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Title MAMMALNET – citizen science data collection from a One Health perspective

Overview

One Health (OH) should not be anthropocentric, but consider people, animals and ecosystem equally. MAMMALNET is a European consortium to collect background data on wildlife distribution, with the specific aims of improving our ability to understand and predict disease spread.

Citizens collect sighting data on an ad hoc basis (using the iMammalia app), or through remote camera traps (using MammalWeb or Agouti web sites), to increase our understanding of mammal distribution across Europe. This improves the resolution of species distribution data, the prediction of species presence in under-reported areas, and aids monitoring the spread of invasive species. Users can see their records and those of others and maintain a list of species sightings. These data are vital to understanding the ecosystem and how this changes over time, providing background data for changes in species distribution or abundance.

These data improve wild animal health reporting, such as recording dead wild boar in outbreak areas of African Swine Fever. Such records are then followed up to monitor the spread and control of the outbreak. The sighting data can also be used to predict the distribution and abundance of wild species, provide the denominator data against which disease reports can be compared and predict the potential for disease spread and control. MAMMALNET is committed to open science since OH requires not only an interdisciplinary approach but collaboration and sharing standardized data.

These data will also help predict the potential spread and control of zoonotic diseases, such as rabies, with benefits for human health.

Authors

Graham Smith[1,3], David Roy[2], Philip Stephens[3], Jim Casaer[4], Patrick Jansen[5], Jose Antonio Blanco-Aguiar[6]

Affiliation

1, Animal and Plant Health Agency, Sand Hutton, York, UK

2, Biological Records Centre, UK Centre for Ecology & Hydrology, Wallingford, UK

3, Conservation Ecology Group, Department of Biosciences, Durham University, UK

4, Research Institute Nature and Forest, Brussels, Belgium

5, Wildlife Ecology and Conservation Group, Wageningen University and Research, Wageningen, The Netherlands

6, Instituto de Investigación en Recursos Cinegéticos (IREC) CSIC-UCLM-JCCM, Ciudad Real, Spain

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Summary/Abstract

Short summary

MAMMALNET facilitates recording of mammal sightings by citizens and professionals using a smartphone app (iMammalia) and two camera-trapping web applications (MammalWeb and Agouti). The sighting data are used to improve biodiversity recording, to monitor the spread of invasive species, and to predict the spread of diseases of livestock and zoonoses.

Abstract

One ambition of One Health (OH) is to focus on people, animals and the ecosystem equally (Tripartite and UNEP support OHHLEP's definition of "One Health" (who.int)). This requires adequate data on wildlife. MAMMALNET is a European consortium set up to collect wildlife occurrence data, with the specific aims of improving our understanding and prediction of disease spread.

MAMMALMET encourages citizens and professionals to report mammal sightings on an *ad hoc* basis (iMammalia app), or through surveys using remote camera traps (MammalWeb or Agouti). This combines data from different sources, increases our understanding of mammal distribution, and aids in monitoring the spread of invasive species. MAMMALNET participants can see their records and maintain a list of species sightings. These data are vital to our understanding of the ecosystem and how this may change over time, providing background data for monitoring species.

These data complement and contribute to reinforcing wildlife health reports, such as recording dead wild boar in outbreak areas of African Swine Fever. Such records are followed up for disease sampling to monitor the spread of disease. The data can also be used to predict the distribution and abundance of wild species, provide the denominator data for disease reports, and predict the potential for disease spread and control. MAMMALNET is committed to open science since OH requires not only an interdisciplinary approach but practical collaboration and sharing standardized data.

These outputs can help predict the potential spread and control of zoonotic diseases, such as rabies, with benefits for human health.

What is the incremental value that makes this a One Health case?

MAMMALNET in coordination with ENETWILD represents a truly transdisciplinary project that encourages citizen science actors, including academics, local hunting and management organizations and members of the public across Europe to record mammal sightings through various means and to help classify submitted images. This can be through *ad hoc* reporting or by setting up experimental camera plots. This work is then available to government agencies

and academics to evaluate changing biodiversity and estimate risk of disease spread for domestic livestock and human health.

