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BIODIVERSITY VIEWPOINT

Beyond scarcity: citizen science programmes as useful tools for conservation biogeography

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ABSTRACT

Aim We assess whether and how datasets collected by the general public, so-called citizen science programmes, can improve biogeographical studies and contribute to large-scale conservation target-setting.

Location Worldwide.

Methods We first set a general framework highlighting the prerequisites of a relevant dataset for conservation biogeography. We then illustrate how many different citizen science programmes currently running in different countries can be placed within this framework.

Results We highlight that citizen science is particularly useful to address issues spanning large temporal and spatial extents. We then show how datasets based on citizen science can be used to investigate major aspects of global change impacts on biodiversity. We further highlight why these programmes are also particularly valuable in developing the preventative and educational component of conservation biogeography.

Main conclusions Conservation biogeography requires considerable amounts of data collected over large spatial and/or temporal extents. Beyond increasing technical advances to collect and analyse these data, citizen science seems to be a highly valuable tool in many aspects. However, while citizen science programmes are now popular and increasingly used in several countries, they are lacking in many others. We argue that the development of citizen science programmes should be encouraged as they can both be highly valuable for conservation biogeography and promote the reconnection between people and nature and more generally between people and science.

Keywords
Biodiversity indicators, citizen science, data collection, environmental education, people involvement, values-led conservation.

INTRODUCTION

The number of biogeographical studies investigating global change impacts on biodiversity has consistently increased during the last few decades (Kerr *et al.*, 2007). Biogeography has become helpful in providing policy-makers with concepts and tools tackling how biodiversity is evolving in a changing world, and how conservation planning should be designed over large spatial extents (hereafter 'large scale' datasets). Conservation biogeography has thus become a discipline of central importance for the setting of global conservation strategies (Whittaker *et al.*, 2005). In fact, the increase in biogeographical studies can be regarded as both the stimulus and the response to the increase in availability of large-scale datasets. Species occurrence data at a large scale have indeed recently exploded in availability, together with environmental electronic coverage, GIS technology, spatial statistics and large-scale niche-modelling techniques (e.g. now $> 10^8$ records of species distribution are freely available through the http://www.gbif.org portal, or from http://www.natureserve.org; while the electronic layers of several abiotic variables for the entire planet can be downloaded from http://www.worldclim.org). However, these datasets are highly heterogeneous in their coverage and quality, and in their ability to serve for modelling species distribution (Araújo & New, 2007; Lozier *et al.*, 2009).

The relevance of using any datasets in biogeography is obviously dependent on whether the quality of the data matches the question addressed. However, while major meth-

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odological advances are recurrently highlighted to improve analysis of large datasets in conservation biogeography (e.g. capture–recapture algorithms, Eraud *et al.*, 2007; spatial autocorrelation, Kissling & Carl, 2008; predictive habitat techniques, Crossman & Bass, 2008), whether and how the process of data collection itself can improve large-scale investigations and global conservation targets has generally been neglected (but see Schmeller *et al.*, 2009).

Useful biogeographical datasets were first produced by field-naturalists and amateurs describing species diversity and distribution, either during pioneer explorations, or for their own interest. Most of these data were generally lost, not collated together, or were available until recently only through the accumulation of voucher specimen collections in national museums and herbaria.

More recently, there has been a new surge in biogeographical studies based on data collected from the general public, that is, from so-called citizen science programmes (Lowman *et al.*, 2009; Nature Editorials, 2009). Citizen science can be defined as 'a method of integrating public outreach and scientific data collection locally, regionally, and across large geographical scales' (Cooper *et al.*, 2007). Despite their obvious potential impact on biogeographical science and conservation, the key strengths of these datasets for conservation biogeography have not previously been highlighted.

The main objective of this study is to assess whether and how citizen science programmes can be useful in large-scale investigations and used to address large-scale conservation issues. Rather than identifying the property of an ideal dataset, or proposing an exhaustive review of all existing citizen science programmes (see Maltby, 2003; for such a review), we highlight the ability of citizen science programmes (using more than 30 projects easily available online) to fulfil major issues previously identified as key needs in conservation biogeography (Whittaker *et al.*, 2005). Therefore, our objective is not to assess the strengths and weaknesses of a particular programme but rather to stress how the data collected by citizen science in general can be used in conservation biogeography.

