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Development of the European Ladybirds Smartphone Application: A Tool for Citizen Science

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Wildlife observations submitted by volunteers through citizen science initiatives are increasingly used within research and policy. Ladybirds are popular and charismatic insects, with most species being relatively easy to identify from photographs. Therefore, they are considered an appropriate taxonomic group for engaging people through citizen science initiatives to contribute long-term and large-scale datasets for use in many different contexts. Building on the strengths of a mass participation citizen science survey on ladybirds in the United Kingdom, we have developed a mobile application for ladybird recording and identification across Europe. The main aims of the application are to: (1) compile distribution data for ladybird species throughout Europe, and use this to assess changes in distribution over time; (2) connect and engage people in nature and increase awareness about the diversity and ecological importance of ladybirds. In developing the application we first constructed a database including ladybird species from the United Kingdom, Czech Republic, Slovakia, Italy, Belgium, and Portugal with associated information on relevant morphological features (e.g., size, main color, pronotum pattern) to inform identification. Additionally, the species were assessed on the basis of probability of occurrence within each country which enables users to reduce the number of species to only those with relevance to the location of the recorder. This is amongst the first collaborative citizen science approaches aimed at involving participants across Europe in recording a group of insects. In the near future, we aim to expand the use of the application to all countries in Europe.

Keywords: coccinellids, community science, species distribution, large-scale, smartphone mobile app

INTRODUCTION

Citizen science, otherwise known as public participation in scientific research or community science, can be a powerful tool to obtain data on insect diversity and abundance across larger spatial scales whilst simultaneously promoting education and awareness about insects (e.g., Eitzel et al., 2017; Gardiner and Roy, 2021). Indeed, considering reports of global insect declines (e.g., Hallmann et al., 2017; Cardoso and Leather, 2019; Wagner et al., 2021), enhancing citizen science or community science, especially in areas where academic or professional infrastructure is lacking, was one of the immediate actions proposed by scientists when formulating a roadmap for insect conservation and recovery (Harvey et al., 2020). Cardoso et al. (2011) recognized the role of citizen science as part of the solution for the scarce and underfunded science on invertebrates, including the declining number of insect taxonomists. There are various typologies of citizen science and viewpoints on what is or is not citizen science (Haklay et al., 2021). Here, we focus on volunteers and their contributions to field-based observations in a coordinated effort involving professional scientists (Bonney, 1996).

Ladybirds (Coleoptera: Coccinellidae) are popular and charismatic insects. More than 6,000–7,000 species have been described worldwide (Seago et al., 2011). The brightly colored forewing patterns of ladybirds enable relatively easy identification to species-level from photographs for most species (e.g., Jouveau et al., 2018). As such, ladybirds from the more conspicuous groups (Coccinellinae, Epilachninae, Chilocorinae) are highly suitable for engaging people within citizen science projects (e.g., Gardiner et al., 2012).

Ladybirds are very diverse in terms of biology and ecology. Different species can be found in many terrestrial habitats (e.g., deciduous and coniferous forest, meadows and marshes, heathlands, croplands) where they exploit a range of prey species (e.g., aphids, coccids, whiteflies, mites, fungi) (for more detail, see Hodek et al., 2012). Some species display specific life history traits such as habitat and/or dietary specialization, myrmecophily and aggregation behavior which make them attractive to naturalists and fascinating to the public (Adriaens et al., 2015a). Although ladybirds are considered one of the most well-studied groups of insects, there are many knowledge gaps and scientific discoveries still to be made about them. Recently there was a first report of parthenogenesis in ladybirds (Magro et al., 2020); a group that, until recently, was considered to have only sexual reproduction.

