External Scientific Report

ENETWILD

Improvement of information technology tools to collect, process and analyse data on wildlife population

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Abstract

ENETWILD consortium with the collaboration of the *MammalNet* project[2] has promoted some informatic tools to improve the data collection of wildlife distribution and abundance: *iMammalia*; *MammalWeb* and *Agouti*. Here we update the activities in relation to (i) the new languages implemented; (ii) new functionalities, (iii) and the improvement and testing of the artificial intelligence module to identify species in *Agouti*. The *iMammalia* app is now available in 17 languages with at least two more to be added soon. *MammalWeb* is available in six languages with more to be added soon. Agouti is available in seven languages. *iMammalia* automates data transfer to the global database GBIF, and *MammalWeb* will consider a similar approach in the near future. Technical improvements were made to meet the needs of *iMammalia* as a carcass reporting app for wild boar, which will favour early awareness in case of ASF outbreak. As for density estimation through camera trapping, processing of big number of images by hand is tedious, and to facilitate the annotation process *Agouti* offers and has continuously improved automatic species recognition using Artificial Intelligence (AI). We summarize several topics for the further development of *Agouti*.

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[1] www.enetwild.com
[2] https://mammalnet.com

ENETWILD

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Summary

<u>Background</u>: Wildlife monitoring involves the regular observation and recording of wildlife on a long-term scale to show trends over time, current distributions, changes in population density or abundance, and how the human factors influence and impact on them. This provides a necessary process and data with which to look at invasive species spread, conservation of rare species, changes in distribution and abundance of species that may carry diseases of human and livestock concern. There are several such tools in use across Europe, but mostly these are national tools, or limited to individual species, or species groups. These risks collecting information that is not publicly available, and not strictly comparable between systems. Here we report on tools initially produced or further developed by the *MammalNet* project and implemented within the framework of the *ENETWILD* project. These tools comply with the Darwin core standard for wildlife monitoring and where appropriate will be able to comply with advancing this standard to include wildlife disease. Data resulting from these apps will be available to help improve modelling species distribution, such as carnivores, ungulates and wild boar.

ENETWILD with the collaboration of the *MammalNet* project (https://mammalnet.com) has promoted some tools to improve the data collection of wildlife distribution and abundance:

- *iMammalia:* a mobile app to incentive the collaboration of citizens to incorporate records about occasional records of wild mammals, but also to promote the collection of dead animals and carcasses which may be of interest for health assessment a by local authorities;
- *Agouti*: a web application focused on managing camera-trapping projects, annotation and archiving of camera trap images and videos, which incorporates artificial intelligence functionalities to automatically identify species and help collaborators of the European Observatory of Wildlife (*EOW*) to calculate wildlife density estimates;
- *MammalWeb*: a web application based on camera-trapping that is aimed at citizens who want to collaborate as spotters, or trappers generating information on the distribution of wild mammals.

This report updates on the activities in relation to:

- The new languages implemented in *iMammalia* and *MammalWeb*;
- A new functionality implemented in *iMammalia* for automatic data transfer to *GBIF*;
- The improvement and testing of the artificial intelligence module to identify species in *Agouti*.

<u>iMammalia</u>: Further language additions include Czech, French, Norwegian, Portuguese, Slovakian and Ukrainian. In addition, Swedish and Turkish have been fully translated and will be added with the next update, and Bulgarian, Lithuanian, and Dutch are partially translated and will be added to the next update if complete. This means the app is currently available in 17 languages, with at least a further two to be added when the app is next updated on the app store. Other languages, such as Finnish, Hungarian, Estonian, Belarusian, Latvian, Romanian and Slovenian could be added in the future, subject to sufficient volunteer translators. To date about 19,000 records (with high spatial accuracy) are now available on

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GBIF, with the automatic updating of these records to occur approximately every six months. Given the high level of use of the GBIF database, these records are likely to contribute to a substantial number of research projects and future citations (>90 citations by June 2023). In total 96 different species have been reported by *iMammalia*. *iMammalia* now allows its use to report wild boar carcasses in any country, including the Balkans. The FAO team was responsible for launching the application in the Balkans. A similar functionality could be set up to report other carcasses or unusual sightings (e.g., non-native species).

MammalWeb: in 2019, *MammalWeb* instigated projects and web translations for the pilot European countries: Croatia, Germany, Poland, and Spain. Since then, the Hungarian language has also been added, along with projects from France, Ireland, Italy, Portugal, and Ukraine. Further language support is being developed to improve the ease with which even more languages can be added, with Italian, Ukrainian and some Dutch (for a specific project) under development. *MammalWeb* is a self-sustaining web portal which will continue independently from any external funding, so further developments will continue. *MammalWeb* is also collaborating on artificial intelligence (AI) image classification and aim to have that facility successfully implemented by the end of 2023.