First, biogeography is, by definition, highly demanding in large-scale datasets. A key strength of citizen science programmes should be to allow the collection of data relevant to conservation biogeography at regional, national or even continental scales. The quality of such large-scale datasets often results from the necessary compromise between the limited amount of information (and/or precision) held by a given record and the number of records. Biases and uncertainties often inherent to these extensive sampling strategies should be accounted for before data analysis (e.g. Hopkins, 2007; Schmeller *et al.*, 2009).

Second, citizen science should be flexible enough to allow the study of different ecological levels (from individual species to ecosystem processes), different aspects of global change impacts (change in phenology, responses of biodiversity to land-use changes) and different conservation issues (impact of climate warming, protected area assessment). Obviously, depending on each particular objective and scale, different levels of knowledge would be required to ensure proper data collection. The protocol of each programme (but also their structure and communication strategy) should therefore be adapted to the participants (i.e. their nationality, language, age, availability, habits and skills).

Finally, value judgments from the general public are now recognized as essential instruments to improve design and communication of biodiversity policies (Miller, 2006; Evans *et al.*, 2007; Fischer & Young, 2007; D'elia *et al.*, 2008). Moreover, it has recently been highlighted that biogeography suffers from a low public profile and may consequently be poorly understood by the public (Ladle, 2008). Beyond the traditional scientific component of large-scale investigations, citizen science should promote public engagement with research and conservation programmes for more values-led global strategies (Jepson & Canney, 2001, 2003). Involving local people in data collection or even in specific conservation plans offers a good route to integrate public views and values concerning what conservation actions should be taken, why and how.

INVESTIGATING LARGE-SCALE PATTERNS AND PROCESSES USING CITIZEN SCIENCE

For a given sampling effort, there is an inherent trade-off in monitoring biodiversity in a few plots continuously, versus monitoring many plots sporadically. The first approach gives very detailed information on what is happening at a few points over space and/or time. The second approach, which is generally adopted by citizen programmes, provides a way of extrapolating very local results to a broader scale, although the raw data of a particular plot only captures a small amount of information. The core principle of citizen science datasets is to use very simple standardized protocols replicated across many surveyed plots to draw broad conclusions across large spatial extents and/or temporal scales.

Most of these programmes thus cover national or continental-wide areas relevant for large-scale investigations (Table 1-a) and involve very large numbers of people (e.g. in 2008, the *Big Garden Bird Watch* running in the UK involved *c.* 400,000 people in 228,000 locations, who recorded more than six million birds). Therefore, from backyards and city streets to forests and farmlands, citizen scientists can be considered somehow as the world's largest research team (Irwin, 1995). These programmes have also recorded among the longest time-series of animal populations (Table 1-b). For instance, the *Christmas Bird Count (CBC)* was launched in 1900 (in US and Canada) and provides data on trends of many species since then. Although most of these programmes have started recently, many have now provided data for at least 10 years. Thus, for example, the impacts of climate warming on birds have been successfully quantified using such datasets (Devictor *et al.*, 2008a). Moreover, citizen science programmes generally seek perennial data collection using schemes specifically designed to be continued despite the turnover in citizen

Table 1 Example of sample size, spatial and temporal scales of citizen science projects

Issue	Type	Name	Characteristic	Website	Country
(a) Spatial scale	Regional	Appalachian Mountain Watch	Mountains	http://www.outdoors.org/conservation/mountainwatch	US
	National	French Garden Butterfly Monitoring	France	http://noeconservation.org	France
	Continental	Spider WebWatch	North America	http://www.spiderwebwatch.org	US, Canada
	Worldwide	e-bird	Worldwide	http://www.ebird.org/content/ebird	World
(b) Temporal scale	Long-term dataset	Christmas Bird Count	Since 1900	http://www.audubon.org/bird/cbc/	US, Canada
	Medium-term dataset	UK Butterfly Monitoring Scheme	Since 1976	http://www.ukbms.org	UK
	Few years old programmes	FrogwatchUSA	Since 1998	http://www.nwf.org/frogwatchUSA	US
(c) Sample size	High	Nest Watch	> 25,000 people	http://www.birds.cornell.edu	US
	Very High	Big Garden Bird Watch	> 400,000 people	http://www.rspb.org.uk/birdwatch/	UK

scientists. Therefore, citizen science programmes are generally more resilient to variation in financial support than other programmes (Couvet *et al.*, 2008).

