar parameter estimates to the sites with no lure.

Material and methods

Study area

The experiment was conducted in Valfurva, in the north-western part of Stelvio National Park, province of Sondrio, central Italian Alps (Fig. 1). The study area extends over approximately 10 km^2 and it is crossed by a river that identifies a north-facing and a south-facing slope. About 75% of the study area is covered by coniferous forests of spruce *Picea abies*, larch *Larix decidua* and stone pine *Pinus cembra*; the remaining 25% consists of low-altitude grasslands. The elevation varies from 1200 to 2000 m a.s.l., and the climate is alpine, with average temperatures of about 7–11° C during the study period.

Data collection

In September 2020, 16 camera traps were randomly deployed over the study site at a minimum distance of 200 m from each other, to avoid contamination between different treatments (cf. Randler et al. 2020). Cameras were mounted on trees at *c*. 40–50 cm of height, in proximity of wildlife trails, about 1 m from wildlife trails, facing north. In October, the same cameras were relocated in different sites, keeping a minimum distance of 200 m between both the current and the past locations, to ensure that treatments could not influence each other. Two blocks of camera traps therefore allowed to increase the number of sampling locations to $n = 32$. The entire sampling period lasted 60 days, including two treatment blocks of 30 days, one per block of

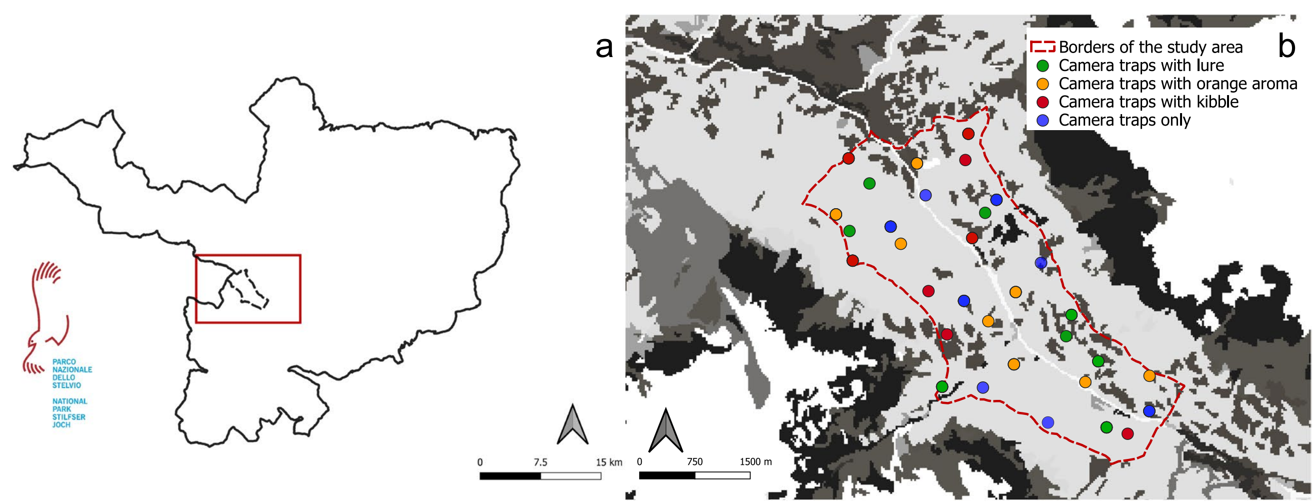

Fig. 1 On the left, location of the study area within the Stelvio National Park where the experiment was conducted to test the effectiveness of a commercial lure to attract red fox, in September–October 2020. On the right, borders of the study area and locations of the camera traps. Different treatments are shown using different colors: camera traps with commercial lure in green, camera traps with orange aroma in orange, camera traps with kibble in red, camera traps only in blue

camera traps: the first treatment period started on the 2nd of September and ended on the 1st of October. The second treatment period started on the 1st of October and ended on the 30th of October.

Each camera site was associated with one of four different treatments (i.e., $n = 8$ camera trap sites per treatment): (1) commercial, strawberry scented lure (with 2,5-dimethyl-4-hydroxy-3-furanone as active substance); (2) orange aroma normally used for baking, to test for the "curiosity" effect, i.e., to mimic an unknown smell; (3) cat kibble, to test for association to a potential source of food, i.e., to mimic a feeding reward; (4) camera trap only, used as a control site. For the treatments, we used respectively: (1) 125 ml of liquid lure; (2) 125 ml of orange aroma (62.5 ml of aroma and 62.5 ml of water); (3) 125 g of kibble pulverized and diluted in water to equal the amount of lure. All treatments were poured on branches in front of the camera, centering the camera field of view, at a distance of about 2 m, under a tree to protect the treatment from washing out effects. Lure were applied only in the first day of the two treatment blocks, and never reapplied afterwards.

