University of Antwerp
Faculty of Science

Department of Biology

Academic year 2023-2024

Roe and fallow deer in the Drongengoed forest and surrounding area: challenges in management and monitoring in function of adaptive multifunctional big game management

REM analysis

By Imke Tomsin

Supervisors:
INBO: Jim Casaer & Lynn Pallemaerts
University of Antwerp: Hannes Svardal

Conservation Internship
Biodiversity: conservation and restoration

Table of contents

Introduction

I am still working on the introduction, but the overall structure and info I want to include is there

Accurate estimates of population density are imperative to successful wildlife management and conservation. They are necessary to inform decision-making and ensure that management actions are evidence-based. Furthermore, long-term ~~population~~ data on population densities can be used to track changes in wildlife populations over time, allowing the detection of population declines and recoveries, and analysing ~~of~~ threats to the population, such as habitat loss, fragmentation, pollution, climate change, poaching, and disease (REFS).

Paragraph about: Obtaining population data via the use of camera traps. A non-invasive and non-labour intensive way to gather population data is via camera trap networks. Whenever an individual passes through the detection zone of a camera trap, an infra-red sensor~~s~~ triggers the camera to take a series of pictures.

The Random Encounter Model (REM, Rowcliffe et al., 2008) can be used to estimate animal ~~density~~ densities using remote sensing data (here camera trap data). Contrary to capture-recapture, an older and widely used method to estimate animal ~~density~~densities, individuals do not have to be identified individually ~~identified~~, making the REM suitable to study populations of species without individually unique (natural) markings. The REM-model assumes that (1) animals behave like ideal gas particles, moving around randomly, and independently from each other, (2) animals move independently from the camera traps, thus all having an equal chance of being encountered, (3) the populations under study are closed, both geographically and demographically (Rowcliffe et al., 2008). The REM has been used for some time, and researchers continue to adapt and refine this method (ENETWILD-consortium et al., 2023).

With this research, we use the REM to estimate the population ~~density~~ densities of roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), and red fox (*Vulpes vulpes*) in the Drongengoed forest, and to study the activity patterns of these species. Furthermore, we assess how deployments with few calibration images influence the estimates, and ~~determine whether~~compare a sampling period of one month ~~would also have provided sufficient data for estimating population density, or if~~with our results of a ~~the~~ three-month sampling period ~~was necessary~~. Insights gained from comparing REMs for different subsets of the data can be valuable for the design of future ecological studies.

The fallow deer population in Drongengoed was founded almost 20 years ago (correct?) by individuals that escaped captivity (Casaer et al., 2021). Although their presence contributes to the recreational appeal of the area, … further introduce the Drongengoed and the species present, and the problems too many deer might cause.

The Research Institute for Nature and Forest (INBO) conducts research on the wildlife, specifically medium- to large-sized mammals, present in Drongengoed. Further explain other research in Drongengoed.

Materials and methods

Study location and period

Camera trap data were collected in Drongengoed forest and its surrounding area. The forest spans across an area of 750 hectares (7.5 km²), making it the biggest forest in East Flanders (Belgium). It is part of the Natura 2000 area 'Forests and moors of sandy Flanders: eastern part' (BE2300005). As shown on figure 1, the study area is divided into several zones that are managed by different actors, ~~including~~ among who the Agency for Nature and Forests (ANB, part of the Flemish government), Natuurpunt (an NGO), and several wildlife management units ('wildbeheereenheden' or WBE).

Hunting is allowed on hunting grounds ~~owned~~ leased by wildlife management units and on part of the grounds owned by ANB (i.e. dark green zones on figure 1).

