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Viewpoint

The importance of open data for invasive alien species research, policy and management

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Abstract

Rapidly changing environmental conditions and the increasing establishment of invasive alien species present many challenges for policy makers, managers and researchers. The traditional policies for data management, or lack thereof, are obstructing an adequate response to invasive alien species, which requires accurate and up-to-date information. This information can only be provided if data regarding invasive alien species are available and useable by all, irrespective of country, status or purpose. The best way forward is for researchers to publish their data openly, by making use of repositories in which the data are licenced in a permissive manner, while making sure they are credited by the adequate provision of citation. Reducing the barriers to data sharing will improve our ability to respond to the growing issue of biological invasions.

Key words: data publication, biological observations, *Lithobates catesbeianus*, American bullfrog, data licensing

Introduction

Biogeography, dispersal biology and pest control were formerly a static study of defined distributions, local dispersal, and well-defined sets of organisms. However, globalization has forced us to think from a dynamic and long distance perspective for a whole suite of organisms, particularly with regard to invasive alien species (IAS). The rate of change confronts managers, policy makers and researchers who have to deal with information that is rapidly out-of-date. Access to recent, accurate and reliable distribution data is key to addressing this problem and reducing the barriers to data sharing will significantly improve our ability to react as quickly as possible to the challenge of biological invasions.

We not only need to manage the issues of IAS today, we also need to predict their impact in the future and design policies that are proactive, adaptable and proportionate. Climate change and other anthropogenic environmental change will have large influences on biota. Greater understanding of these complicated systems will aid our ability to manage them. Invasion biologists and managers are currently developing early warning and rapid response protocols for IAS (NOBANIS 2010; Genovesi et al. 2010; Katsanevakis et al. 2012, 2013; Vanderhoeven et al. this issue; pers. com. A.C. Cardoso). Such systems are only useful if they are derived from up-to-date and accurate data at appropriate spatial scales.

A rapid response is essential to tackling invasive species and requires quick dissemination of records of newly detected problematic invaders. Species of particular concern are quarantine species of plant and animal health regimes, and species of international concern, such as those listed in the new European Union Regulation No 1143/2014

(Official Journal of the European Union 2014) on the prevention and management of the introduction and spread of IAS which entered into force on 1 January 2015. This regulation obliges Member States to react on new incursions of such species within three months after notification to the European Commission. Withholding data on such species might hinder effective application of IAS rapid response protocols.

Up-to-date and accurate data is also particularly relevant for the "horizon scanning" initiatives, an essential component of IAS management prioritising potentially new IAS which are not yet established within a region (Copp et al. 2007; Parrott et al. 2009; Shine et al. 2010; Gallardo et al. 2013; Roy et al. 2014). Also, predictive distribution and niche modelling are increasingly applied in risk assessment of IAS at global and continental scales (Guisan and Thuiller 2005; Ficetola et al. 2007) as well as for the assessment of climate change impacts on IAS distributions (Bellard et al. 2013). For this purpose, cross-border access to data is important particularly with respect to species occurrences within a common biogeographic region. Efforts towards control and mitigation of IAS need data to be evaluated effectively, particularly when biological methods are involved. Risk assessment protocols, including host range testing, need to be applied before the release of any biocontrol agent. Such assessments can only be successful if data related to potential negative consequences are available (van Lenteren et al. 2003).

Despite the obvious advantages of fast and free data availability, IAS science struggles to meet the current growing demand for IAS data. As we intend to highlight here, the reasons for this are many and range from lack of awareness of the importance of sharing data to technical and operational constraints.

Increasing the value of data

Numerous societies and public bodies invest in data collection, but too often the involved researchers restrict data access and analysis to a limited few. This may lead to bad science, as it allows conscious and subconscious bias to influence the analysis of data. If we want decision makers and managers to make evidence based decisions (Cook et al. 2010) regarding IAS, then the research they rely upon should be as free of bias as possible. By opening up the data, research can be done in a transparent and verifiable way, and used for the common good. Peer-reviewing is standard in the validation of scientific results. Why shouldn't it be the case for data?