To avoid potential biases related to the use of different models of camera trap, the same camera model (Cuddeback C123) was used for all treatments and locations, using the same settings. Each camera trap was equipped with black flash to minimize disturbance to the animals and set in video mode. Videos had a duration of 30 s and activation time was kept as short as possible (0.25 s). Fox videos taken at 5-min time intervals were considered independent events.

Statistical analysis

To investigate the effectiveness of the commercial lure as fox attractant, in comparison with other treatments, we used two different metrics as response variables. First, the occurrence of fox visits, i.e., whether foxes visited the site in a given day or not (binary variable 1/0), was chosen as a proxy for the ability of a treatment to increase detection probability. Next, visit duration, i.e., how many seconds foxes spent in front of the camera (count variable), was chosen as a proxy for the ability of a treatment to increase visiting time. The explanatory variables were the same for both response and included as follows: type of treatment (categorical variable with 4 levels: "lure"; "orange"; "kibble"; "camera"), treatment day (numeric variable from 1 to 30), and Julian day (numeric variable from 245 to 303). Treatment day and Julian day allowed to investigate daily temporal variation, i.e., how the effectiveness of treatments changed over time. Notably, our response variables entail two different data generating processes: in the event occurrence (1/0), zeros indicate that the animal did not visit the camera site in any given day; therefore, they denote absence and cannot be counted as time spent in front of the camera; only when the animal visited the trapping site, it was possible to count how many seconds the animal spent in front of the camera. Zero/one and count data therefore had to be modeled separately. To this aim, we built a global hurdle model where the zero/one part was modeled assuming a binomial conditional distribution, and the count part was modeled assuming a zero-truncated negative binomial conditional distribution. In the global model, the linear predictor included, for all parts, the interaction between treatment and treatment day, and the additive effect of Julian day. Dependency among events within the same camera site was accounted for by including camera ID as a random effect; furthermore, temporal autocorrelation between daily events within each camera was accounted for by including an autoregressive term, while spatial correlation between camera-events was mitigated by including the camera trap coordinates (longitude and latitude) as fixed covariates. Next, we adopted a stepwise-like model selection approach to find a simpler, optimal model, starting with the binomial part. In the first step, we compared the global model with a model without temporal correlation. In step 2, we compared the model selected in step 1 with a model without spatial correlation, while maintaining all other parametrizations fixed. In the third step, we compared the model selected in step 2 with a model where Julian day was removed. In the fourth step, we compared the model selected in step 3 with a model where the interaction between treatment and treatment day was substituted by an additive effect. In the final step, we compared the model selected in step 4 with a model without treatment day. In all steps, models were compared based on their value of Akaike Information Criterion corrected for small samples (AICc: Hurvich & Tsai, 1989), and the model with the lowest AIC value was selected at each step. Once the optimal structure for the binomial part was defined, the same stepwise-like procedure was repeated for the count data part (see details in Table 1). Both the global model and the final model were validated by visual inspection of quantile residuals (Dunn and Smyth 2018).

All analyses were conducted with R 3.6.1 (R Core Team 2019) in RStudio 1.2.5019 (RStudio Team 2019). The package "glmmTMB" (Brooks et al. 2017) was used for fitting hurdle models, the package "MuMIn" (Bartoń 2020) was used for computing AICc, while the package "DHARMa" (Hartig 2020) was used for residual diagnostics. The package "visreg" (Breheny & Burchett 2017) was used to visualize marginal effects.

Results

Throughout the sampling period, we recorded 95 fox visits: 11 at "plain" camera trap sites; 29 at camera trap sites with commercial lure; 28 at camera trap sites with orange; 27 at camera trap sites with kibble.

