

# Citizen Science and Open Data: a model for Invasive Alien Species in Europe

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## Abstract

Invasive Alien Species (IAS) are a growing threat to Europe's biodiversity. The implementation of European Union Regulation on IAS can benefit from the involvement of the public in IAS recording and management through Citizen Science (CS) initiatives. Aiming to tackle issues related with the use of CS projects on IAS topics, a dedicated workshop titled "*Citizen Science and Open Data: a model for Invasive Alien Species in Europe*" was organized by the Joint Research Centre (JRC) and the European Cooperation in Science and Technology (COST Association). Fifty key stakeholders from all Europe, including two Members of the European Parliament, attended the workshop. With a clear focus on IAS, the workshop aimed at addressing the following issues: a) CS and policy, b) citizen engagement, and c) CS data management. Nine short presentations provided input on CS and IAS issues. Participants discussed specific topics in several round tables ("*world café*" style) and reported back their conclusions to the audience and full assembly moderated discussions. Overall, the workshop enabled the sharing of ideas, approaches and best practices regarding CS and IAS. Specific opportunities and pitfalls of using CS data in the whole policy cycle for IAS were recognized. Concerning the implementation of the IAS Regulation, CS data could complement official surveillance systems, and contribute to the early warning of the IAS of Union concern after appropriate validation by the Member States' competent authorities. CS projects can additionally increase awareness and empower citizens. Attendees pointed out the importance for further public engagement in CS projects on IAS that demonstrate specific initiatives and approaches and analyze lessons learned from past experiences. In addition, the workshop noted that the data gathered from different CS projects on IAS are fragmented. It highlighted the need for using an open and accessible platform to upload data originating from CS sources or to mirror validated data into a single, easy-to-use web service, in line with the EU Open Science Strategic Priority. The workshop provided ten key recommendations of best practices for CS projects on IAS, addressed to researchers, policy makers and implementing authorities, indicating future research and policy directions and opportunities.

## Keywords

Invasive alien species, citizen science, policy, data management, open science, Europe

## Contributors

List of authors and the rest of the workshop participants (Table 1).

## Date and place

8 February 2017

European Cooperation in Science and Technology (COST) meeting facilities, Brussels, Belgium

## List of participants

Table 1.

Table 1. List of Workshop Participants.	
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## Introduction

Invasive Alien Species (IAS) are a growing threat to Europe's biodiversity, causing severe ecological and socioeconomic impacts, and a possibly underestimated annual cost of € 12 billion in the European Union (Millennium Ecosystem Assessment 2005, Kettunen et al. 2009, Ricciardi et al. 2013, Jeschke et al. 2014). In addition, there is an increasing trend towards introduction of new IAS in Europe, with the vast majority being introduced unintentionally (Essl et al. 2015, Roques et al. 2016).

Recognizing the need for robust action to control biological invasions, the European Parliament and the Council have adopted the Regulation 1143/2014 (EU 2014; hereafter referred to as the IAS Regulation) on the prevention and management of the introduction and spread of IAS, which entered into force on 1<sup>st</sup> January 2015. The IAS Regulation gives priority at European level to a subset of IAS, named as invasive alien species of Union concern (Art. 4 "the Union list", hereafter referred to as the IAS of Union concern). Species are included in this list, *inter alia*, because they can cause significant damage to European biodiversity, ecosystems and related services, including impact on human health or the economy, requiring the adoption of concerted measures at a Union level (EU 2014). A comprehensive risk assessment provides the evidence base for listing IAS of Union concern (Art. 5 of the IAS Regulation).

The effective implementation of the IAS Regulation requires accurate, detailed, and timely information on IAS occurrences and distribution for efficient prevention, early detection, rapid response, and also to allow for evaluation of management measures. The contributions of citizens to these tasks not only add to the number of records of IAS, but also raise awareness and increase public support for the IAS Regulation. Citizen Science (CS) initiatives on IAS are therefore worth exploring.

The European Commission (EC) defines CS as "*production of knowledge beyond the scope of professional science, often referred to as lay, local and traditional knowledge*" (EC, Science Communication Unit 2013). Participants to CS projects can provide experimental data and facilities for researchers, raise new questions and hypotheses and co-create a new scientific culture (Chandler et al. 2017). While adding value, volunteers acquire new learning and skills and gain understanding of scientific work (EC 2014). CS has now become a mainstream approach for collecting data on ecosystems and biodiversity (Newman et al. 2012, Chandler et al. 2016, McKinley et al. 2017).