Journals have an important role to play in this. The Journal Research Data Project recently reviewed journal data sharing policies (Sturges et al. 2015). They found considerable variation between journals, with 50% (n = 371 journals) having no data policy at all. Of the 230 journal policies found, only a quarter (24%) was strong, mandatory data sharing policies. Most policies lacked consistency and direction and the "where, when and what" of data sharing were mostly vague. Among researchers ignorance of suitable repositories, licensing and standards is common place and journals are ideally placed to give guidance (Bayer-Schur 2012; Ferguson 2014). In many scientific disciplines access to the raw data, preferably at the point of peer review, is a prerequisite of publication and so it should be in the field of invasion biology (Lin and Strasser 2014). Incidentally, REABIC open access journal *Management of Biological Invasions* has a data access policy that supports free availability of data (http://www.reabic.net/journals/mbi/About.aspx). Fortunately, such journal requirements are becoming more frequent in the life sciences (Ferguson 2014).

Frequently, the root cause of data withholding is fear of losing funding. Using data as leverage for funding, as if it were currency, is an unproductive way to support data collection. Business models should be based upon the expertise of the data providers and their reliability to collect quality data. Funders should encourage such business models by evaluating and supporting projects on the basis of traceability and openness and recipients of funding should encourage their funders to do so. Open data also have the potential to be used in new and innovative ways, increasing the return of investment, and allow the public to benefit more directly from the research it funds.

Another important advantage to sharing data is ensuring data persistence and security. Given the time researchers invest in collecting data, and the trust other people put in the curators of data, they need to be certain the data are secure, not just for the short term, but for posterity. There is an understanding among scientists that many old datasets are lost, despite the often high cost of their creation and their potential for future use (Gibney and Van Noorden 2013). Research projects can anticipate this by adopting data management plans during their set-up phase. Such practices should be required by scientific institutions and

funding agencies, so that data are treated like a public investment, rather than the leftovers from dinner.

Data licensing problems

To ensure proper attribution, many data publishers are relying on copyright licenses and data use agreements, even though they are often legally and practically ineffective (Rees et al. 2013; Egloff et al. 2014). Recently, the Global Biodiversity Information Facility (GBIF) - the largest aggregator of biodiversity data - conducted a consultation on data licensing (GBIF Secretariat 2014). They did this because of the multitude of data licenses, use conditions and requirements currently stipulated by their data publishers, which makes conforming to all the different agreements practically impossible (Figure 1). Even simply requiring attribution can be a serious hindrance to modelling ecosystems at a global scale, especially since attribution information is often not provided or standardized. Non-commercial stipulations, on the other hand, often restrict legitimate not-for-profit research that licensees may assume is allowed (Hagedorn et al. 2011). Although data users should, wherever possible, acknowledge the data publishers, any absolute requirement to do so in all use cases blocks easy use of the data. Furthermore, even with attribution there is currently no clear mechanism whereby these data publishers can become aware of the use of their data in order to demonstrate the value of their work. To mitigate this, GBIF is planning to apply standard machine-readable licenses to all GBIF-mobilized data and is seeking mechanisms to provide metrics of data use back to data providers, while making it easy for users to provide proper citation (GBIF 2014).

Citizen scientists, often important primary data providers of invasive species (e.g. Adriaens et al. 2015), typically assume their data can be used for the common good of conservation. They are rarely aware of licensing issues that might potentially hinder the application of their data in managing biological invasions. However, conserving local biodiversity and environmental responsibility in general are important motivational drivers for volunteer engagement in IAS citizen science programmes (Jackson 2014). Therefore, citizen science programme managers should strive to maximize the use of their data by applying well-known, machine-readable licenses and seeking to provide more clarity on these issues to their contributors.

Providence and citation

One of the fears expressed by scientists is that if they share their data they won't get credit for their work (Ferguson 2014). Even worse, many of them feel robbed if others publish using their data. Using data without adequately citing the sources is against all conventions of science and reporting. Taking data and claiming it as one's own is fraud. Data agreements are a reminder of the social conventions of citation, but they should not be a hindrance to legitimate and useful research. Unfortunately, only people who follow rules will adhere to data use agreements.

Data collectors and researchers should get credit for their work and if they work in a competitive field they will want to publish it first. Under such circumstances there are good reasons to withhold data, the fear of being scooped may be a major inhibitor (Van Noorden 2013). But all too often data withheld are data lost forever. Once a person has used the data they lose interest. An embargo period can protect researchers in a competitive field, yet a more open approach can be even more useful, particularly to scientists promoting their research or looking for collaborations. Pressure to publish results should not be a hindrance to bringing out such data and journals exist for rapid publication (e.g. *Aquatic Invasions*, *BioInvasions Records*, *Biodiversity Data Journal*).