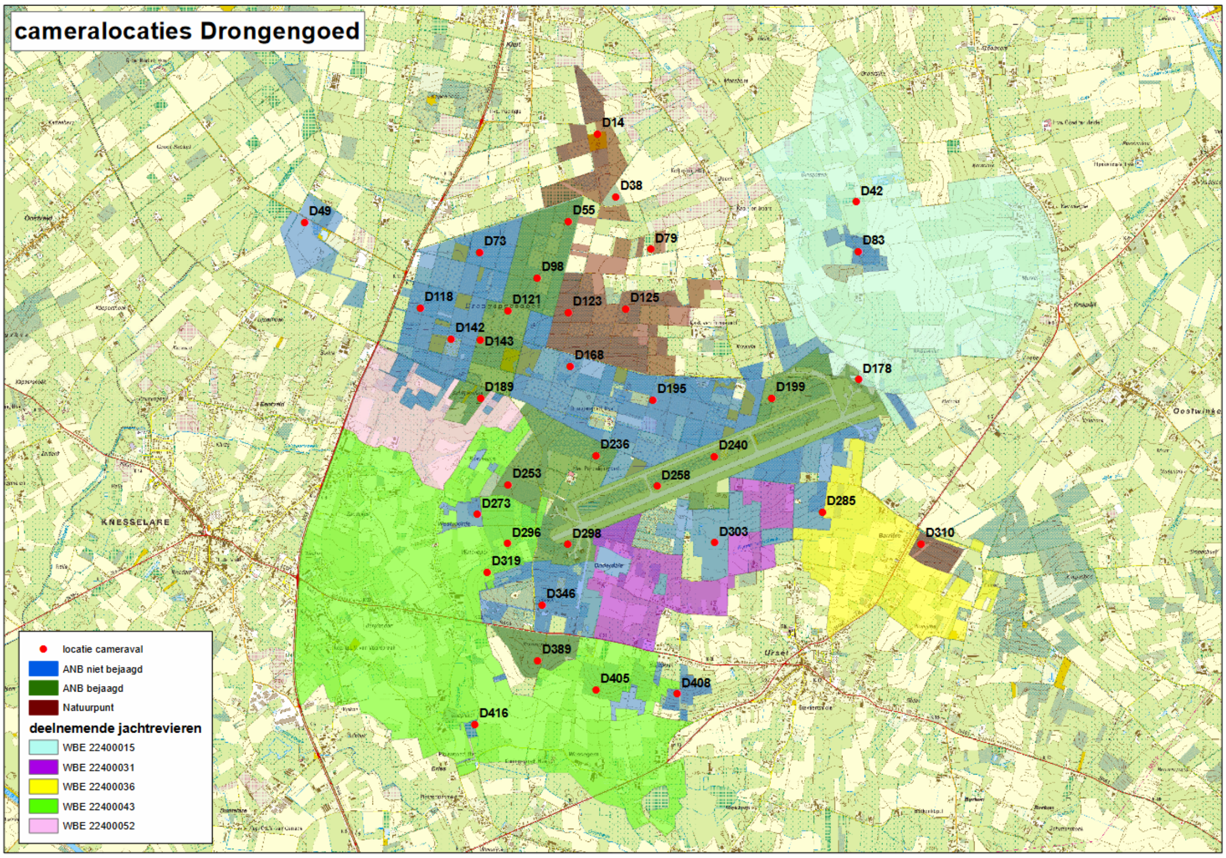

Figure 1. Map of the study area showing the sampling design. *Camera trap locations are indicated with red dots. Colours indicate ownership by different actors. Abbreviations: ANB = Agency for Nature and Forests, WBE = wildlife management unit.*

The camera trap network in Drongengoed and the surrounding area consisted of 36 camera traps insert info about brand/type of camera trap. Camera trap data used for this study were collected from the end of September 2023 until the end of January 2024. The cameras remained at the same location during the entire sampling period and~~, but their~~ SD-cards and batteries were swapped monthly. The period from installing a camera trap with an empty SD card and charged batteries, to switching these again, is considered one deployment. More info needed on sampling design or not?

Field work

The field work consisted of taking images of calibration poles ~~with~~ on each location where a the camera traps was deployed in the field (see figure 2). The calibration poles were straight, wooden poles that were marked with bands of black duct tape at intervals of 20 cm. The calibration pole was marked with one band of tape at 20 cm, two bands at 40 cm, three bands at 60 cm, four bands at 80 cm, and five bands at 100 cm height, with the height being ~~indicated by~~ the top of the group of bands. Deployment calibration images were taken by positioning the pole in front of the camera trap, perpendicular to its line of sight, and waiting ca. ten seconds to ensure a clear image could have been taken. This way, the pole was positioned at least 10 times, but ideally 20 times, at different locations across the detection zone of the camera trap. Locations ranged from very close to the camera trap, to as far as we expected the camera trap to be triggered by animal movement (ENETWILD-consortium et al., 2023).