Agouti: within the *ENETWILD* project, *Agouti* has facilitated the camera trap surveys that aimed to estimate densities of several mammal species across Europe. Within the *ENETWILD* 2022 sampling season 34 projects used *Agouti* to conduct the camera trap survey. In total, this yielded 1,165 deployments and around 134k observations of wildlife. Processing such a large number of images by hand is tedious, and to facilitate the annotation process, Agouti offers automatic species recognition using AI. To be more effective at the European level, the *Agouti* AI model was expanded and trained with the wildlife observations from the *ENETWILD* surveys. Overall performance of the entire model across all supported species is 76%. However, performance varies between species. Common species are generally predicted much more accurately, while species that show poor performance, such as rodents, are predicted at a higher taxonomic level, such as genus, family, or order. A major improvement to the AI model in *Agouti* is the option to use follow-up classification models. This means if a group of similar species are often confused by the AI, we can use a two-step approach to improve performance. This approach will be gradually implemented for species groups that are now often confused. We acknowledge that developments in the field of AI are rapid, and *Agouti* is not the only one working on species classification models. *Agouti* supports model from other sources as well and welcomes anyone that has trained a model to offer it to users through *Agouti*. Currently, we have implemented the model *Deepfaune* and *MegaDetector* in addition to our own. With feedback from *ENETWILD* members, we have improved the *Agouti* interface to become more user friendly in general. Specifically, we have added a real-time AI function that automatically produces observations while users annotate by hand. This improvement speeds up annotation, but also allow users to evaluate AI models in Agouti more quickly.

Conclusions and recommendations:

- Citizen science projects in the widest sense can contribute a vast amount of data in wildlife biodiversity. *iMammalia* has collected 20,000 records of 96 species, *MammalWeb*

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125,000 records of at least 66 species, and concerning Agouti, within the *ENETWILD* 2022 sampling season, 32 projects used Agouti to conduct the camera trap survey. In total, this yielded 1,165 deployments and some 134k observations of wildlife.

- The *iMammalia* app is now available in 17 languages with at least two more to be added soon. *MammalWeb* is available in six languages with more to be added soon. Agouti is available in seven languages.

- *iMammalia* is automating data transfer to the global database GBIF, and *MammalWeb* will consider a similar approach in the near future.

- Technical improvements were made to meet the needs of *iMammalia* as a carcass reporting app for wild boar, which adds the possibility of recording sex, age, whether the dead animal has been hunted or not, or the degree of decomposition observed. This information together with the photograph that the user can send facilitates its verification and evaluation by the experts. This will favour early awareness in case of ASF outbreak. In 2022 this functionality was added to the app with the ability to automatically generate an alert email for any dead wild boar records. This email is generated within about an hour of the record being submitted. Local veterinary authorities can request these emails alerts in regions where ASF is suspected.

- As for camera trapping for density estimation, processing such of such a high number of images by hand is tedious, and to facilitate the annotation process Agouti offers and has continuously improved automatic species recognition using AI. A major improvement to the AI model in *Agouti* is the option to use follow-up classification models. This means that, if a group of similar species are often confused by the AI, we can use a two-step approach to improve performance. The new *Agouti* interface is available for all users from July 2023.

- For the further development of *Agouti,* we recommend considering the following topics:
  o Further scale the AI models to include more species and more data, to improve the performance of the species classifier.
  o Build AI models to identify individuals, using spot and stripe patterns.
  o Use AI the track animals within image sequences, to automatically generate input data for density estimation (REM/REST). Now, tracking animals is done by hand, which is time consuming.
  o Explore whether AI can classify the age, sex, behaviour, or animals.
  o Improve data export so density estimates and key numbers can be exported directly from Agouti, in a standard reporting format (PDF/Excel).
  o Build a pipeline to automatically submit data from Agouti to GBIF, facilitating data sharing.

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1. Introduction

1.1. Background and terms of reference

Wildlife monitoring involves the regular observation and recording of wildlife on a long-term scale to shows trends over time, current distributions, changes in population density or abundance, and how the human factors influence and impact on them. This provides a necessary process and data with which to look at invasive species spread, conservation of rare species, changes in distribution and abundance of species that may carry diseases of human and livestock concern. There are several such tools in use across Europe, but mostly these are national tools, or limited to individual species, or species groups. These risks collecting information that is not publicly available, and not strictly comparable between systems. Here we report on tools initially produced or further developed by the *MammalNet* project and implemented within the framework of the *ENETWILD* project. These tools comply with the Darwin core standard for wildlife monitoring (*ENETWILD* consortium et al. 2020) and where appropriate will be able to comply with advancing this standard to include wildlife disease (*ENETWILD*-consortium et al. 2022a). Data resulting from these apps will be available to help improve modelling species distribution, such as carnivores (*ENETWILD*-consortium et al. 2023), ungulates (*ENETWILD*-consortium et al. 2022b) and wild boar (*ENETWILD*-consortium et al. 2022c; *ENETWILD*-consortium et al. 2022d; *ENETWILD*-consortium et al. 2021).

This contract was awarded by EFSA to Universidad de Castilla-La Mancha, contract title: Wildlife: collecting and sharing data on wildlife populations, transmitting animal disease agents, contract number: OC/EFSA/ALPHA/2016/01 – 01.

The terms of reference for the present report (specific contract 11, deliverable 5.6) indicates "to improve the *iMammalia* app: to automate the data transfer to GBIF and increase the number of languages the app is available for (the number of languages will also be increased in *MammalWeb* app). Expanding the Artificial intelligence infrastructure of *Agouti* app by enlarging the training library and improve the models as to cover the whole of Europe".

The deliverables (Activities reported in this document) are: 1) report detailing new languages implemented in *iMammalia* and *MammalWeb*; 2) a new functionality implemented in *iMammalia* for automatic data transfer to GBIF, and 3) the improvement and testing of the artificial intelligence module to identify species in *Agouti.*

2. Data and Methodologies

ENETWILD (www.enetwild.com) with the collaboration of the *MammalNet* project (http://www.mammalnet.com) has promoted some tools to improve the data collection of wildlife distribution and abundance:

- *iMammalia*; a mobile app to incentive the collaboration of citizens to incorporate records about occasional records of Wild Mammals, but also to promote the collection of dead animals and carcasses which may be of interest for health assessment a by local authorities;
- *Agouti:* A web application focused on managing camera-trapping projects, annotation and archiving of camera trap images and videos, which incorporates artificial intelligence functionalities to automatically identify species and help EOW collaborators calculate wildlife density estimates;
- *MammalWeb*: A web application based on camera-trapping that is aimed at citizens who want to collaborate as spotters, or trappers generating information on the distribution of wild mammals.