In recent years, CS initiatives have flourished thanks to the development of web-enabled tools that connect and interact with a much wider audience than ever before (Silvertown 2009, Roy et al. 2012, Daume 2016). New technologies such as smartphone applications

(apps) are increasingly being made available and are used to involve citizens in the reporting of species in Europe (Graham et al. 2011, Teacher et al. 2013). Apps can support the generation of georeferenced records of IAS which, once validated, can complement professional monitoring schemes and return useful data for early warning, rapid response programs and management schemes (Adriaens et al. 2015). These developments increase the amount of data generated, inevitably raising issues of interoperability, openness and sustainability to maximize the usefulness of the collected information.

Aiming at tackling issues related with the use of CS initiatives on IAS topics, such as monitoring in the context of policy implementation, a dedicated workshop titled “*Citizen Science and Open Data: a model for Invasive Alien Species in Europe*” was organized by the EC Joint Research Centre (JRC) and the European Cooperation in Science and Technology (COST). Fifty key stakeholders from all over Europe, including two Members of the European Parliament, attended the workshop (Fig. 1). The workshop was organized in the context of the Memorandum of Understanding (N. 33870, 25 February 2015) signed between JRC and COST. The aim of the workshop was to provide recommendations for best practices related to CS projects on IAS and the efficient use of CS data in science and policy, as well as to indicate future research and policy directions and opportunities. The current paper presents the workshop report, highlighting the main discussion points and conclusions.



Figure 1. [doi](#)

Participants of the workshop on “*Citizen Science and Open Data: a model for Invasive Alien Species in Europe*”. Image: COST Association.

## Structure of the workshop

Focused on IAS, this workshop brought together key stakeholders to address the following issues:

**Session 1. Citizen Science and Policy:** identify examples and key obstacles to recognize citizens as stakeholders in policy, and how currently available data collected by citizens can be used in IAS environmental policy and by implementing authorities.

**Session 2. Engaging citizens:** identify best approaches and initiatives engaging citizens in collecting and sharing data on IAS.

**Session 3. Open Data: Citizen Science data management:** identify the technical constraints and solutions for data sharing, data management, data quality and communication to the relevant IAS authorities.

The detailed program of the workshop is given in Suppl. material 1.

## Methods

Each session followed a different method for discussion and engaging workshop participants.

### Session 1: Citizen Science and Policy

A short introduction with the aims of the session was provided by the moderator. Then three short presentations provided input on examples and needs of CS in IAS policy processes (~20 min). After the presentations participants were invited to discuss in tables (“world café” style) for approximately 40 min (Figs 2, 3), tapping into their experience and knowledge of examples of how results from CS initiatives have helped authorities in policy design and in implementing specific policies. Each table reported its main points of discussion to the plenary session (Fig. 4). In addition, specific outputs that can be used as information for designing better consultation and participatory processes were discussed. The following questions were discussed:



Figure 2. [doi](#)

Discussion of a round table through the “world café” method, addressing the topic “List of successful case-studies and examples of good practices in environment and IAS” during Session 1. Image: COST Association.



Figure 3. [doi](#)

Discussion of a round table through the “world café” method, addressing the topic “List of methods for mainstreaming inputs from CS in policy making including quality assurance and validations and other parameters” during Session 1. Image: COST Association.

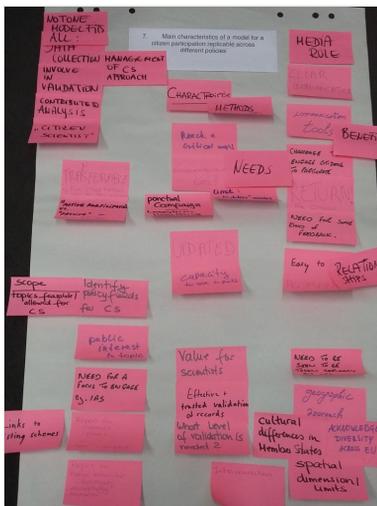


Figure 4. [doi](#)

Flipchart with participants notes addressing the topic “Main characteristics of a model for a citizen participation replicable across different policies” during Session 1. Image: COST Association.