Learning Outcomes

1. Three platforms were made available or adapted for citizen science mammal recording across Europe, but a greater overall effort was required to publicize and ensure sufficient public involvement than the development of the apps.
2. Citizen science engagement requires continuous but low-level resources to maintain interest.
3. The multi-organizational effort and networking required to maintain these platforms increases interactions, which can translate into an improved ability to work collaboratively on upcoming issues.

Background and Context

More than 25% of terrestrial European mammals are classified by the IUCN as threatened, vulnerable, endangered or critically endangered; more than 40 exotic and introduced mammal species occur in Europe; mammal recording is poor (particularly in the south and east of Europe) due to the often nocturnal nature of many species; there are no consistent systematic reliable maps of their distribution and abundance to help monitor biodiversity changes over time and to help inform disease risk analysis; mammals carry many diseases that can affect livestock and human health.

Wild mammals are thus a central part of a truly One Health approach, being a 'canary in a coal mine' for climate and habitat change, a connection to outdoor spaces to improve human health and wellbeing, and a potential route of disease transmission between livestock, humans and wildlife. However, wild mammals are under-represented in zoonotic transboundary disease surveillance programs in Europe (ENETWILD-consortium *et al.* 2022a). Therefore, (i) improving our knowledge on their distribution, and (ii) facilitating reporting (e.g., passive surveillance of wildlife) are key to OH disease surveillance, which does not respect national borders.

To improve these data for disease risk assessments, and to see if citizen science action could engage enough support to create substantial new data, the European Food Safety Authority (EFSA) funded the MAMMALNET consortium. This was used to create a smartphone mammal recording app, further develop two existing camera trapping platforms, and produce a website to link this all together, providing resources and education (Table 1).

Approaches Used

To maximize data collection, we need to appeal to a variety of different actors: people with different levels of ability regarding, or involvement with, mammals. This included targeting people who could record *ad hoc* sightings when they are outside; collating images from people who already own and use camera traps to maximize the benefit of such incidental

data; and engaging nature organizations or academics who may own several camera traps and have the resources to place them systematically.

Table 1. Tools created or further developed by MAMMALNET. Details correct as of January 2023.

Name	Tool	Web site	Number of languages
iMammalia	Smartphone app	https://european-mammals.brc.ac.uk/en	17
MammalWeb	Camera trapping	https://www.mammalweb.org/index.php/en/	6
Agouti	Camera trapping	https://www.agouti.eu/	7
MAMMALNET	Web site	https://mammalnet.com/	10

A number of national mammal recording apps exist across Europe, primarily in the west, but data are very sparse in eastern Europe. While some recording apps will work and record species anywhere, none were designed for general public use, easy to use and available in suitable languages. Therefore, we created iMammalia (Fig 1), a picture-oriented smartphone app which is available in many Balkan and east European languages to target areas of limited data.

