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Update on the activity of the European Observatory of Wildlife (EOW) - campaign 2024

ENETWILD-consortium, Guerrasio T, Acevedo P, Alves PC, Apollonio M, Arakelyan M, Arnon A, Beatham S, Berde L, Berdión O, Bicho C, Blanco-Aguiar JA, Bleier N, Blūms K, Burgui Oltra JM, Bužan E, Carniato D, Carvalho J, Casaer J, Conte LA, Csányi S, Dal Mas M, Del Frate M, Della Libera F, Del Val H, De Waele V, Dijkhuis LR, Duniš L, Durova J, Dutta T, Ertürk A, Fernandes N, Ferroglio E, Forti A, Gačić D, Gavashelishvili A, Gruychev G, Guimaraes N, Gutiérrez I, Henrich M, Heurich M, Hillström L, Jansen PA, Janječić M, Ježek M, Kashyap B, Keuling O, Kropil R, Licoppe A, Liefting Y, Martínez-Carrasco C, Olano I, Olejarz A, Ozoliņš J, Palencia P, Platovšek Z, Plis K, Podgorski T, Pokorny B, Radonić M, Rodrigues M, Rodríguez D, Rowcliffe M, Santos J, Smith GC, Sola de la Torre J, Soyumert A, Šprem N, Stoyanov S, Tanjević T, Thomas E, Torres RT, Vergara M, Vicente J, Watthez Q, Wierzbowska I, Zanet S, and Scandura M

Abstract

The European Observatory of Wildlife (EOW), developed within the ENETWILD project, has been active since 2021 as a collaborative network dedicated to designing and applying standardized protocols for harmonized data collection on key mammal species and their pathogens. By doing so, the EOW enhances the quality and consistency of information available for wildlife management and risk assessment across Europe. Since its establishment, the network has generated data through a camera-trapping protocol based on the Random Encounter Model (REM) for density estimation. Image sequences from camera traps are processed using the Agouti platform, which provides dedicated tools for managing camera-trapping projects. The workflow also integrates photogrammetry and an analytical pipeline that streamlines the direct estimation of REM parameters from acquired images. During the 2024 campaign, 58 study sites across 23 European countries were monitored by 36 institutions. This effort produced density estimates for numerous mammal species. In this report, we present results for the five most intensively monitored species: wild boar, European roe deer, red fox, red deer, and European badger. We also describe efforts to extend the network to areas affected by African Swine Fever (ASF) or located near infected zones, providing valuable information for disease management. Protocol improvements further standardized results generation and reduced human error. Together with the adoption of a new data policy, these advances led to the creation of the EOW database—an openly accessible resource containing REM-based density estimates from EOW sites. Finally, networking activities have been undertaken to build connections with other international initiatives and to promote EOW's work at international conferences.

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Key words: harmonized protocol, camera trapping, density estimation, random encounter model, wildlife monitoring

Correspondence: biohaw@efsa.europa.eu

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Summary

Background: The European Observatory of Wildlife (EOW), established under the ENETWILD project, aims to strengthen Europe's capacity to monitor wildlife populations by adopting international standards for data collection, refining methodologies for density estimation, and promoting collaborative open-data frameworks for transnational wildlife monitoring and management. As part of this effort, the EOW team developed a standardized protocol for estimating mammal population densities using camera trapping and the Random Encounter Model (REM). A key feature of this protocol is the integration of photogrammetry, which generates a three-dimensional reconstruction of the camera's field of view through calibration. This enables direct derivation of REM parameters—such as speed, activity, and day range—from recorded image sequences. Image processing and parameter estimation are supported by the Agouti platform, which has been enhanced to streamline the workflow. Since 2021, ENETWILD partners and stakeholders have applied this protocol to estimate mammal densities at an expanding network of study sites across Europe.

Objectives: This report summarizes activities carried out during the 2024 EOW campaign, detailing network development, protocol implementation, and results. Particular focus is given to the five species with the most density estimates: wild boar (Sus scrofa), European roe deer (Capreolus capreolus), red fox (Vulpes vulpes), red deer (Cervus elaphus), and European badger (Meles meles). The report also highlights the creation of an open-access EOW database and the release of a new data policy.

EOW campaign 2024: A total of 36 institutions from 23 countries monitored 58 study sites—the highest number in a single campaign to date. These efforts produced numerous density estimates, with wild boar being the most monitored species (55 estimates), followed by roe deer (45) and red fox (40).

Networking initiatives: The EOW initiative was promoted through presentations at major international conferences, including the IX European Congress of Mammalogy (ECM9), the 14th European Vertebrate Management Conference, the 98th meeting of the German Society for Mammalian Biology, and the International Wildlife Congress 2025. Collaborations with international initiatives such as Euromammal, Snapshot Europe, EUP AH&W, and Commission-supported projects like Biodiversa+ continued through 2024–2025, fostering synergies in wildlife monitoring and disease prevention.

Conclusions: Between 2021 and 2024, the EOW expanded its network of study sites while refining methodologies and technological tools. The resulting data, unprecedented in scope, have already been used to improve wild boar spatial models for African Swine Fever (ASF) risk assessments. Notably, nine study sites within infected areas and nine near infection borders provided valuable data for managing this disease. Minor protocol improvements further standardized data and reduced human error. These advances led to the creation of the openly accessible EOW database on Zenodo (https://doi.org/10.5281/zenodo.14961352), governed by a new data policy that regulates

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access and collaborative use for scientific publications. The scale and precision of results demonstrate the success of the collaborative approach.

Perspectives and recommendations: The network has expanded significantly, but further efforts are needed to establish study sites in every European country and improve representation of the northern bioregion. Outreach and collaborations are expected to attract new participants, further strengthening the network. Continuous protocol refinement will enhance data quality and utility. Finally, new pilot initiatives are integrating REM-based density estimation with data collection on vectors and pathogens, aligning with the broader goal of large-scale harmonized wildlife monitoring in Europe.

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1. Introduction

Addressing health risks that arise from interactions between wildlife, domestic animals, humans, and their activities increasingly depends on accurate information about animal populations. In particular, data on species abundance are essential for evaluating the likelihood of pathogen transmission from wild hosts to livestock and people. Diseases such as African Swine Fever (ASF) in pigs and Avian Influenza in birds and mammals are major global threats to animal production systems, having already inflicted heavy economic losses on the pig and poultry sectors.

Wild mammals are central to the dynamics of these pathogens: wild boar is the principal reservoir of ASF, whereas small- to medium-sized carnivores are most frequently implicated in the spread of Avian Influenza (ENETWILD consortium et al. 2024a). To improve preparedness and response, European and national institutions increasingly call for reliable density estimates of several mammalian species, which are fundamental inputs for risk assessments linked to disease outbreaks.

In this context, the ENETWILD consortium, during its first framework contract entitled "Wildlife: collecting and sharing data on wildlife populations, transmitting animal disease agents" (Specific Contract number: OC/EFSA/ALPHA/2016/01–07) put substantial efforts in evaluating and refining approaches for estimating wildlife numbers. Over recent years, the group has published open-access protocols tailored to wild boar (ENETWILD consortium et al. 2018), wild ruminants (ENETWILD consortium et al. 2020a), and wild carnivores (ENETWILD consortium et al. 2020b). The consortium has also compiled and harmonized hunting statistics, making them a useful source of data for large-scale spatial analyses (ENETWILD consortium et al. 2019). Such analyses, however, require consistent and trustworthy information gathered from a broad range of representative areas and countries across Europe.

Among the various techniques examined, automated monitoring tools such as camera traps (CT) offer a practical balance between accuracy and cost, making them suitable for standardized use over wide areas. Building on this, ENETWILD designed a unified protocol that integrates camera-trapping methods with digital tools, enabling applications not only by academic researchers but also by trained professionals in the field.

Since 2021, the consortium has started to complement the initial approach, i.e. collating available wildlife data at a continental scale and harmonize them, with a reversed one, aimed at collecting data in a harmonized way using common protocols. With this purpose, ENETWILD started to establish an international framework based on voluntary collaboration in coordinated monitoring at observation sites, that gave birth to the European Observatory of Wildlife (EOW, www.wildlifeobservatory.org, ENETWILD Consortium et al. 2022a, 2022b, 2023a). The EOW has grown year after year recruiting collaborators across Europe, reaching over 30 participating institutions and 44 observation sites in 2023.

In the last years, the activity of collecting wildlife abundance data at the EOW sites was paralleled by new activities on pathogens, with the aim to upgrade to an integrated monitoring (wild animals and pathogens) under the one-health paradigm.

1.1 Background and terms of reference as provided by the requestor

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The contract entitled "Wildlife and One Health: wildlife ecology, health surveillance and interaction with livestock, human population, and environment" (framework contract number: OC/EFSA/BIOHAW/2022/01) was awarded by EFSA to the University of Torino, leading a partnership that includes 27 institutions among partners and subcontractors. Being this project developed on the footprint of the previous ENETWILD (2017-2023), from here, we refer to this framework contract as to the ENETWILD2.0 project. The Specific Contract 3 (SC3) of the framework contract refers to "Wildlife ecology, health surveillance and interaction with livestock, human population and environment".

Within SC3, Work Package 3 (WP3 – Data generation) refers to the generation of new data of presence and abundance of wildlife and its pathogens in a network of sites across Europe.

Specifically, task 3.1. of WP3 deals with the generation of density estimates through camera traps (CTs) in Europe, especially for wild boar monitoring.

Deliverables of this task are:

- EOW results (CT based data) from season 2024 of all target species.
- Storage of the density data in Zenodo.

1.2 Scope of the report

This report summarizes the activities carried out in 2024, in relation to the generation of reliable density data of wildlife (selected species of wild ungulates and carnivores) using the CT-based harmonized protocol implemented by the network of observation sites of the EOW in Europe.

The report describes the CT campaign 2024 and the development of the network. Results are summarized for five target species, three ungulates and two carnivores, namely wild boar (*Sus scrofa*), European roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), red fox (*Vulpes vulpes*) and European badger (*Meles meles*).

Here are also provided details about the efforts made to further improve the protocol implementation raising levels of standardization and automatization, as well as to define an official data policy and to expand networking activities.

2. The observatory approach

The main aim of the EOW is to increase Europe's capacities to monitor wildlife populations by establishing international standards for data collection, offering guidance on estimating wildlife densities, and fostering collaborative, open-data networks to advance comprehensive wildlife monitoring.

The EOW is designed to function as an international observatory, bringing together a network of monitored sites where various stakeholders and institutions collaborate on systematic data collection. Each year, participants voluntarily join a specific data campaign (e.g., «campaign 2024»), committing to implement the proposed protocol and providing all necessary information for their selected locations. Once part of the network, they gain access to comprehensive resources, including detailed documentation, online training modules, digital

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tools, continuous guidance from the EOW coordination team and have the chance to be involved in outreach initiatives and scientific production.

Applying a standardized, validated protocol ensures that collected data are fully comparable across sites, eliminating the need for later harmonization, unlike datasets such as hunting bags. By participating in the EOW, stakeholders gain access to reliable wildlife density estimates that can be used for a variety of purposes, including setting hunting quotas, mitigating damages, or evaluating disease risks. Data can be compared between regions with different ecological conditions or management approaches, offering valuable insights into population dynamics and the consequences of specific management regimes.

More recently, parallel activities have been launched at EOW sites focusing on vectors and pathogens, leading to the promising use of these areas as open-air observatories to monitor possible changes in the circulation of potential biological hazards.

This approach is particularly beneficial for administrations and institutions seeking to promote integrated, evidence-based strategies for managing wildlife populations and diseases.

2.1 Network constitution and organization

The European Observatory of Wildlife (EOW) was created in 2021 to function as a coordinated international framework for monitoring wildlife species and pathogens. Its foundation built on earlier pilot efforts to apply a common field protocol (ENETWILD consortium et al. 2019), but for the first time it brought together a structured network of study sites. In its inaugural year, 19 sites across 13 European countries tested an experimental approach for estimating wild boar density based on camera trapping and implementing the Random Encounter Model (REM; Rowcliffe et al. 2008), which estimates abundance without requiring the individual recognition of the animals. To support implementation, participants received training embracing survey design, field operations, and data analysis. The outcomes of this first coordinated effort were promising, marking the start of the network's growth.

During the following campaign, in 2022, the observatory included 36 partners, monitoring 48 sites in 28 countries (ENETWILD consortium et al. 2023a). Although the initial ENETWILD project was scheduled to close by July 2023, another EOW campaign was launched that summer, running until December and overlapping with the beginning of ENETWILD 2.0. This transitional year still achieved strong engagement, with 30 institutions contributing data from 44 sites in 22 countries. During 2024 the EOW network faced a further considerable expansion that led to the monitoring of 58 study sites over 23 different European countries.

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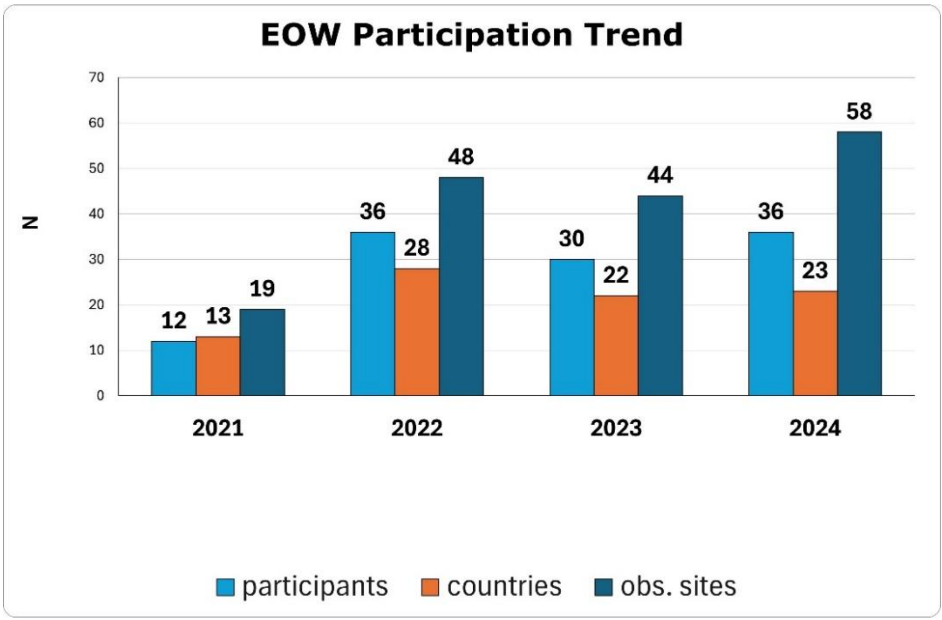

Figure 1. EOW participation over the years.