- Benefits of using CS in policy making, in general and more specifically for IAS;
- Methods for mainstreaming inputs from CS in policy making, including data quality assurance, data validation and other parameters;
- Successful case-studies and examples of good practices in environment and IAS;

- Analysis of the relationships at different levels of governance and involvement of the EU;
- Assessment of actual and potential number of CS initiatives in Europe;
- Main input from citizens in the current EU policies;
- Main characteristics of a model for citizen participation replicable across different policies.

## Session 2: Engaging citizens

A short introduction with the aims of the session was provided by the moderator. Then, four short presentations were given to stimulate the debate, followed by a round table discussion between the moderator and the speakers. Finally, an open discussion took place with the audience. The session discussion was based on the following questions:

- How to motivate citizens to contribute to IAS monitoring and prevention? What is working and what is not?
- How the scientific community, competent authorities and policy makers can contribute to the growth of a CS community?

## Session 3: Open Data: Citizen Science data management

The method followed was the same as in Session 2. The following questions were addressed:

- Best practices for validation and quality assurance of CS data;
- How to best manage, share and facilitate access to such data.

In addition to these specific questions each table group addressed the question: “*what is in your view the issue that needs immediate attention and how can we tackle it*” and reported back to the audience.

## Key outcomes and discussions

### Session 1: Citizen Science and Policy

Citizen science was recognised as an important tool for supporting the policy cycle. IAS can be a model for best practice in involving citizens that can be mainstreamed to the development of other policies. The current opportunities for using CS in policy processes, considering both funding and European Union (EU) initiatives (e.g. Open Science Policy Platform), were highlighted. Participants agreed that using CS in the IAS policy cycle can be beneficial in multiple ways:

a) policy making; by providing useful input to the consideration of species for inclusion in the list of IAS of Union concern of the IAS Regulation.

b) policy implementation; CS projects can significantly expand the spatial and temporal scale of the produced data, both in terms of range and quantity, otherwise not achievable (see also Chandler et al. 2017). New geo-referenced IAS occurrences can be submitted swiftly and directly from the field, which is highly suitable for early warning mechanisms (Kampen et al. 2015, Schneider et al. 2016). Therefore, CS data can complement official Member State (MS) surveillance in detecting the occurrence of a new IAS of Union concern under the IAS Regulation. This is particularly relevant for the implementation of Art. 16 and 17 of the IAS Regulation concerning early detection and rapid eradication of IAS of Union concern. At the same time, CS could reduce administrative burden for the national authorities. In such a scenario, specific tools should be made available for issuing species alerts to the relevant authorities, thus promoting timely and smooth data flow and communication. Still, it was pointed out that there is a strict necessity for validation and acceptance of CS data by MS competent authorities, if these are to be used for law enforcement. Furthermore, it was noted that an additional contribution of CS to policy implementation could be the identification of pathways of introduction of alien species.

c) policy evaluation; CS data could contribute to the evaluation of management measures against IAS of Union concern. Some CS projects allow users to deploy specific tools for managing IAS (e.g. *EEIKO*, *KORINA*).

Citizen science projects can educate participants and improve public awareness on IAS with various sectors of society, which is fundamental for effective prevention and management of these species. However, it was pointed out that the awareness-raising effect of CS projects has never been objectively quantified. Still, increased democratic legitimacy of policy, enhanced transparency, trust-building, increased scientific literacy and general activation and strengthening of citizens' interactions are important outcomes of CS projects. In addition, CS could induce a behavioral change on IAS management (e.g. when eradicating certain IAS). Through CS activities, people can contribute to both scientific issues and policy processes, thus creating a sense of ownership of the produced outcomes.

Despite the possible benefits, the group agreed that CS projects could be recognized as a (possible) complement (but not replacement) to other workflows and sources of data (e.g. scientific monitoring schemes, official surveillance systems). In addition, CS approaches are not cost-free or cheap and may not always be the most cost-effective approach for tackling IAS. On the contrary, CS programs require adequate resources and competencies to address challenges such as data quality, privacy, intellectual property or ownership, to retain citizens' involvement and interest by providing them with training and feedback on their contributions, and to maximize their potential contributions.