A major strength of using datasets from citizen science in conservation biogeography is precisely their large sample size (Table 1-c) (Greenwood, 2007), which ensures a great statistical power (e.g. the probability of detecting a trend of interest using a regression) and high robustness (e.g. the stability of the trend to change in datasets). Additionally, although based on time-saving techniques (without specialist training), data from citizen scientists and from specialists often yield similar results (Newman *et al.*, 2003; Schmeller *et al.*, 2009).

The relevance of a particular dataset for large-scale investigations is not a matter of scale and numbers: large datasets can still be flawed by bias and pitfalls resulting from the sampling design (Lepczyk, 2005). In this respect, an important methodological source of bias has been emphasized concerning animal or plant surveys; the so-called heterogeneity of species detection. This bias is inherent to the process of counting individuals (or species) in the field. These counts are shaped by the true presence (or absence) of individuals, but also by the ability of the observer to actually detect individuals. Therefore, if variation in detectability is not accounted for, an unknown part of the variation in presence or abundance of individuals will result from variation in detectability. In fact, using such count data to construct an index of abundance (as commonly the case in citizen science programmes) has long been considered to be scientifically hazardous (Burnham, 1981). However, with regard to the protocols employed in most biodiversity monitoring schemes, such as point counts, there is a body of scientific literature allowing conversion of raw detections to actual population estimates (e.g. capture–recapture algorithms, see Williams *et al.*, 2002 for a review). Once these sampling biases are clearly established, methods and statistics can thus be specifically developed to properly handle these features of citizen science datasets (Link *et al.*, 2006). To investigate the effect of a particular factor on the relative abundance of a given species (or on community indices), raw count data can also be used without any correction when the sources of variation in detectability are independent of the factor of interest (Bas *et al.*, 2008).

Citizen science monitoring programmes are also designed to maintain major sources of variation (observer, the sampled area, duration, time of day) consistent over time. Impacts of biases on trends produced by the collected data are thus minimized because they are held constant. This basic standardization greatly enhances the statistical power of the analysis when testing change in relative abundance of species in space and/or time. Moreover, most programmes only rely on a selected list of the most common species. These chosen species are generally the easiest to detect and the most abundant. They thus provide less biased data as they carry fewer false (and non-detection) events. Finally, spatial patterns of species richness, as well as turnover in community composition, are often better described by recording distributions of common rather than rare species (Lennon *et al.*, 2004).

The robustness of citizen science data can also be explicitly assessed. For instance, one can check whether population trends are consistent among different citizen science surveys (LePage & Francis, 2002) or using cross-validation (Henry *et al.*, 2008). The former method would confirm that results are not dependent on the particular observers or protocol used (e.g. by testing whether national population trends are similar in different, independent, citizen science programmes, Rosenberg *et al.*, 1999). In cross-validation, part of the data are used for building a statistical model, and part of the data are used to assess whether and how this model is affected by change in the data used.

Overall, as soon as an adequate quantity of data is available from well-designed protocols, there are many techniques for extracting useful information from imperfect datasets (e.g. Hopkins, 2007; Nakagawa & Cuthill, 2007). In fact, because statistical power is a function of sample sizes, which are maximized by volunteer involvement, the common belief that volunteer-based schemes can only provide noisy, imprecise results is most generally wrong (Schmeller *et al.*, 2009).

A TOOL-BOX FOR MEASURING GLOBAL CHANGE IMPACTS ON BIODIVERSITY

The best way to study consequences of global changes on biodiversity is to use data from large multi-site/multi-species monitoring programmes, best able to provide considerable amounts of standardized data across taxa (Balmford *et al.*, 2005). A major strength of using citizen science data in conservation biogeography lies in their ability to produce biodiversity indicators essential for scientists and policy makers. For instance, the UK wild bird indicator is based on the population trends of wild breeding birds. This indicator, adopted by the UK Government, is one of 15 headline indicators of the sustainability of lifestyles in the UK (Gregory *et al.*, 2005). Other ecological indicators reflecting finer signatures of land-use change impacts on communities (e.g. the biotic homogenization process) have also been quantified using data from citizen science programmes (Devictor *et al.*, 2008b).