While Jarić et al. (2020) reported that the charisma of a species (*sensu* Ducarme et al., 2013) highly affects the public's approach toward it, Groom et al. (2021) suggest that the target species/group needs to also evoke emotion or connection in the participants and that this is probably more important than simply the degree to which the species is considered charismatic. It is known that in zoo gardens, an animal's beauty and (large) size are generally more important to visitors than is conservation status (Frynta et al., 2013). In citizen science the connection to volunteers (i.e., citizens, scientists, biodiversity managers, policy-makers, local authorities, industry, schools, and other participants) can be positively (e.g., Sequeira et al., 2014) or negatively emotive (e.g., Gallo and Waitt, 2011; Palmer et al., 2017; Porter et al., 2019). European ladybirds are deeply rooted in popular culture and are undoubtedly regarded as both emotive and charismatic. They may invoke positive or negative emotions (e.g., Shipley and Bixler, 2017). As an example, the arrival of the invasive alien harlequin ladybird, *Harmonia axyridis* (Pallas) has been the motivation for increasing participation in established ladybird recording schemes worldwide (e.g., Roy and Brown, 2015; Grez et al., 2016; Hiller and Haelewaters, 2019). This species was introduced to many countries, has spread rapidly across the globe and is considered a threat to native biodiversity (Roy et al., 2012, 2016). *Harmonia axyridis* is regarded both positively, for being charismatic and for the ecosystem services it provides (Riddick, 2017), and negatively, adversely affecting other species of aphid natural enemy through competition and intra-guild predation (Roy et al., 2012; Brown et al., 2015a; Kenis et al., 2017; Masetti et al., 2018; Zaviezo et al., 2019). Additionally it is considered a nuisance to humans in some contexts.

Mobile applications (apps) have played a key role in facilitating the participation of volunteers in citizen science projects (August et al., 2015; Chandler et al., 2017). Mobile apps can help record the location of a species and allow for fast and easy submission of records without data loss when connectivity is good (Teacher et al., 2013). Nowadays, there are numerous mobile apps available for biological recording, with a general or specific taxonomic scope, and some with advanced built-in image recognition tools to facilitate species identification (e.g., iNaturalist, Observation.org or Pl@ntNet). Most Europe-wide biodiversity projects capture occurrence information (opportunistic data) to support atlas projects (e.g., butterflies—Settele et al., 2008; birds—Herrando et al., 2019; mammals—Mitchell-Jones et al., 1999), and increasingly use records collected via citizen science initiatives using mobile apps. Recent statistical developments provide methods for assessing biodiversity trends and indicators (e.g., Termaat et al., 2019) at large scales, using opportunistic data collected through citizen science (Isaac et al., 2014). Structured, abundance sampling schemes and partnerships also provide biodiversity assessments at the European scale. Schemes for butterflies are the most established for insects and provide European indicators for measuring progress toward biodiversity targets (e.g., Sustainable Development Goal: *Life on Land*; van Swaay et al., 2019). It is widely recognized that there is potential to increase the contribution of citizen science to enhance our understanding of trends across many insect groups (Gardiner and Roy, 2021).

Here, we provide an overview, including the rationale, of the development of a dedicated mobile app for European ladybird identification and recording. Our main aims in designing the application were to engage diverse audiences in sharing their sightings of ladybirds whilst providing information on ladybird ecology and identification to participants, in order to improve appreciation of the diversity and value of these popular beetles. We provide technical specifications of the application, including mechanisms for data sharing, data quality and record validation. Finally, we outline potential approaches for using

this recording tool to enhance trans-national collaboration on ladybird mapping in Europe.

MONITORING OF EUROPEAN LADYBIRDS IN SEMINAL NATIONAL PROJECTS

Various European countries have operated ladybird recording schemes of different kinds for several decades. Some of the schemes are run at a national level whilst others are regional. Such schemes, as detailed below, were key in developing the ideas for a pan-European approach to ladybird recording.

United Kingdom

There has been a national recording scheme for ladybirds in the United Kingdom since 1971. This evolved into the United Kingdom Ladybird Survey[1] in 2005, one of the first online wildlife recording schemes (Brown et al., 2008). Together these have engaged tens of thousands of people with recording the distribution and ecology of ladybirds in the United Kingdom, contributing over 229,000 verified records. The United Kingdom Ladybird Survey launched the smartphone app iRecord Ladybirds in 2013. The current European Ladybird App builds on that model. The substantial recording effort in the United Kingdom has greatly increased our understanding of the distribution and ecology of native and introduced ladybird species. In particular, verified records of *H. axyridis* have allowed the unusual opportunity of highly detailed mapping of the spread of a new invasive species (Brown et al., 2008, 2018).