To date, there has been an increasing number of CS projects dealing with IAS in Europe; there are at least 15 IAS schemes of CS in Europe (European Environmental Agency 2015). Common examples are several smartphone apps for recording IAS (Adriaens et al. 2015), including the *JRC-Invasive Alien Species Europe*\*1, *That's Invasive!*\*2, *KORINA*\*3, *EEIKO*\*4, *Mosquito Alert-Atrapa el tigre*\*5. More generalist apps can also play an important

role in detecting IAS, such as *iNaturalist*\*6, *Natusfera*\*7, *iSpot*\*8, and *ArtPortalen*\*9. The advantage of using smartphone apps include high accuracy of occurrence data, swift reporting, avoiding data loss and an increase in public awareness. Besides smartphone apps, there are also other examples of CS projects on IAS, such as social media, specific channels, and online platforms (Marchante et al. 2016) which can also include a smartphone app (e.g. *Invasoras.pt*\*10). Another example is the Mediterranean Science Commission initiative *Jellywatch*, which has produced important information on the spread of the comb jelly (Boero et al. 2009). Moreover, amateur divers in Greece recently identified 28 alien marine species, four of which had previously a restricted distribution and therefore were not considered as invasive (Zenetos et al. 2013). Although several overviews are available (e.g. Roy et al. 2012), an assessment of the actual number of CS initiatives in Europe is difficult. This hinders estimation of the actual impact of CS initiatives on IAS and how to increase it.

Despite the increasing number of CS data produced, these are not yet widely used for official monitoring and reporting of EU environmental legislation, although the potential is very often noted (see also Cohn 2008, Davies et al. 2013). Still, CS data on IAS of Union concern have been recently taken into account in the establishment of a distribution baseline of those species across EU, which is an important tool supporting the implementation of the IAS Regulation (Tsiamis et al. 2017a). Within this baseline CS data have been taken considered, such as in the case of the Belgian distribution of IAS of Union concern (Adriaens et al. 2017). However, some workshop participants highlighted the potential or perceived low quality of the generated CS data, which may hinder their uptake in policy processes (see also Roy et al. 2012). The discussion group noted that a deeper understanding of the opportunities and pitfalls of CS on European policy-processes is needed, including innovative ways to measure the impact of CS initiatives, thus promoting communication and building trust among all involved actors (citizens, researchers and policy makers).

The workshop participants highlighted the need for mainstreaming all inputs from CS projects on IAS policy processes. To this end, reliability and quality of data should be ensured. Focus should be given to the coordination of existing CS initiatives on IAS at national, regional, European and international levels, avoiding duplication of work. The group stressed the need to foster and disseminate best practices and tools (see also Tweddle et al. 2012, Pocock et al. 2014) supporting both technical developments (e.g. data collection tools, quality assessment, data infrastructures and management) and social issues (e.g. analysis of the impact of CS on environmental behavior, legal and ethical issues, drivers and motivators of citizens' engagement).

There is no unique model for a successful CS initiative on IAS. Modalities can be adapted based on citizens' involvement (e.g. targeted short term campaign or long term survey), the project objectives (aiming to benefit citizens, scientists and/or government authorities), and the project's subject (generic or specific). However, successful CS initiatives seem to share common traits which can be replicated across different policies: a) data should always be of good quality, b) data should be openly findable, accessible, interoperable and reproducible, c) the fate and use of the data should be shown and highlighted, d) feedback

mechanisms for citizens and stakeholders should be promoted, e) the commitment and involvement of people at local level must be ensured, f) the motivation of citizens should be kept high and leverage bottom-up driven decision making, and g) a multi-tier governance is essential, including local, regional, national, EU and global-scale initiatives and interactions between those different levels.

## Session 2: Engaging citizens

In general, citizens who would be interested in CS activities related to IAS could be volunteers, hobbyists, naturalists, conservation technicians, researchers or others. However, local groups (e.g. anglers, beekeepers, farmers, hunters, birdwatchers, gardeners, divers) represent priority targets, since these groups contain individuals knowledgeable about their local environment, who show greater commitment to help protecting the natural environment, and are usually able to identify at least some species with high accuracy. The latter is crucial for IAS early warning mechanisms defined by the IAS Regulation. In addition, it would be beneficial to engage local authorities' representatives and even decision makers in CS projects about IAS, which would increase these groups' awareness of IAS threats and highlight the potential effectiveness of CS projects to decision making. Students and scholars can also be a target audience, although health, safety and liability issues should be cautiously considered. In that case, teachers should be continuously engaged, which can sometimes be a limitation due to the frequent rotation of the educational staff. Identifying and recognizing local volunteer leaders ("*citizen champion*") on IAS, who could provide constant support to CS projects, could offer a solution.