A central element of the EOW's strategy has been the adoption of Agouti (Casaer et al. 2019, ENETWILD consortium et al. in press; Fig. 2), an online platform developed and managed by two consortium partners—Wageningen University (WUR) and the Research Institute for Nature and Forest (INBO, Brussels).

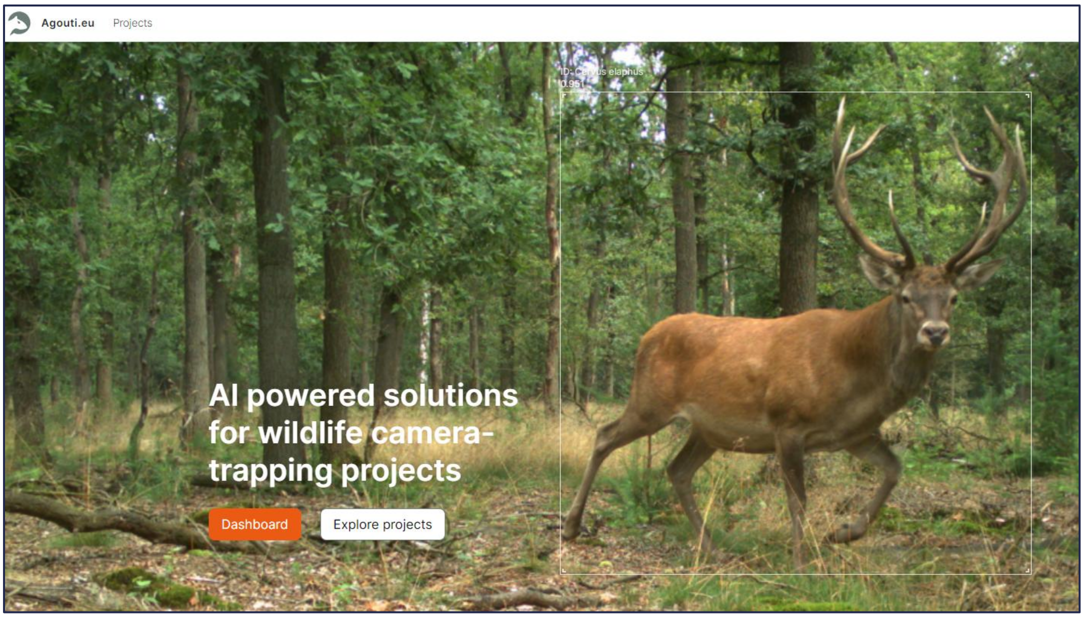

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Figure 2. Homepage of the Agouti (agouti.eu) platform for management of camera trapping projects.

Agouti acts as both a digital archive and platform for the processing of camera-trap material. It supports all steps of the workflow, including calibration of devices and sampling areas, annotation and identification of species in image sequences, and tracking of animal movements in front of the camera. Continuous updates have added functions aimed at automating the process, thereby reducing operator workload, increasing standardization and accelerating the production of final estimates.

At first the EOW began with a limited number of participants, many of which were ENETWILD partners already involved in other monitoring activities. Participation has since grown through voluntary enrolment, now comprising academic institutions, wildlife and forestry research bodies, environmental administrations, territorial authorities, non-governmental organizations, natural parks, and hunting associations.

Network coordination is entrusted to UNISS and IREC, which oversee administrative and technical management. Coordinators’ tasks include securing annual agreements with participants, circulating revised protocols and documentation, organizing scheduled training and online meetings, and providing methodological support for survey planning, field execution, data processing, and analysis. They also maintain collaboration with the Agouti development team to optimize digital infrastructure, collect feedback from members, consult the advisory board (see below), and compile periodic reports on the observatory’s activities.

In 2024, an advisory board was formally appointed, consisting of Marcus Rowcliffe (Institute of Zoology, Zoological Society of London), Jim Casaer (Research Institute for Nature and Forest – INBO, Brussels), and Pablo Palencia (University of Oviedo). Role of this board is to advise on methodological standards, analytical improvements, and assurance of data quality.

2.2 Protocol for density estimation

Though the European Observatory of Wildlife was established to enable coordinated and collaborative collection of wildlife and pathogens data across a network of “observatory” sites in Europe, its primary aim has been to improve estimates of population abundance for target species that can serve as potential hosts for pathogens responsible for emerging diseases.

To generate robust density estimates across multiple species, the consortium reviewed the advantages and limitations of available methods (ENETWILD consortium et al. 2018, 2020a, 2020b) and selected camera trapping as the most suitable approach. Camera trapping is non-invasive, widely applicable, cost-effective, and capable of providing reliable population data. Its main limitation is the restricted spatial coverage of each sampling unit, which reinforces the suitability of a network-based observatory approach.

Camera-trap surveys typically require the definition of multiple trapping locations arranged according to a specific sampling design. Cameras are deployed with pre-defined settings for a minimum duration, capturing images or short videos whenever triggered by animal

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movement. Collected images are then classified for species identification, often assisted by artificial intelligence (AI), and subsequently analysed.

Over the past two decades, numerous camera-trap-based methods have been developed to estimate wildlife abundance. Some require individuals to be identifiable through natural markings or tagging. Since this is not feasible for most species targeted by the EOW, the observatory considered approaches that do not rely on individual identification. The most widely used methods include:

- Random Encounter Model (REM; Rowcliffe et al. 2008)
- Camera Trap Distance Sampling (CTDS; Howe et al. 2017)
- Random Encounter and Staying Time Model (REST; Nakashima et al. 2018)
- Time-to-Event Model (TTE; Moeller et al. 2018)
- Association Model (AM; Campos-Candela et al. 2018)

Following preliminary trials in the Iberian Peninsula (Palencia et al. 2022), the EOW adopted a standardized REM approach. This model applies the "ideal gas theory" to animal movements (Hutchinson & Waser 2007), estimating density based on encounter rate, animal speed, and intrinsic characteristics of the camera's detection field. Animal speed is the most challenging parameter and can be derived either from spatial ecology studies using GPS collars or directly from camera-trap data (Rowcliffe et al. 2016).

The REM density formula is expressed as:

$$D = \frac{y}{t} \frac{\pi}{vr(2 + \theta)}$$

Where:

- y = number of encounters
- t = total survey effort
- v = daily movement range (activity × speed)
- r = effective detection radius
- θ = effective detection angle

The REM method relies on the following assumptions:

I. Camera traps are randomly positioned relative to animal spatial distribution.

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II. Animals within the camera's detection area are detected with certainty.

III. Camera presence does not influence animal movements or behaviour.

IV. The population remains closed during the survey period.

REM has proven robust even in the presence of non-random or non-independent animal movements (Rowcliffe et al. 2013) and its reliability has been validated across multiple mammal taxa (Anile et al. 2014; Cusack et al. 2015; Caravaggi et al. 2016; Waltert et al. 2020; Palencia et al. 2021, 2022; Guerrasio et al. 2022; Jensen et al. 2022; Morrison et al. 2022). Nonetheless, precise application is critical, as technical errors can bias parameter estimation. The EOW has progressively refined procedures to reduce manual steps and associated biases (ENETWILD et al. 2022c, 2024b).

The updated REM-based protocol implemented by EOW participants is fully documented (Appendix A) and comprises the following steps:

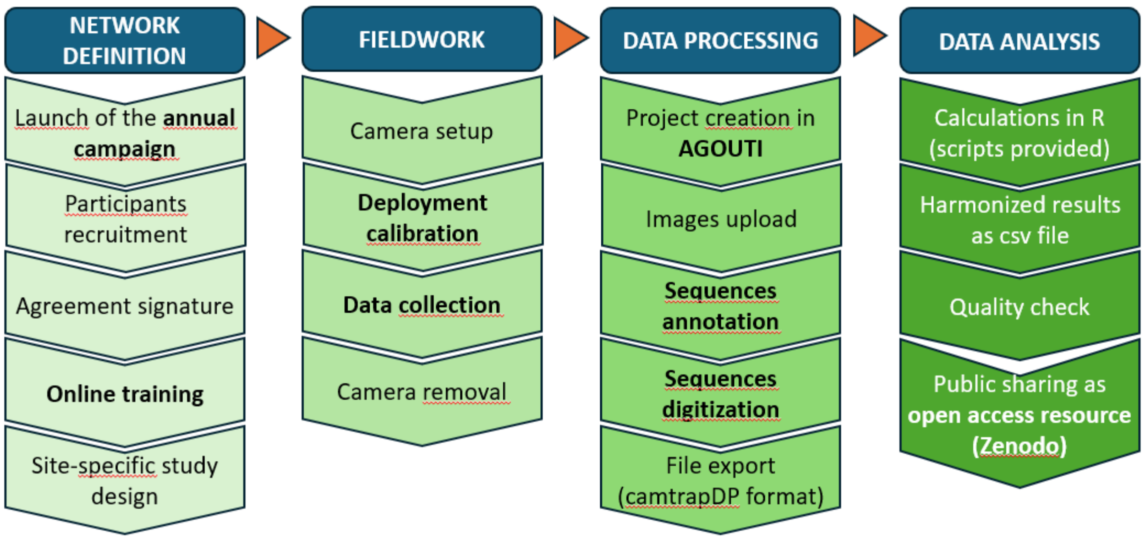

Figure 3. EOW protocol diagram showing the steps of each phase of the campaign.

When defining a study area, choices are often driven by management priorities or logistical considerations, but the area must also fulfil certain conditions. Camera-trap sampling points can be placed using a completely random, systematic random, or grid-based random strategy. In most cases, researchers establish a systematic grid with evenly spaced locations. A minimum of 36 sites should be monitored, either all at once or divided into two or three sessions lasting at least four weeks each, after which cameras are relocated to new grid points. Importantly, no lure or attractant must be used at camera trap sites.

A key step in REM studies is determining the speed of animals while they are active. This is achieved through photogrammetry, which produces a 3D digital reconstruction of the camera's field of view. The process involves two calibrations: one for the camera model and

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one for each deployment (Wearn et al., 2022). Camera calibration, carried out before the field survey, is specific to the type of camera and its settings and is only performed once in Agouti. Deployment calibration is conducted *in situ* using a calibration pole. The pole is placed upright on the ground at several positions within the camera's field of view while photographs are taken. These calibration images are later processed in Agouti allowing the implementation of photogrammetry.

In Agouti, the workflow begins with project creation and the import of calibration and deployment images. The software aggregates images into sequences and enables annotation with details such as species identity, group size, sex, age, and behaviour. Artificial intelligence can assist with this process by excluding blanks and human triggers or, if desired, by directly identifying species. Within the annotated sequences the animal paths are then tracked within the camera's detection zone using a specifically designed tool, providing measurements of both distance travelled and time spent (Fig. 3).

Figure 4. Screenshot of the Agouti tracking tool allowing to mark the animal position in each picture and necessary to estimate instantaneous speed and day range

In the final stage, processed data are exported from *Agouti* in **camtrapdp** format as a compressed zip file. These files are then imported into **RStudio** (Posit Team, 2024; *RStudio: Integrated Development Environment for R*, Posit Software, PBC, Boston, MA. Available at: http://www.posit.co/). The analysis is carried out using the **camtrapDensity** package (https://github.com/bencevans/camtrap-detector), which was designed specifically to compute and visualize model parameters as well as density estimates.

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The analysis procedure is standardized and does not require the user to be skilled in the use of R. The final product of the analysis process is a csv table where the results obtained are neatly summarized. This is then shared with the EOW Team, which merges it to the main EOW database where all the results obtained within the EOW are listed and made openly accessible in Zenodo after quality check.

3. EOW campaign 2024

According to the EFSA requests, big efforts were made towards a network expansion and the inclusion of new study sites with specific features. Specifically, study sites with presence of ASF or close to the infected areas were prioritized, as well as study sites with presence of wetlands as environment of possible interest for the Avian Influenza.

3.1 Monitored areas

In total, 58 study sites were monitored by 36 collaborating institutions over 23 countries. This is the highest number of study sites ever monitored within the EOW during a single campaign, showing that the approach proposed by the EOW is being successful, with new collaborators willing to join each campaign.

