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An agenda for the future of biological recording for ecological monitoring and citizen science

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The UK has a rich legacy of biological recording, developed through the expertise and commitment of volunteer participants. The Biological Records Centre has supported this activity in the UK since 1964, in close partnership with recording schemes and societies. Vast datasets have been built up and enabled a range of ecological questions to be addressed. We consider the future priorities for the role of biological recording for ecological monitoring and citizen science. We propose a 10-point plan for activities helping to ensure that biological recording continues to thrive and plays a major role. © 2015 The Linnean Society of London, *Biological Journal of the Linnean Society*, 2015, **115**, 779–784.

ADDITIONAL KEYWORDS: Biological Records Centre – Britain, UK – distribution – monitoring – participation – volunteer.

INTRODUCTION

The world is experiencing a period of rapid environmental change linked to human development, increasingly referred to as the age of the Anthropocene (Corlett, 2015). The resulting biodiversity change is associated with pressures such as habitat change, pollution, and climate change, with consequences for the benefits gained from wildlife through ecosystem services (Roy, Preston & Roy, 2015a). Monitoring biodiversity and ecosystems is therefore of increasing importance for informing conservation management, measuring progress against actions and as a rich resource for ecological researchers.

Monitoring by professional ecologists alone is not sufficient to tackle the scale of environmental challenges; there are too few ecologists, they have different demands on their efforts, and they are limited in their geographical and taxonomic scope. The development of citizen science approaches, which engage nonprofessionals in scientific research, has dramatically increased the extent and efficiency of data collection for studies in ecology and conservation (Dickinson *et al.*, 2012; Pocock *et al.*, 2015). Participatory approaches combined with professional support and co-ordination therefore comprise a highly effective approach for monitoring biodiversity (Devictor, Whittaker & Beltrame, 2010; Pescott *et al.*, 2015b) and monitoring conservation interventions (Spooner, Smith & Sutherland, 2015).

The Biological Records Centre (BRC), as an organization with professional data managers and researchers, has fostered a close partnership with voluntary recording organizations since 1964 (Pocock *et al.*, 2015). The BRC has provided standardization and collation of data on the occurrence of species, combined with innovative analysis, visualization, and publication, aiming to understand the impacts of a range of environmental pressures on biodiversity. This volume celebrates the 50th anniversary of the establishment of the BRC. It would be attractive to consider what form the BRC might take at the time of its centenary anniversary but, of course, we can only be sure that it will be nothing like we could possibly imagine. Instead, we have considered an agenda for what we consider the monitoring community, whether in the UK or elsewhere in the world, should strive to achieve in the next decade. We have constructed a 10-point plan. This is a mix of actions that would be appropriate to adopt in the very near

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future, with some that will require both longer-term developments in technology and substantial extra funding.

10-POINT PLAN

1. Collectively identify gaps as to what would be most useful to record

In common with the rest of the globe, the UK has major biases in the taxa that are monitored (Roy *et al.*, 2012; Gurney, 2015). Worldwide, there are also large differences in coverage across countries (Amano & Sutherland, 2013). We suggest that the monitoring community comes together to identify the taxa that would be most beneficial to survey bearing in mind the practicalities of doing so (Pocock *et al.*, 2015). Although not wishing to prejudge such an exercise in the UK, the lack of information on changes in soil biotic communities, such as earthworms and Mycorrhiza, is an obvious gap that badly needs filling, considering their importance in providing ecosystem functioning and services (Balvanera *et al.*, 2006; Power, 2010). There have also been no formal monitoring programmes for pollinators in the UK (Vanbergen, 2013). We then suggest considering how it is realistic to fill these gaps. Technological advances (August *et al.*, 2015) may help monitor such overlooked species, although we consider that volunteer recorders will remain as a primary source of information for the foreseeable future.

2. Place substantial effort into assessing effort, identification error, and bias

This is especially true because there is a great proliferation of wider citizen science approaches. Failure to account for variability in survey efforts and observers' skills can introduce substantial bias in conclusions (Link & Sauer, 1999; Kujala *et al.*, 2013). Considerable progress is being made in the development of statistical models to account for the primary forms of bias such as variation in recording over time and space (Isaac *et al.*, 2014; Powney & Isaac, 2015), although information is lacking on aspects of the data collection process, such as search effort, sampling techniques, and the apparency of species (Isaac & Pocock, 2015).