Czech Republic

Monitoring of ladybirds in the Czech Republic has been partially covered by the work of the Nature Conservation Agency of the Czech Republic (AOPK CR), which monitors all living organisms using the BioLog and iNaturalist applications. There is also monitoring of *H. axyridis* on the popular BioLib server. In 2019, the *NAJDI.JE*[2] platform was launched for monitoring invasive invertebrates in the Czech Republic using citizen science, including *H. axyridis* overwintering sites. Additionally the databases of taxonomists Ivo Kovář and Oldřich Nedvěd contain a large amount of data, obtained by determining records for a very large base of amateur entomologists within the Czech Entomological Society.

No targeted ladybird monitoring project has yet been created in the Czech Republic, so the European Ladybird App will enable widespread recording of ladybirds in the country.

Belgium

In Belgium, a large-scale citizen science ladybird mapping project was launched in 1999. Skilled volunteer recorders collected standardized data on ladybird occurrence and ecology using a standard recording form (Adriaens et al., 2008). The aim was to use these data to publish distribution atlases (Branquart et al., 1999; Adriaens and Maes, 2004) and a Red List (Adriaens et al., 2015a). The project was supported by the Research Centre for Nature, Forests and Wood in the Walloon Region and the Institute for Nature Conservation (INBO) in Flanders. Observations were underpinned with pictures or other means of verification (e.g., based on recorder experience). Updated distribution maps were published regularly and people were actively stimulated to fill gaps through dedicated searches in insufficiently sampled grid squares. The project engaged about 800 volunteers actively submitting records. The data gathered were openly published on the Global Biodiversity Information Facility in 2012 (Adriaens et al., 2021). Since 2008, after the launch of the online reporting portal[3] and its mobile phone applications by the conservation NGO Natuurpunt (cf. Swinnen et al., 2018), paper recording was replaced by online recording which greatly increased the number of ladybird observations, the speed of record submission, the number of volunteers as well as the spatial resolution and quality of ladybird records. As this platform is well established for recording, the European Ladybird App is anticipated to be used less used in Belgium by the established naturalist community, though it might still appeal to people wanting to increase their ladybird identification skills, wanting to contribute to European ladybird mapping specifically, as well as to a crowd outside the classical recording community. As several recording tools generate useful ladybird data, the focus should be on openly publishing data and sharing them through the application of data standards and interoperability (Adriaens et al., 2015b; Groom et al., 2016).

Slovakia

Haviar (2007) contributed much to the knowledge of occurrence, distribution and ecology of ladybirds in Slovakia. Related short-term monitoring and research activities in this country targeted communities of arboricolous ladybirds in forest and urban habitats (Panigaj et al., 2014; Viglášová et al., 2017; Holecová et al., 2018) and the year-round dynamics of *H. axyridis* in Scots pine forest habitats (Zach et al., 2020). The citizen science project Ladybirds of Slovakia (2015–2017)[4] focused on ladybird data collection from volunteers via Facebook.

Portugal

In the Azores (Portugal), since 2019, a project that allows citizens to assist in the monitoring of ladybirds is available.[5] Under this project, face-to-face activities are organized for schools of all levels of education and institutions with children in need. Scientists and students undertake field work and training to collect and record ladybirds. Under this project, two important outputs were already produced; an updated checklist of the ladybird species of Portugal, including the Azores and Madeira archipelagos (Soares et al., 2021) and a biodiversity database of ladybirds (Coleoptera: Coccinellidae) of the Azores archipelago (in prep.). There is no equivalent project for mainland Portugal, so the European Ladybird App will enable widespread recording of ladybirds in the country.

[1] https://www.coleoptera.org.uk/coccinellidae/home/

[2] https://www.najdije.cz

[3] www.waarnemingen.be

[4] https://www.facebook.com/lienkyslovenska

[5] www.joaninhasdosacores.com

Italy

Many short-term monitoring and research activities informed the knowledge of habitats and distribution of ladybirds in Italy. Many local papers updated the distribution of *Harmonia axyridis* at regional level and data from citizen science, i.e., iNaturalist or local bioblitzes (see Menchetti et al., 2016), have been used in scientific literature. There is no global recording scheme for ladybirds in Italy, so the European Ladybird App will enable widespread recording of ladybirds in the country (**Figure 1**).