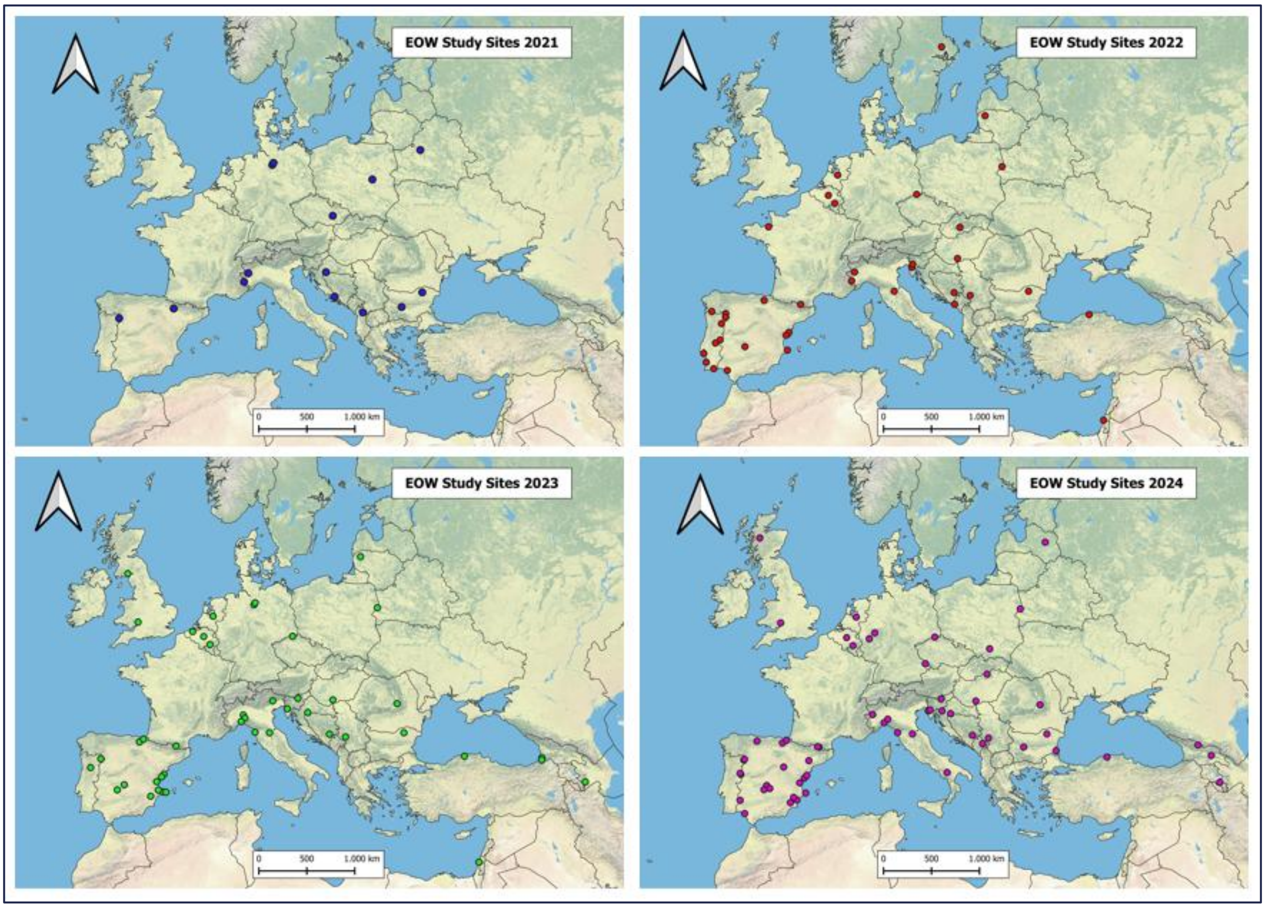

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Figure 5. Maps of the distribution of the EOW study sites during the different annual campaigns from 2021 to 2024. The number of monitored study sites was 17 in 2021, 39 in 2022, 44 in 2023 and 58 in 2024.

Maps in Fig. 5 show how the EOW, from its constitution onwards, gradually increased the number of study sites monitored. The current distribution of the study sites within the EOW network is comprehensive of the vast majority of the European countries, with very few still missing (considering that Belarus, Russia and Ukraine are out of the picture due to conflicts).

The current study sites distribution also provides valuable insights in the dynamics related to the ASF spread. In fact, of the 58 study sites monitored during the 2024 campaign, nine are in ASF infected areas, while nine were closer than 100 km from the ASF frontline (Fig. 6). The implementation of the EOW protocol in such areas represents an important chance to collect valuable information about how wild boar population density, together with other ecological and management variables, influence the spread of the virus and how it may change after the onset of an outbreak.

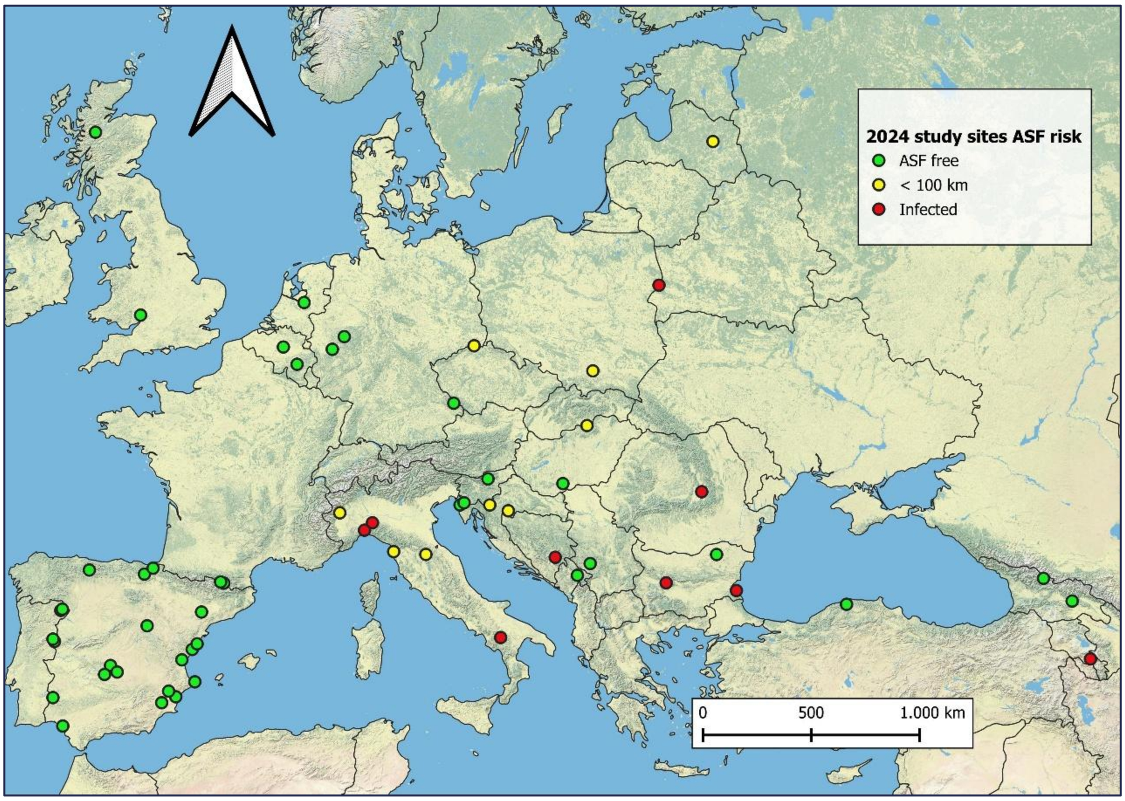

Figure 6. Distribution of the 58 EOW study sites during the 2024 campaign with respect to the presence of African Swine Fever (ASF). Study sites with no presence of ASF are shown in green, those closer than 100km from an infected area are shown in yellow and infected ones in red.

3.2 Monitored Species

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The protocol implemented within the EOW network allows to target multiple species optimizing the efforts of the collaborators. In fact, each medium to large mammal present in a study site and having a sufficient number of contacts, can be targeted with the proposed methodology. With this approach, density estimates for multiple species, that most times would have required specific monitoring activities, can be obtained implementing a single and standardized protocol and then digitizing the movements of the target species.

The bar graph in figure 7 shows the number of density estimates obtained for different species over the 58 study sites monitored during the 2024 campaign.

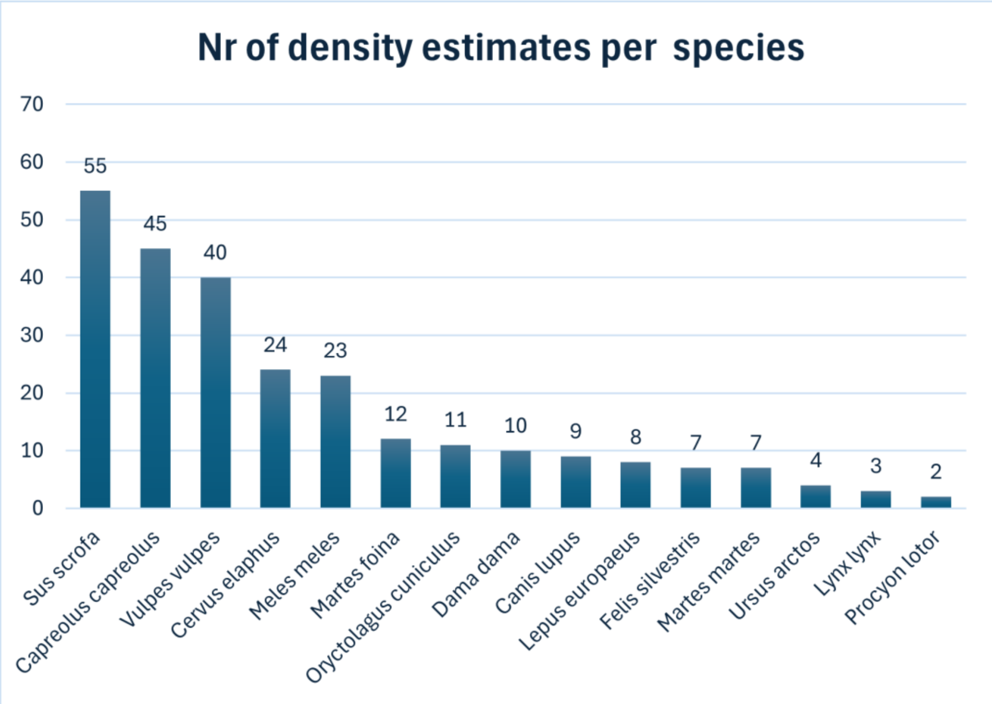

Figure 7. Graph showing the number of density estimates obtained for a selection of species (wild ungulates, carnivores and lagomorphs) during the 2024 campaign over the 58 monitored sites.

It must be noted that not all the requirements stated in the protocol to obtain unbiased estimates were always matched.

In this report, we focused on five, relatively common, species with the highest number of density estimates in the network: wild boar, European roe deer, red fox, red deer and European badger.

The results described in the following sections only considered the estimates obtained with at least 40 observations.

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The results commented in the following paragraphs are reported in the EOW database, available at the following link: https://zenodo.org/records/17083924.

3.2.1 Wild boar

During the 2024 campaign, wild boar (Fig. 8) density estimates were provided for 55 study sites from 23 countries, however five of these estimates were obtained from less than 40 observations and were therefore not included in the statistics below.

Figure 8. Wild boar (*Sus scrofa*).

The number of wild boar CT sequences obtained during the field activities ranged between 5 and 5864. Five areas did not reach the minimum number of observations.

In more than two thirds of the 50 sites considered wild boar density estimates were lower than 10 ind/km^2, while only six study sites had densities higher than 15 ind/km^2 (Fig. 9). About two thirds of the study sites returned a trapping rate lower than 0.5 events/day, while only three had it higher than 1 events/day.

Most of the monitored wild boar populations had a day range between 5 and 10 km/day with only four populations reaching values above 25 km/day.

Almost all the considered density estimates had a CV lower than 40% with 17 study sites returning density CV lower than 30%. Only four density estimates had a CV higher than 50%.

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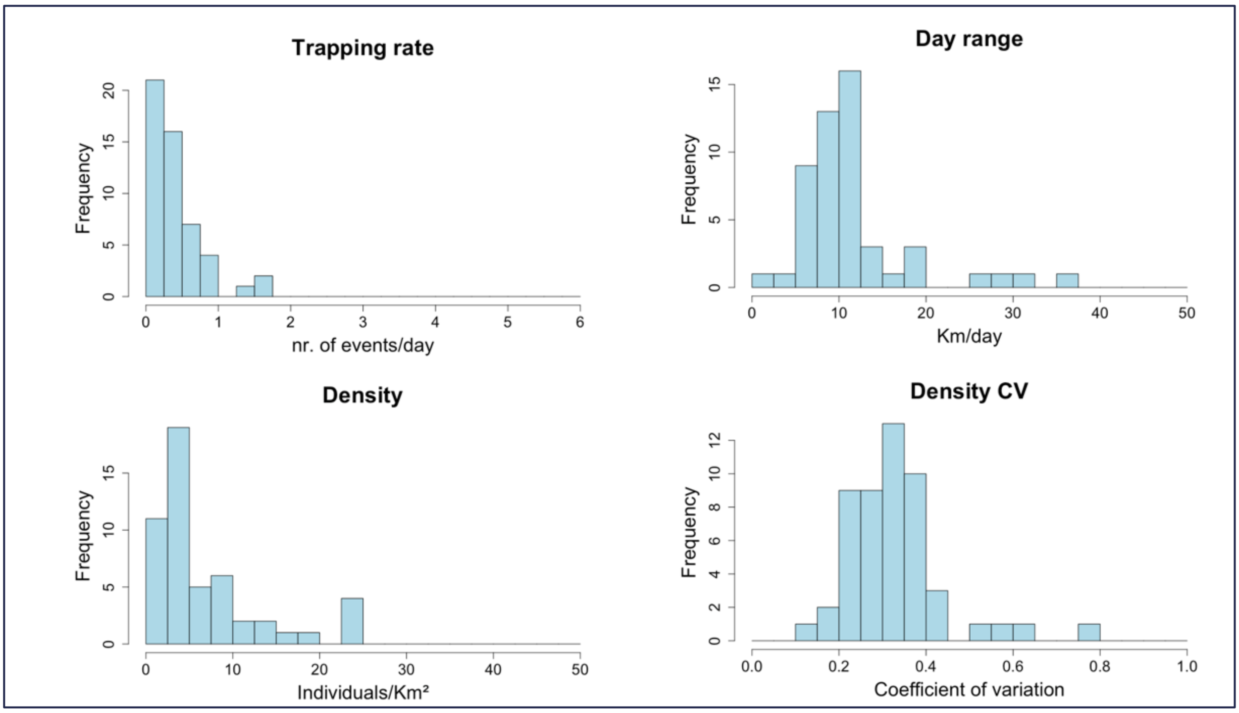

Figure 9. Distribution of trapping rate, day range, density and its coefficient of variation (CV) estimated from wild boar CT sequences in 50 study sites in 2024.