Here, we report update the activities developed in relation to:

- The new languages implemented in *iMammalia* and *MammalWeb*;
- A new functionality implemented in *iMammalia* for automatic data transfer to *GBIF*;
- The improvement and testing of the artificial intelligence module to identify species in *Agouti*.

3. Results

3.1. *iMammalia*

iMammalia is a smartphone app for recording opportunistic mammal sightings, developed under the EFSA funded *MammalNet* (https://mammalnet.com) project for citizen science use. It was aimed at general members of the public, including those people with limited experience and skills in mammal identification. Thus, species selection is by image and limited to those species present in the country of choice. For smaller species, which are more difficult to tell apart, a generic selection can be made (Figure 1). Records can be submitted with photos, and a comment box which may include a description, or exact species and the reason for its selection.
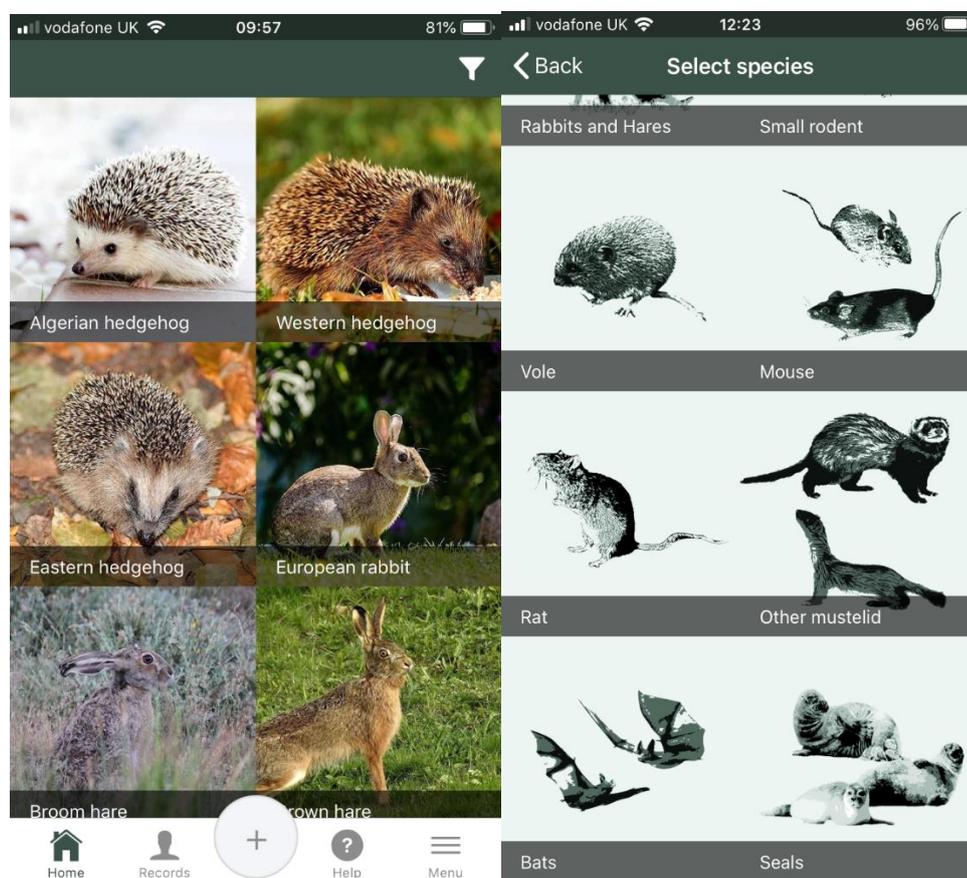
Figure 1. The English version of *iMammalia* showing the home screen and the generic species selection screen for difficult to identify mammals

The records can include live sightings, camera trap records, hunted or caught animals and roadkill, as well as prints, droppings, or den sites. All records are submitted to a web site (https://european-mammals.brc.ac.uk/records/explore/all) where registered users may examine the submitted records. All records are examined by a mammal expert who verifies them. This can be based on supplied photos, descriptions, and previous experience.

The app was launched in October 2019 in English, and four pilot countries Spanish, German, Polish and Croatian, along with a publicity and social media campaign in the four pilot countries. In 2020 the app was further developed to include all European mammals and all countries. Thus, any mammal could be recorded in any country (even outside Europe), and the species list was refined for all European countries, so the user can choose the country they are in to limit the choice of species. In early 2021 further languages were added to the app; Albanian, Italian, Greek, Macedonian, Montenegrin and Serbian, along with local publicity in countries including Kosovo[3] and Bosnia. This report details further language additions: Czech, French, Norwegian, Portuguese, Slovakian and Ukrainian. In addition, Swedish and Turkish have been fully translated and will be added with the next update, and Bulgarian, Lithuanian, and Dutch are partially translated and will be added to the next update if complete. This means the app is currently available in 17 languages, with at least a further two to be added when the app is next updated on the app store. Other languages, such as Finnish, Hungarian, Estonian, Belarusian, Latvian, Romanian and Slovenian could be added in the future, subject to sufficient volunteer translators.