3. Improve the identification of species

There is an ongoing decline in both amateur (Hopkins & Freckleton, 2002) and professional taxonomists within museums and universities (House of Lords Science Committee, 2009). Support for the identification of species therefore requires a broadening in the range of approaches. The relatively recent availability of online forums and social media has permitted the organic growth of communities of recorders who can support each other (e.g. through sharing notes on identification and sampling approaches). The iSpot project (http://www.ispotnature.org) is an excellent example of a purpose-designed platform to facilitate learning in species identification (Silvertown *et al.*, 2015). Multi-access keys are effective within online data capture system and a priority is to increase their scope and availability as new knowledge becomes available. Online data capture systems can support identification by providing immediate feedback to individuals through automated verification tools. In the UK, such rules are embedded within open source data capture tools (e.g. Indicia; http://www.indicia.org.uk) whereby potential misidentifications can be identified at the point of entry based on geographical location, time of year, and ease of identification. Currently, there are verification rules for 14 763 species from 27 taxonomic groups available in the UK. Other citizen science projects have developed a similar framework of automated and expert verification (Sullivan *et al.*, 2014). A priority is to extend the taxonomic scope of automated checking procedures, enabling them to adapt to new knowledge and facilitate their use within a range of systems.

4. Encourage the collection of associated data on species

Biological recording has largely focused on documenting the occurrence of species to map distributions, although associated volunteer-based programmes are focused on monitoring changes in abundance and/or phenology (Powney & Isaac, 2015). A future priority is to extend existing projects and design new ones to collect information on environmental information associated with sightings. Options include: habitat information, associated species (Stewart *et al.*, 2015), behaviour, routes of invasion, hybridization (Preston & Pearman, 2015), conservation need, life history, etc. Comparative trait-based studies that link trends with species' traits has helped determine the mechanisms driving biodiversity loss (Fuller *et al.*, 1995; Powney *et al.*, 2013; Thomas *et al.*, 2015) and richer sighting data can increase the utility of species occurrence information to inform a range of ecological questions.

5. Find means of combining different types of data on occurrence of species

Technological advances are enabling biological records to be collected in novel ways (August *et al.*,

2015) and to be used for novel applications (e.g. quantifying plant phenology) (Chapman *et al.*, 2015). Museum records, data obtained via recording societies, data obtained via focused surveys, wide-participation citizen science, automated species recognition and environmental DNA (eDNA) all contribute to datasets on the occurrence of species and all have biases and associated errors. For example, DNA obtained directly from environmental samples (eDNA; Lawson Handley, 2015) has increasingly been recognized as an effective tool for detecting and quantifying, for example, threatened (Thomsen *et al.*, 2012) and invasive species (Darling & Blum, 2007). Devising and testing appropriate statistical models would allow us to combine different types of data (Pagel *et al.*, 2014) and overcome reporting and detection biases (van Strien, van Swaay & Termaat, 2013; Isaac & Pocock, 2015), as well as geographical biases (Higa *et al.*, 2015) in citizen science data.

6. Collectively identify features that would be most likely to help interpret species changes in the future

Understanding species' changes requires data on explanatory variables, although this is often missing; for example, a major challenge in understanding the loss of farmland birds was the lack of data on the shift from spring sown to autumn sown cereals. Where data do exist, they can be complicated to access or integrate at a scale relevant to ecological questions. For example, the paucity of comprehensive data on insecticide usage has hampered our understanding of the impacts of neonicotenoid pesticides on pollinating insects. Future research and the need to undertake ecological forecasting and validation (Oliver & Roy, 2015) may require information on emerging drivers of change, such as light levels, nanomaterials or sward height, as well as on established environmental pressures such as climate change, land-use, and air pollution. Development of suitable datasets and improving their availability and inter-operability is a challenge for both informatics and biodiversity researchers.