3.2.2 Roe deer

During the 2024 campaign roe deer (Fig. 10) density estimates were provided for 45 study sites from 21 countries, however six of these estimates were obtained from less than 40 observations and were therefore not included in the statistics below.

Figure 10. Roe deer (*Capreolus capreolus*).

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Roe deer density was mostly lower than 10 ind/km^2, and more than half of the density estimates considered were lower or equal to 5 ind/km^2 (Fig. 11).

Trapping rate was mostly lower than 0.4 events/day, with only two study sites with a higher rate than 0.8 events/day.

More than half of the monitored populations had a day range between 2.5 and 7.5 km/day, with the maximum value of 23.8 km/day obtained in one study site in Latvia.

Density CV was lower than 45% in all but one study site. For more than half of the estimates the CV value was lower than 30%, with six study sites where it was lower than 20%.

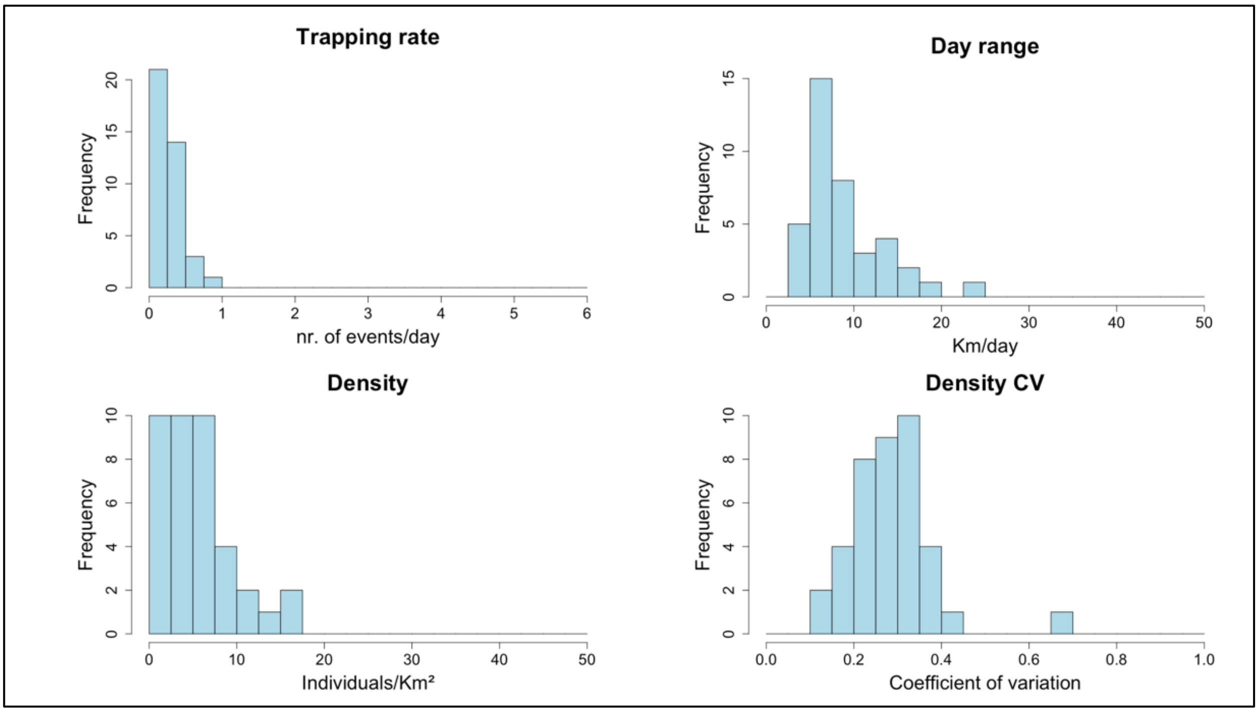

Figure 11. Distribution of trapping rate, day range, density and its coefficient of variation (CV) estimated from roe deer CT sequences in 39 study sites in 2024.

3.2.3 Red fox

During the 2024 campaign red fox (Fig. 12) density were provided for 40 study sites from 15 countries; however seven estimates were obtained from less than 40 observations and were therefore not included in the statistics below.

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Figure 12. Red fox (*Vulpes vulpes*).

Red fox density was mostly lower than 3 ind/km^2, and more than half of the density estimates considered were lower or equal to 1.5 ind/km^2 (Fig. 13).

Trapping rate was mostly lower than 0.2 events/day, with only two study sites with a rate higher than 0.5 events/day.

About half of the monitored populations had a day range lower than 15 km/day while only three populations had higher day ranges than 30 km/day.

Density CV was mostly lower than 35% and only in three study sites it was higher than 50%.

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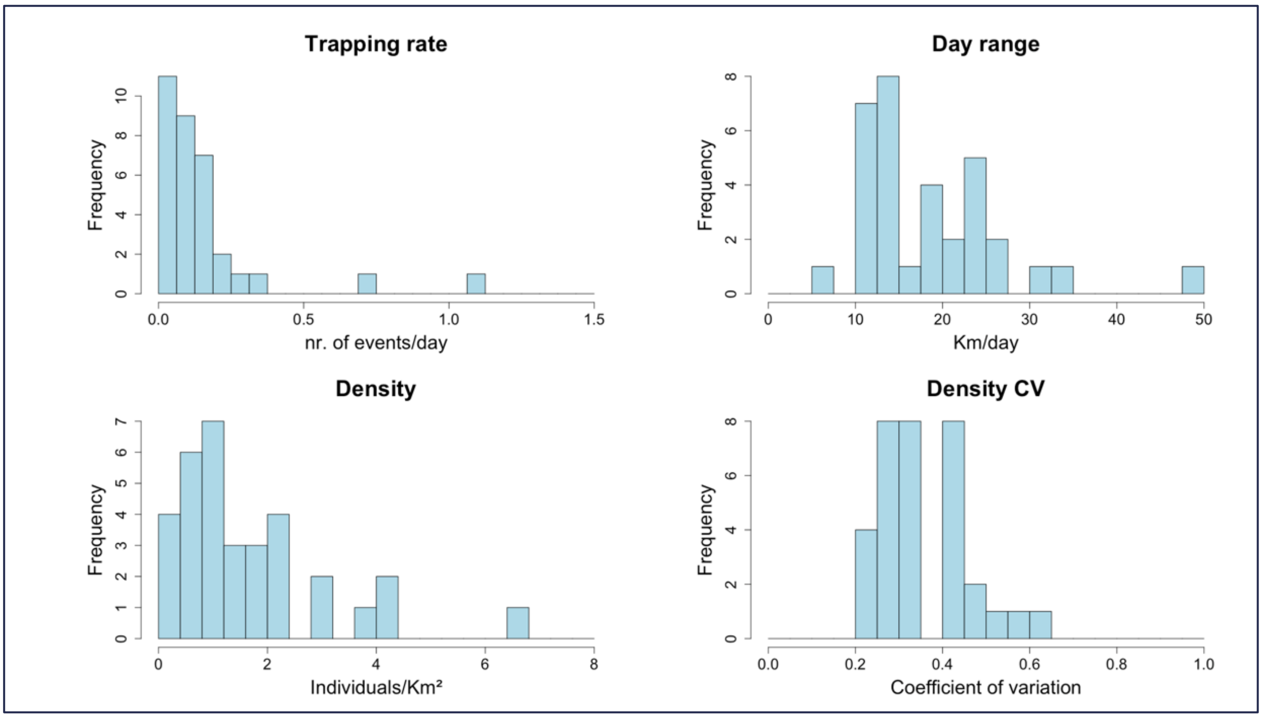

Figure 13. Distribution of trapping rate, day range, density and its coefficient of variation (CV) estimated from red fox CT sequences in 33 study sites in 2024.

3.2.4 Red deer

During the 2024 campaign red deer (Fig. 14) density estimates were provided for 24 study sites from 18 countries; however, one of these estimates was obtained from less than 40 observations and was therefore not included in the statistics below.

Figure 14. Red deer (*Cervus elaphus*) female with calf.

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Red deer density (Fig. 15) was mostly lower than 10 ind/km^2, and half of the density estimates considered were lower or equal to 5 ind/km^2. A single study site, in Spain, showed very high red deer density (>40 ind/km^2).

Trapping rate was mostly lower than 0.5 events/day, with only four study sites with a higher rate (one with an exceedingly high rate, i.e. >5 events/day).

About half of the monitored populations had a day range spanning between 2.5 and 10km/day, with maximum values of 22.6 km/day in a Spanish study site.

Density CV was mostly lower than 50% and in more than half of the estimates the CV value was lower than 30%, while only two study sites had it higher than 50%.

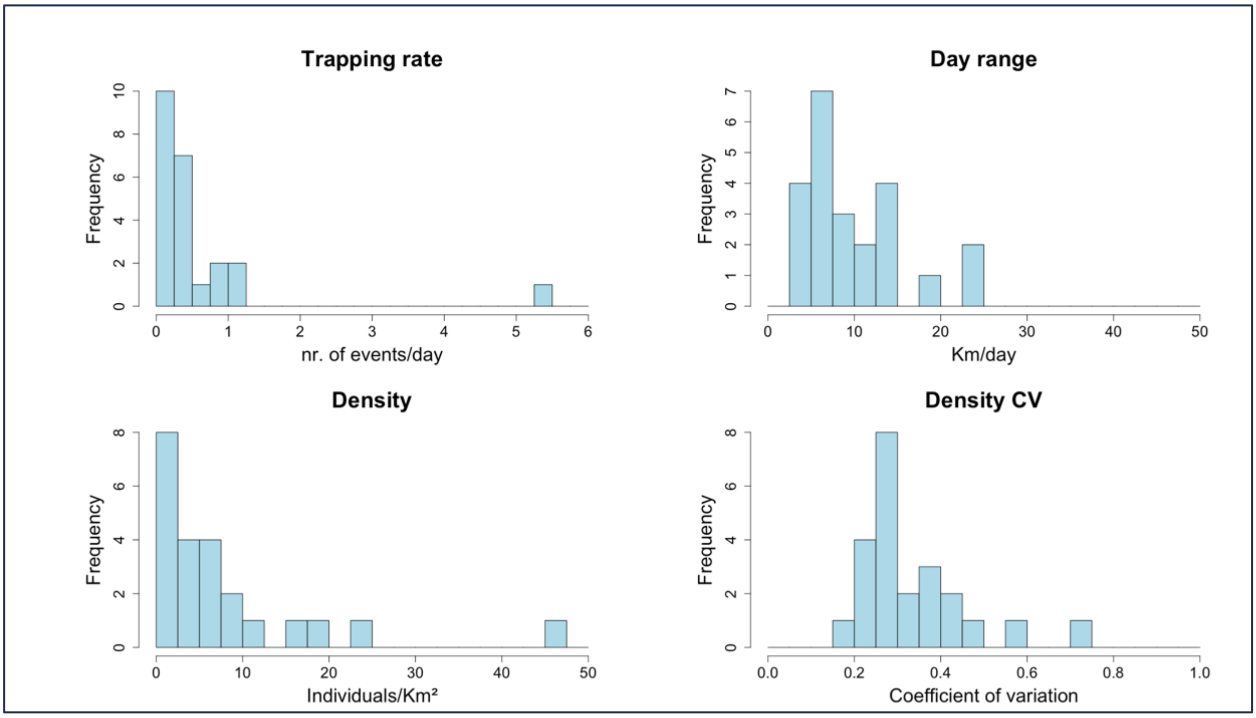

Figure 15. Distribution of trapping rate, day range, density and its coefficient of variation (CV) estimated from red deer CT sequences in 23 study sites in 2024.

3.2.5 European badger

During the 2024 campaign badger (Fig. 16) density estimates were provided for 23 study sites from 18 countries; however, 17 of these estimates were obtained from less than 40 observations and were therefore not included in the statistics below.

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Figure 16. European badger (*Meles meles*).

Badger density was mostly <1 ind/km^2, but one study site in Belgium and one in Italy had densities of 2.4 and 3.6 ind/km^2, respectively (Fig. 17).

Trapping rate was mostly lower than 0.05 events/day, with only two study sites with higher rates.

Two thirds of the monitored populations considered had a day range spanning between 6 and 10 km/day, with maximum values of 15 km/day in a Spanish study site.

All values of density CV were between 30% and 50%.

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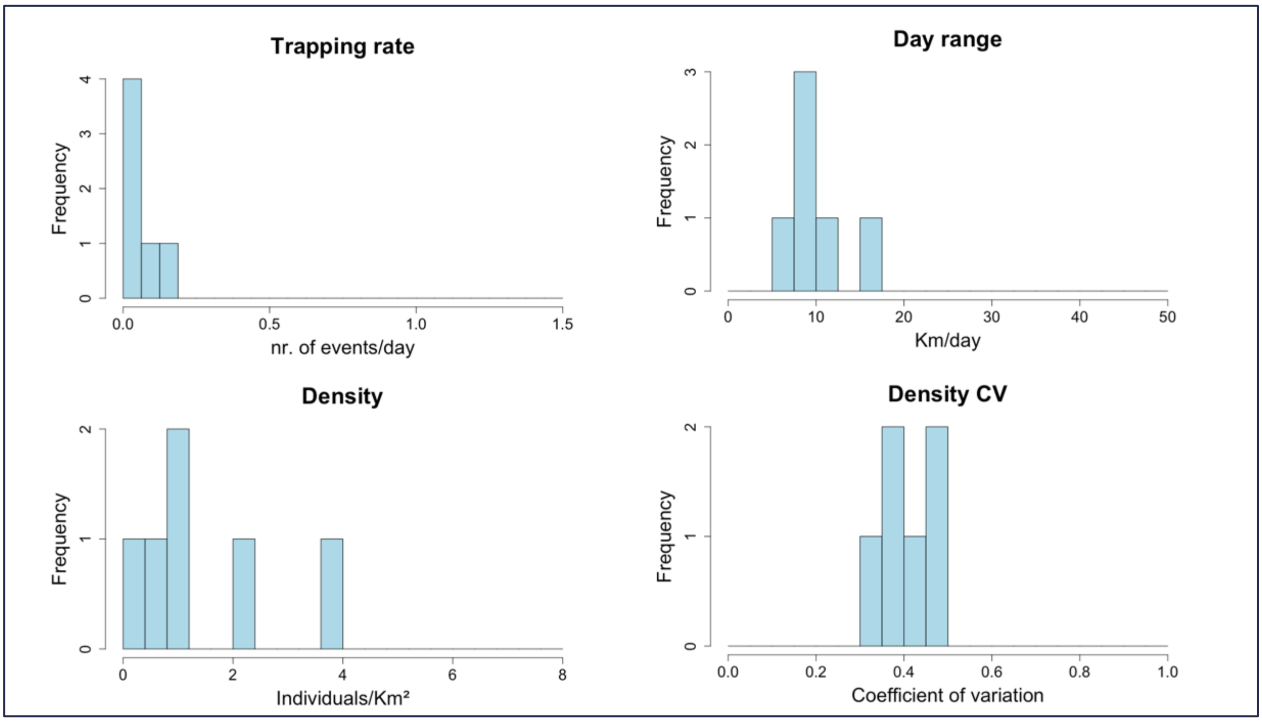

Figure 17. Distribution of trapping rate, day range, density and its coefficient of variation (CV) estimated from European badger CT sequences in 6 study sites in 2024.