Since its initial launch, over 20,000 records have been submitted from 31 European countries (and South Africa, Mexico and Kazakhstan), with over 18,000 of these verified by experts (Figure 2). A high number of submissions has occurred in those countries with local publicity launches. The launch in Montenegro in 2021 clearly worked well, given the number of records submitted per unit area for that country (Figure 3).
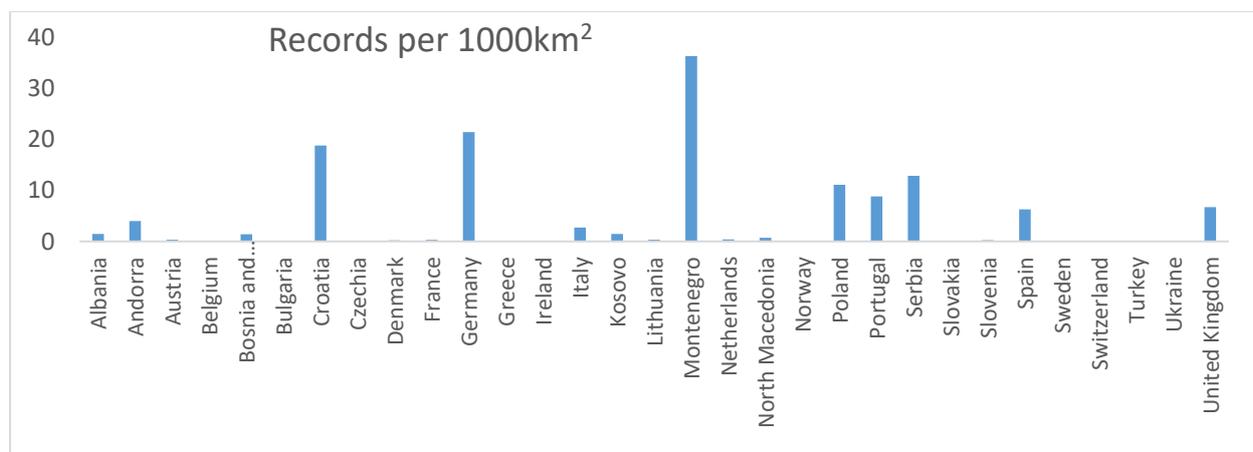

Figure 2. The number of submitted records from each country in Europe with some records (as of April 11th 2023)[3]

The most reported species was the roe deer (*Capreolus capreolus*), which is widespread and common, but the stone marten (*Martes foina*), beaver (*Castor fiber*) and wolf (*Canis lupus*) were also among the top 15 recorded species despite being relatively uncommon (Figure 3). This demonstrates that unusual sightings are recorded disproportionately frequently as has been reported elsewhere (Croft et al. 2017).

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[3] Kosovo: This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence
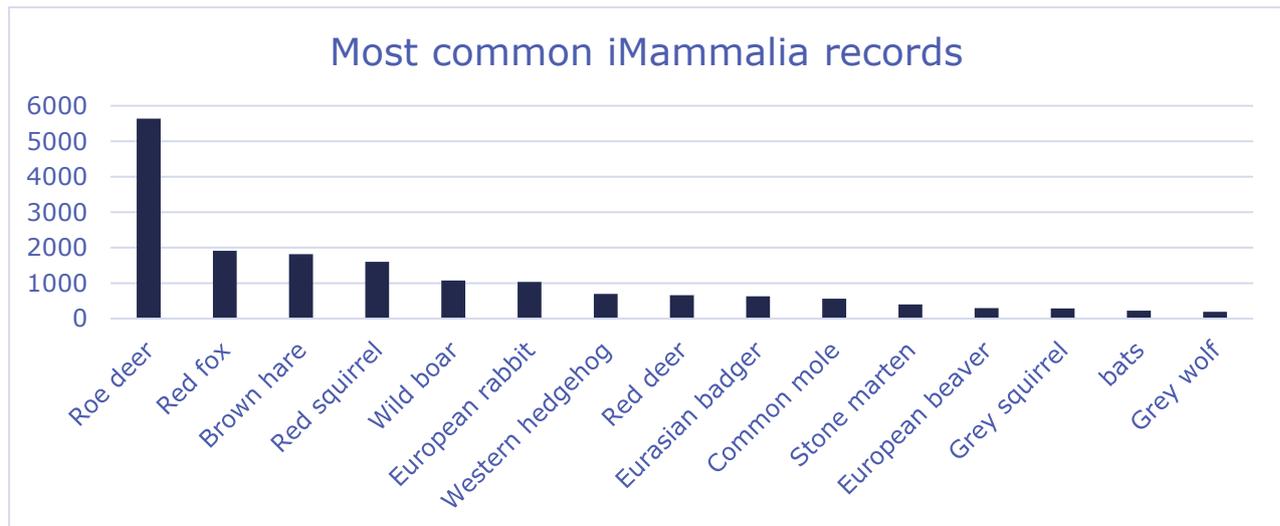
Most common iMammalia records

Figure 3. The top 15 most reported mammals in *iMammalia* to date

In May 2020 the dataset was registered with the Global Biodiversity Information Facility (GBIF) to make them publicly available in the largest open data biodiversity database. In June 2022 a total of 15,000 records had been submitted. Since then, there have been over 13,000 data downloads that include at least some of these data, with more than 90 citations recorded by GBIF. With currently about 10 new records reported everyday it is important to ensure that the public database is up to date, so an automatic update approach is being utilised to ensure that regular updates are supplied to GBIF. To date about 19,000 records are now available on GBIF, with the automatic updating of these records to occur approximately every six months. Given the high level of use of the GBIF database, these records are likely to contribute to a substantial number of research projects and future citations. In total 96 different species have been reported by *iMammalia*.
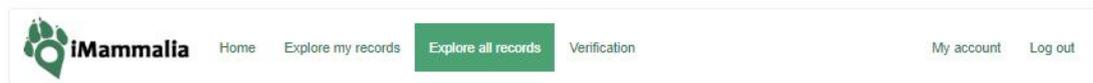
Carcass alert system