COLLABORATIVELY DEVELOPING THE EUROPEAN DATABASE OF LADYBIRDS

In developing this application we first set up a team with expertise in coccinellids from six countries (United Kingdom, Czech Republic, Slovakia, Italy, Belgium, and Portugal) (**Figure 1**). We collaboratively prepared a database of ladybird species established within each country. We excluded small, so-called inconspicuous ladybird species, which are known to be difficult to identify (e.g., the genus *Scymnus*). Currently, 72 taxa are documented in the database, including various color forms for some species (e.g., *H. axyridis* has six color forms across the countries) (**Figure 1C**). For each species, we included the following information to support identification (**Figure 1B**): (1) morphology (size, elytral coloration, pattern on pronotum, presence of melanic forms, information about spot fusions, coloration of legs, number of spots), (2) ecology (prey, habitat, plants and overwintering habitat), and (3) three photos of adults (where available). To maximize accessibility to volunteers across the participating countries, we translated all the text into the official languages for each country.

Technical Specifications

This open-source mobile application (*link*)[6] was developed using standard web-based technologies (HTML, CSS, JavaScript). This way we were able to reuse many supporting open-source libraries and tools which helped to streamline the development process. The app is essentially a responsive website that is designed to work well on small mobile devices. As a website it couldn't be directly installed onto users' smartphone devices therefore it was wrapped with a Cordova container. Traditionally, mobile applications are re-written for each mobile platform but packaging the code in such a way allows reuse of the same codebase for multiple platforms. Such an app is called a Hybrid and it can be deployed to both iOS and Android app stores.

The app has species names and other related content translated and managed by multiple collaborators from different countries (**Figure 1G**). The species datasheet is extensive and currently holds over 160 columns with species-related information. We are hosting the datasheet online on OneDrive cloud which essentially is our simple but flexible real-time content management system. We have agreed on a custom column header formatting schema which allowed us to write a command-line script to transform the columns into a JSON-formatted file which is then pulled into the app programmatically. In such a way, collaborators from multiple countries can update the content in parallel and the updates can then be imported into the app with little effort and few errors.

Using a Microsoft Excel spreadsheet for translations for multiple countries wasn't very practical, so we use the Transifex web platform for managing species and app interface translations. At the time of writing, it is free for open-source projects such as this and allows us to pull the translations into the app.

The app is linked to an open-source Indicia database (warehouse)[7] where the records are stored. It has a lot of tooling to streamline the verification process and to export and exchange data with other systems. Indicia has extensive online documentation[8] of all aspects of installing and maintaining a data warehouse to support data capture projects, including mobile application approaches such as European Ladybird App (**Figure 1**). The system architecture, data model and coding conventions allow any developers to contribute to the open source development of the software through the project Github repository.[9]

Data Quality and Validation

The use of Indicia for data storage gives a flexible solution for data sharing agreements and allowing species records to be linked to the same user accounts from multiple connected mobile applications and websites. One of the sites our mobile app is linked to is iRecord[10] which is used in the United Kingdom for sharing wildlife observations, supports multiple recording apps such as this and has a big community of recorders and verifiers.

iRecord incorporates verification rules developed by national recording schemes for a desktop application (the National Biodiversity Network Record Cleaner). Validation is assisted by automated record checks which highlight records outside the known spatial or temporal range of the species, and records of species which are difficult to identify. If records are highlighted by Record Cleaner the observer receives a message, with the option of editing the record. The expert verification of records on iRecord applies a two tier approach. Verifiers choose from a set of validation categories that they can apply to a record. A record is *accepted* as meeting the standard required for inclusion by the recording scheme or project in question when a verifier accepts it as *correct* on the basis of the submitted photo or is *considered correct* when the verifier has not seen photo/s or specimen/s (or cannot be absolutely sure of the identification from submitted photo/s) but has a high degree of confidence that the record is likely to be correct, based on difficulty of ID, date, location and recorder skills/experience etc. Other categories include *unable to verify*, *incorrect*, *unconfirmed* or *plausible*.