Table 1 Stepwise-like model selection based on Akaike's Information Criterion (AIC) for models examining the effectiveness of lure in comparison with other treatments to attract red fox, in a study area within the Stelvio National Park in September–October 2020. Model selection for the binomial part and the count data part is presented separately. The selected model is in bold (Final model). "Treatment" indicates the four treatment types (lure, kibble, orange, and camera); "treatment day" the number of the day after treatment (from 1 to 30); "*X*" and "*Y*" longitude and latitude; "autoregressive" indicates the temporal correlation term; "(1cam)" indicates the random effect of camera trap ID. For both parts, models were compared in a pairwise manner at each subsequent step (see details in the text)

Step	Binomial part	Count data part	AICc
Global model	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	1169.6
Simplify binomial part			
Step 1 (remove temporal effect)	~ treatment · treatment day + Julian day + *X* + *Y* + (1|cam)	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	1175.7
Step 2 (remove spatial effect)	~ treatment · treatment day + Julian day + autoregressive + (1|cam)	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	1177.6
Step 3 (remove Julian day)	~ treatment · treatment day + *X* + *Y* + autoregressive + (1|cam)	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	1167.5
Step 4 (remove interaction)	~ treatment + treatment day + *X* + *Y* + autoregressive + (1|cam)	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	1166.5
Step 5 (remove treatment day)	*~ treatment + X + Y + autoregressive + (1|cam)*	~ treatment · treatment day + Julian day + *X* + *Y* + autoregressive + (1|cam)	*1164.8*
Simplify count data part			
Step 1 (remove temporal effect)	*~ treatment + X + Y + autoregressive + (1|cam)*	~ treatment · treatment day + Julian day + *X* + *Y* + (1|cam)	1162.9
Step 2 (remove spatial effect)	*~ treatment + X + Y + autoregressive + (1|cam)*	~ treatment · treatment day + Julian day + (1|cam)	1159.0
Step 3 (remove Julian day)	*~ treatment + X + Y + autoregressive + (1|cam)*	~ treatment · treatment day + (1|cam)	1158.3
Step 4 (remove interaction)	*~ treatment + X + Y + autoregressive + (1|cam)*	*~ treatment + treatment day + (1|cam)*	*1152.3*
Step 5 (remove treatment day)	*~ treatment + X + Y + autoregressive + (1|cam)*	~ treatment + (1|cam)	1160.2
Final model	**~ treatment + *X* + *Y* + autoregressive + (1|cam)**	**~ treatment + treatment day + (1|cam)**	**1152.3**

The selected model (Table 1) included the effects of treatment, spatial and temporal correlation, and the random effect of camera trap in the visit occurrence (binomial) part. Instead, the model included the type of treatment in addition to days of treatment and the random effect of camera trap in the visit duration (count data) part. The final model selected did not show major violation of model assumption, as suggested by the unsystematic distribution of quantile residuals. Parameter estimates are given in Table 2. Treatments increased detection probability significantly, compared to plain camera trap sites, but there was no evidence for statistically different detection probability among treatments (Table 2, Fig. 2): daily detection probability with lure was 0.078; 0.086 with orange; 0.075 with kibble; 0.031 with camera only. The three treatments (lure, orange, and kibble) had an overall positive effect on visit duration compared to camera trap only (Fig. 3). Visit duration with lure was significantly greater than with camera trap only, while no statistically significant difference was found with orange. Kibble significantly increased visit duration compared to lure. In the first day after treatment the expected number of seconds an animal spent in front of the cameras with lure was 9.97; 16.61 s at camera sites with orange; 33.78 s at camera sites with kibble; 0.38 s at sites with only cameras. In the 15th day after treatment, it was 4.22 s, 7.03 s, 14.30 s, and 0.15 s, respectively, while in the 30th day after treatment, it was 1.70 s, 2.83 s, 5.75 s, and 0.06 s.

In the final model, for the visit occurrence part, the conditional R^2 was 0.22, while the marginal R^2 was 0.16. For the visit duration part, the conditional R^2 could not be computed because some variance components equaled zero, suggesting that the random term did not contribute to the final estimates; the marginal R^2 was 0.73.

Discussion

This study investigated the efficacy of different lures to improve detection probability and visiting time using an experimental approach in the field. The use of attractants improved red fox detection probability with camera traps. In particular, visits were similarly more frequent in camera traps with either one of the three attractants, as compared to control cameras. The presence of attractants also increased visiting time. We did not find evidence of commercial lure being significantly most effective than other used attractants.