Technical improvements were made to meet the needs of *iMammalia* as a carcass reporting app for wild boar, which adds the possibility of recording sex, age, whether the dead animal has been hunted or not, or the degree of decomposition observed. This information together with the photograph that the user can send facilitates its verification and evaluation by the experts. This will favour early awareness in case of ASF outbreak. For example, this could be very helpful in remote forest areas where ASF is detected in dead wild boar, such as the recent ASF positive cases reported in Serbia or northern Italy (Piedmont).

The email alert and the online search for the record is shown below (Figure 4). In 2022 this functionality was added to the app with the ability to automatically generate an alert email for any dead wild boar records (*ENETWILD*-consortium et al. 2022e). This email is generated within about an hour of the record being submitted. Local veterinary authorities can request these emails alerts in regions where African Swine Fever (ASF) is suspected. Several such alerts have been produced, and although most occur in areas where ASF is not suspected, alerts have been generated in Serbia and Italy where ASF outbreaks are ongoing. *iMammalia* now allows its use to report wild boar carcasses in any country, including the Balkans. The FAO team was

responsible for launching the application in the Balkans. A similar functionality could be set up to report other carcasses or unusual sightings (e.g., non-native species).

*** This email is for information only and any replies will go to an email inbox that is not monitored. Please use a project-specific email address for any questions or for more information. ***

Date	Species	Comment	Observation type	Latitude	Longitude
2022-11-12	Wild Boar	Notification that a Wild Boar carcass has been recorded.	Dead - other	44.66566	8.61957

Figure 4. The email alert generated for a dead wild boar sighting in northern Italy, and the record that generated this alert shown on the web site

Disclaimer: The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the European Food Safety Authority concerning the

legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

3.2. *MammalWeb*

The use of automatic cameras for recording wildlife has grown in the last decade or so. These are used by amateurs and professionals alike. We have two camera trap tools to ensure that we can capture the maximum amount of data from people with ad hoc or projects placements (*MammalWeb*), through to those utilising a systematic camera distribution to collect data on density and abundance (Agouti).

MammalWeb is a portal initially designed for UK-wide camera trapping for citizens scientists to contribute and classify camera trap data. *MammalWeb* was initially trialled in 2013 at Durham University in northern England, an area identified as a 'data desert' due to lack of mammal biodiversity records (Croft et al. 2017). *MammalWeb* permits anyone with camera traps to submit the images to the platform, where they, and other registered users, can classify the images (Figure 5). Photo sequences and videos can be submitted to specific projects, and each image can be classified by multiple people to ensure a consensus is reached (Hsing et al. 2018).

In 2019, *MammalWeb* instigated projects and web translations for the pilot European countries: Croatia, Germany, Poland, and Spain. Since then, the Hungarian language has also been added, along with projects from France, Ireland, Italy, Portugal, and Ukraine. Further language support is being developed to improve the ease with which even more languages can be added, with Italian, Ukrainian and some Dutch (for a specific project) under development. *MammalWeb* is a self-sustaining web portal which will continue past the life of any external funding, so further developments will continue.
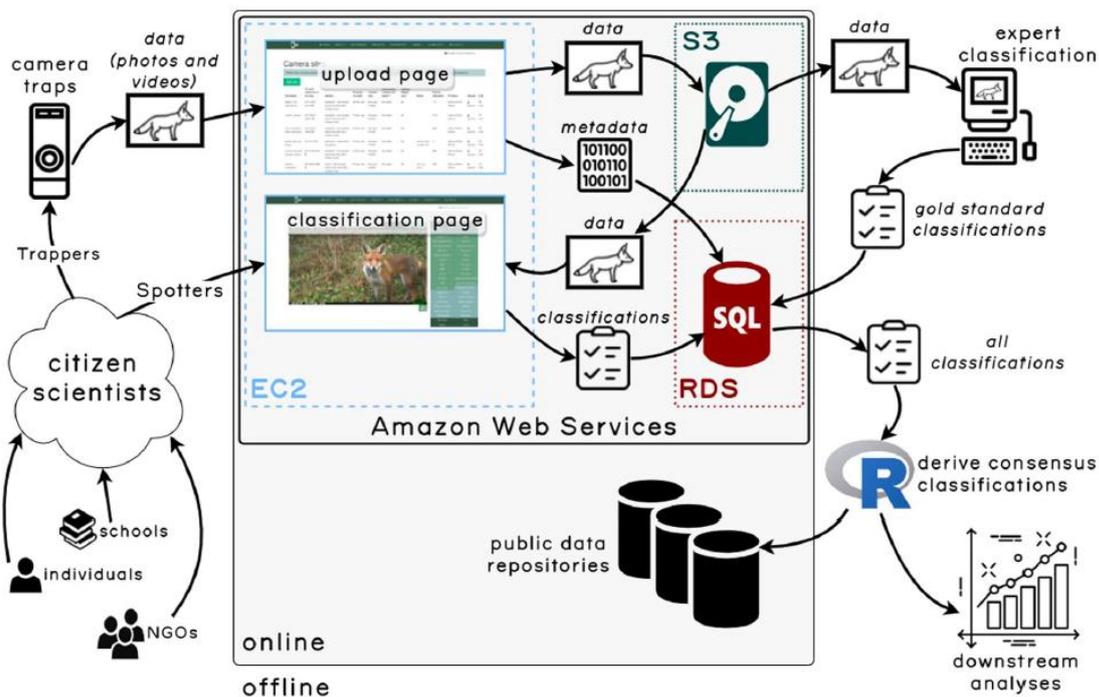
Figure 5. *MammalWeb* project organisation. NGOs, non-governmental organizations; EC2, Amazon Elastic Compute Cloud 2; S3, Amazon Simple Storage Service; RDS, Amazon Relational Database Service (from Hsing et al. 2022)