Beyond their relevance to derive interesting biodiversity indicators, citizen science projects have contributed to the study of many specific targets (Table 2-a), such as mechanisms driving species responses to land-use changes (Rosenberg *et al.*, 1999), species-specific traits mostly affected by global warming (Jiguet *et al.*, 2007), impacts of acid rain on birds (Hames *et al.*, 2002) and changes in plant phenology (e.g. the *BudBurst* program). These data have also been used to assist with the conservation of various organisms (Greenwood, 2007) and to assess protected area efficiency (Devictor *et al.*, 2007).

Citizen science programmes are also flexible enough to be implemented for very different taxonomic groups (Table 2-b).

Table 2 Ecological characteristics of citizen science programmes

Issue	Type	Name	Characteristic	Website	Country
(a) Specific target	Phenology	Seasons Observatory	Plant bloom and migratory birds	http://www.obs-saisons.fr	France
	Invasive species	WSU Beach Watchers —green crabs	Green crab abundance	http://www.beachwatchers.wsu.edu	US
	Disease spread	House Finch Disease Survey	Occurrence of diseased birds	http://www.birds.cornell.edu/hofi	US, Canada
	Fragmentation	Birds in Forested Landscapes	Birds in fragmented forest	http://www.birds.cornell.edu/bfl	US, Canada
	Migration ways	Migrant Watch in India	Birds in migration	http://www.ncbs.res.in/citsci/migrantwatch	India
	Car collision	RoadKill	Animals killed on the road	http://roadkill.edutel.com	US
	Hybridization patterns	Golden-winged Warbler Atlas Project	Repartition of 2 species and their hybrids	http://www.birds.cornell.edu/gowap	US, Canada
	Colonizing species	Migrant watch in UK	Two butterfly species moving northward in UK	http://www.butterfly-conservation.org/migrantwatch	UK
(b) Taxonomic groups	Mammals	French Common Bat Monitoring	~6 species	http://www.mnhn.fr/vigie-nature/	France
	Birds	Pan European Common Bird Monitoring	~135 species	http://www.ebcc.info/pecbm.html	Europe
	Amphibians	FrogwatchUSA	~50 species	http://www.nwf.org/frogwatchUSA	US
	Reptiles	Ontario Turtle Tally	~10 species	http://www.torontozoo.com/adoptapond	Canada
	Butterflies	German Butterfly Monitoring	~60 species	http://www.science4you.org	Germany
	Spiders	Spider WebWatch	~9 species	http://www.spiderwebwatch.org	US, Canada
	Flies	Anglers Monitoring Initiative	~280 species	http://www.riverflies.org	UK
	Nocturnal insects	Garden Moths Count	~20 species	http://www.mothcount.brc.ac.uk	UK
	Worms	Great Lake Worm Watch	~20 species	http://www.nrri.umn.edu/worms	US
	Plants	Plant Watch	~32 species	http://www.naturewatch.ca	Canada
(c) Ecological level	One or few species	Journey North	Few well-known migrant species	http://www.learner.org/jnorth	Mexico, US, Canada
	Community	Breeding Bird Survey	Bird communities	http://www.bto.org/bbs/index.htm	UK
	Combinatiom of taxonomic units	Great Lake Worm Watch	Monitorimg of worms, soil, tree and plants	http://www.nrri.umn.edu/worms	US
	Ecosystem	WSU Beach Watchers – Intertidal monitoring	Monitoring of intertidal fauna	http://www.beachwatchers.wsu.edu	US

Most large-scale citizen science programmes are based on bird census, among which twelve programmes are currently running in the USA (indeed, more than 50 were listed in The Duluth Audubon Society Website in August 2009, http://www.duluthaudubon.org/citizen_science-birding.htm). In fact, birding citizen science has even been promoted as a showcase of the happy marriage between science and conservation (Greenwood, 2007). The reasons for this success are that birds are relatively easy to census for amateur naturalists and that many volunteers are willing to contribute because this taxonomic group is attractive. However, several projects are increasingly being designed for other taxonomic groups, including plants, insects, worms, reptiles, amphibians and mammals (see Table 2-b). Finally, citizen science allows the monitoring of different ecological levels (Table 2-c): programmes are now running to specifically monitor one targeted species, communities, a combination of different taxonomic groups or even ecosystems.