Citizen Focus

The application requires participants to create a record of the ladybird they observe and so, it is necessary for them to identify

[6]https://github.com/NERC-CEH/leu-app

[7]http://www.indicia.org.uk/

[8]https://indicia-docs.readthedocs.io/en/latest/index.html

[9]https://github.com/Indicia-Team/

[10]https://www.brc.ac.uk/irecord/

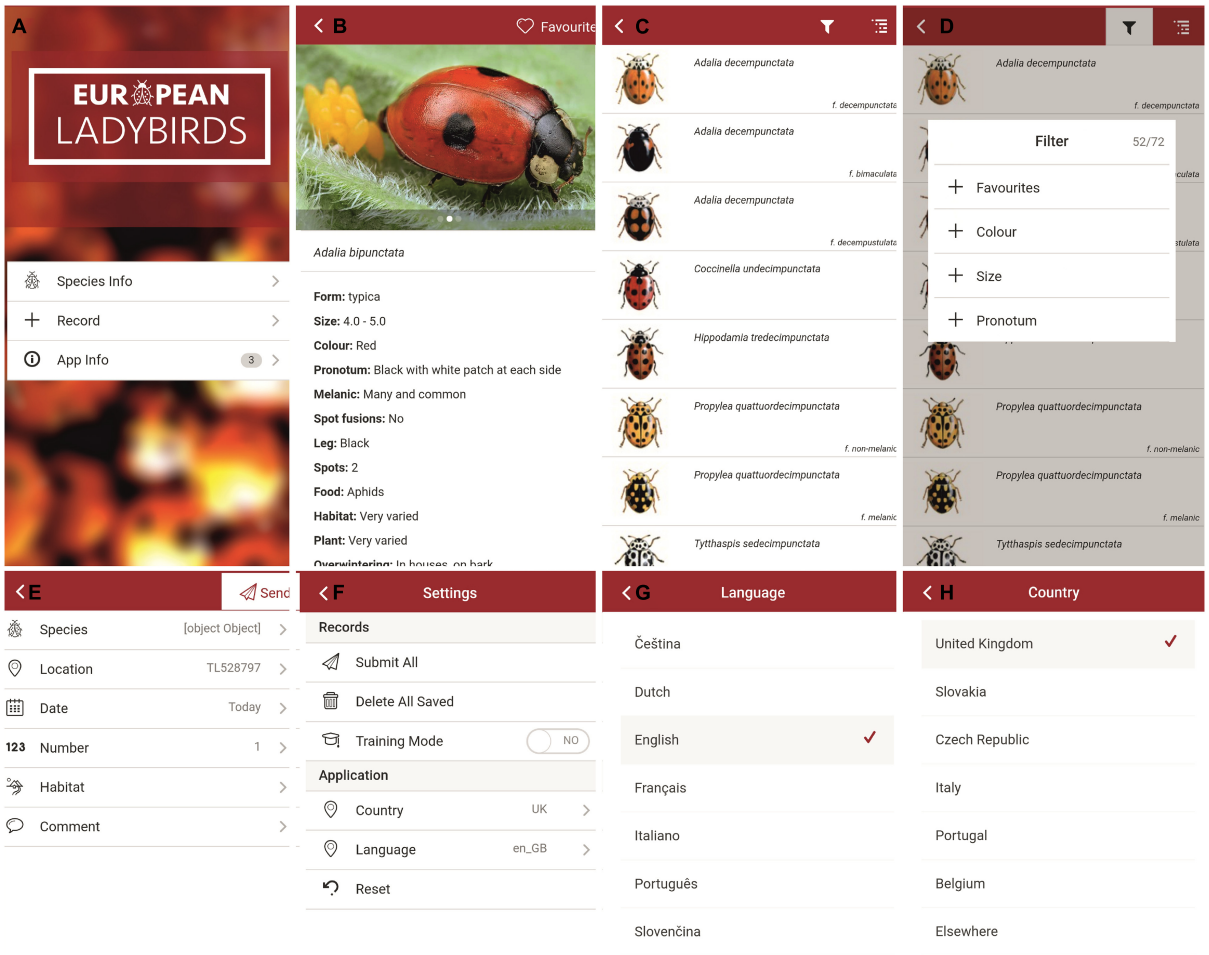

FIGURE 1 | Screenshots from the European Ladybirds smartphone application (app) used to record ladybird species, with *Adalia bipunctata* used as an example throughout. Records submitted are checked iRecord: **(A)** opening screen; **(B)** ladybird guide: providing identification information for the species selected, in this case *Adalia bipunctata*; **(C)** ladybird guide: first screen, showing a list of species available to record, ranked by likelihood of occurrence; **(D)** ladybird guide: first screen, showing a list of species available to record, filtered by four traits of the ladybird; **(E)** adding a record: main recording screen once a species has been selected; **(F)** information: screen provides background information about the app; **(G)** information: screen provides for language selection; **(H)** information: screen provides for country selection.

the species, which will later be verified by an expert. Additionally, the following information is requested: the coordinates of the location (usually derived from mobile phone GPS), date, number of individuals, habitat where the individual was found, and a photo (to enable identification). To increase the ease of use we selected the three most specific morphological features (main color, size, and pronotum pattern) and coupled these with country-based ranking of the relative occurrence (based on the total number of grid cells with observations of the species) for each species. Such filters (**Figure 1D**) enable the users to select from a reduced number of likely species when recording, thus helping to reduce misidentifications.

Potential Use of Data

Information collated through the European Ladybird App will be openly available to address many potential questions but we focus on three main areas: (1) Understanding the ecology and distribution of ladybird species; (2) Informing ladybird conservation; (3) Education and engagement in biological recording and entomology. In a preliminary release of the European Ladybird App, we received over 1,600 records of 26 species between January 2019 and May 2021, mostly from GB and Ireland but also from other places in Europe. About 75% of these records have been accepted as accurate, indicating the high potential of this app for citizen science.

This initiative is the first step of a collaborative approach involving the recording of ladybirds through citizen science across Europe[11] (**Supplementary Figure 1**). Currently, the application builds on existing collaborations between six countries that have ladybird recording, but in the long-term we aim to include additional countries and use the data generated to produce a European ladybird distribution atlas. This will also