7. Identify the interests, motivations, and skills of observers

Biological recording encompasses a range of activities, from structured sampling (Pescott *et al.*, 2015b) to opportunistic/unstructured recording (Pocock *et al.*, 2015). In a general sense, biological recording has not been question-led, nor has it had specific monitoring aims, although it has revealed important insights into the causes of change in biodiversity. In common with much citizen science, biological recording relies upon and is effective at harnessing the enthusiasm and passion of volunteer participants (Ellis & Waterton, 2004). The interest of individual recorders may be for a species group, geographical area or site and may be supported by a community with shared interest. There is, therefore, a growing recognition of the need to understand the motivation of participants in citizen science (Nov, Arazy & Anderson, 2014) and its potential for studies that integrate human and natural systems (Ellis & Waterton, 2005; Crain, Cooper & Dickinson, 2014). Enthusiasm is an intrinsic motivation (Blackmore *et al.*, 2013). Maintaining and expanding the success of biological recording (in terms of quantity and quality of data, plus retention of keen recorders and experts) is consequently dependent on the support of people's enthusiasm, rather than imposing obligations on participants (Foster, 2015). A priority is to identify the interests of recorders alongside the design of new approaches or introduction of novel technology, being sensitive to these needs. The use of focused consultation and prioritization, combined with information extracted from recording datasets (Isaac & Pocock, 2015), should be used to address this question.

8. Motivate and facilitate individuals to target species in specific locations using their known skills and interests

Options for targeting could include a resurvey of locations of historic records, obtaining data to test specific models, or a focus on range contractions (Hill & Preston, 2015) or expansions linked to climate change (Gillingham *et al.*, 2015; Mason *et al.*, 2015; Thomas & Gillingham, 2015), invasions (Roy *et al.*, 2015b), disease outbreaks (Purse & Golding, 2015) and pollution (Pescott *et al.*, 2015a), or repeat surveys of rare and restricted species to improve estimates of change for Red Listing (Maes *et al.*, 2015). Directed surveys require co-ordination, support, and feedback to participants that reflect their interests and motivations. Fostering partnerships between land-owners and the recording community can also help improve access to areas with the aim of making biodiversity monitoring more comprehensive and representative.

9. Engage society

The rising prominence of citizen science provides opportunities to engage society in natural history and the wider environment (Silvertown, 2009). The societal context in which biological recording sits is continually changing, with the increased affluence, leisure time, and mobility in recent decades being beneficial. Concurrently, there has been even more rapid growth in communications and information technology. Through the use of information technology, it may be relatively easy (depending on the taxon) to confirm identifications or even harvest records (e.g. from photographic observations) via online social media platforms, and the use of personal online blogs makes it easier than ever to record and share interesting sightings. Much of the rapid growth of eBird has been built upon the engagement of birdwatchers helping to shape new developments that provide valuable end-use tools and rewards (Sullivan *et al.*, 2014). Recording of many species groups is likely to remain highly technical, requiring traditional sampling and identification approaches and therefore is reliant on a relatively small pool of volunteers (Pocock *et al.*, 2015). A priority for systems to support recording is the provision of means by which the range of participants can store the information that they want (e.g. notes, photos, data on fish catches, etc.) at the same time as generating and sharing data. Computer-generated text for providing feedback can facilitate efficient engagement by giving context to observations (e.g. informing about other records, supporting identification and giving supplementary information about species, such as its ecology and how it can be conserved). Feedback should be tailored to the type of observer, either from a question or from the types of record submitted.

10. Encourage debate about the future role of naturalists

With radical changes, such as eDNA and other technologies (August *et al.*, 2015), there is a pressing need to consider how the remarkable expertise of 'biological recorders' can be most usefully supported. We suggest a need to debate the roles that naturalists can play in the future as processes become more automated. For example, naturalists could make observations on behaviour or habitat choice or be involved in monitoring different conservation treatments (Smith *et al.*, 2014). One approach is to bring together the community of naturalists, academics, and practitioners with the aim of identifying the most important questions that naturalists could answer (Sutherland *et al.*, 2011).

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