Table 2 Parameter estimates for the final model, selected to investigate the effectiveness of a commercial lure ("lure") in comparison with other treatments (orange aroma: "orange"; cat kibble: "kibble"; camera trap only: "camera") to attract red fox, within the Stelvio National Park in September–October 2020. The table reports mean estimates of beta coefficients, with lower (LCL) and upper (UCL) bounds of their 95% confidence interval

Parameter	Estimate	95% CI	
		LCL	UCL
Count data part			
(Intercept: lure)	2.36	1.63	3.09
Treatment: orange	0.51	−0.20	1.22
Treatment: kibble	1.22	0.50	1.94
Treatment: camera	−3.28	−4.96	−1.59
Treatment day	−0.06	−0.09	−0.03
Binomial part[1]			
(Intercept: lure)	2.47	1.85	3.10
Treatment: orange	−0.11	−0.91	0.69
Treatment: kibble	0.04	−0.80	0.89
Treatment: camera	0.98	0.04	1.92
X (longitude)	−0.74	−1.18	−0.29
Y (latitude)	−0.80	−1.25	−0.35
Autoregressive term	−0.93	−1.51	−0.35

[1]In hurdle models fitted with the function glmmTMB, the binomial part estimates the probability of an extra zero. Consequently, a positive contrast indicates a higher chance of absence

Scent lures may increase detection probability when carnivores are the target species (Holinda et al. 2020). Notably, in our study, the increase in detection probability was similar with all types of attractants. Visiting time was always greater when using treatments, compared to control camera traps. While there was no support for statistically different visiting duration between commercial lure and orange essence, the use of kibbles substantially increased parameter estimates. These results do not allow us to exclude the "curiosity" or "likability" effects from the potential drivers of lure attractiveness, as this would have implied either treatment to return similar estimates to the control cameras (cf. hypotheses in the "Introduction" section). This may be partly explained by the possibility that kibbles, albeit pulverized, were more conspicuous than scents, and foxes tried to eat the remaining (as could be observed in some of the videos): in turn, commercial lure may arouse less interest in foxes compared to kibbles. For all treatments, visiting time in front of camera traps decreased steadily in the first 5 days after deployment, presumably due to the decay of the used essence (Avrin et al. 2021). Seasonality can also impact the efficiency of the essence (Heinlein et al. 2020): scent diffusion increases in hot and humid seasons, but also leads to a more rapid decay (Schlexer 2008).

Our results suggest that the use of attractants may be of aid in wildlife ecology studies: for example, the use of attractants associated with the application of capture-recapture (Garrote et al. 2012) and mark-resight (Forsyth et al. 2019) could improve estimates of abundance, both because it enhances detection probability, and because longer visiting time facilitates individual recognition (Tourani et al. 2020). The use of scents may also allow to improve occupancy estimation (Avrin et al. 2021). Nonetheless, attractants could alter movements of animal, bringing them to areas where

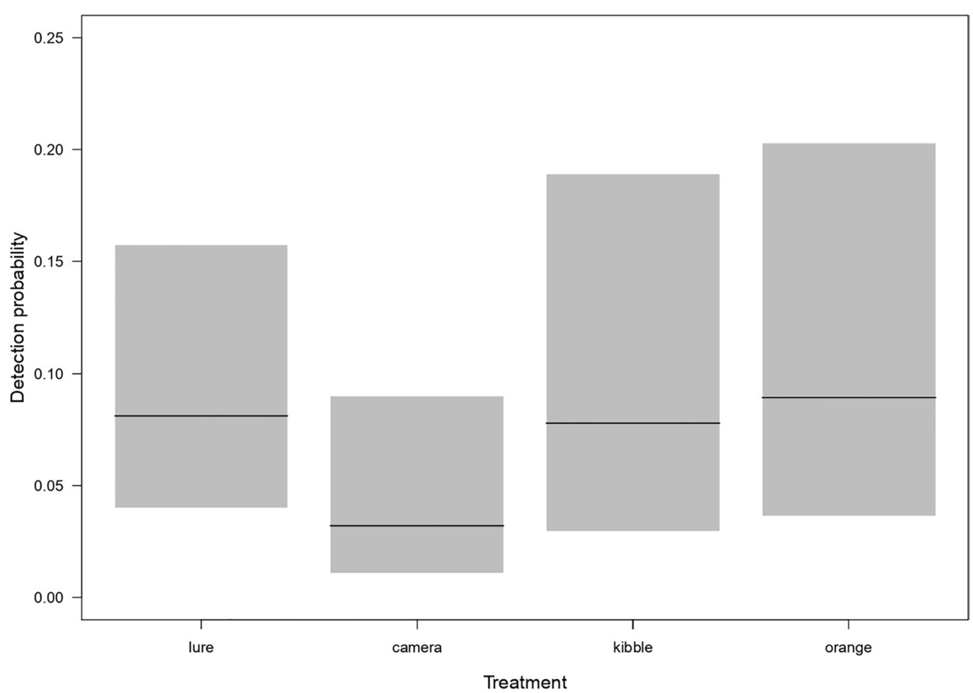

Fig. 2 Detection probability of red fox using four treatment types (commercial lure: "lure"; orange aroma: "orange"; cat kibble: "kibble"; camera trap only: "camera") at camera trap sites deployed in the Stelvio National Park in September–October 2020. Shaded areas represent the 95% confidence intervals