People usually like to measure things, contribute to science and have fun, but the motivation of citizens might differ across different interest groups, regions and countries. CS initiatives on IAS should be open to new ideas by citizens and learn from experience: what the citizens liked and what they did not. There is therefore a need for a design phase which allows citizens to be informed and get involved from the inception of every CS project on IAS. In addition, the workshop noted that CS projects should acknowledge the cultural diversity across the EU. A case of a Portuguese CS activity on IAS (*Invasoras.pt*) revealed lower involvement of citizens than what could be expected if applied in northern European countries. The approach to the citizens would need to be inclusive and accessible to all sectors of society; not restricted by education and access to resources and technology (see also EC, Science Communication Unit 2013). Indeed, there can be a bias in participation favoring well-educated, well-paid individuals who have the time and resources to take part in CS projects (see also Haklay 2012).

The use of social media (Internet, YouTube, Twitter, Facebook, Instagram, newsletters) can contribute to the publicity and dissemination of CS activities, resulting in an increased awareness and engagement of citizens. Other actions might, however, be necessary to recruit new participants, such as the use of the national, local or regional press or utilizing different types of media (e.g., TV, radio, print, online) and specialist publications (see also

Chandler et al. 2017). In any case, the identification of the target group and its motivation to be engaged should always be clear to ensure high involvement and retain interest.

How to achieve high level of citizens' engagement and retain their involvement on the long term in CS projects is a real challenge, and initiatives dealing with IAS topics are no exception. There are several methods and tools which can be used for increasing citizens' engagement, e.g. feedback on contributions through newsletters, the organization of workshops, meetings, and field campaigns such as bioblitzes, which can provide valuable face-to-face contact and fit nicely in the IAS scope. Hands-on training sessions can be really helpful, since they encourage longer term participation (see also Den Berg et al. 2009) and educate the public about the threat posed by IAS. In most cases of smartphone apps used in CS initiatives, many users do register but only a small portion of them (about 20%) remain active (see also EC 2014), again emphasizing the constant need to find new ways of keeping the target audience engaged and improving the user experience (see also Adriaens et al. 2015).

New app initiatives should carefully consider the existing recording community and the tools that it already uses to ensure effective use, complementarity with existing recording schemes and to avoid duplication. They should therefore build on existing user communities. The data collection kits and tools should always be simple, intuitive, easy to use, attractive, and accessible in the mother tongue, or at least easily translated (see also Tweddle et al. 2012). If the collection method is too complex or too time consuming, volunteers often lose their interest to participate, and thus understanding and adapting the program to the skills, expectations and interests of the participants is critical (see also Roy et al. 2012).

Although continuous and rapid feedback mechanisms to the participants are essential, most IAS apps so far offer little feedback to the users. A user should always be informed about the validation of his/her IAS observations, but also about the final use of the data: how these will be effectively used in science e.g. use of data in scientific publications, such in the case of *Invasoras.pt* (Marchante et al. 2016), and for management of IAS or for policy decisions (e.g. *iRecord* in UK informing local stakeholders). Specific press releases, field events and the use of social media can be used for that purpose. A sense of ownership of the data by the users is important. By this way, citizens can feel recognized, proud to contribute to something useful, while at the same time a relationship of trust with the CS projects can be achieved. This is a crucial element, since lack of trust by users can be a tremendous barrier to any CS effort. A more systemic approach could be beneficial, e.g. including CS activities on IAS as a supplementary tool to official surveillance systems on IAS of Union concern. Finally, a system of rewards in which the most active users are given some form of credit has proven to be an effective solution to keep up citizens' interest in participating in CS programs (see also Tweddle et al. 2012).