3.3 Integrated monitoring

Recent emerging priorities in wildlife disease surveillance have created the need for integrated monitoring approaches across Europe. These methodologies, which merge passive and active surveillance with population monitoring, are essential for enhancing early pathogen detection, evaluating epidemiological dynamics, and assessing the progress or results of disease management interventions. One of the aims of the EOW is to serve as a pilot initiative for integrated wildlife monitoring. The Enetwild consortium, in the frame of specific contract 2, delivered a report focused on the use of eDNA in light of the need for integrated wildlife health monitoring. This study aimed to test several hypotheses to further these goals: firstly, test if camera trap data can effectively inform the selection of sampling sites; secondly, the effectiveness of combining metabarcoding with metagenomic approaches for pathogen surveillance; and thirdly, the development of a harmonized strategy for selecting sampling sites to optimize sensitivity. Using as pilot areas three study sites monitored within the framework of the European Observatory of Wildlife, we had the opportunity of confronting three areas similar in terms of biodiversity (i.e. number of vertebrate species detectable by camera traps), all within the southern and western bioregions of Europe. In these three study areas wildlife trapping rates were coupled with topo-hydrographic data to identify suitable areas for environmental sampling characterized by high and low presence of animals respectively. Water and soil were used as environmental matrices. eDNA extracted from collected samples was analyzed in parallel using metabarcoding and metagenomics. Obtained results confirmed the optimal complementarity of both sample matrix and sequencing

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methodology which greatly contributed to increase detected biodiversity, both for mammals as well as for arthropod vectors and wildlife-related pathogens. The strategy for sampling site selection combining topo-hydrographic and wildlife trapping rate showed no significant difference in terrestrial biodiversity (considering only mammals and birds which are likely to be detected by camera trapping). The possibility of improving species detection (and thus of related pathogens') is suggested when considering only sampling sites close to known areas of high occupancy (Camera traps with high trapping rate). While both methods provide valuable insights, they detect overlapping but distinct subsets of the community, highlighting the importance of integrating multiple approaches for biodiversity assessments. This pilot study represents a significant step toward standardizing eDNA methods and enhancing the efficacy of wildlife surveillance systems. The integration of eDNA-based approaches with prior knowledge of the hydrographic features and watersheds of the study areas, together with prior knowledge of wildlife presence and abundance gives significant guidance to further pursue this line of research to integrate eDNA in wildlife health surveillance. Currently, in the frame of specific contract 3, we plan to expand this pilot experience to a larger number of study sites of the EOW, focusing on sampling a widely distributed species, the roe deer, for pathogen screening, as a demonstrative initiative on integrated harmonized monitoring at European level.

3.4 Discussion

The results for these five species show large differences in estimates of activity level and speed between speed. This variation can partially stem from differences in the local circumstances, such as the presence of predators, hunting or intense recreation, all of which are known to influence behaviour. It is however likely that variation also reflects measurement error, such as imperfect photogrammetric georeferencing, low sample size or biased placement. Future surveys should reduce such error by improving the protocol and training.

Likewise, estimates of density are large, and sometimes higher than seems biologically reasonable and credible. Here too, there may be biases. The most important bias to consider may be that the tracking of movement paths is biased towards animal passages near the camera, as passages further away often come with invisible or partially concealed feet, hindering accurate tracking. If no entry points are recorded for these distant passages, the effective detection distance will be underestimated. If the far passages are nevertheless included in the capture rate, the density estimate will be inflated. To achieve more accurate density estimates, we plan to experiment with truncation, such that passages beyond a certain distance are included neither in the detection distance estimation nor in the capture rate.

4. Networking initiatives

The efforts started during the previous campaigns to establish collaborations with other international initiatives in the field of wildlife disease and disease prevention, continued over 2024 and 2025 ensuring the development of the synergies previously started. Networking activities were aimed at promoting the EOW activities to ensure visibility and to get in contact with new potential collaborators; furthermore, an additional goal was sharing the experience

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and knowledge matured over the years of activity of the EOW to improve and harmonize wildlife monitoring in Europe.

The advertisement of the EOW activities and results has been carried out through oral presentations and posters presented at several international conferences: the IX European Congress of Mammalogy (ECM9, Patras, Greece; 31 March - 04 April 2025), the 14th European Vertebrate Management Conference (EVMC, Ankaran, Slovenia; 12-16 May 2025.), the 98th Meeting of the German Society for Mammalian Biology (Siena, Italy; 1–5 September 2025) and the International Wildlife Congress 2025 (Lillehammer, Norway; 1-4 September 2025). Participation in such events helped spread the experience gained over the EOW campaigns within the international scientific community and promote the exploitation of outcomes of the network activities among scholars and stakeholders.

Links have been established with other related initiatives:

The **European Partnership on Animal Health and Welfare (EUP AH&W)** (https://www.eupahw.eu) is a Horizon Cofund initiative of the European Commission (call HORIZON-CL6-2023-FARM2FORK-01). With 90 participating organisations from both EU and non-EU countries, the partnership promotes cross-sector collaboration and places particular emphasis on aligning and harmonising monitoring schemes for wild birds and mammals.

The **BIG_PICTURE project** (https://www.biodiversa.eu/2024/04/15/big_picture), supported by the Biodiversa+ framework, is focused on making large-scale biodiversity monitoring data more accessible and coherent. The project brings together stakeholders engaged in camera trapping and seeks to resolve the legal, social, institutional, and technical obstacles that currently prevent the effective processing and sharing of the immense volumes of wildlife imagery gathered across Europe.

The **Euromammals network** (https://euromammals.org) connects specialists in mammal spatial ecology who collaborate to answer research, conservation, and management questions at the European scale. A distinctive aspect of the network is its commitment to pooling and sharing datasets, thereby enabling science that would not be possible from isolated studies. Several members of the EOW are also members of Euromammals, ensuring a strict cooperation between the two networks. A joint initiative was started to compare estimations of speed for target species based on telemetry and camera trapping data.

Aligned with this spirit of collaboration, **Snapshot Europe** (https://app.wildlifeinsights.org/initiatives/2000166/Snapshot-Europe) coordinates the collection of camera trap records on wildlife across the continent. Its data feed meta-analyses of species occurrence and distribution and link directly to the parallel **Snapshot USA** initiative. Members of the EOW were invited at a workshop in Konstanz, Germany on 11-14 November 2024, where the foundations were laid for the establishment of a European camera trapping community. The efforts in this collaboration led to the possibility for the EOW collaborators to include the dataset obtained from the 2023 and 2024 campaigns within the Snapshot database. A specific R code was created to subset the EOW dataset respect to the monitoring periods of the Snapshot protocol ensuring that the same data could be used in both projects.

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Finally, **PRO-COAST** (https://www.pro-coast.eu/en/c) takes a community-driven perspective on biodiversity. Funded under Horizon Europe, the project addresses the intertwined ecological and social dynamics of coastal areas, working to empower local communities and citizens to actively participate in ecosystem restoration and conservation.

5. Conclusions

The aim of this report is to summarize the activities carried out in 2024 within the EOW and that led to the implementation of a standardized protocol over an expanded network of study sites. The efforts made towards an expansion of the network ensured the monitoring of 58 study sites over 23 different European countries.

The continuous improvement of the network and the protocol implemented led to the constitution of an unprecedented number of collaborators estimating wild population densities that are then going to be comparable and available for risk assessments for ASF and other shared diseases. In this regard, the presence of 9 study sites located in infected areas and 8 that are close (< 100km) to the infection front, shows the potential of the EOW collaborative approach in collecting relevant data to gain a better understanding of the dynamics related to the spread of a highly impactful pathogen (like the ASF virus with regards to wild boar populations).

The field protocol implementation was already satisfying over the previous years and therefore did not undergo any major modifications (Annex A). However, trying to increase quality and reliability of the results further developments of the protocol are being considered (See chapter 3.3). In fact, we believe that some refinements on the protocol could reduce potential biases in the estimates. The introduction of a change in the production and submission of summary statistics produced outstanding benefits. In fact, through the use of new scripts, a CSV file is produced that condenses all the relevant parameters used by REM. This ensures a considerable improvement in the standardization of the results submission, while saving time and reducing the risk of human error.

In the last year, adhering to the EU recommendations on open science, the policy adopted by the EOW was to make the estimates publicly available to stakeholders and to the scientific community. Therefore, the growing EOW database, incorporating summary data (estimates) produced during the different annual campaigns, has been shared as open access resource on Zenodo (https://zenodo.org/records/17083924). In this regard, the production of an EOW Data Policy document (Annex B) is fundamental to state in detail how the data produced within the network activities can be accessed and used. The document also specifies how each EOW collaborator can propose specific data analyses and scientific writing exploiting the data collected during the EOW campaigns. This will contribute to promote the dissemination of scientific knowledge arisen from the EOW activity.

The large number of species monitored is further evidence of the potential of the protocol promoted by the EOW and its collaborative approach. Furthermore, the number of density estimates obtained for target species relevant on a management and epidemiological perspective, such as wild boar, roe deer and red fox, demonstrates that the EOW is succeeding in providing the institution with the data required to try and improve wildlife monitoring and management.

A methodological limitation is represented by the limited number of observations for some, even common, species (like the badger) that prevents from obtaining unbiased density estimates. In case of special interest for species with a low contact rate, it is recommendable

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to increase the number of cameras used or to extend the time span of data collection in order to ensure a greater number of observations.

Further effort was put in networking activities aimed at interacting with other international projects that share the EOW main goals. In particular, joint activities like the one developed between the EOW and Snapshot Europe, allow collaborators to optimize the efforts while maximizing the outcomes of their data collection activities.

6. Perspectives and recommendations

The expansion of the network in recent years has certainly been remarkable and can be considered satisfactory in terms of the number of study sites involved. Efforts have also been made trying to include study sites from countries and bioregions not yet represented, but these have not always been successful. Further attempts could be made in future campaigns to improve the representativeness of the network in these regards. The introduction of a clear policy to share data and cooperate in their exploitation for scientific publications can increase the appeal of the network by attracting new participants. In fact, one of the objectives of the EOW is to stimulate meta-analyses at the continental scale to answer specific research questions.

Further improvements of the protocol implementation and of the quality of the results obtained represent a constant goal for the EOW, and efforts will be made to further optimize the data production.

Networking activities have proved crucial in advertising the EOW among the large community of wildlife ecologists and stakeholders. They have also contributed to maximise the dissemination of results and to start promising collaborations to make progresses in the methodology, and in data interoperability and data sharing. These constructive interactions will be strengthened in the future.

Our preliminary experience on the evaluation of the complementarity of eDNA (for host and pathogens) and camera trapping (overall, the idea of integrated monitoring) indicates that while both methods detected overlapping community subsets, each also highlighted unique elements of the biodiversity present. This underscores the importance of using multiple biodiversity assessment techniques to capture a complete ecological and multi-host multi-pathogen picture. Our perspectives are to reinforce and develop demonstrative cases on harmonized integrated wildlife monitoring to booster similar approaches at national and European level.

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Abbreviations

AI	artificial intelligence
ASF	African Swine Fever
CT	camera trap
EFSA	European Food Safety Authority
EOW	European Observatory of Wildlife
FOV	field of view
IT	information technology
MS	Member State
REM	Random Encounter Model
REST	Random Encounter and Staying Time

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Annex A – Updated EOW protocol (v. 2.1) for field activities and density estimation

1. STUDY SITE SELECTION

The following are the criteria for the selection of a good study site for the project:

- Study site extension ideally between 2000 - 6000 ha.
- It is safe for camera trap deployment.
- It contains forest habitat (interspersed with other habitats)
- Intensive feeding is not provided to wild ungulates (occasional feeding when the cameras are not in field or baiting for hunting is not a problem)
- Hunting statistics are recorded by event (hunting*day) (in case collective hunting is practiced). When ungulates are hunted mainly by communal hunting (drive hunts), fine resolution hunting statistics per event (nº animals shot, sighted and surface beaten) must be recorded (see form attached).
- A temporal overlap of camera trapping and hunting activities must be avoided to the extent possible. The optimum situation is hunting activities to start immediately once the camera trap field trial ends, but partial overlapping is possible (e.g., camera trapping carried out in Sep-Oct and hunting is from Oct onwards).

2. STUDY DESIGN

Unmarked camera trap density estimation methods require representative sampling, placing cameras randomly with respect to animal movement. This is best achieved by preselecting camera deployment locations using computer-generated random points. Usually, these points should be in a systematic grid with fixed spacing between them across a defined study area (if you don't have the necessary GIS skills in your team, follow the instructions found at this link: GridMaker).