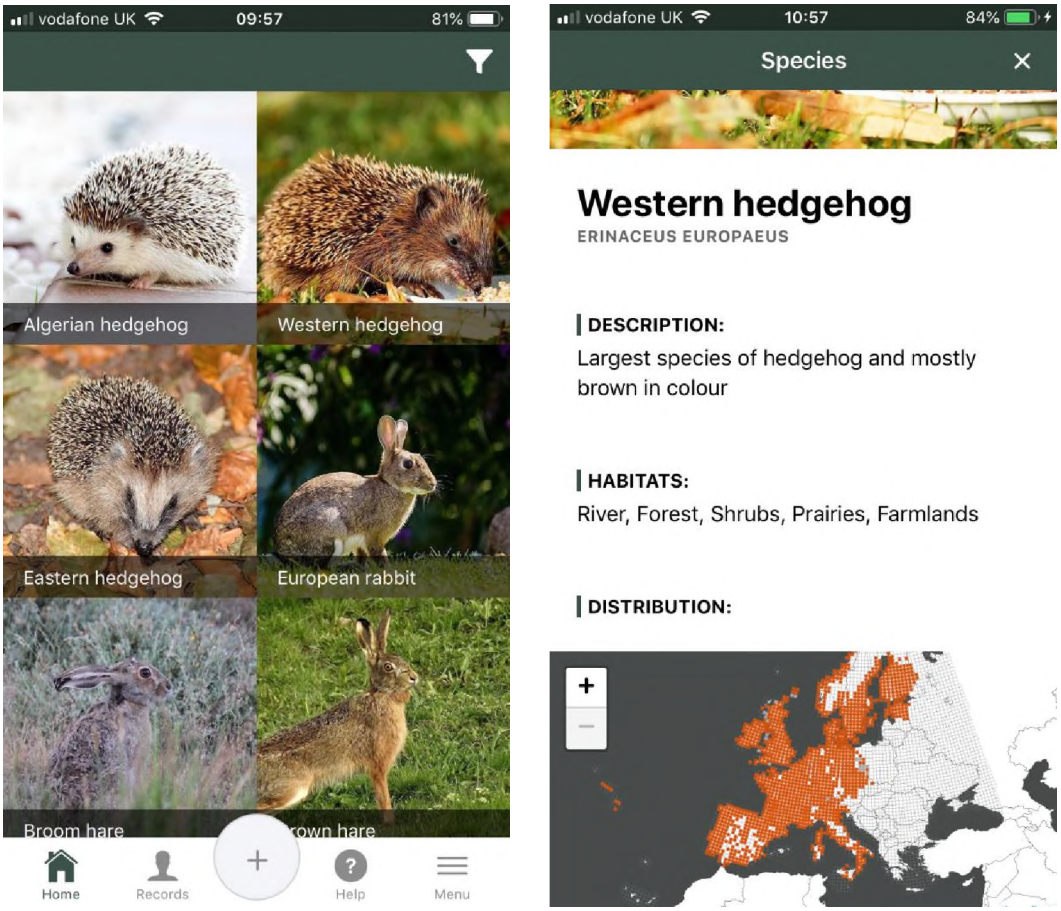

Fig. 1. The iMammalia smartphone app interface in English, and an example description for the Western Hedgehog.

This app permits easy submission of records for all 79 larger mammal species which are relatively easy to identify. Photographs can be added to the record. Smaller mammals are often difficult to identify to species, making it hard to verify any such records without a photo or good description. Thus, they can be submitted as a generic 'mouse' 'rat' or 'rodent'. For those with good identification skills a description of the animal can be added to the record to help verification. One additional function, funded by the FAO and EFSA, is that when wild boar carcasses are reported in iMammalia, an email is immediately generated to inform national veterinary bodies, who can then follow up these records if there is suspicion of disease in the area. This is particularly important across Europe now with the spread of African Swine Fever (ASF).

All records are verified by experienced mammalogists. This verification relies on users submitting photos or good descriptions of the record. Since mammals do not often stay still long enough to get a photo, verifiers can see the history of submissions from a user to see if they have previously correctly recorded that species. Records can also be submitted of tracks, dens or scats; here, a photo is easier to take, and often submitted with a scale (e.g., one Euro coin or a key). Users who can correctly identify a fox or badger track are clearly familiar with that species and can be trusted to report visual sightings without photos. These records are then

submitted to the Global Biodiversity Information Facility (GBIF), a public repository for biodiversity records of all species from mammals and insects to plants and fungi, and are thus available for anyone to use.

Another approach are camera traps: cameras in waterproof housing that are triggered by passing mammals. They are typically equipped with a flash and attached to trees or other objects (Figure 2). They can be active 24 hours a day and work for weeks without needing a change of batteries. The latest versions can even email the image to users as soon as it is taken.

Fig. 2. A camera trap attached to a tree using a security lock. The bit of wood wedged behind the camera is placed to ensure the camera angle is correct with respect to the ground in front.

Many people now own such cameras to monitor wildlife in their garden, or in a nearby woodland; land managers often use them to assess the occurrence of game and wildlife. They are also used by NGOs and academics to estimate the density of various wildlife.

We used two different platforms to target these actors. The first, MammalWeb, is a citizen-science platform to collate, validate and curate camera-trap data to increase our knowledge of mammals (Hsing *et al.* 2022). The public can register as 'trappers' and submit data from any camera trap by specifying the camera model, location and dates of use, or as 'spotters' by looking at image sequences and classifying what they see. To ensure the classification is correct, multiple classifications can be obtained per image, and the consensus used as the identifier (Hsing *et al.* 2018).