### **Session 3: Open Data: Citizen Science data management**

Tackling IAS demands international collaboration, integration, harmonization and promotion of management coherence. IAS data from CS should be always open and transparent. The

sharing of existing tools and experiences on CS are also crucial. To this end, smartphone apps codes should be open source and available for re-use, as is the case of JRC smartphone application *Invasive Alien Species Europe* (Tsiamis et al. 2017b). Similarly, the sharing of data is a prerequisite for maximizing the benefits from a CS project on IAS (see also Groom et al. 2015, Groom et al. 2016), since decision makers and managers need all available data for a specific area through a single aggregator/entry point or a similar federated structure. Although there are plenty of CS projects on IAS (see also Adriaens et al. 2015), there seems to be a fragmentation in the data produced, concerning the format, species, habitat and geographical scale. Workshop participants pointed out that there is little interoperability and reusability among CS projects, while the use of the data produced is quite restrictive (see also Schade and Tsinaraki 2016, Groom et al. 2016). The group highlighted the need for a consistent approach for data coming from all available CS sources on IAS, interconnecting existing data repositories and reducing barriers to data sharing. Ideally, data should follow internationally agreed common standards (e.g. Darwin Core Archive for occurrences) and be published using a compatible machine-readable formats (see also McGeoch et al. 2016). Data should be openly shared in ways that are findable, accessible and interoperable, encouraging exchange and dissemination of data with other existing data platforms (Groom et al. 2015, Groom et al. 2016, Lucy et al. 2016), such as GBIF (Global Biodiversity Information Facility; <http://www.gbif.org>) and EASIN (European Alien Species Information Network; <https://easin.jrc.ec.europa.eu/>). These two examples of open platforms provide aggregation, integration and harmonization of data coming from multiple sources. GBIF already hosts CS data on IAS and works towards an increased capacity to integrate and deliver more geographically extensive and timely occurrence data on IAS at national scales. EASIN, the official information system supporting the implementation of the IAS Regulation, including the early warning and rapid response requirements, is also hosting CS data coming from the EASIN Data Partners. Moreover, EASIN is planning to host CS data on IAS of Union concern coming from the related JRC smartphone application *Invasive Alien Species Europe*. EASIN could host validated records of IAS of Union concern across the EU originating from all related IAS apps. Managers can then find and access aggregated data through web services and analyze them according to their needs. Guidance on data management and best practices regarding CS IAS data and their required formats remains necessary.

Validation of CS data is becoming more and more pressing as CS initiatives on IAS develop in Europe. Data validation mechanisms are related to the intended use of the data, and the required associated confidence levels. The vast amount of data poses a challenge to quality assurance efforts. There is a series of available approaches for technical and content validation that can contribute to data quality. For example, there are automated mechanisms for validation, such as filters to remove data that fall outside a study's temporal and spatial range. However, these filters might not be accurate enough when species-level identification is required, for instance in case of early warning mechanisms. Training users before their actual involvement could be valuable for ensuring high quality of the data produced; face-to-face training seems to be the most effective (see also Newman et al. 2003). For example, *Atrapa El Tigre*, a project on invasive mosquito monitoring, provides training sessions to volunteers on how to make photographs useful for record

validation. In addition, the social validation technique (crowd-sourced validation) used in CS projects (e.g. *iSpot*, *iNaturalist*) seems to be one of the most promising approaches to ensure data quality. These online communities of users can confirm the identification of a species. A reputation-based system can reflect the individual abilities of community members, establishing of hierarchy of observers in which more experienced users assess and moderate data supplied by less experienced users in a learning environment (see also Chandler et al. 2017). In addition, innovative smartphone applications, such as *Leafsnap* which uses visual recognition software to help identify tree species from photographs of leaves, can further advance accurate species identification. Moreover, the requirement to register in order to report observations can contribute to data quality, though this represents a trade-off with removing barriers for involvement. The purpose of a CS project can differ depending on its relation to policy. Specific guidance is needed for implementing such validation criteria when it comes to reporting IAS of Union concern of the IAS Regulation.

Citizen science data quality should take into consideration biases of the reported data. For example, species differ in detection probability with conspicuous and easy to identify species being reported more frequently. Other sources of bias include uneven recording intensity in space and time and sampling effort per visit. Good protocols for data collection and statistical methods to correct for different types of bias in the data can prevent such problems and make the data more useful for the purpose they are intended for.