As the calibration process has to be repeated ~~after~~ each time the position of a camera has moved, calibration images were taken each month after the batteries and SD cards of the cameras were swapped (ENETWILD-consortium et al., 2023). From September to November each camera trap was visited once a month to take calibration images (i.e. three visits per camera trap in total). Calibration images were taken by two people, so one person could pose with the calibration pole, while the other could trigger the camera by moving around in front of it. In December, eight locations were revisited, as in the previous three months at least one of the three deployment calibrations of that location turned out to have less than 10 successful calibration images. We expected this to be a problem, as sufficient deployments and sufficient calibration images are thought to be needed to have a large enough sample size.

Figure 2. Example of a calibration image. *The top of each group of bands on the calibration pole is positioned at a predetermined height above the ground, spaced at 20 cm intervals. Image taken with camera 364 deployed at location D42.*

Image processing

The processing of the camera trap images involves three steps: annotation, calibration, and tracking animal movement through picture series. Camera trap data were processed using the online platform Agouti (https://www.agouti.eu), designed for the storage, annotation, archiving and exporting ~~and processing~~ of camera trap data.

1. Annotation

Camera trap images were annotated to identify the species and number of animals present in each sequence of images. The annotation process was sped up by using the Agouti AI, trained to automatically detect, classify, and count animals in camera trap images. Furthermore, some of the motion triggered images deployments (i.e. image sequences captured between two moments of swapping batteries and SD card because animals were detected) were annotated by volunteers.

All sequences classified as containing images of roe deer, fallow deer or~~, and~~ red fox were manually verified. Sequences with observations of species not known to be present in the area, such as wolf (*Canis lupus*), red deer (*Cervus elaphus*), or wild boar (*Sus scrofa*) were also reviewed. Verifying the images was necessary, as the AI still regularly makes errors in recognising the species and counting the number of individuals, and in general to ensure that the annotation had been done in a standardised manner.

2. Deployment calibration

Agouti facilitates density estimation ~~with the~~using REM ~~with~~ given ~~its implemented~~the built-in deployment calibration tool. Deployment calibration is a part of the annotation process. Calibration images are hereby checked for all deployments, and for each different calibration pole position two points of known height on the pole are marked in the image and labelled.

3. Tracking animal movements

After annotation and deployment calibration were finished, animal movement was digitised for all image sequences containing images of roe deer, fallow deer, and red foxes. In total, 3844 image sequences contained images of these target species. Animal movement was digitised using the tracking function of Agouti. This entailed marking the position of one ~~paw~~ feet of an individual whenever it touched the ground throughout an image sequence. Whenever a sequence contained multiple individuals of the same species, only the first individual was tracked. Whenever a sequence contained multiple target species, one individual was tracked for each species. A few times, the camera trap was pushed out of position by deer, in which case the remaining image sequences from that deployment were not tracked further, as the deployment calibration would not be correct anymore.

It was not possible to track animal movement when:

- Animals walked past the camera trap too quickly
- Animals were too close to the camera, so their paws were not visible
- Animals were too far away from the camera
- Camera trap images were not clear, e.g. due to fog
- Vegetation was too high, so it was not possible to see where the paws touched the ground

Data analysis and the REM

All analyses were performed using R statistical software (v4.3.2, R Core Team, 2023). Data manipulation was done using the R packages tidyverse (v2.0.0, Wickham et al., 2019) and dplyr (v1.1.4, Wickham et al., 2023). The R packages camtraptor (v0.25.0, Oldoni et al., 2024) and camtrapDensity (v0.1.9, Rowcliffe, 2024) were used for the processing of camera trap data and REM analyses. The ggplot2 R package (v3.5.0, Wickham, 2016) was used to visualise data in bar plots.

REMs were made for different subsets of the data, and their output ~~was~~ were compared. Separate REMs were made for each species for:

1. All deployments starting in September and ending in October
2. All deployments starting in October and ending in November
3. All deployments starting in November and ending in December
4. All deployments from September until December
5. All deployments, including eight extra deployments from December-January, excluding eight deployments with less than ten calibration images
6. All deployments, including eight extra deployments from December-January, excluding eight deployments with less than ten calibration images

Results

While a considerable amount of output was generated during the data analysis, only a selection of the most interesting findings is discussed in this report.

Activity models

Part of the REM output consisted of an activity model, of which the output is shown in figure 3 (A-C). It plots the number of animals observed at each hour of the day over the whole monitoring period. These figures show that all three species are crepuscular, meaning they are most active during the dawn and dusk hours. Fallow deer (figure 3B) were more active during the day than roe deer (figure 3A) and red fox (figure 3C), and red foxes were more active during the nighttime.