In cases where the study area covers more than one clearly distinct habitat, and especially when animals of interest are strongly attracted to a relatively rare habitat, it may be useful to stratify your grid, selecting a similar number of points in each habitat, rather than planning a single consistently spaced grid across the whole area.

Study designs that CANNOT be used to estimate the density of unmarked populations include preferentially placing cameras on animal or human trails, targeting spots preferred by the animals such as water sources, mineral licks, or high value foods, and using bait to attract animals. Using unmarked density estimation analysis on data gathered in these ways will give results that are biased to an unpredictable extent, and therefore of no value.

For a study area of 2000-6000 has the suggested minimum number of CT locations is 36 but we strongly recommend monitoring a higher number of locations whenever possible, ideally 60. In fact, a higher number of camera locations will ensure higher precision of the estimates, especially for highly aggregated species. The distance between locations in the study area can vary, however, in cases of larger study areas a higher number of CT points is

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recommended. Each CT should be active for at least 4 weeks, ideally 6 weeks. Unless you have enough CTs to simultaneously cover all the CT points you will be performing more rounds, in this case each round is going to uniformly cover the whole surface of the study area (see Figure 1). To obtain that you can simply select one point every other (or more depending on the number of rounds). The number of rounds should be the minimum possible to monitor all the camera locations. If possible, the grid should cover at least one patch beaten for hunting big game during the hunting season.

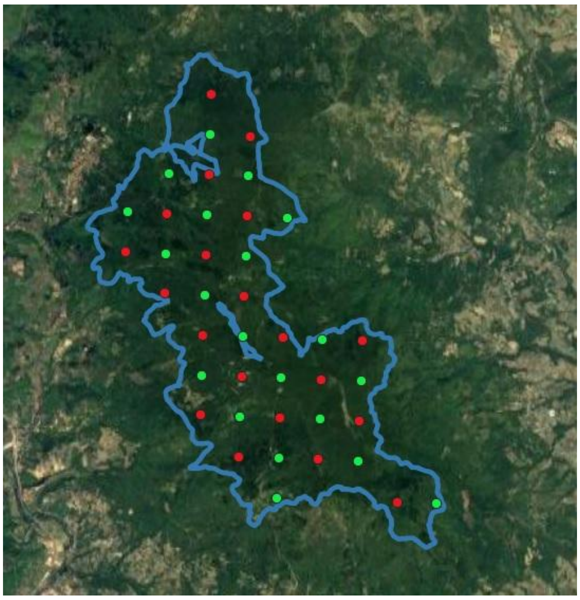

Figure A1. Example of study design. Red dots represent round #1 while green ones represent round #2.

3. CAMERA SET-UP

- If the exact location is not suitable for the deployment of the CT (extremely steep, too dense vegetation…etc) aim for the nearest suitable point but always aiming for the same environment. If the there is no suitable spot with the same environment of the original one, then aim for the nearest suitable point within 100 m even if the environment is different. If it is not possible to find a suitable spot to set up the camera within 100 m from the original point skip the point.
- The CT will be placed on poles or vegetation 50cm above the ground.
- The CT is configured with the operation of 24 hours per day and to take up to eight consecutive images (the maximum number possible), with the minimum waiting time (0 sec. if possible) between activations and, when possible, chose the rapid-fire setting (less time between pictures of the same sequence). Use medium sensitivity. Make sure the time lapse between consecutive pictures is not > 2-3 sec. as this might influence the protocol application.
- The flash intensity should be set at medium (if possible) to avoid “overexposed photos”.
- Check that the date and time are correctly set, and that they are printed automatically on each image.

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- If CTs are active for about 4 weeks, then no check should be necessary, but if the monitoring period of each camera location is much longer (i.e. 8 weeks or more), then a check of batteries and SD card might be necessary. Please note that at every check a new calibration would be required. Choose a field of vision of the CT that is cleared of vegetation (it is not necessary to be totally clean, but that allows the detection of any wild boar that passes within the first 5 m), being better a north orientation.
- A form (see Table 1) must be filled in, collecting the information of each CT during its placement (see below). All the information that is subsequently extracted must keep the traceability of the CT (mark the source camera of each memory card extracted and keep this nomenclature in the folders that are created on the computer to archive the images). Shortly, Enetwild will provide an app based on Smart which will be useful to collect this information in the field.

See "Field protocol" for the recording of the course about chapter 3.

4. CALIBRATION POLE

Thoroughly follow the detailed explanation found at this link to make your calibration pole: Calibration pole instructions

5. DEPLOYMENT CALIBRATION

Once the CT has been firmly set up and all the settings have been checked you are ready to switch it on (please note that it won't have to be touched again until it is removed or checked) you will take the deployment calibration pictures which are fundamental to allow Agouti to perform the automatic estimation of camera parameters (radius and angle of detection) and animal day range.

- Starting about 1m directly in front of the camera, hold the pole with its base on the ground so that it is clearly visible to the camera. Take care to ensure that the pole is held perpendicular to the camera's line of sight. On level ground with camera line of sight roughly parallel to the ground surface, the pole should be roughly vertical, but if the camera is angled to observe a slope the pole may need to be tilted accordingly (see Fig. 2).

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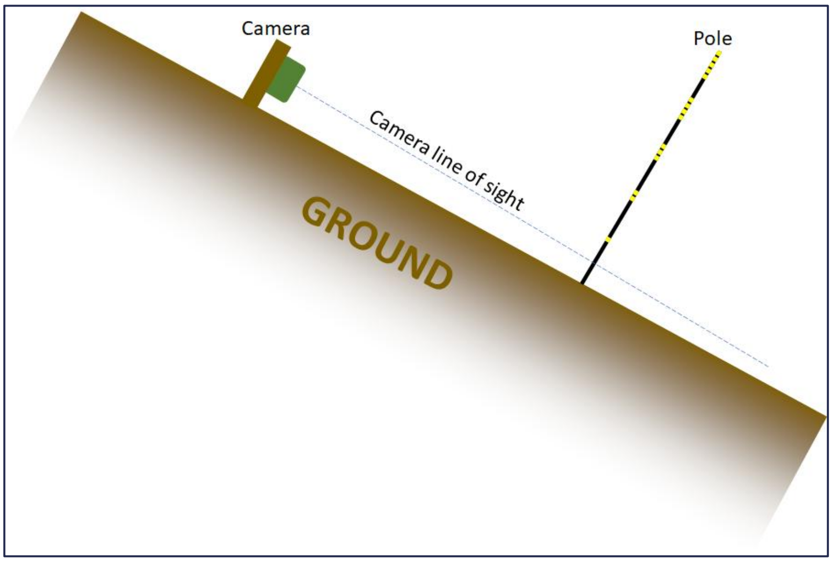

Figure A2. Diagram illustrating a camera set up to observe sloping ground, and the orientation of the calibration pole required to keep it perpendicular to the camera line of sight. Orientation can be judged by eye and need not be measured precisely in the in the field.

- Hold the pole still long enough to ensure a clear image (5-10 seconds). In order to indicate when the pole is resting on the ground, give a distinctive hand gesture when this is the case. For example, thumbs up! **This is fundamental, as often it is not going to be visible whether the pole is actually touching the ground or not and, if it is not, the picture is not going to be useful**.
- Repeat this for further pole placements (at least 25-30) across the field of view and away from the camera, with placements spaced about 0.5 m apart. Continue away from the camera to the maximum extent that any animals are likely to be captured, or if possible, a bit beyond. As you reach greater distances, it may help to have a second person next to the camera to keep it triggering. See figure 3 for an example of a good coverage of deployment calibration pictures. **Before going to the field, it is important to run trials of the deployment calibration process.** Complete the deployment calibration process described above in a convenient location and inspect the images making sure that the results is good.

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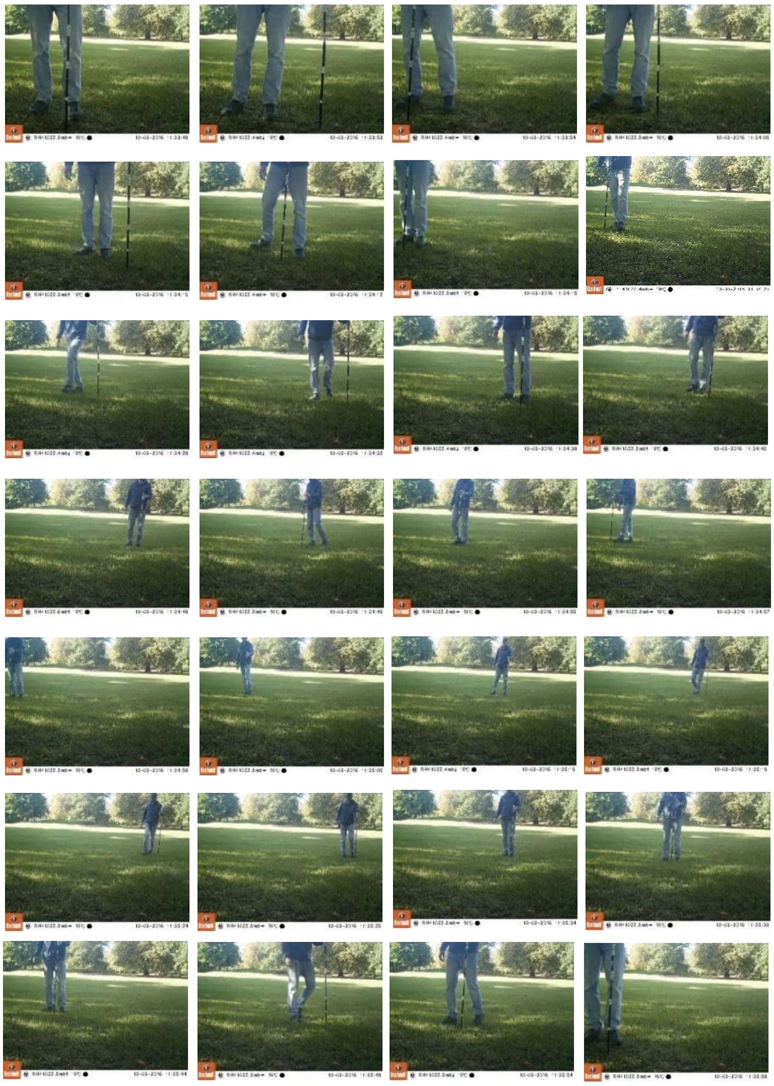

Figure A3. A set of deployment calibration images showing 28 pole positions with good coverage of the detection zone.

- This is another crucial stage of the calibration as you are not going to be able to see how many pictures have been taken and if the pictures are not enough the precision of the estimates for that deployment is going to be low. Make sure you spent enough time on this process and, **if in doubt, take some more pictures as the precision of the estimates strongly depend on this process**. See figure 4.
- Every CT deployment needs its own calibration. If you change the batteries and/or card, which indeed typically changes the camera view in most circumstances, you effectively start a new deployment on the same location. **Therefore, the calibration should be repeated when removing the camera, as well as when setting and checking it**.
- In figure 4 you can see an example of a good distribution of pictures for a deployment calibration.

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See "Deployment calibration" for the recording of the course about chapter 5.

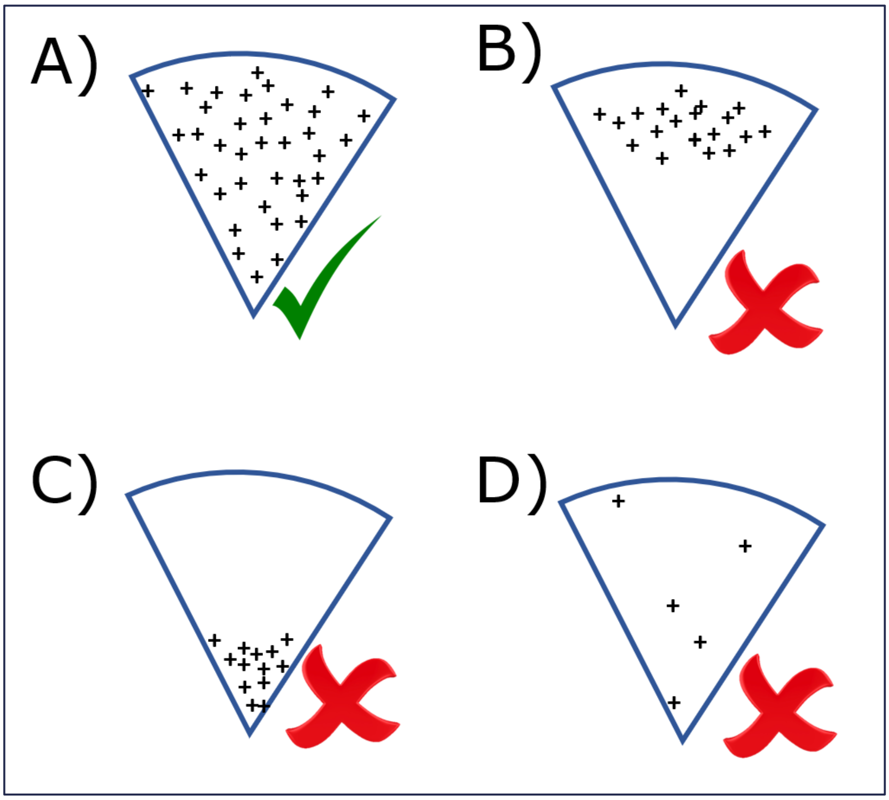

Figure A4. Example of four schemes of calibration of a single camera trap. Crosses represent all the locations of the calibration pole. Panel A represents an adequate calibration (more than 20 points covering homogenously all the detection zone). Panels B, C and D represent wrong calibrations; in panels B and C the points are not homogenously distributed; in panel D, few points were recorded.

6. TAKING CAMERA CALIBRATION IMAGES

The goal is to take pictures of objects of known size at a range of known distances from the camera to calculate the camera model's intrinsic properties, which then allow us to calculate the distance of calibration poles in deployment calibration. This needs to be done for each combination of camera model and image resolution setting used in the field. It's best to keep image resolution consistent throughout deployments; if you do this, and use a consistent camera model, you only need to calibrate one camera, once (no need to repeat it if you already did it last year for the same combination of camera model and resolution). The steps are as follows:

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1. Set up the camera in a convenient location in front of a level surface, either indoors or outside.