MammalWeb has collected over 1.7 million images and video files at over 2300 sites across Britain (Hsing et al. 2022). The *MammalNet* project has collected over 125,000 uploaded sequences, and more than 64,000 of these have been classified. These include mammal and bird records, as both can trigger the camera. Like *iMammalia*, the most recorded mammal species include the roe deer, wild boar, and red fox (*Vulpes vulpes*) (Figure 6). However, camera trapping has the benefit of being active 24 hours a day and independent of the biases of human observers, thus making it easier to record nocturnal and small mammals. *MammalWeb* (UK) is currently finalising automatic upload of data to the UK biodiversity database (National Biodiversity Network; NBN); when this is completed, we will repeat the approach to contribute the European data to GBIF. *MammalWeb* is also collaborating on AI image classification and aim to have that facility successfully implemented by the end of 2023.

In total, 66 different mammal species (or species groups such as small rodent – unknown species) have been recorded and classified in the *MammalNet* project.
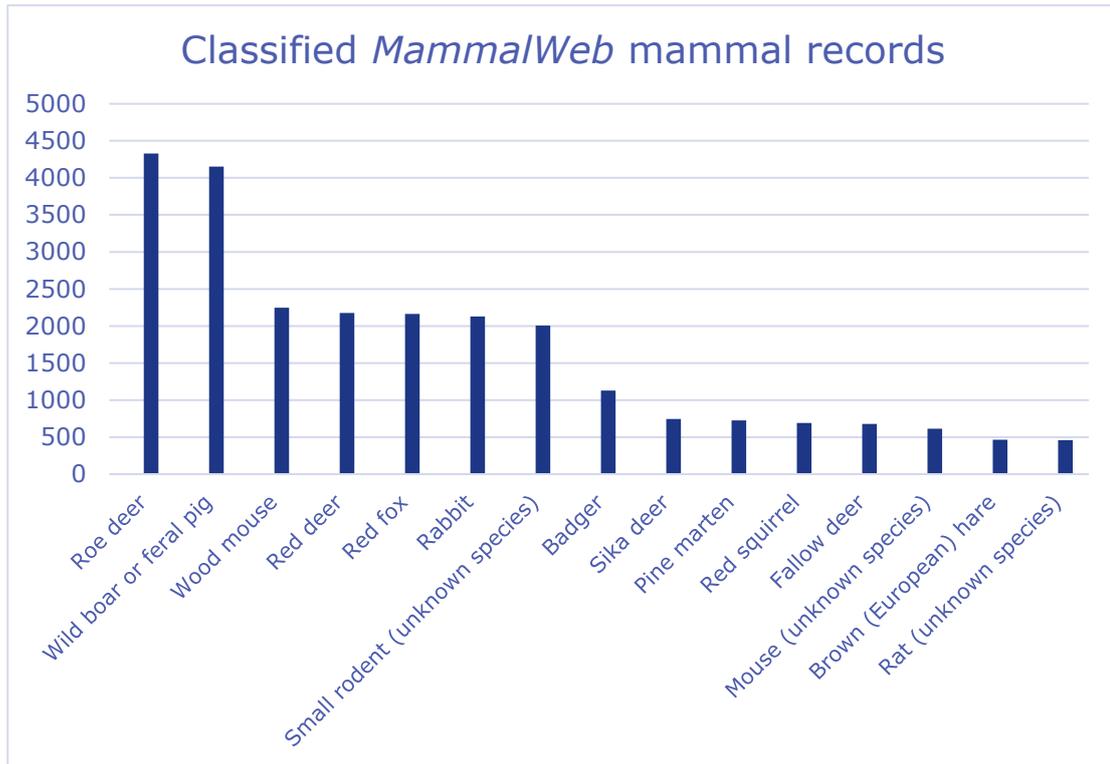
Figure 6. The top 15 mammal classifications by species for the *MammalNet* project on *MammalWeb*

3.3. *Agouti*

Agouti (https://www.agouti.eu/) is an AI powered solution for organizations and professionals that use camera traps to survey wildlife. It lets camera trappers organize surveys, efficiently process images, obtain standardized output of the results, and safely archive your data. Agouti follows the [Camera Trap Data Package](https://www.agouti.eu/) (Camtrap DP) standard, a community developed data exchange format for camera trap data.

Within the *ENETWILD* project *Agouti* has facilitated the camera trap surveys that aimed to estimate densities of several mammal species across Europe. Within the *ENETWILD* 2022 sampling season 32 projects[*] used *Agouti* to conduct the camera trap survey. In total, this yielded 1,165 deployments and some 134k observations of wildlife (Table 1).

*some projects operate multiple sites

Table 1. *Agouti* deployments and observations.