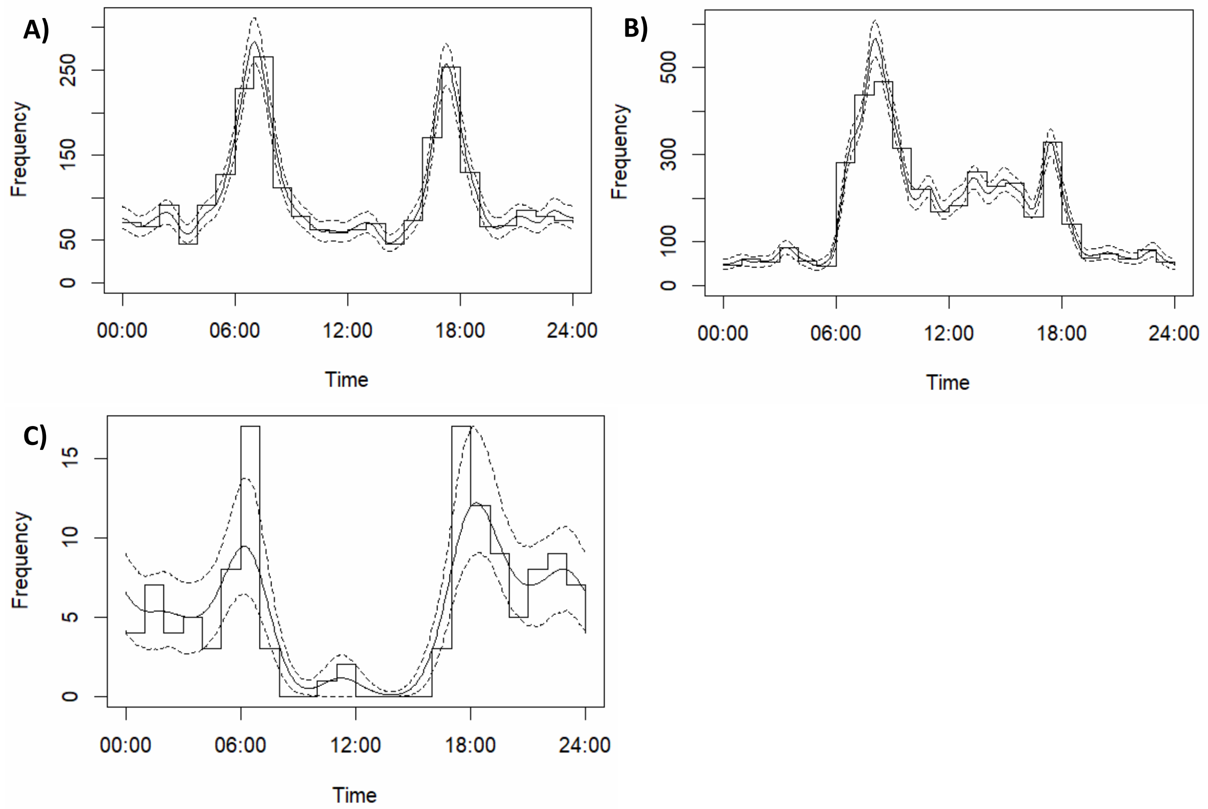

Figure 3. Activity patterns for A) roe deer, B) fallow deer, and C) red fox in the Drongengoed forest in Belgium. *The graphs shows the total number of animals observed (frequency) at a certain time of the day throughout the monitoring period. Based on camera trap data collected from September 2023 until January 2024.*

REM estimates

Table 1 shows a summary of the estimated REM parameters for the three target species. The roe deer population in Drongengoed is estimated to have a density of 29.52 ± 5.04 individuals/km². When multiplying this density estimate with the size of the Drongengoed forest, 7.5 km², we get an estimate of ca. 221 roe deer in the area. There are more fallow deer than roe deer, with a density of 43.79 ± 11.41 individuals/km², or a total estimate of 328 fallow deer in the Drongengoed forest. There are only a few red foxes, with a density of 0.37 ± 0.15 individuals/km², or a total estimate of ca. 3 red foxes in the Drongengoed forest.