2. Mark out nine positions at a range of radial and angular distances from the camera, measuring the distances from camera accurately. Fig. 4 gives an example of placement positions, with poles at three distances (1, 2 and 4 m), and a range of angles. It's not necessary to measure angle, but it should be variable, and within the camera's field of view (usually about 20 degrees either side of the midline), but you may need to check the field of view for your camera.

3. With a camera positioned in front of the arena and switched on, take images of a calibration pole (making instructions: Calibration pole instruction) at each position on the array, holding up some visible marker of the distance. For example, in Fig. 5, the pole is placed at 2 m from the camera, with distance indicated in metres by the number of fingers displayed. As in the deployment calibration process, care should be taken to hold the pole perpendicular to the camera's line of sight.

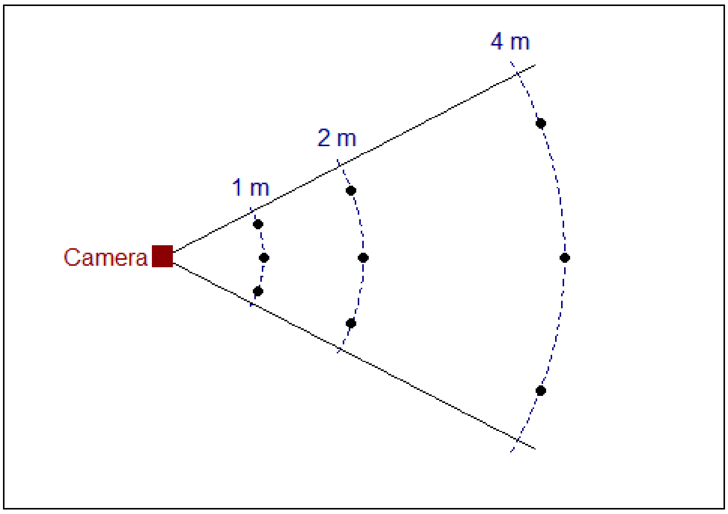

Figure A5. Plan view of an example layout for a camera calibration pole grid.

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Figure A6. A camera calibration image with pole in position 2 m from the camera.

7. AGOUTI PLATFORM

7.1. Project creation

Navigate to https://www.agouti.eu/ and create your own account. Then follow the following steps for the creation of a new project:

- From the agouti homepage or directly from your email write a message to agouti@wur.nl. please include whether you are working in a commercial or non-profit setting.
- You will receive a response with an invitation link to your newly created project. Please use the link and notify agouti@wur.nl when that's done.
- The admins will make you PI on the project. You can now enter the project from your personal dashboard and get started.

7.2. Project settings

- In the main project menu go to "Project settings". In the "General" page choose the "Default UTC offset" keeping in mind to also consider the eventual daylight-saving time (DST). So, if the CTs are deployed in a country using the DST and during a period of DST application remember to also consider that when choosing the UTC offset. So, for example, in a project implemented in Italy (UTC +1:00) during in summer is going to have the Default UTC offset of +2:00 (Kaliningrad, South Africa), in this way all the projects are going to have the Greenwich standard time.
- Below, if you like you can add project description and picture. Further down specify the project owner, PI and organisation.
- In the "Sampling design" section select "No bait", 0 seconds quiet period and "Systematic random".
- In the "Annotation" section the sequence cut-off will be set on 120 seconds by default, and it won't be possible to modify this setting as it has to be the same for all the projects.
- In the automatic annotation box, you can select an AI model to automatically process your deployments. You can either select a "species model" (e.g., "Western Europe species model", if more versions are available make sure you selected the latest) or the "Generic blank/human model", that is only going to annotate for you the blank pictures and those with humans, leaving to

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you the sequences with animals. After selecting a model, a button 'Annotate by AI' will show up for each deployment listed on the Annotate page.

- In the "Species" page press "Add species list" and select the list for your study area. Once you saved the species will be available for the manual annotation. If you were to record any species that is not included in the list, you can then manually add it using the "add species" button and then browsing the species.
- In the "Behaviour" section you can decide which behavioural classes to add to the annotation page.

Se "Project creation and settings" for the recording of the course about chapters 7.1 and 7.2.

7.3. Add new deployments

In your project, in the "Locations" section you can add the locations of your study site by uploading a CSV file (see "Example CSV" in the top right corner of the page).
Within the "Deployments" section, select "Add Deployment" and then select the location from the drop-down menu. If you didn't already add this location you can add it now by pressing "add sampling point". You can now press "Select Files" in the window that pops up (or drag all the pictures of the deployment onto the window), then browse to the folder of the deployment and select all the pictures that you want to upload for that camera deployment and press "ok". Note that files with the same name will be considered duplicates and will not be uploaded, it will be therefore necessary to rename the files that have the same name. If possible, make sure that you have a good internet connection. Especially if the deployment counts many pictures, it might take some time to complete the import.

7.4. Image processing and animal tracking

The animal tracking procedure, together with the deployment calibrations is going to allow the calculation of both, camera parameters and animal movements.

1. Upload images and run the appropriate AI detection and classification model.
2. From the "Deployments" section, annotate each deployment. For each AI-defined observation, EITHER:
   a. Tick the Validate box to confirm the AI-defined species and amount; OR
   b. Edit the observation to correct species and/or amount. NB amount should be a count of the number times an animal passes through the camera detection zone, which AI will often get wrong. Be careful to pick up cases where animals leave and enter multiple times within a sequence; keeping an eye on the timestamp can help to identify such cases.
3. In the "Observations" section, filter by species (type a species scientific name into the "Scientific" box), then edit observations to digitise animal tracks. In the sequences where a group of animals is recorded you only have to digitize one of them.

You can EITHER:

   a. If the total number of observations after filtering is less than or equal to 100, or you plan to track all observations regardless, edit all the available sequences for this species; OR:
   b. If you are sampling sequences for tracking to reduce time requirements, and the total number of results after filtering is greater than 100, randomise the

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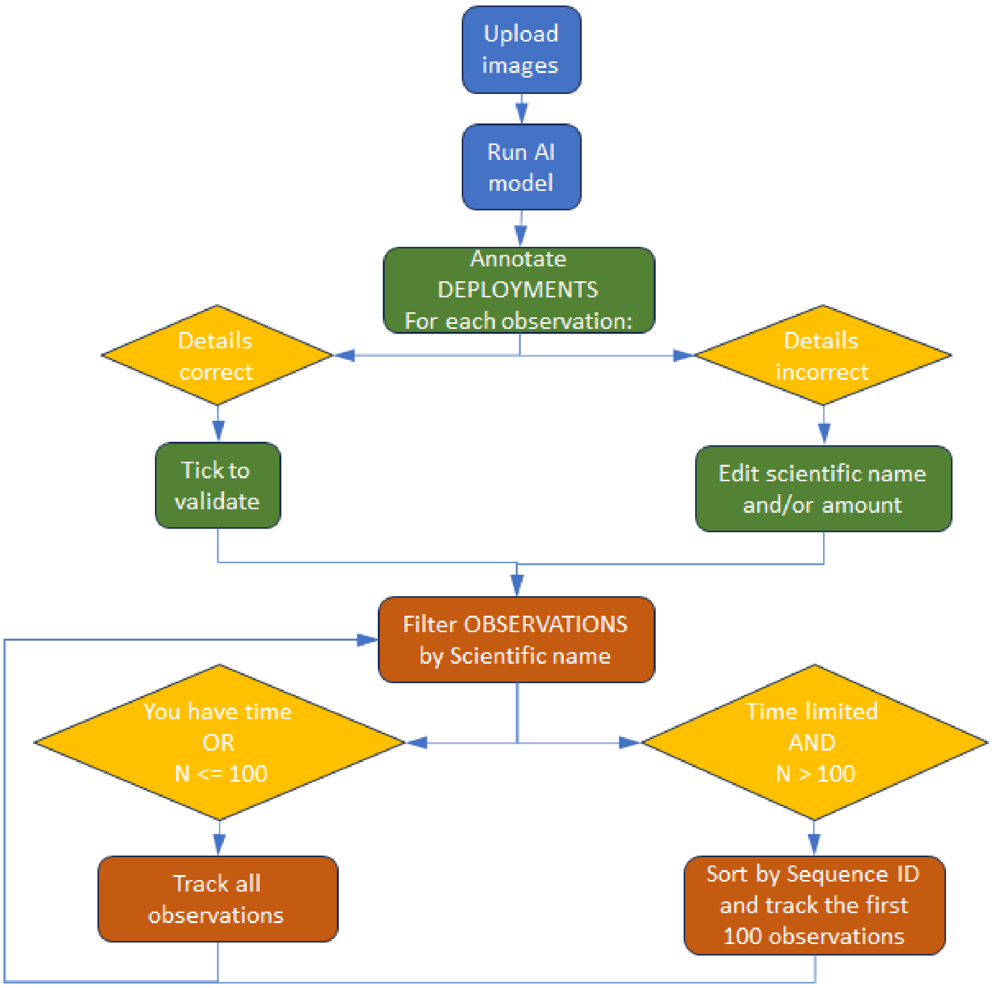
sequences by sorting the Observations table by "Sequence ID", then track just the first 100 observations. Please note that, despite 100 digitised observations are enough, whenever possible, digitizing about 200 observations would be preferable.

4. Repeat step 3 for each species.



The performing of the tracking is going to be allowed only when you are editing a sequence, to do so you just have to click on the point on the picture to create a point. For each picture of a sequence (and within a specific observation) you can only add one point. The animal tracking must be performed on the point of contact of the **frontmost foot with the ground** (often further down the image than you think). The first point is the point of entry, and you then keep tracking **the same foot** (when on the ground) throughout the sequence. If the foot is not visible (e.g., covered by a stone or behind a tree) you can still mark it as the point on the thing covering it where you believe the foot is. The most steps tracked the more accurate is going to be the estimate, however if the path is straight the most important are the first and the last points.

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7.5. Manual Annotation

In "Annotate" section select "Annotate" next to the deployment. The pictures of the deployment will be shown as divided in sequences; each sequence is made of the group of pictures the camera took until it stopped being activated for 120 seconds. Browsing through the pictures of each sequence you will then press "Add Observation" when you recognize an animal activating the camera. In the "Identification" menu select the species, quantity, sex, age and behavior, then press "Save Observation". It is fundamental that you create different observations in the same sequence for animals belonging to different classes (e.g., sow with piglets will need an observation for the sow, adult female, and one for the piglets, juvenile with unknown sex). Remember that **every time an individual goes out from the field of view of the camera and then comes back in it must be counted as a new individual**.

In case there is no observation to add you will be able to select one the following options:

- Blank: empty sequence (e.g., activated by the wind)
- Setup/Pickup: people deploying or collecting camera.
- Deployment calibration: pictures of the "taped stick" for the photogrammetry method.
- Unknown: unknown species in the sequence.
- Vehicle: camera activated by some kind of vehicle.

See "Sequence annotation and animal tracking" for the recording of the course about chapters 7.3, 7.4 and 7.5.

8. REM ANALYSIS

1. If you don't already have them, install:
    - R: https://cran.r-project.org/
    - RStudio: https://posit.co/download/rstudio-desktop/

2. Extract your data from Agouti
    - in your Agouti project, go to the "Export data" section, create a new export file and download the zip file.
    - Unzip the Agouti export file to a specific destination folder.

3. Download example files:
    - Go to: https://github.com/MarcusRowcliffe/camtrapDensity - here you will find a description of steps for the REM analysis (scroll down to the ReadMe section, click the table icon in the top left of that section for a table of contents).
    - Download the camtrapDensity_example.R file (linked from the page or using this link), this contains R codes for running REM density analysis. Move the file from the downloads to the folder where you unzipped the Agouti export.

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4. Open RStudio and set up a new project
    - File > New Project > Existing Directory > Browse to the folder you just extracted from the Agouti export > Create Project.
    - In the lower right RStudio pane you should see a tab called Files – click on this (if not already highlighted) and you will see your project files. Click on camtrapDensity_example.R.
    - Before you can start analysing, you will need to install some additional packages as a one-off (code chunk 1 in the camtrapDensity_example file). These will then be available in future analysis sessions without having to reinstall. Running the first chunk of code (INITIAL SETUP) does this installation. To run a line of code, place the cursor on it and press Ctrl+Enter (Win) or Cmd+Enter (Mac), or click run at the top of the code pane.

5. Start analysing.
    - At the start of each session, load the necessary libraries (run code chunk 2, LOAD PACKAGES).
    - Load the data using the function `read_camtrapDP` (code chunk 3). If you set up the project in the directory created by unzipping the Agouti export (as directed above), you only have to run the code

    ```
    pkg <- read_camtrapDP("./datapackage.json")
    ```

    (without the "." On Mac). See here for details on loading data from other folders if you have stored it elsewhere.

6. Create a subpackage (code chunk 4). **Note: you only have to do this in case you have deployments from previous years in the same Agouti project.** In the example line with the function `subset_deployments` should return only the deployments made in the 2023 campaign, but will need to be edited if any of your deployments cover dates outside that year. **Note: in this case you must then change the object of the following lines from `pkg` to `subpkg` (or whatever name you choose to give to it). Take care to always use the correct data object.**

7. Check deployment schedule (code chunk 4). This allows you to check visually whether all the expected deployments are present in the data, and whether all observation timestamps fall within their given deployment periods (see here).

8. Check deployment calibration models (code chunk 5). Running the lines in this section, R asks you to check all the deployment diagnostic plots and say which species you want to analyse before running the analysis. Diagnostic plots should show reasonably good fits between trend line and data points. Very poorly fitting models should be marked for exclusion so that the unreliable animal position data from these deployments can be excluded from detection zone and speed models. If you don't remember the explanation of how to evaluate diagnostic plots, see this recording of the online courses. Also refer to the document "*Interpreting deployment model diagnostic plots*" for guidance on how to decide whether a calibration model is adequate, available here.