CS projects must also address legal and ethical issues with their data, including the intellectual property rights around users' audio-visual evidence and privacy issues regarding to the location of the recorder. The group remarked that the terms and conditions of participation need always to be clearly stipulated. Similarly, licensing of data should be precise and standardized. For instance, GBIF datasets carry one of the three Creative Commons designations (CCO, CC BY & CC BY-NC).

The continuity of the CS project management and data verification is an important aspect which needs special attention. Many IAS apps fade after the project funding ends. Thus, the group emphasized the need for guaranteeing the long term sustainability of CS projects, and recruitment and retention of the participants, to anticipate technological advances and ensure high quality data.

## Conclusions

The workshop enabled the sharing of ideas, approaches and best practices regarding CS and IAS. Specific opportunities of using CS in the policy cycle for IAS were recognized, especially concerning the IAS Regulation. In this case, CS data could complement MS official surveillance systems, and contribute to the early warning of the IAS of Union concern after appropriate validation by the MS competent authorities. While they are not cost-free, CS projects can enhance cost-effectiveness of monitoring and surveillance programs while increasing public awareness and engagement in ways that empower citizens. Both the illustrations of specific tools and approaches and the analysis of lessons

learned from past experiences suggest the value of further expanding these efforts. The workshop pointed out that tools and data gathered from different CS projects on IAS are currently fragmented, and highlighted the need to use an open platform for uploading data originating from CS sources or to mirror validated data into a single easy-to-use web service. This is in line with the Open Science Strategic Priority defined in June 2015 by the Commissioner for Research, Science and Innovation with the policy actions identified in the Draft European Open Science Agenda, and the ambitious plan of the EC to develop the European Open Science Cloud.

## Recommendations

Finally, the workshop agreed on the following ten key recommendations for researchers, policy makers and implementing authorities, indicating future research and policy directions/ opportunities regarding CS and IAS:

1. Mobilize and promote available expertise and share guidelines about the use of CS for IAS related matters across all MS.
2. Tackle the skepticism of governmental authorities in relation to CS by showcasing successful projects and initiatives.
3. Enhance timely CS data flows, in particular for issuing alerts on IAS of Union concern to MS competent authorities.
4. Improve quality assurance and decrease bias of CS data on IAS through a) implementation of robust validation flows including automated mechanisms and expert validation, b) dedicated training of database managers and citizen scientists, including the provision of guidance on validation criteria for the IAS of Union concern coming from CS initiatives.
5. Build on and strengthen existing user communities but at the same time coordinate and aggregate validated CS data on IAS to open repositories.
6. Ensure the long-term sustainability of CS projects, e.g. by increased understanding of drivers and motivators of citizen scientists and by greater acknowledgement of citizen's contributions; long-term funding of CS projects is a prerequisite.
7. Promote reuse and sharing of interoperable CS data, avoiding duplication, by promoting the use of standards for CS (meta)data and clear licensing.
8. Encourage dissemination of existing tools, by promoting free and open access to IAS smartphone apps, ensuring and disseminating re-usable source codes, facilitating translations into multiple languages, and aligning and coordinating IAS CS efforts within Europe and beyond.
9. Increase public participation in targeted IAS field campaigns that use good experimental designs and appropriate methods and tools, including the removal of barriers to the use of smartphone applications.
10. Address legal and ethical issues by clearly defining the terms and conditions of participation, and adhering to data protection obligations.

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## Supplementary material

### Suppl. material 1: Appendix 2. [doi](#)

**Authors:** Workshop's program

**Data type:** Workshop's program

**Filename:** Appendix 2.docx - [Download file](#) (14.27 kb)

## Endnotes

- \*1 <http://digitalearthlab.jrc.ec.europa.eu/app/invasive-alien-species-europe>
- \*2 <http://www.rinse-europe.eu/smartphone-apps>
- \*3 <http://www.korina.info/>
- \*4 <http://www.eeiko.es/>
- \*5 <http://www.mosquitoalert.com/en/>
- \*6 <https://www.inaturalist.org/>
- \*7 <http://natusfera.gbif.es/>
- \*8 <http://www.ispotnature.org/communities/global>
- \*9 <https://www.artportalen.se/>
- \*10 <http://invasoras.pt/mapa-de-avistamentos/>