The overall average speed of the animals, also called the daily range, was lower for roe deer, with 4.29 km/day, and fallow deer, with 3.51 km/day, than for red fox, with 19.68 km/day. The trap rate was highest for fallow deer with 1.19 individuals/day (individuals/camera/day, or individuals/day?), followed by roe deer with 0.73 individuals/day, and red fox with 0.04 individuals/day. The estimates for radius and angle of detection correspond to expected values for the type of camera trap used.

Table 1. Random encounter model (REM) estimated parameters for roe deer, fallow deer, and red fox. *Trap rate is the number of animal observations per unit time, v represents the overall average speed or daily range of the animals, radius and angle represent the effective detections radius and angle respectively, density is the estimated number of individuals per unit area. The standard error (SE), 95% confidence interval and coefficient of variation (CV) of the density estimate are given.*

Species	Trap rate (ind/day)	v (km/day)	Radius (m)	Angle (°)	Density (ind/km²) ± SE	95% confidence intervals	CV (%)
Roe deer	0.73	4.29	6.77	39.91	29.52 ± 5.04	21.17 - 41.16	17.08
Fallow deer	1.19	3.51	8.91	40.22	43.79 ± 11.41	26.50 – 72.36	26.05
Red fox	0.04	19.68	5.72	37.08	0.37 ± 0.15	0.17 – 0.81	40.57

Comparison of different REMs

~~The output of the different REMs was compared~~. First, a comparison was made between the REM for all deployments, and the REM for all deployments but excluding the eight deployments with less than ten calibration images. This was done to investigate the influence of including a number of deployments, in this case eight, with less than ten calibration images. There were no clear differences in the output of both REMs, except that the confidence intervals were a littler smaller when also including the deployments with less than ten calibration images.

Second, a comparison was made between the REMs for each separate month (September-October, October-November, and November-December) and the REM that combines the three months (but not the additional deployments from December-January). The comparisons are shown for each target species in figure 4 (A-I).

Discussion

The density estimates for the three target species are consistent with what we expected. They were high for both roe and fallow deer populations in the Drongengoed forest~~, but~~ and low for red fox. (maybe I can also compare this to density estimates in the literature). In general, carnivorous species, such as the red fox, tend to be less numerous than herbivores, such as roe and fallow deer. This is primarily attributed to the inefficiency of energy transfer from lower to higher trophic levels in ecosystems, leading to a higher number of herbivores necessary to sustain a smaller number of carnivores. Furthermore, there is currently no natural predator of roe and fallow deer present in the Drongengoed forest to regulate their population densities. The area is generally known for its high deer densities, as many tourists seek it out for deer spotting. Red foxes are generally solitary animals. They typically establish territories within which they live alone, except during the breeding season when they may have a mate (REF). Roe deer are mostly solitary, but can sometimes form smaller groups, while fallow deer tend to form larger herds (REFS). This was also observed in the field and on the camera trap images.

The activity pattern of red fox showed that the animals were predominantly crepuscular and nocturnal, consistent with activity patterns reported in literature (REF). Their extensive daily range compared to the deer species could be explained by their predatory behaviour, covering significant distances in search of prey, and the need to mark their territory (REFS). The lower daily range of the deer species compared to red fox could be explained by the large amount of time they spend grazing or browsing, not needing to move as far to find food (compare to findings in literature).