164		Users
32		Projects
1165		Deployments
83	k	Images
138	k	Image sequences
134	k	Observations
21	k	AI-generated observations
10.4	k	Tracked animals

Processing such a large number of images by hand is tedious, and to facilitate the annotation process Agouti offers automatic species recognition using Artificial Intelligence (AI). Before the start of *ENETWILD*, *Agouti* offered an AI model focused on species that occur in the Netherlands, Belgium, and Luxemburg. To be more effective at the European level, the *Agouti* AI model was expanded and trained with the wildlife observations from the *ENETWILD* surveys. This yielded a much-improved model that covers 67 mammal and bird species that occur in Europe. Overall performance of the entire model across all supported species is 76%. However, performance varies between species. Common species are generally predicted much more accurately, while species that show poor performance, such as rodents, are predicted at a higher taxonomic level, such as genus, family, or order. A list of species supported by the *Agouti* AI is show below. Figure 7 shows a confusion matrix for the *Agouti* European AI model. The darker the diagonal, the better the performance of the AI model.

A major improvement to the AI model in *Agouti* is the option to use follow-up classification models. This means if a group of similar species are often confused by the AI, we can use a two-step approach to improve performance. For example, in the first step we only classify deer to the level 'Cervidae'. In the second step, another classification is done by a model that was trained to specifically classify deer species. The 'Cervidae' then becomes '*Cervus elaphus*' or '*Dama*

dama'. This approach will be gradually implemented for species groups that are now often confused.

We acknowledge that developments in the field of AI are rapid, and *Agouti* is not the only one working on species classification models. *Agouti* supports model from other sources as well and welcomes anyone that has trained a model to offer it to users through *Agouti*. Currently, we have implemented the model Deepfaune and MegaDetector in addition to our own.

Many AI tools are difficult to use and require users to setup local compute environments or write scripts themselves. We have integrated AI into the *Agouti* user interface so camera trappers can use AI with the click of a button. With feedback from *ENETWILD* members, we have improved the *Agouti* interface to become more user friendly in general. Specifically, we have added a real-time AI function that automatically produces observations while users annotate by hand. This improvement speeds up annotation, but also allow users to evaluate AI models in *Agouti* more quickly. Also, we have introduced public project pages and portals that organizations can use to showcase their projects. However, projects in *Agouti* are still hidden by default and project owner always have full control over their project's visibility and data. The new *Agouti* interface is available for all users from July 2023.

For the further development of *Agouti* we recommend considering the following topics:

1. Further scale the AI models to include more species and more data, to improve the performance of the species classifier.
2. Build AI models to identify individuals, using spot and stripe patterns.
3. Use AI the track animals within image sequences, to automatically generate input data for density estimation (REM/REST). Now, tracking animals is done by hand, which is time consuming.
4. Explore whether AI can classify the age, sex, behaviour, or animals.
5. Improve data export so density estimates and key numbers can be exported directly from *Agouti*, in a standard reporting format (PDF/Excel).
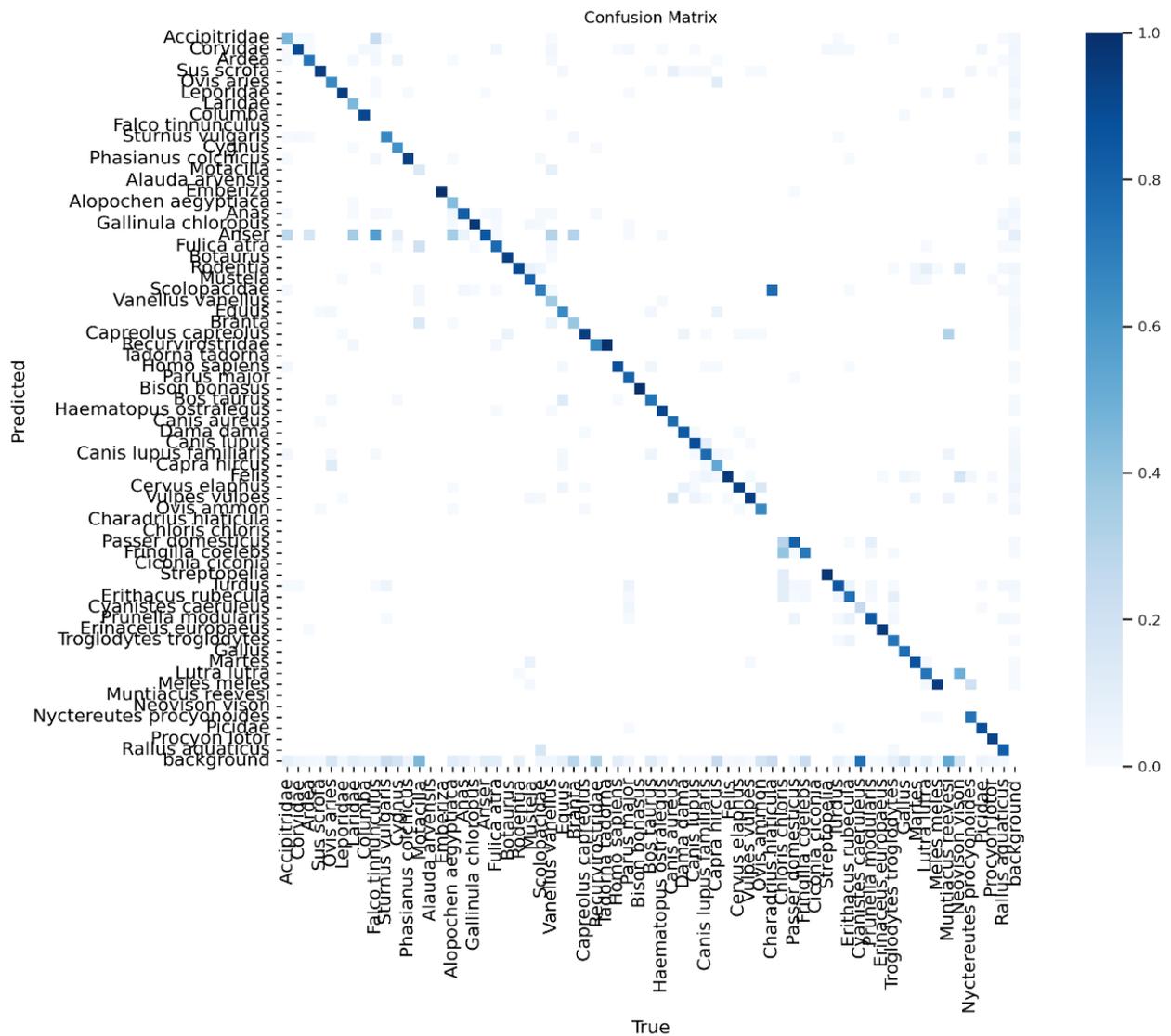6. Build a pipeline to automatically submit data from Agouti to GBIF, facilitating data sharing.