Recent advances now permit Artificial Intelligence approaches to aid classification (Green *et al.* 2020), although this should not replace 'spotters' but simply act as an additional spotter, so that any benefit of seeing wildlife, particularly rare wildlife, and any educational aspects remain. MAMMALNET has further developed this website by including multiple languages and promoting its use across Europe (Figure 3). Those data that have been classified will also be transferred to public biodiversity data sets and currently trials are progressing to automatically submit such data to the British database (NBN), which then acts as a contributor to GBIF.

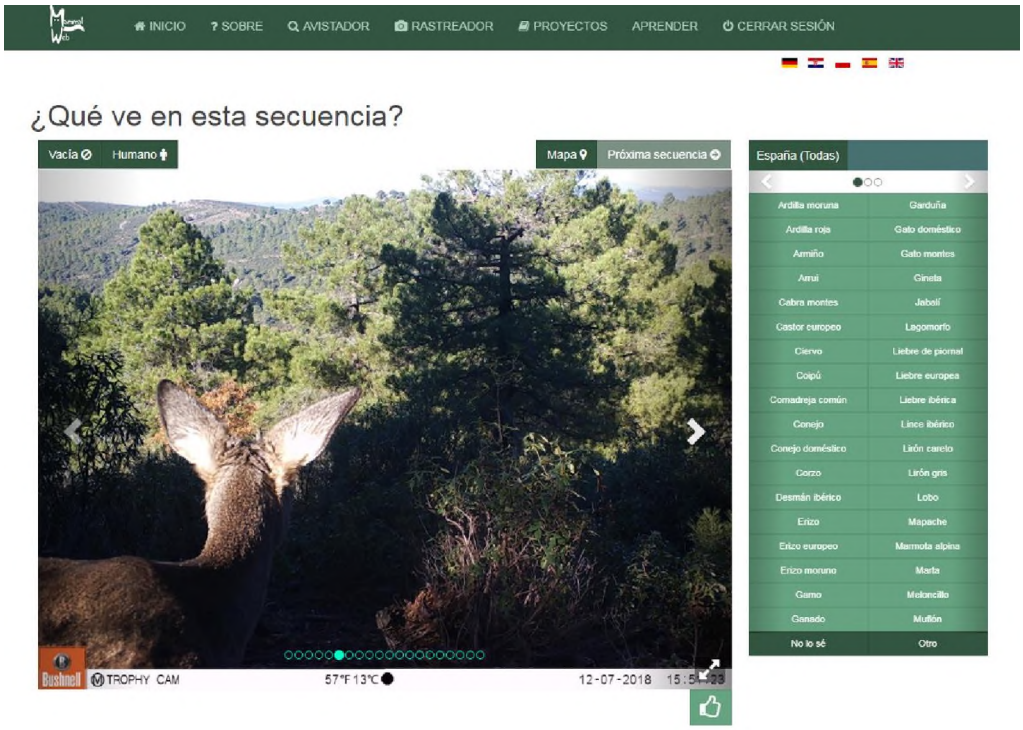

Fig. 3. The Spanish MammalWeb interface for spotters where they can click on the species they think is in the image sequence. This example has several such images taken in quick succession (indicated with circles at the bottom) so the user can move through the sequence to improve identification.

The second platform, Agouti, is an online application and database for the management of camera-trapping surveys, including standardized processing of images supported by Artificial intelligence, storage and archiving of data, in a standardized output (Casaer *et al.* 2019). Agouti is aimed at researchers and wildlife professionals who manage projects that involve multiple cameras, often located at random points or in a grid (Figure 4). Images are imported, grouped into sequences that represent events, and classified by specified users or AI (Figure 5). A unique feature of Agouti (ENETWILD consortium *et al.* 2022) is a tool to calibrate the views of cameras and the tracking of animal movement paths. Using photogrammetry, these tracks can then be used to calculate animal movement speed and the effective detection area of camera traps, two key parameters of models to estimate the absolute density following the latest

approaches, such as the Random Encounter Model (REM) or camera distance sampling (CT-DS) (Palencia *et al.* 2021). Agouti is the reference tool for a harmonized approach for wildlife monitoring by the recently created European Observatory of Wildlife (EOW), and will also be contributing these data to GBIF.