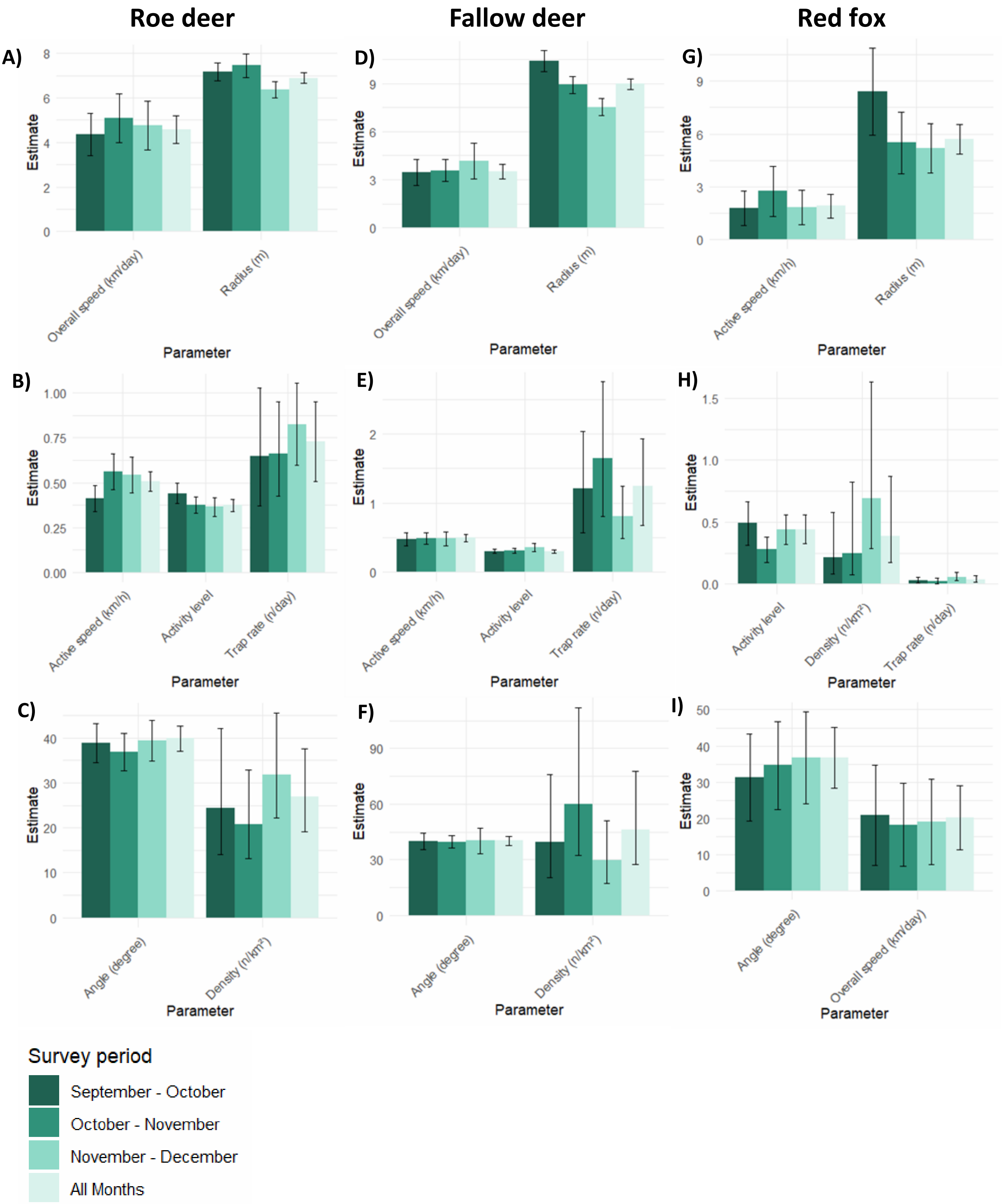

Figure 4. Comparison of estimates from four different REMs for each target species. Target species are roe deer (figures 4A-C), fallow deer (figures 4D-F), and red fox (figures 4G-I). For each species, an REM was made for: deployments starting in September and ending in October, starting in October and ending in November, starting in November and ending in December, and for the combination of all three months ('all months'), as shown in bar plots from left to right on the graphs. Error bars show the 95% confidence interval around the point estimates.

+ Maybe I should say something about the large confidence intervals.

+ Add paragraph about the comparison between the different REMs

+ Add paragraph about: implications for conservation and for future studies

Summary

I will add a short summary about the research and findings here.

Internship reflection

During the second year of my master's studies in biology: biodiversity, conservation and restoration at the University of Antwerp, I had the privilege of doing my conservation internship at the Research Institute for Nature and Forest (INBO, an independent research institute of the Flemish government), under the guidance of Jim Casaer and Lynn Pallemaerts. I was very excited to do my internship at this institute, as it had long been a place that I thought I would really love to work at as a biologist. Having greatly enjoyed my time as an intern in the wildlife management and invasive species team, I can say that this still holds true. I hope to work with them a lot more in the future. To begin, hopefully, through a research collaboration for my PhD, for which I am in the process of applying for a scholarship.

During my internship, I primarily focused on gathering population data and testing a method to estimate the population density of roe deer, fallow deer, and red fox in the Drongengoed forest in Belgium. In doing so, I learned a lot about the collection, processing, and analysis of camera trap data. Furthermore, I gained more insight into the workings of wildlife management, and the disciplines it encompasses beyond ecology.