Figure 7. Confusion matrix for the *Agouti* European AI model. The darker the diagonal, the better the performance of the AI model

Table 1. To be more effective at the European level, the *Agouti* AI model was expanded and trained with the wildlife observations from the *ENETWILD* surveys. This yielded a much-improved model that covers 67 mammal and bird species that occur in Europe listed below.

Agouti AI - European model (V4a)	
Accipiter gentilis	*Gallus*
Alopochen aegyptiaca	*Laridae*
Anas platyrhynchos	*Larus fuscus*
Anas strepera	*Lepus europaeus*
Anser	*Lutra lutra*
Ardea	*Martes*
Ardea alba	*Meles meles*
Aves	*Motacillidae*
Bison bonasus	*Muntiacus reevesi*
Bos taurus	*Mustela erminea*
Botaurus stellaris	*Mustela nivalis*
Branta leucopsis	*Mustela putorius*
Buteo buteo	*Myocastor coypus*
Canis aureus	*Neovison vison*
Canis lupus	*Nyctereutes procyonoides*
Canis lupus familiaris	*Oryctolagus cuniculus*
Capra hircus	*Ovis ammon*
Capreolus capreolus	*Ovis aries*
Castor fiber	*Passeriformes*
Cervus elaphus	*Phasianus colchicus*
Columba	*Pica pica*
Columbidae	*Procyon lotor*
Corvidae	*Rallus aquaticus*
Crocidura russula	*Rodentia*
Cygnus olor	*Sciurus carolinensis*
Dama dama	*Sciurus vulgaris*
Dendrocopos major	*Scolopax rusticola*
Equus	*Streptopelia*
Erinaceus europaeus	*Sus scrofa*
Erithacus rubecula	*Tadorna tadorna*
Falco tinnunculus	*Turdidae*
Felis	*Vanellus vanellus*
Fulica atra	*Vulpes vulpes*
Gallinula chloropus	

4. Conclusions and recommendations

- Citizen science projects in the widest sense can contribute with a vast amount of data in wildlife biodiversity. So far, *iMammalia* has collected 20,000 records of 96 species, *MammalWeb* 125,000 records of at least 66 species, and concerning Agouti, within the *ENETWILD* 2022 sampling season, 32 projects used Agouti to conduct the camera trap survey. In total, this yielded 1,165 deployments and some 134k observations of wildlife.
- The *iMammalia* app is now available in 17 languages with at least two more to be added soon. *MammalWeb* is available in six languages with more to be added soon. Agouti is available in seven languages.
- *iMammalia* automates data transfer to the global database GBIF, and *MammalWeb* will consider a similar approach in the near future.
- Technical improvements were made to meet the needs of *iMammalia* as a carcass reporting app for wild boar, which adds the possibility of recording sex, age, whether the dead animal has been hunted or not, or the degree of decomposition observed. This information together with the photograph that the user can send facilitates its verification and evaluation by the experts. This will favour early awareness in case of ASF outbreak. In 2022 this functionality was added to the app with the ability to automatically generate an alert email for any dead wild boar records. This email is generated within about an hour of the record being submitted. Local veterinary authorities can request these emails alerts in regions where ASF is suspected.
- As for camera trapping for density estimation, processing such a number of images by hand is tedious, and to facilitate the annotation process, *Agouti* offers and has continuously improved automatic species recognition using AI. A major improvement to the AI model in Agouti is the option to use follow-up classification models. This means if a group of similar species are often confused by the AI, we can use a two-step approach to improve performance and precision. The new Agouti interface is available for all users from July 2023.
- For the further development of *Agouti* we recommend considering the following topics:
  - Further scale the AI models to include more species and more data, to improve the performance of the species classifier.
  - Build AI models to identify individuals, using spot and stripe patterns.
  - Use AI the track animals within image sequences, to automatically generate input data for density estimation (REM/REST). Now, tracking animals is done by hand, which is time consuming.
  - Explore whether AI can classify the age, sex, behaviour, or animals.
  - Improve data export so density estimates and key numbers can be exported directly from Agouti, in a standard reporting format (PDF/Excel).
  - Build a pipeline to automatically submit data from Agouti to GBIF, facilitating data sharing.

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