TOWARDS MORE VALUES-LED CONSERVATION BIOGEOGRAPHY BASED ON CITIZEN SCIENCE

By 2050, as many as three quarters of the world's human population will live in cities and suburbs. Humans may thus have progressively fewer opportunities for first-hand experience of wild species and progressively get disconnected from nature. Yet, real contacts with wild species may be vital in stimulating an appreciation of the natural world. This progressive extinction of cultural and aesthetic experiences of the natural world may increase collective indifference for conservation problems (Miller, 2005).

Most of the citizen science programmes explicitly deal with this issue in proposing practical tools for monitoring their focal taxa very easily (for instance, the colours of the light to differentiate the three genera of fireflies in the programme *Firefly Watch*, occurring in the USA). Using citizen science could therefore be a promising way for reconnecting people to nature (Miller, 2005). Indeed, while some programmes require specific skills, others can be conducted by anybody (Table 3-a). Similarly, some protocols only require a limited contribution (e.g. 1 day each year) while others are time-demanding (Table 3-b). Such diversity in protocols fills the gap between people who ''know'' nature and others.

Moreover, the strength of citizen science programmes directly relies on the curiosity and pleasure of the volunteers to learn and observe things that they have never noticed in their most familiar places. Citizen science projects are often based on how biodiversity is related to 'the scale of human experience' (Horwitz *et al.*, 2001; Miller, 2005), which in turn, of course, influences peoples' attachment to particular areas (Evans *et al.*, 2005). In this respect, these programmes are particularly effective in monitoring the 'familiar species', 'wider countryside', 'ordinary nature' and 'everyday nature', which are terms now frequently used in conservation biology and land-use policy. These terms all refer to the part of nature located within or next to where people live and work and that everyone can experience easily. Ordinary nature is thus mostly composed of native common species and habitats (or assimilated introduced species), which are generally abundant (at least locally). As mentioned by Gaston & Fuller (2008), although these common species 'shape the world', conservation biology has often neglected their importance. Conservation biologists should thus pay more attention to the fate (i.e. the causes and consequences of both increase and decrease) of this ordinary nature.

Citizen science programmes also directly involve adults and children in scientific programmes that offer great opportunities to demystify scientific approaches. The aim is not, as in a pedagogic action, to have them 'play the scientist', but to let anyone *become* a scientist coordinated by a recognized institution (Trumbull *et al.*, 2000). To reinforce their scientific education component, some programmes also provide specific materials to be used by children with their parents or with their teachers at schools (Table 3-c). These additional materials can explain how to perform a statistical analysis or to initiate experiences related to the species under study (e.g. caterpillar breeding and metamorphosis observation…). Volunteers can also be asked to participate in large-scale experiments. For instance, *Monarch Watch* is a citizen science project where volunteers across North America tag individual butterflies. The tagging programme helps to answer questions about the geographical origins of species, the timing and pace of the migration, mortality during migration and changes in geographical distribution.

Coordinating thousands of volunteers involved in a real scientific work also has implications for professional scientists themselves. First, scientists must explain clearly the global objectives of the programme: what we want to study and why. In this respect, recontextualizing the programme in a larger context can be very motivating (e.g. regional effects of climate change for the *BudBurst* project, fragmentation for the *Birds in Fragmented Landscape* project, both of which are running in the USA) and is a good opportunity to highlight the key strength and reasons for such investigations. Second, the protocol (and any aspect of the particular methodology chosen) has to be clearly set. Third, scientists must inform participants about the programme (e.g. number of participants, data collected and species seen) and communicate their results regularly. For these reasons, most programmes involve regular feedback to observers, including visualization of data online or specific newsletters focusing on the most important results (Table 3-d). Involvement in citizen science therefore encourages scientists to come down from their 'ivory tower'.

Overall, citizen science is based on a general framework linking citizens and scientists together, allowing the implementation of a complete scientific approach (Fig. 1a): this framework addresses a particular question, tests hypotheses with appropriate data collected from a well-designed protocol, allows the interpretation and understanding of new results and can help to derive and spread original educational outputs. However, a good combination of critical issues is needed to