[11]https://european-ladybirds.brc.ac.uk/home

require integrating the data from the ladybird app with other available data on ladybird distribution. This can be achieved through an open approach to publishing and sharing data from the app and the promotion of the app with other active mapping projects in Europe. Long-term conservation trends for ladybirds are so far only available for very limited regions (e.g., United Kingdom; Roy and Brown, 2018) or databases (e.g., GBIF—the Global Biodiversity Information Facility) and we aim to use the European data to inform Red List assessments (Maes et al., 2015)[12] Additionally the app has the potential to generate timely data on the arrival of new ladybird species in a country: for example in the United Kingdom, the first records of *Oenopia conglobata* L. were received via similar citizen science tools (Brown et al., 2015b).

Furthermore, ladybirds offer an appealing way of encouraging people to have an interest in entomology; in many ways ladybirds represent an "easy way in" to entomology, which can appear a daunting field. We consider the successful engagement of people to be as important as the ecology and conservation knowledge gained from the records themselves. The engagement benefits come from encouraging an interest in wildlife and the environment, as well as encouraging the next generation of entomologists and biological recorders. Additionally, connecting with nature is known to enhance the well-being of participants (Pritchard et al., 2020).

CONCLUSION

In conclusion, the development of the European Ladybird App highlights the value of collaborative partnerships in citizen science. By working on a shared platform and using infrastructures employed for other similar, but national initiatives, we have been able to cost-effectively develop an approach for people across Europe to engage with studying and recording ladybirds. Future work could focus on how the app is performing in different countries, which species are reported, recording biases etc. and how it can be improved to suit the needs of the recording community. There is an urgent need to gather evidence on the status and trends of insects over large spatial scales to inform conservation action going forward. Providing resources, such as this smartphone application, will play an important part in maximizing the potential of citizen science and increasing access and participation in the field of entomology.

[12] https://www.iucn.org/commissions/ssc-groups/invertebrates/ladybird

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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SUPPLEMENTARY MATERIAL

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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