9. One step REM analysis (code chunk 6). Run the line in this section and enter the row number of the species you want to run the analysis for. Here you can also see the number of sequences available for

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the analysis of each species. Clearly the analysis can only be run for the species for which sufficient sequences have been digitized in Agouti.

10. Evaluate how well the activity, detection radius and detection angle models fit (plots produced by code chunk 7). This can reveal potential problems with limited data that might suggest a less reliable result.

    Run the analysis (steps 9-10) for other species.

11. Inspect model estimates and export the results csv table (code chunk 8). Run the lines to inspect the estimate values and save results with additional information about the species and project, including the option to save a single data table of results for multiple species. Having fitted one or more rem_estimate models (e.g. resulting in objects red_deerREM, roe_deerREM, wild_boarREM), pass the outputs to this function: write_rem_csv(red_deerREM, roe_deerREM, wild_boarREM).

12. When leaving RStudio, save your workspace so your work is preserved (code chunk 10).

See "REM_analysis" for the recording of the course about chapter 8.

9. Results reporting

Once all the analysis processes are complete, you can proceed with reporting the results for your study site/s. From 2024 results must be reported using the EOW Results Form where all the necessary information is going to be collected. You should fill in a separate form for each of your study sites. In the "Results" section of the EOW Results Form you will be asked to attach the results' csv table resulting from the analysis process.

10. TRAINING RECORDINGS

At the following links you can find the full recordings of the 2024 training sessions:

- First Training Session – Field protocol
- Second Training Session – Agouti and data analysis

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EOW Vocabulary

- **Agouti**: An online platform for the processing and storage of camera-trap images and data. Also used for processing calibration images and digitizing animal movement paths. The output of Agouti is a zip-file in camtrapdp-format.
- **Annotation:** process, performed in Agouti, during which a sequence of images is labelled with one or more observations. Animal observations typically include species, n. of individuals, sex and age classes and, when possible, behaviour.
- **Calibration pole:** 1-m long pole marked at known intervals, used to perform calibrations of the field of view of the camera deployments.
- **Camera model calibration:** process of taking pictures with the calibration pole laterally and centrally with respect to the camera field of view at known distances. It only has to be performed once per combination of camera model and image resolution (picture quality) and is performed at a convenient location (not in the field).
- **Camera locations**: the actual points in the field where the cameras are deployed.
- **Day range:** average distance travelled by an individual of a certain species in a day.
- **Deployments**: use of a camera trap to record wildlife at a specific location during a specific period. Each deployment has its own deployment calibration. A single "camera location" typically has multiple deployments: one per year.
- **Deployment calibration:** process of having an installed camera trap take pictures with the calibration pole standing at many different positions within the camera trap's field of view, with the calibration pole held resting on the ground and perpendicular with respect to the line of sight of the camera trap.
- **Detection zone:** sector-shaped area in which cameras detect animals, defined by the interaction between sensor and environment. Usually defined by radius and angle.
- **Digitizing:** process of marking key points in images. It is performed using the Agouti tools to digitize deployment calibration images and the tracking of the target species.
- **Encounter:** each time that an individual enters detection zone.
- **Encounter rate:** number of encounters per unit of sampling effort.
- **Field of view:** space in front of the camera where animals can be photographed, defined by camera optical properties. It may be larger than the detection zone.
- **Observation:** event of detection of a given animal or group.
- **Photogrammetry:** mathematical technique to extract information on the physical three-dimensional scene captured by the camera from two-dimensional images.
- **Rounds**: the number of subsets the overall number of "camera locations" has been divided into. If, for instance, you have 20 cameras to sample 60 "camera locations" you will deploy the cameras in 3 different "rounds/sessions".
- **Sequence:** group of photos taken by the camera trap that are separated by less than 120 sec, usually representing a single event. A single image sequence can contain one to hundreds of photos, but more typically contains around 10 images.
- **Session:** synonym for round.
- **Study design:** distribution of the camera locations over the study site. Typically, a grid with fixed interspacing.
- **Survey:** field activity aimed at collecting data on wildlife populations.
- **User**: Person involved in a camera-trap survey. Users can have various roles that come with different data access rights, which are assigned in Agouti.

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Table A1. Field sheet (print as many as you need to report the data from all the CT deployments).

N° of the study point	N° CT and SD card	Coordinate X	Coordinate Y	Date setting-up CT in the field	Time setting-up CT in the field	Deployment calibration performed? (Y/N)	Date CT removal	Time CT removal	Deployment calibration performed? (Y/N)	Observations: any eventuality, aspects of functioning of the CT, if it dropped down, if still correctly attached, any failure etc.
	CT - SD -									
	CT - SD -									
	CT - SD -									
	CT - SD -									
	CT - SD -									
	CT - SD -									
	CT - SD -									
	CT - SD -									
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	CT - SD -									
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Annex B – EOW data access and collaborative publishing policy (v. 1.0)

Premise

- The European Observatory of Wildlife (EOW) is an open collaborative network collecting wildlife data at observation sites using harmonized protocols.
- The EOW was launched by the ENETWILD consortium, funded by the European Food Safety Authority (EFSA), and is coordinated by ENETWILD partners.
- Data collection is strategically prioritized to align with specific epidemiological and geographical scenarios, as mandated by the commitments of the ENETWILD consortium, that adheres to the directives of EFSA.
- EOW members can join the network on a voluntary basis and undersign an agreement to adhere to an annual campaign for data collection.
- Raw and summary data are produced for each study site during the EOW activity. Raw data consists of the collected during field work and all related annotations made during their processing; summary data is cumulative data summarized at the end of each annual field activity (e.g., effort, capture events, recorded species, etc.) or quantities estimated through the analysis of raw data, using the dedicated EOW analytical tools and following the EOW protocols.
- By signing the EOW agreement, each member assumes responsibility for the scientific accuracy of the data collected at their respective study sites and retains ownership of the raw data.
- Raw data is used to produce summary statistics and estimates through shared protocols and IT tools, and summary data are annually reported to EFSA by the ENETWILD consortium.
- All estimates produced by the activity of the EOW are used by ENETWILD for spatial modelling and to respond to the requests by EFSA which supports the European Commission as part of its institutional mandate.
- All data generated by the EOW is valuable and can be used for scientific purposes and science-based wildlife management.
- ENETWILD and EOW promote the use of collected data and metadata by adopting a participative approach to answer scientific questions, and share summary data and model outputs with the scientific community by embracing 'open science'.

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Data policy

Data access

- Raw data obtained from the EOW activities in each study site is elaborated by EOW members and submitted as summary output to the EOW coordination team.

- EOW members grant access to their project in the online platform (Agouti) to EOW coordination team to assist in data processing.

- Once produced, summary data is shared with the EOW coordination team, which, after verifying its completeness and correctness, adds it to the EOW database, a data repository managed transparently and responsibly by EOW coordinators.

- The EOW database is made openly accessible in Zenodo at the following link: https://doi.org/10.5281/zenodo.14961352. Data becomes therefore downloadable and citable by third parties.

- The EOW warmly encourages its members to also make their raw data accessible in an open repository (e.g., in GBIF). This would promote their use and make single datasets citable.

Data use

- The use of data stored in Zenodo for scientific or institutional purposes does not require a permission; however, users must cite the source (or DOI) in any publication or public presentation.

- Access and use of raw data of any specific EOW site must follow a direct request to the data owner who grants permission. Obtained raw data must only be used for the approved purpose stated in the request.

- Data use must align with EOW's mission, i.e. science-based animal health and wildlife management.

- Summary data may not be used for commercial purposes or modified without prior written consent by EOW coordination team.

Collaborative publishing policy

Submitting a paper proposal

- All EOW members can propose topics for research papers. This may include collaborations with other initiatives/projects.

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- The proposal should be submitted to the EOW community via the EOW paper proposal file (LINK).
- Any new proposal should not be identical (or largely overlapping) with other previously submitted proposals, that are already listed in the shared file.
- The submission of a proposal corresponds to a call for the use of data collected within the EOW framework.
- The required data and metadata should be explicitly stated in the proposal.
- Any EOW member, who is responsible for data collected in one or more EOW sites, can freely join a proposal and provide data and metadata for the analyses.
- Only data provided by the EOW members who have explicitly adhered to a proposal can be used for the corresponding publication.
- Once the submitted proposal has been joined by EOW members, the proposer will constitute the team of participants, create a mailing list for communications and start data analyses.
- Any changes to the initial plans stated in the proposal should be communicated to all participants.
- If, after 2 years, a proposed topic has not led to a paper draft, it will be suitable for a new proposal.

Authorship and Acknowledgements

- The proposer will lead the research and, accordingly, will appear as first or last author in the publication (unless he/she voluntarily renounces this role).
- EOW members who contribute with their data gain the right to co-author the paper and may indicate additional contributors from their research team to be listed as coauthors, and people and institutions to be mentioned in the acknowledgements.
- Any inclusion as coauthor should be justified by a real contribution to the workflow (from data collection to paper writing) in line with international standards for authorship in scientific publications.
- The final draft should be shared with all participants. Any participant can approve it, suggest modifications or withdraw co-authorship.
- Any publication deriving from an EOW paper proposal should mention the European Observatory of Wildlife in the Acknowledgments as follows: “This paper was conceived and written within the European Observatory of Wildlife initiative (www.wildlifeobservatory.org), launched by the ENETWILD consortium, in the framework of a project funded by European Food Safety Authority (EFSA tender nr. OC/EFSA/BIOHAW/2022/01)”.

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• Disclaimer to be added: This paper is published under the sole responsibility of the authors and may not be considered as an EFSA output. The positions and opinions presented are those of the authors alone and are not intended to represent the views of EFSA.

For inquiries, please contact: eow@uniss.it

Annex C – EOW study sites 2024

Study Site	Country	Bioregion	Institution
Vall de Ransol	Andorra	Western	Govern d'Andorra
Ordino Valley	Andorra	Western	CREAF
Artavan	Armenia	Eastern	Yerevan State University
Game Management Unit 8	Belgium	Western	INBO
Marche-en-Famenne	Belgium	Western	SPW-DEMNA
Romanija	Bosnia and Herzegovina	Western	University of Belgrade, Faculty of Forestry
Ropotamo	Bulgaria	Eastern	University of Forestry
Sredna Gora	Bulgaria	Eastern	University of Forestry
Voden - Iri Hisar	Bulgaria	Eastern	University of Forestry
Prolom	Croatia	Western	University of Zagreb
Bohemian Switzerland National Park	Czechia	Eastern	Czech University of Life Sciences
Lukhuni - Ilia State University	Georgia	Western	Ilia State University

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Tbilisi National Park	Georgia	Western	NACRES
Bavarian Forest National Park	Germany	Western	Bavarian Forest National Park
Siebengebirge	Germany	Western	European Forest Institute
Ebbegebirge	Germany	Western	European Forest Institute
Gemenc	Hungary	Eastern	Szent István University
Marcarolo	Italy	Western	Department of Veterinary Sciences - University of Turin
Mandria	Italy	Western	Department of Veterinary Sciences - University of Turin
Varzi	Italy	Western	Department of Veterinary Sciences - University of Turin
Alpe di Catenaia	Italy	Western	University of Sassari
Parco Nazionale dell'Appennino Lucano Val d'Agri - Lagonegrese	Italy	Southern	University of Molise
State Forest Management Unit ''Lubans'' (SFMU Lubans)	Latvia	Eastern	Latvian State Forest Research Institute ''Silava'' (LSFRI Silava)
Bjelasica Mountain (NP Biogradska gora)	Montenegro	Western	NGO Wildlife Montenegro
Niepołomice	Poland	Eastern	Jagiellonian University
Białowieża Forest	Poland	Eastern	Mammal Research Institute PAS
Herdade da Coitadinha	Portugal	Southern	EBM - Estação Biológica de Mértola
Homem-Pedra	Portugal	Southern	University of Aveiro
Médio Côa	Portugal	Southern	University of Aveiro
ZCA Santulhão	Portugal	Southern	Palombar - Associação de Conservação da Natureza e do Património Rural

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ZCM Freguesia de Vimioso	Portugal	Southern	Palombar - Associação de Conservação da Natureza e do Património Rural
Covasna	Romania	Eastern	UNISS
Studenica	Serbia	Western	University of Belgrade, Faculty of Forestry
Cerova Vrchovina PLA	Slovakia	Eastern	TUZVO
Sinji Vrh	Slovenia	Western	Faculty of Environmental Protection
Oljka	Slovenia	Western	Faculty of Environmental Protection
Strunjan	Slovenia	Western	University of Primorska
Rižana	Slovenia	Western	University of Primorska and Faculty of Enviromental Protecion
Arriola	Spain	Southern	Araba Cazadores Gestión
Parc Natural del Montgó	Spain	Southern	Generalitat Valenciana
Parc Natural de la Serra Calderona - Porta Coeli Public Forest	Spain	Southern	Generalitat Valenciana
Parc Natural del Desert de les Palmes	Spain	Southern	Generalitat Valenciana
Parc Natural de la Serra d'Irta	Spain	Southern	Generalitat Valenciana
Leitzaran	Spain	Western	Diputación Foral de Gipuzkoa
Parc Natural El Hondo	Spain	Southern	Generalitat Valenciana
Solanillos	Spain	Southern	Rewilding Spain
Daimiel	Spain	Southern	IREC
Quintos de Mora	Spain	Southern	IREC
Riaño	Spain	Southern	IREC
Carche	Spain	Southern	IREC
Utxesa	Spain	Southern	IREC
Rosario	Spain	Southern	IREC
La Esperanza	Spain	Southern	IREC
Doñana	Spain	Southern	IREC
Veluwe	The Netherlands	Western	WUR
Kartdag Wildlife Reserve	Türkiye	Southern	Kastamonu University

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Forest of Dean	United Kingdom	Western	Animal and Plant Health Agency
Loch Ness	United Kingdom	Western	Animal and Plant Health Agency

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