Table 3 Citizen science, people involvement and scientific communication

Issue	Type	Name	Characteristic	Website	Country
(a) Skill	Beginner	French Garden Butterfly Observatory	No skill required	http://noeconservation.org	France
	Intermediate	Nocturnal Owl Survey	Ability to identify few species	http://www.bsc-eoc.org/volunteer	Canada
	Confirmed	French Rhopalocere Monitoring	Ability to identify many species	http://www.mnhn.fr/vigie-nature	France
(b) Time required	Occasional observation	e-bird	No commitment	http://www.ebird.org/content/ebird	World
	One-day event per year	Bailly Birdathlon	During a 24-hour period in May, to find as many bird species as possible	http://www.bsc-eoc.org/support/birdathon	US, Canada
	Regular commitment throughout a season	Firefly Watch	Ten minutes, one evening a week throughout the summer	http://www.mos.org/fireflywatch	US
	High commitment	UK Butterfly Monitoring Scheme	26 counts a year and 5 hours by count	http://www.ukbms.org	UK
(c) Education	Special training tools	Frog Watch	Frog call records	http://www.naturewatch.ca	Canada
	Field training/workshop	Anglers Monitoring Initiative	1 day workshop obligatory	http://www.riverflies.org	UK
	Special activities for children	Great Lake Worm Watch	Downloads of educative games	http://www.nrri.umn.edu/worms	US
	Special tools for teachers	RoadKill	12 interactive activities proposed	http://roadkill.edutel.com/	US
	Special tools for university students	Project BudBurst	Exercises of data collection	http://www.windows.ucar.edu/citizen_science	US
	Tools to analyse its own data	e-bird	Access to maps and data important to the observer	http://www.ebird.org/content/ebird	World
(d) Communication	Press room	Feeder Watch	Free downloads of reports, videos and press articles	http://www.birds.cornell.edu/pfw	US, Canada
	Pollution and conservation alert	Anglers Monitoring Initiative	Update of species conservation status	http://www.riverflies.org	UK
	Results on-line	All of them to varying extents (interactive maps, graphs, reports …)			

ensure the success of citizen science projects (Fig. 1b). Many projects have not been particularly successful, have not led to useful scientific results, or have collected much data that have never been effectively used. Among critical factors of success, the simplicity of each component of the framework, the structure of the scheme, the regular feedback of results to participants and a good communications strategy are crucial. Moreover, for long-term projects, the sustainability of the framework (often demanding sources of funding and people with permanent positions) should be carefully thought through.

So far, assistance from the general public is often limited to data collection in classical citizen science (Fig. 1a). Moreover, whether and how people actually perceive the educational outputs of citizen science programmes is generally lacking. In fact, whether citizen science itself is considered by participants as useful for conservation is not guaranteed, although it is generally assumed to be the case by scientists. Alternatively, several approaches have been developed over the last two decades in a general framework known as community-based conservation (Berkes, 2004), to encourage participatory management of local resources or to implement local conservation plans.

Community-based conservation is not a panacea and has often failed in dealing with multiple and complex objectives, or in integrating local communities as real partners (instead of objects) (Berkes, 2007). However, the benefits of shifting from an expert-based approach to participatory approaches in conservation are increasingly acknowledged (Berkes, 2004). For instance, Fernandez-Gimenez *et al.* (2008) have studied the objectives, processes and outcomes of five community-based forest management projects in the USA. They showed that such projects can promote social learning, lead to shared ecological understanding