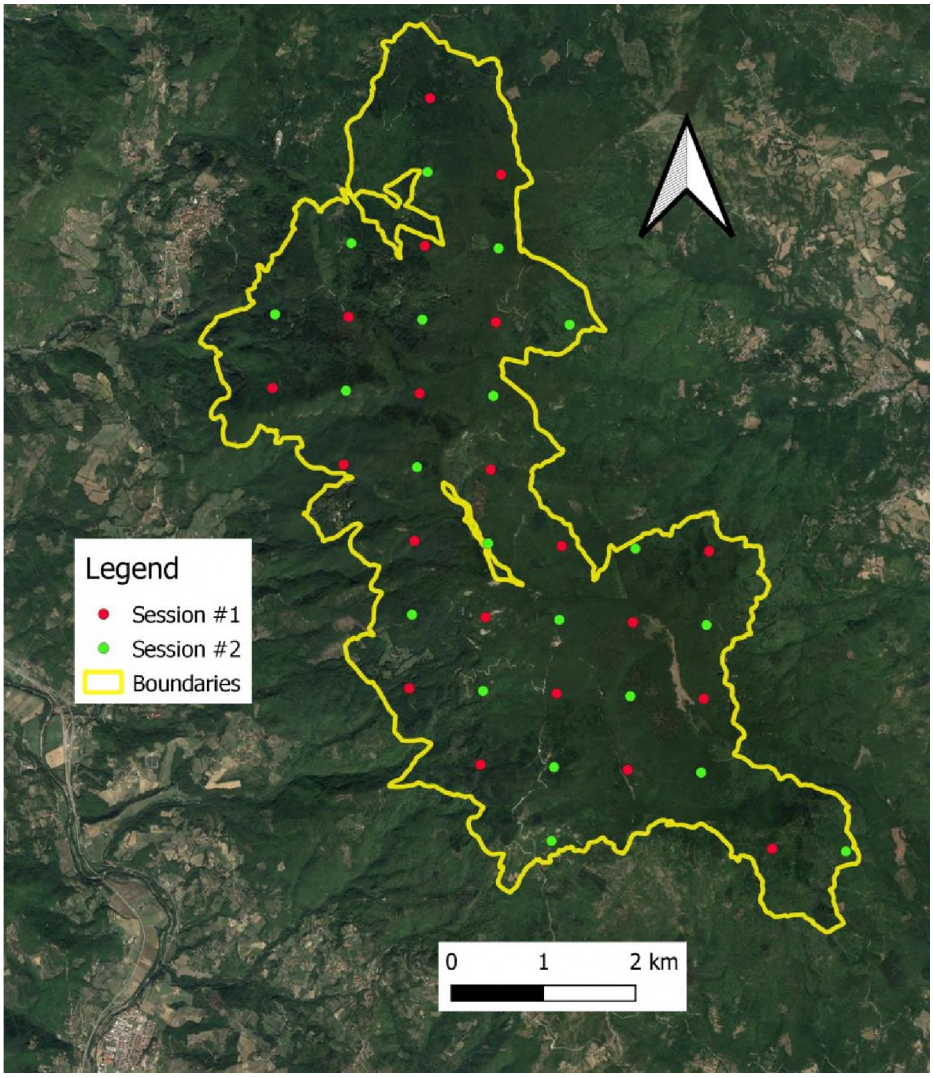

Fig. 4. Camera-trap locations are dispersed on a grid within a study site. Cameras are placed in one location for 30 days before being moved for the second session of 30 days. The origin of the grid is randomized, and cameras placed as close to each point as possible with no alignment toward wildlife paths or feeding sites to avoid any bias toward high recording.