Unexpected events, such as the theft of three camera traps, highlighted the complexities of doing fieldwork in a public space. Encountering people who expressed frustration or concern about us driving through the forest, and our presence in restricted areas, showed the importance of effective communication with locals and having a friendly, open attitude. I learned how my supervisors are actively prepared for discussions and awkward situations when encountering frustrated people. Furthermore, some of the locals we met posed challenging questions about the ethical implications of wildlife management, particularly concerning hunting practices. This further broadened my perspective on the different opinions stakeholders can have, and how to communicate with them about this.

~~Additionally, an~~An information evening was organised during my internship for the volunteers responsible for monthly visits to the camera traps, ~~where~~ when they change batteries and SD cards and upload the images to the Agouti platform. My supervisors and some colleagues of the INBO wildlife management team were present. They gave a presentation about preliminary results of the camera trap research and future goals of the project. It was very interesting to hear the questions asked by the volunteers, as there were a lot that I wouldn't have expected. I learned that you need to be prepared for much more than just questions about the presentation and specific project, as some volunteers can have very strong opinions and will wish to discuss different topics related to hunting as well.

Another valuable experience I gained during my internship was attending a driven hunt for wild boar. In this type of hunt, a group of people systematically moves through a forest or field to drive game animals, such as wild boar, towards hunters waiting at ~~tree stands~~highseats. I helped the researchers of INBO with collecting uteri of the harvested female boar, and learned how to determine the age of wild boar based on their dentition. Data ~~was~~ were also collected on the weight of the empty carcasses. All this information is used by INBO to assess ~~the health of the wild boar population~~population characteristics of the wild boar in this study area. Even though this experience was not directly relevant to the research for my internship, I learned a lot from it, as this was the first time that I attended a hunt. I found it very interesting to talk to the hunters, and to learn about their perspectives and ideas, their backgrounds etc. I was also happy to explain what I was doing there, and to learn what aspects of my internship they found most interesting. This experience changed my perspective on hunters and hunting in general, and makes me feel more confident to interact with these stakeholders later in my career.

In conclusion, my internship at INBO has not only provided me with valuable insights into wildlife management and conservation but has also broadened my perspective on interdisciplinary approaches and stakeholder engagement. I felt very welcome at INBO, had the feeling that my work was useful, and now have a clearer picture of what my job as a conservation biologist might look like in the future. Most importantly, I now know that I would really enjoy doing this type of work!

References

Casaer, J., Boone, N., Neukermans, A., Vercammen, J., Pallemaerts, L., Adriaens, T., & Huysentruyt, F. (2021). *Basisrapport voor de wetenschappelijke onderbouwing van beheerkeuzes voor grofwild in het Drongengoed*. Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.39649791

ENETWILD-consortium, Guerrasio, T., Pelayo Acevedo, P., Apollonio, M., Arnon, A., Barroqueiro, C., Belova, O., Berdión, O., Blanco-Aguiar, J. A., Bijl, H., Bleier, N., Bučko, J., Elena Bužan, E., Carniato, D., Carro, F., Casaer, J., Carvalho, J., Csányi, S., Lucía del Rio, L., … Vicente, J. (2023). Wild ungulate density data generated by camera trapping in 37 European areas: First output of the European Observatory of Wildlife (EOW). *EFSA Supporting Publications*, *20*(3), 7892E. https://doi.org/10.2903/sp.efsa.2023.EN-7892

Grolemund, G., & Wickham, H. (2011). Dates and Times Made Easy with lubridate. *Journal of Statistical Software*, *40*, 1-25. https://doi.org/10.18637/jss.v040.i03

Oldoni, D., Desmet, P., & Huybrechts, P. (2024). *Camtraptor: Read, Explore and Visualize Camera Trap Data Packages* (0.25.0) [Software].

R Core Team. (2023). *R: A Language and Environment for Statistical Computing* (version 4.3.2) [Software]. R Foundation for Statistical Computing. https://www.R-project.org/

Rowcliffe, J. M., Field, J., Turvey, S. T., & Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology*, *45*(4), 1228-1236. https://doi.org/10.1111/j.1365-2664.2008.01473.x

Rowcliffe, M. (2024). *camtrapDensity: Density Estimation Functions for camtrapDP Data* (0.1.9) [Software].