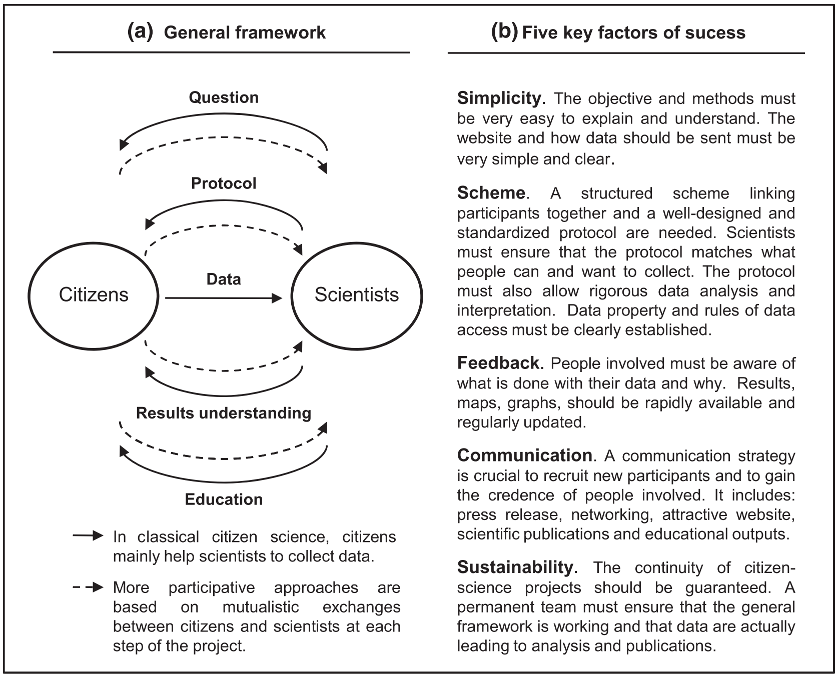

Figure 1 Conceptual framework and key factors of success of a citizen science programme. (a) A general framework generates a reciprocal connection between scientists and citizens from the question being asked to the educational benefit. This framework can range from top-down projects (black arrows) to more bottom-up and participatory approaches (dashed arrows) depending on whether and how citizens are involved (adapted from Cooper *et al.*, 2007). (b) To ensure that the framework is actually working and maintained requires several key factors that encourage success.

among diverse participants (sometimes involving adversarial interests), as well as increase internal trust and external credibility of the project. Citizen science programmes were shown to be particularly efficient in such adaptive and integrated management (Berkes, 2004), as well as in community-based conservation, involving local people in the description, the watching and management of the natural resources (Gaidet *et al.*, 2003).

More generally, Cooper *et al.* (2007) have recently argued that for large-scale projects, placing citizen science in an adaptive management framework (Fig. 1a), whereby citizens not only collect data but also intervene in ecosystems (e.g. by manipulating habitats), could have powerful ecological and social impacts. In fact, citizen science programmes vary from top-down to more bottom-up approaches depending on how people are involved (Fig. 1a) (e.g. if a fixed species list to monitor is decided or if people negotiate with the scientists about the protocol and about which species are important to them). We argue that such participative citizen science approaches could be even more effective in promoting positive re-connection between the general public and conservation issues. Assessing how such citizen science programmes are perceived by citizens themselves would also offer opportunities to initiate more challenging levels of participation, and favour stimulating connections between conservationists, biogeographers/ecologists, social scientists and the general public.

In the near future, citizen scientists could thus not only help to set surveys and scientific investigations, but also become the best allies of managers and stakeholders in setting large-scale conservation targets. Involving citizen participants directly in monitoring and active management of residential lands can generate very powerful management efforts, leading to positive, cumulative and measurable impacts on biodiversity (Cooper *et al.*, 2007). For instance, recreational fishers can be successfully involved to reduce drivers of fishery declines (Granek *et al.*, 2008) and citizen scientists can be of great help for wetland restoration (Miller, 2005).

Although it is increasingly recognized that landscape management, informed by local knowledge and citizen observations, may be a better option than any top-down conservation restrictions (Evans *et al.*, 2007), practical means to implement conservation strategies using citizen science as a social process are still largely missing (but see Cooper *et al.*, 2007). In this context, citizen science could be of great help to promote a conservation biogeography based on local ecological knowledge in several socio-economic contexts (i.e. not limited to the most developed countries).

CONCLUSION

Citizen science programmes are geographically explicit, standardized and cover large spatial and/or temporal scales. Although citizen science is not a panacea, these programmes share specific characteristics generally needed for large-scale investigations. Given the scientific success of these programmes (e.g. we know of more than 200 scientific publications investigating large-scale pattern and processes, including papers published in the best scientific journals, which are based wholly or largely on citizen science), we believe that they should increase and be encouraged in the future. Yet, although their number has increased in some countries (specifically the USA and UK) during the last decade (Nature Editorials, 2009), they remain relatively rare in others.

Nature protection is no longer solely considered as set apart from human activities (the so-called 'fortress conservation' approach), or restricted to emblematic or rare species, or the subject of pure academic science. The protection of a social nature encompassing a variety of environments and cultural contexts has gained credence (Kaplan *et al.*, 1999). The role played by biogeographical science in the emergence of conservation guidance is now gaining increasing recognition (Whittaker *et al.*, 2005). We believe that developing conservation biogeography towards common and familiar species using citizen science should provide a good opportunity to go beyond the measurement of biodiversity loss to look at the values and visions that people hold for their own landscape.

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BIOSKETCH

All co-authors are interested in defining and measuring conservation issues at large geographic scales. This paper results from ideas and perspectives discussed and shared by co-authors on how datasets collected from the general public can be used in conservation biogeography.

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