Fortunately new platforms, such as Dryad, Figshare, Zenodo and the GBIF Integrated Publishing Toolkit, have emerged to lower the technical barriers for sharing data and elevate this act to data publication by the creation of citable data resources recognisable by resolvable Digital Object Identifiers (DOI) (Kahn and Wilensky 2006). In addition by providing metadata and a standard format, this allows users to easily discover, use and cite data. In addition, data resources can be described and peer reviewed to ensure quality in the form of data papers (Chavan and Penev 2011; Costello et al. 2013).

Additional problems and solutions

Restricting access to data is also defended on the basis of protecting rare species, yet the vast majority of records are of common species. Conservation is often used to justify obfuscation of record locations, yet this is done to IAS as well as records of species of conservation concern. This argument should not be used with regards to IAS occurrence data where restricting access impedes the goals of conservation itself.

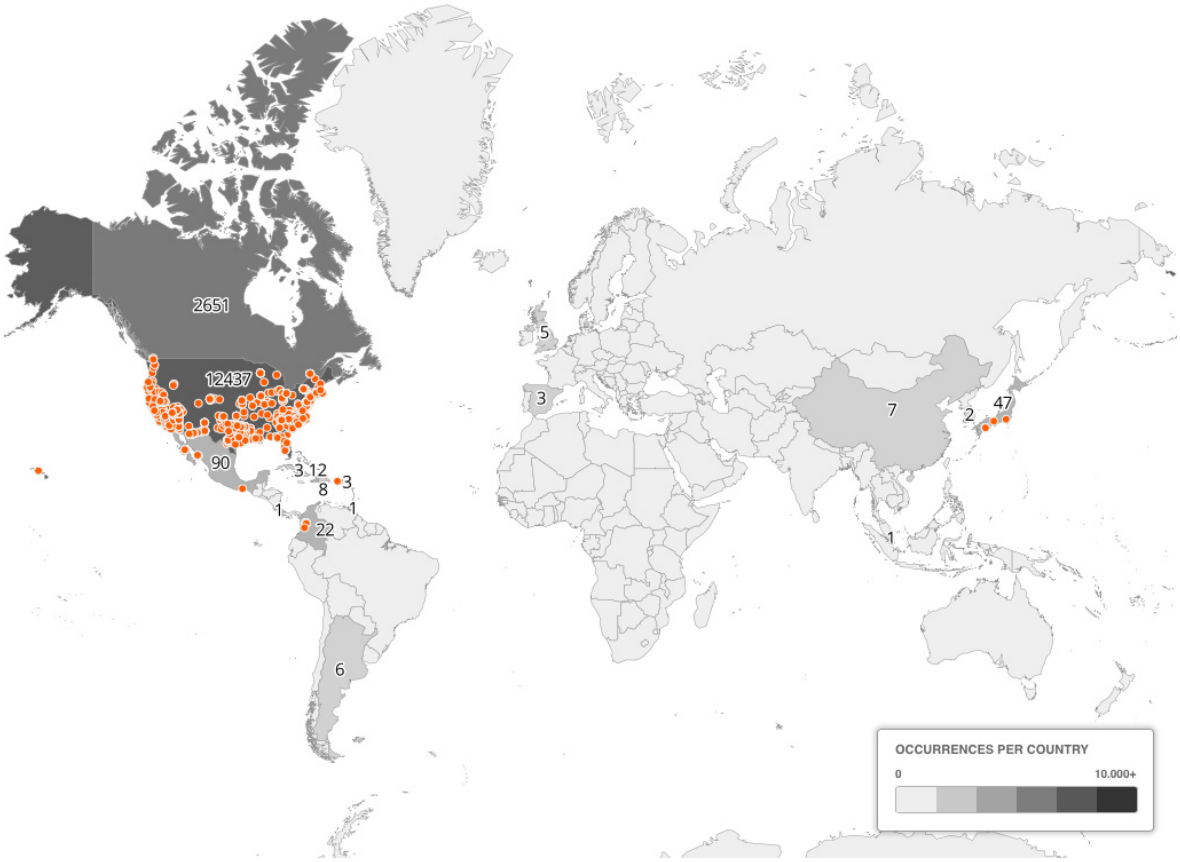

Figure 1. A demonstration of how variation in the licensing of biodiversity records restricts their use, using the example of American bullfrog records. This map is based on all 15,299 georeferenced American bullfrog (*Lithobates catesbeianus* (Shaw, 1802)) occurrence records with valid coordinates downloaded from the Global Biodiversity Information Facility (Desmet 2014) on 18 November 2014. American bullfrog is native to eastern North America, with the Rocky Mountains providing the western boundary of their natural range (Bury and Whelan 1984). This species is suspected to cause substantial ecological damage in large parts of the globe through competition, predation and the transmission of pathogens, exerting an additional pressure on already declining amphibian populations (Adams and Pearl 2007). It is therefore listed by the IUCN Invasive Species Specialist Group as one of the top 100 most invasive alien species in the world (Lowe et al. 2000). As a consequence, it is probably one of the best documented IAS in the world in terms of distribution and impact. Bullfrogs have been reported in about 40 countries on all continents, except Antarctica and Africa (Santos-Barrera et al. 2009). The orange dots represent the 2,253 occurrences (15%) published under a Creative Commons Zero (CC0) waiver. These records are dedicated to the public domain by their data owners and can be used by anyone without restrictions or requirements, which represents the ideal situation for optimal data use. Countries are shaded on a logarithmic scale from light to dark grey based on the total number of bullfrog occurrences found within their borders (indicated with a label). Clearly, a considerable number of the records (85%) are available, but cannot readily be shown on a public map nor used for analysis, due to licenses, terms or conditions which require attribution (52%) or notification (29%), restrict distribution (47%), derivatives (34%) or commercial use (35%), or are missing (13%) or unclear (11%). Moreover, the distribution map shows important gaps, notably in the invasive range e.g. in Europe, Oceania and Asia and Central and South America (cf. Ficetola et al. 2007; Santos-Barrera et al. 2009; Scalera et al. 2012; Adriaens et al. 2013). This potentially imposes problems when modelling the potential niche (Robertson et al. 2004). When using publicly available biodiversity databases, researchers should be aware of potential error due to incorrect taxonomy (Lozier et al. 2009) or data gaps such as illustrated here and should therefore not solely rely on data aggregators as a source of occurrences. On the other hand, clearly, a wealth of distribution data are available through published articles on this species, yet these data did not make it into GBIF and for those that did, only a small percentage can be readily and legally used.