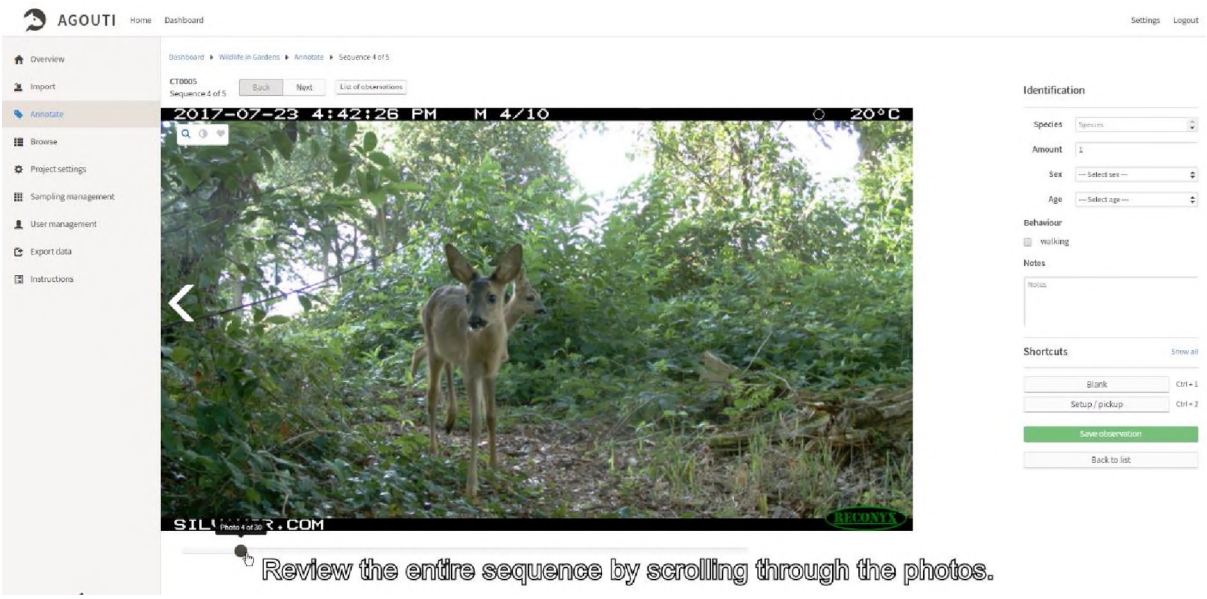

Fig. 5. The Agouti interface for classifying images. This example is viewing image 4 of 30 in the sequence.

MAMMALNET also has a website that hosts pages with details and photos of European mammals, with links to the GBIF data and Wikipedia page for that species, and links to the various projects which help fund it. It also hosted a Massive Online Open Course (MOOC) and held workshops on camera trapping methodologies for Agouti, now available on YouTube. Thus, we can appeal to everyone who has an interest in nature from countryside walkers, through to research institutes and hunting organisations.

Data Created

These apps have been actively collecting data since 2019 for MAMMALNET. Despite national lockdowns during the covid pandemic in Europe, the number of iMammalia records continued to increase during 2020, with some possible evidence of a slowdown during winter months of that year (Figure 6). Most records submitted so far, have come from those target countries which hosted a publicity launch and continued to engage with citizens through social media, in particular Spain, Poland, Germany and Croatia, although some smaller countries such as Montenegro have recorded more records per person despite a later and more limited launch.

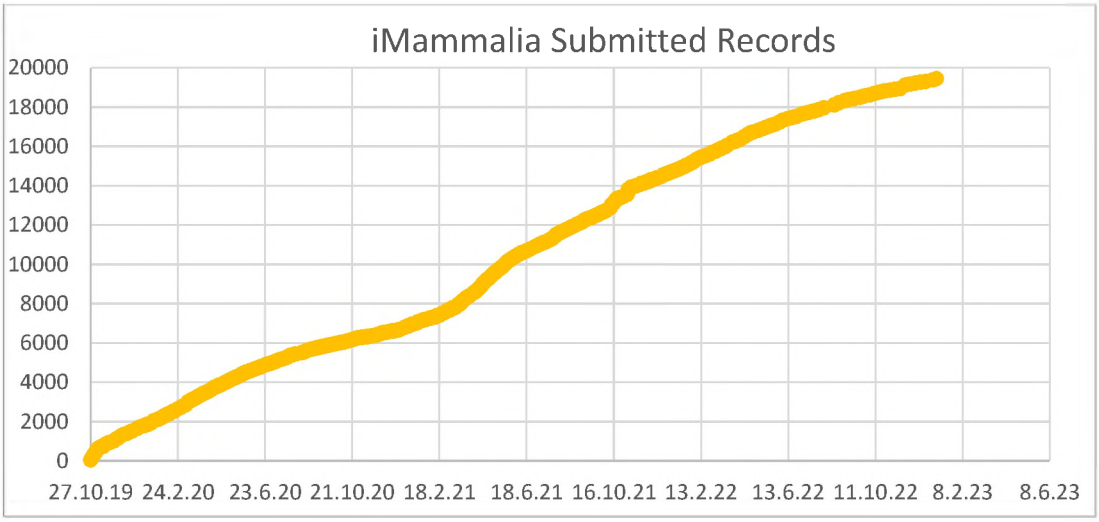

Fig. 6. The cumulative number of records submitted to iMammalia since its launch in October 2019. This has been averaging about 17 records per day.