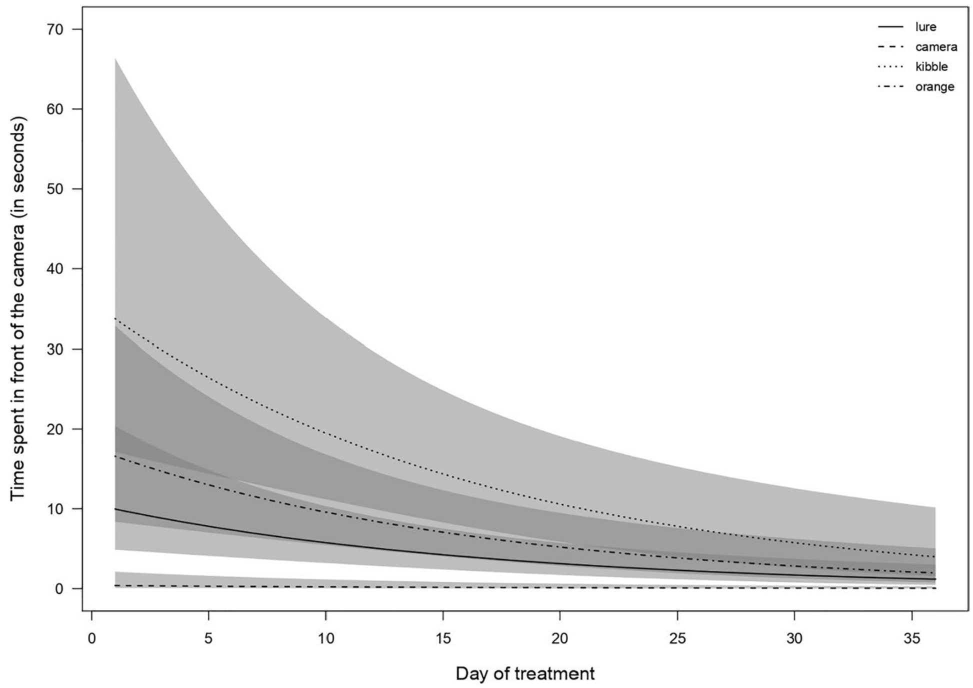

Fig. 3 Marginal effects of the final model fitted to investigate the over-time variation in time spent in front of the camera with a different treatment (commercial lure: "lure"; orange aroma: "orange"; cat kibble: "kibble"; camera trap only: "camera") to attract red fox, in a study area within the Stelvio National Park in September–October 2020. Shaded areas represent the 95% confidence intervals

they usually do not occur (Schlexer 2008; Holinda et al. 2020): in turn, this could introduce sampling bias in some estimators, either for occupancy of for abundance (cf. Fidino et al. 2020). Furthermore, the essence must be carefully selected because some lures could have different effects on both prey and predators, possibly decreasing their detectability (Fidino et al. 2020). Further studies are needed to investigate the functionality of attractants in studies with more elusive and rare predators and to understand if their pattern is similar to the one found for the fox.

Overall, our results do not support the use of the specific strawberry scented lure based on 2,5-dimethyl-4-hydroxy-3-furanone, both for detection probability and duration time in red fox, when costs and benefit are accounted for. The attractant used in this study costs about 25 euros per bottle (500 ml), for a total of 50 euros for the 8 cameras that received this treatment; similar costs were sustained for the cameras treated with orange aroma, while cameras treated with kibbles costed *c*. 4 euros overall. Considering the detection probabilities and visiting time duration obtained with the use of orange flavor and kibbles, the costs for the fox-specific commercial attractant used appear unjustified. However, it is worth noting that there are many different commercial lures on the market, and it is not possible to generalize our results to other lures and species. Tests of different attractants on other species would help to assess the effectiveness of a broader range of commercial lures on wildlife detection probability.

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Author contribution All authors contributed to the study conception and design. Material preparation and data collection were performed by Francesca Cozzi and Elisa Iacona. Data analysis was performed by Luca Corlatti. The first draft of the manuscript was written by Francesca Cozzi and Luca Corlatti and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics approval No approval of research ethics committees was required to accomplish the goals of this study because experimental work was conducted without the need for handling animals and without collection of biological material.

Competing interests The authors declare no competing interests.

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