The map is made with CartoDB and inspired by Desmet 2013. The licenses associated with the records are derived from the metadata and interpreted using Desmet and Aelterman 2013. The data providers for records published under CC0 are Cornell Lab of Ornithology (2014), Fundación Trópico (2014), Georgia Southern University (2014), Museum of Biological Diversity (2014), Museum of Vertebrate Zoology (2014), Natural History Museum of Los Angeles County (2014), North Carolina State Museum of Natural Sciences (2014), Texas A&M University Biodiversity Research and Teaching Collections (2014), The University of Texas at Austin - Texas Natural History Collections (2014), Universidad de Antioquia (2014), University of Colorado Museum of Natural History (2014), and University of Nevada, Reno (2014).

Not all the problems with data sharing are cultural. Information technology can be both an obstacle and a solution to data sharing. Unfriendly software using bespoke formats can prevent effective data sharing, but high quality software using standard formats can facilitate the exchange. Future systems for managing biological records should have unique record identifiers to aid citation, track usage and avoid duplication (Hyam et al. 2012). Unique identifiers are also promoted by the Bouchout Declaration for Open Biodiversity Knowledge Management (pro-iBiosphere Consortium 2014).

Sharing data can help coordinate the gathering of data and avoids repeating the work of others. The latter seems to be the case with IAS databases in Europe, with many parallel initiatives of data collation emerging, each having to deal with harmonisation of terminology, inconsistent taxonomy and interoperability of data across different environments. One of the biggest hurdles to data analysis is the unevenness of surveying effort and anything that helps distribute this more uniformly is a good thing.

Sharing data also has an important role in improving data quality. Errors can be hard to spot in one data set, but in combination with others exceptions are glaringly obvious (Chapman 2005). Data hubs can provide an important service to recorders by feeding back their mistakes, preferably as quickly as possible. Secrecy fosters sloppiness and errors.

Conclusion

Science-based strategies towards tackling the invasive species problem create a high demand for species distribution records. Accurate analysis of present distributions and effective modelling of future distributions of IAS are both highly dependent on the accessibility of occurrence data. Also, effective rapid response programmes require rapid dissemination of IAS records and management evaluation needs to be informed by up-to-date species records.

The comparatively recent change from paper to digital records has changed the way we look at biological data and how we manage them. Openness of data has more advantages than secrecy, but we need to conquer our fears. It needs a change in culture whereby the presumption is that data will be shared and software systems should support this sharing. There are disadvantages of openness but these can be managed without obstructing our need for biological data.

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