MammalWeb now has projects in ten new European countries with over 110,000 image sequences submitted from over 270 different camera placements. These have been submitted by single camera placements from members of the public, local nature organisations and even from school projects, with an average of 1500 image sequences submitted per month.

Agouti hosts data from over 600 projects, with >75,000 camera deployments totaling about 103 million images. This includes the 48 study sites in 28 European countries that currently form the European Observatory of Wildlife, which encompass a variety of hunting grounds and protected areas monitored by a growing network of at least 15 universities and 10 nature conservation organisations, as well as research institutes and hunting bodies. The 2022 EOW survey yielded over 1,100 camera placements totaling about 2,388,000 images, which were uploaded to Agouti in late 2022. The aim is to repeat this survey every year to monitor trends in density and encourage new locations to join.

Project Impact

MAMMALNET has already had numerous impacts across a One Health spectrum that can be hard to quantify: iMammalia has >1000 users, MammalWeb has >2000 spotters across all projects, Agouti has >150 users on MAMMALNET projects and >3400 users overall, and the training courses and MOOC has been attended by >1000 people. This has connected lots of people with similar interests, provided education and training in animal identification and, hopefully, improved the wellbeing of some individuals directly. School projects in Spain used MammalWeb as a pilot educational tool to bring science and conservation closer to students. Camera trapping has been continuing in thirteen protected areas of the Carpathian Mountains in Ukraine with the support of the Frankfurt Zoological Society. Conservation areas in Italy have also adopted MammalWeb to monitor wildlife biodiversity. It seems that members of the public and conservation/wildlife organisations are keen to utilize these tools. Uptake by national or regional government agencies has been less as they often feel a need to be in control of the apps being used, but we are keen to stress that these apps do not have to replace other

reporting tools. If people are already using these tools, wildlife health agencies can benefit from any information gained with zero cost, and can still produce specific apps for their own staff surveys.

Most data from iMammalia have already been uploaded to GBIF, making them publicly available and have led to more than 70 publications so far. These have looked at species extinction risks, range expansion of invading mammals such as American mink (Vada *et al.* 2023). It is also being used to look for the recently introduced non-native greater white-toothed shrew in the UK (Bond *et al.* 2022). The data are being used to estimate the distribution, abundance and density of European mammals (e.g. ENETWILD-consortium *et al.* 2022b). Output from this may then feed into risk assessments for disease spread and control (EFSA *et al.* 2022). These techniques can also look at the potential for a renewed spread of rabies now that other hosts, such as raccoon dogs and jackals, have become more common in Europe.

Case studies

Initially, the interest is in ASF spread across Europe, with ENETWILD producing updated distribution maps (ENETWILD-consortium *et al.* 2022b), new estimates of local density (ENETWILD-consortium *et al.* 2023), the overlap with domestic pigs (ENETWILD-consortium *et al.* 2021) and with iMammalia recording 82 boar carcasses, at least one of which has been confirmed as ASF positive.

The public database GBIF reports 3500 mammal records in the Balkan area of south-east Europe since the start of 2020. iMammalia provided 2000 of these, with long running international apps such as Observation.org and iNaturalist.org recording 800 and 600 respectively. Recent records from iMammalia, and those from MammalWeb and Agouti have yet to be added. This demonstrates the benefit of producing simple to use recording apps with local publicity to maximise uptake.

Conclusions

One of the ambitions of One Health is also to consider wildlife. Here, we demonstrate the utility of the MAMMALNET approach of engaging with people who have a shared interest in wildlife to help collect data. As part of this process there are clear educational and training benefits to the users, and the collection of data focused toward areas which historically have limited data also helps benefit countries with a lower engagement with wildlife science.

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