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis.* Springer-Verlag New York. https://ggplot2.tidyverse.org

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., … Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, *4*(43), 1686. https://doi.org/10.21105/joss.01686

Wickham, H., François, R., Henry, L., Müller, K., & Vaughan, D. (2023). *dplyr: A Grammar of Data Manipulation* (1.1.4) [Software]. https://CRAN.R-project.org/package=dplyr

Appendix 1: Time schedule

Table A1: time spent on the different internship activities expressed in full days and half days, and a description of the activities.

Date	Time spent	Description of activities
11/09/2023	Full day	Meeting, discussion of internship and field work, explanation on how to use Agouti to annotate camera trap images
26/09/2023	Full day	Field work Drongengoed
26/10/2023	Full day	Field work Drongengoed
8/11/2023	Full day	GitHub explanation, attended monthly meeting of the wildlife management and invasive species team, annotation of camera trap images in Agouti
19/11/2023	Full day	Attended a pressure hunt on wild boar and helped with data collection on dead boar
27/11/2023	Full day	Field work Drongengoed
6/12/2023	Full day	Annotation and calibration of camera trap images in Agouti
20/12/2023	Full day	Annotation and calibration of camera trap images in Agouti
17/01/2024	Full day	Annotation and calibration of camera trap images in Agouti, introduction to the code in R used for tracking animals throughout picture series
31/01/2024	Half day	Information evening with the Drongengoed volunteers that swap camera trap SD cards and batteries
4/03/2024	Full day	Annotation and calibration of camera trap images in Agouti
8/03/2024	Full day	Writing additional code in R for the tracking of animals throughout picture series, start writing report
11/03/2024	Full day	Finalising R code, starting on report, making an export of Agouti
22/03/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
25/03/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
26/03/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
11/04/2024	Half day	Tracking roe deer, fallow deer and foxes through photo series
14/04/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
15/04/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
17/04/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
23/04/2024	Full day	Tracking roe deer, fallow deer and foxes through photo series
26/04/2024	Full day	REM analyses in R, writing report
28/04/2024	Full day	Writing report
29/04/2024	Half day	Meeting to discuss results, tracking of additional deployments
03/05/2024	Full day	Writing code for additional analyses in R and visualisation of results
08/05/2024	Full day	Writing report and meeting to discuss new results
09/05/2024	Full day	Writing report, writing code for additional plots
10/05/2024	Full day	Writing report

Appendix 2: Signed initial summary of goals and activities

Summary conservation internship

For my conservation internship, I will be working at the Research Institute for Nature and Forest (INBO) in Belgium with Dr. ir. Jim Casaer, Lynn Pallemaerts, and colleagues from the research group Wildlife Management and Invasive Species. My internship is titled 'Roe and fallow deer in the Drongengoed forest and surrounding area: challenges in management and monitoring in function of an adaptive multifunctional big game management'.

So, I will work on a case about wildlife management in the Drongengoed forest in Belgium, where INBO aims to reduce the numbers of fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*) via deer management, as their big populations pose a threat to vulnerable plant species and forest rejuvenation and expansion. A monitoring proposal has already been developed, and management and monitoring have started.

I will be working on a smaller project within this major project, in which I will use camera traps to test a photogrammetry method for measuring the distance of animals relative to the camera. This knowledge can be used to determine the effective area sampled and the speed of movement of the animals based on consecutive images, which together allow to estimate the density of unmarked animals.

At each camera trap in the field, images will be taken of calibration poles at different distances from the camera. Calibration poles will be at least one meter long and marked at 20 cm intervals. They will allow to map pixels of the images to real world ground positions relative to the camera. The 'map' of each camera trap will then be used to estimate the positions of animals on pictures taken by that trap.

I will spend about a week doing fieldwork in the Drongengoed forest to take the calibration images. I will be doing this in the first semester, in October, and will then have to wait a few months to receive the camera trap data. The rest of my internship I will spend at the headquarters of INBO in Brussels, where I will learn to work with the Agouti platform for the processing of camera trap images. The work for my internship will thus be spread over the whole academic year (2023-2024), with the fieldwork in the first semester, and the data analysis and writing of my report in the second semester.

With this internship, I hope to further improve my modelling skills, and to learn new skills such as the use of the Agouti platform. I also hope to gain a lot more insight in general in big game management and the challenges that go with it. Finally, I am excited to experience what it's like working at the INBO, a vital research institute for nature conservation in Flanders.

Supervisor signature: