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The role of citizen science in a global assessment of extinction risk in palms (Arecaceae)

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Citizen science networks and tools offer researchers innovative ways of gathering data which can be used for conservation purposes. By engaging multiple stakeholders (from non-specialist members of the public to professional researchers), harnessing the enthusiasm and goodwill of a global community of interested parties can enormously speed up the collection of data. Conservationists urgently need to accelerate the rate at which the extinction risk of species are assessed, ideally using International Union for Conservation of Nature (IUCN) Red List criteria. The palms are a group of plants with a particularly high risk of extinction, across the family, in the face of increasing habitat destruction and overexploitation of economically important taxa; as many as 83% of palm species in Madagascar are threatened with extinction. A global assessment of conservation status for the palm family was recognized as being urgently required nearly 20 years ago, but < 20% of palm species are on the IUCN Red List of Threatened Species. The citizen science tool iNaturalist may be one way in which we can promote communities working together to gather data for prioritization and conservation outcomes. The palm community could work together using this tool to achieve this urgent target for the palm family. © 2016 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2016

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INTRODUCTION

Global biodiversity remains in crisis. Species extinction rates are still increasing and habitat loss and degradation as a result of land conversion and overexploitation of species around the world continue at increasing rates (Secretariat of the Convention on Biological Diversity, 2014). Current policy measures aimed at halting the loss of biodiversity are not working (Secretariat of the Convention on Biological Diversity, 2014; Titensor *et al.*, 2014), as governments continue to allow and even subsidize damaging land and marine use practices. The identification of species and sites for conservation prioritization is needed in the face of such challenges and limited resources. Evidence-based assessments of the extinction risk of species and the threats they face are urgently needed to inform policy and legislation. Assessments are also needed to guide conservation practitioners on appropriate development and conservation planning, conservation action for specific species and sites, and the guidance of essential research. The rate at which plant assessments in particular are being published is slow and a major hindrance is the lack of data on species in the wild. New ways of thinking about how to collect such data, employing new innovations and technologies and working with different partners rather than solely traditional methods of research, offer opportunities to fast track information gathering and assessments. Engaging the public to a greater extent with increasingly pressing conservation issues, especially if directly and practically linked with these new ways of collecting data, could drive a significant change in the rate at which researchers can provide evidence for and monitor the biodiversity crisis, and result in the development of a culture change in the personal connection of the public with these issues.

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ASSESSMENT OF EXTINCTION RISK USING THE IUCN RED LIST CRITERIA

The most widely used, scientifically rigorous and comparable methodology for the assessment of the risk of extinction of species is the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (hereafter referred to as the IUCN Red List) (Lamoreux *et al.*, 2003; Rodrigues *et al.*, 2006; Mace *et al.*, 2008; Vie *et al.*, 2008). Using data on the distribution, habitat and ecology of a species and evidence of threats, the IUCN Red List categories and criteria (IUCN, 2012a) have been applied to determine the level of extinction risk of 77 340 species to date (IUCN, 2015). If sufficient data are available for the assessment of a taxon and relevant thresholds within the criteria are met, it may qualify for a 'threatened' category of: 'Vulnerable', 'Endangered' or 'Critically Endangered'. When close to meeting the thresholds, a species may be classified as 'Near Threatened', and when the species is deemed to be stable or at minimal risk of extinction it is 'Least Concern'. When there are insufficient data, to the extent that a plausible category for a species could range from 'Critically Endangered' to 'Least Concern', it is deemed 'Data Deficient' (IUCN, 2012a). The assessment process incorporates a peer-review stage to ensure that data are valid and the criteria have been correctly applied, thereby maintaining standards and consistency between assessments (IUCN, 2012a).

The IUCN Red List is widely recognized as the most authoritative source of information on the extinction risk of species (Hoffmann *et al.*, 2008; Vie *et al.*, 2008; IUCN Red List Committee, 2013; Brummitt *et al.*, 2015a) and has become the 'gold standard' for conservation assessments internationally. Recognizing that the conservation of biodiversity is profoundly under-resourced (McCarthy *et al.*, 2012), governments, policymakers and funding agencies are increasingly dependent on measures of biodiversity value and extinction risk to determine the relative 'importance' of biodiversity. The prioritization of species and habitats for conservation, action plans and monitoring of environmental change all rely on species and/or habitat conservation assessments having been completed and, increasingly, IUCN Red List assessments of extinction risk are specifically required. Several funding sources, such as the Mohamed bin Zayed Species Conservation Fund (2015) and Conservation International, specify that species-orientated projects must focus on taxa that have been assigned an IUCN assessment of 'Critically Endangered' or 'Endangered'. The World Bank has incorporated IUCN Red Lists into its Environmental and Social Performance Standards (International Finance Corporation (World Bank Group), 2012), thus emphasizing their importance in leveraging policy change and funding for conservation action. Increasingly it can be said that without a 'recognized' conservation assessment a species may as well not exist in a policy maker's eyes.

Plants form the basis of all terrestrial ecosystems on Earth and the survival of healthy plant communities is critical for all other groups of organisms. Nevertheless, there are few complete global conservation assessments for plants using the IUCN Red List criteria (Brummitt *et al.*, 2015a, b), unlike an increasing range of zoological taxonomic groups, including amphibians, birds and corals (Secretariat of the Convention on Biological Diversity, 2010). Of the *c.* 380 000 known plant species (Paton *et al.*, 2008), < 20 000 (*c.* 5%) have been assessed globally and published on the IUCN Red List (IUCN, 2015). The rate at which new species of plants are being described is higher than that at which species are being assessed (> 2000 new species vs. 1500 assessments per annum; Brummitt *et al.*, 2015b). Recent work has shown that > 20% of plant species are likely to be threatened with extinction, using IUCN Red List criteria (i.e. 'Critically Endangered', 'Endangered' or 'Vulnerable') (Brummitt & Bachman, 2010).

Members of the palm family, Arecaceae, are likely to be highly threatened with extinction in the wild. Palms have been shown to be fundamental components of tropical ecosystems, especially of rainforests, one of the most threatened vegetation types in the world (Couvreur & Baker, 2013). Many palm species are also known to be economically important in different parts of the world, with a large number of uses for food, timber, medicines and cultural practices, especially at subsistence levels (Balick, 1984; Zambrana *et al.*, 2007). Unsustainable harvesting practices lead to overexploitation of targeted palms, in turn endangering species, e.g. the harvesting of *Oenocarpus bataua* Mart. for its oil-rich fruits in north-western South America, and *Astrocaryum chambira* Burret in the Amazon region for fibres (Bernal *et al.*, 2011). At the same time, many palms are only found in small populations and in habitats already at high risk from land use conversion, deforestation and fragmentation (Johnson, 1996). Palms are important taxa for ecosystem functioning and the survival of other species, and for human livelihoods (Johnson, 1996). Stands of species, such as *Mauritia flexuosa* L.f., hold together and contribute to the production of soils of swamps (Kahn & de Granville, 1992). *Phytelephas macrocarpa* Ruiz & Pav. provides a habitat for a range of vertebrate and invertebrate life (Couturier & Kahn, 1992). The measurement of the extinction risk to species of Arecaceae has been too long an area of research that has needed to be addressed.

BRIEF OVERVIEW OF PALM RED LIST CONSERVATION ASSESSMENTS

There are currently only 286 palm species on the IUCN Red List, with up-to-date global assessments (i.e. assessed in the last 10 years, IUCN, 2015), out of nearly 2600 species in the family (Palmweb, 2015), < 12% of all currently accepted palm species. Of these recently assessed species, *c.* 60% are threatened with extinction (i.e. in the top three IUCN categories). Two-thirds of these are from a recent assessment of all endemic palm species in Madagascar (Rakotoarinivo *et al.*, 2014), which found that 83% of the endemic palm species of this mega-biodiverse island are threatened with extinction. This strongly contrasts with the global average of 21% of species being threatened (Brummitt & Bachman, 2010; Brummitt *et al.*, 2015b).

Progress has been made with the completion of national and regional assessments of palm species, such as the Colombian Red List of Palms (Calderón, Galeano & García, 2005). National and regional assessments may or may not follow the precise IUCN criteria and guidelines for what IUCN officially terms 'Regional Assessments' (IUCN, 2012b). If a country has assessed endemic taxa, the assessments are, by default, global assessments. To be included on the IUCN Red List of Species, however, all assessments must meet the minimum requirements (IUCN, 2012a) and be global in their scope. Although it may take extra effort to convert regional assessments into global assessments, they are invaluable 'stepping stones' towards the production of full global assessments.

Palms have been specifically identified by the IUCN Red List Committee (2013) as a priority group for completion of a full global assessment of extinction risk, together with the need to expand the taxonomic coverage of plant species more widely, as emphasized by Stuart *et al.* (2010). Work has recently been attempted to use a triage approach (Jones, Fielding & Sullivan, 2006; Davidson *et al.*, 2009) to prioritize efforts towards the production of a global Red List assessment of all palms (Motoki, 2013). Although such triage and prioritization approaches may help to prioritize species and regions in need of full extinction risk assessments, the process of completing full Red List assessments remains challenging. Alternative, novel techniques to speed up or scale up the process of Red List assessment need to be investigated (Bachman *et al.*, 2011; Pimm *et al.*, 2014).

Twenty years ago, the IUCN Palm Specialist Group (Johnson, 1996) urgently recommended that the palm community should assess/reassess all palm species using the IUCN Red List criteria as a priority, ideally coordinated by the IUCN Palm Specialist Group.

THE DATA IMPEDIMENT AND CITIZEN SCIENCE

Rigorous IUCN Red List assessments of extinction risk for taxa need robust data on which to base decisions (Hoffmann *et al.*, 2008). Most commonly, plant Red List assessments are based on geographical distribution, often using georeferenced herbarium specimens as verifiable evidence of where a taxon is known to have occurred on a particular date. Using an assessment triage algorithm on 5726 US National Herbarium specimen records, Krupnick, Kress & Wagner (2009) estimated that up to 73% of all palms may be threatened globally. However, many plant taxa are known from only a few herbarium specimens (Schatz, 2002) and distributions based on such specimens may substantially underestimate their true geographical extent. Botanical collecting patterns also exhibit numerous idiosyncrasies that lead to bias (Ponder *et al.*, 2001; Kadmon, Farber & Danin, 2004), e.g. a lack of collections may be a result of rare taxa being hard to find or common taxa being overlooked as they may be considered as lower priorities. Taxa that are difficult to collect, such as palms, are often not recorded at all. At the same time, depending on the part of the world and taxon being studied, large expanses of a possible distribution may never have been surveyed for that taxon at all. The absence of specimens from a site does not mean that the species is not present there. Genuine absence of a species is rarely if ever recorded and is difficult to infer from other records. Although species distribution modelling techniques can be used to overcome partially the lack of data points for many taxa (e.g. Syfert *et al.*, 2014), distribution maps for palms, based only on limited herbarium specimens, can be difficult to interpret reliably. Such maps, if they are to be used for Red List assessments, would benefit greatly from some way of enhancing their information content and reliability.

Much more representative indications of true species ranges can be obtained from the inclusion of properly documented sight records and georeferenced photographs of taxa in the wild. In zoological fields, such as those concerned with studies of birds or large mammals, researchers have become much more adept at the systematic collection of sighting information and its incorporation into their studies. The eBird project (Sullivan *et al.*, 2009; Wood *et al.*, 2011; www.ebird.org) is an extraordinarily successful citizen science (Hand, 2010) project, utilizing crowd-sourced observations by members of the public. eBird harnesses the input of tens of thousands of birdwatchers worldwide to generate large quantities of freely available, high-quality data. Growth of the dataset has been rapid. In 2011, 1.7 million observation records were submitted from > 210 countries (Wood *et al.*, 2011). In May 2015 alone, > 10 million records were added. Currently, eBird comprises 262.6 million records, an immense source of data for conservation researchers and practitioners. Members of the public are able to engage with conservation and research in a productive manner and scientists are provided with tools with which to collate their sighting records in a consistent format. Records can be collated for analysis and interpretation, but can also be assigned a degree of confidence and utility through the incorporation of expert verification and review.

The phenomenal success of eBird in collecting vast numbers of data may not be fully representative of all citizen science projects, but, even in more modestly successful projects, the engagement of citizen scientists offers a relatively low-cost means of harnessing volunteers' enthusiasm and contributions, at the same time as building civic engagement and interest in conservation and research. Large geographical areas can be assessed, at remarkably fine levels of detail, over long periods, with a community of active and engaged participants, providing essential baseline information that would be prohibitively expensive and unrealistic to assemble via conventional means of data collection (Dickinson, Zuckerberg & Bonter, 2010; Powney & Isaac, 2015).

NOVEL APPROACHES TO GATHERING DATA

A range of different tools and approaches are now available and/or being developed for different citizen science projects, including iSpot (www.ispotnature.org, Silvertown *et al.*, 2015), Old Weather (www.oldweather.org, Brohan *et al.*, 2009) and SETI@Home (www.setiathome.berkeley.edu, Korpela *et al.*, 2001), recording all kinds of information in different subject fields, including biodiversity observations, weather conditions, transcription of old handwritten manuscripts and analysis of astronomical images.

iNaturalist (www.inaturalist.org), founded in 2008, is one such online citizen science network, and is based at the California Academy of Sciences (CAS). The network collates biodiversity observations and identifications and presents them in a manner accessible and suitable for scientific and conservation research. With > 1.9 million contributed observations, iNaturalist represents an enormous data resource and an active global community effectively surveying and monitoring the natural world.

Pimm *et al.* (2014) cited iNaturalist as an important tool for helping scientists to 'fill the gaps' in knowledge about species in the wild. Joppa *et al.* (2012) showed how an iNaturalist project, the Global Amphibian BioBlitz, collated photographic observations of 90% of amphibian families and 11% of all species over a few months, all with georeferenced locations; a report of the use of this project in Madagascar was published by Andreone *et al.* (2013).

At one of the simplest levels of engagement, a registered user of iNaturalist can add observations (ideally including at least one photograph, but purely sight records can be added too) to the website or iOS or Android app, via their free account on the network. Observations need to have an associated date and at least some idea of geographical location, ideally embedded GPS coordinates extracted from the photographs or manually added coordinates taken at the same time as the photograph or field notes. Additional notes and a field determination can be added to the observation by the user, but are optional, and a determination can be left blank or be as simple as 'palm'. The user can click a 'request identification' button to flag the observation up to other users as being one that requires identification or checking of their initial identification.

All participants of the network can set up their own projects in iNaturalist, based on specific regions, taxonomic groups and/or time frames, such as 'The Palms of the Andes' or for a BioBlitz event (usually a 24-h intensive attempt to document the biodiversity of a specific area). Existing observations on iNaturalist can be added to these projects and the project can be used to stimulate new observations to be made in the field, uploaded and linked to the project. The 'owners' of a project can specify set fields to be completed when new observations are added, such as habitat details or dimensions, thus enhancing the quality and value of the data and the likelihood that a good identification will be possible to be assigned to the observation by other users. Project owners can also create accompanying 'guides' to help users to at least narrow down the possible identity of each taxon they observe.

Another simple way in which users all over the world can engage with iNaturalist is to log on and identify observations on the site, adding verifications and determinations to any observation from the photographs and information recorded. Users can filter all records by project, taxonomic group and/or region to review all observations of interest to them or specifically to review those marked with ‘request identification’.

Observations on iNaturalist are assessed from ‘casual’ to ‘research’ grade, depending on the consensus of multiple community identifications of each observation and the completeness of the data accompanying an observation. Research-grade observations from iNaturalist are now served to the Global Biodiversity Information Facility [Global Biodiversity Information Facility (GBIF), 2015], and are therefore being incorporated into studies which use large-scale datasets and meta-analyses. GBIF collates data from a wide range of sources around the world and relies on accurate, reliable records being contributed via those sources. Users can filter which data sources they used, and the fact that iNaturalist only contributes research-grade observations gives users increased confidence that the iNaturalist data on GBIF is of good quality for their own work.

One recent development with the iNaturalist platform is the ability to view draft IUCN Red List assessments. The format allows each section of the Red List assessment, e.g. distribution, habitat, threats, etc., to be visualized with an option to receive input from the iNaturalist community via a simple-to-use forum mechanism. Ultimately, not only can iNaturalist become a mechanism for the collation of occurrence data to support mapping of species, but the forum structure also provides a cheap and scaleable tool for the gathering of associated data for use in IUCN Red List assessment, addressing the long-term challenges of resourcing a project like the Red List (Rondinini *et al.*, 2014).

Precise locations of threatened or high-profile taxa, such as orchids, can be manually or automatically obscured from public view by iNaturalist ‘curators’ and project initiators. The geographical coordinates of any observation of a taxon with a published IUCN Red List assessment with a threat category other than ‘Least Concern’ or ‘Data Deficient’ will be automatically obscured to deter illegal collection of threatened taxa.

There are still challenges with the citizen science approach, e.g. in ensuring identification quality. For some groups of organisms, it may be impossible to ever provide an accurate species identification from images and associated data, although considerable success has been reported for some projects (Silvertown *et al.*, 2015). Improvement of ‘how to’ files, integrated identification guides and filtering on iNaturalist and specific projects, and project-specific fields, and guidelines on what data to collect about an observation and ideal attributes to try to capture in accompanying photographs, may help to improve the likelihood of reliable identifications being made. A project such as Old Weather requires at least three transcriptions of each piece of data, by three different users, before the record is considered to have been ‘completed’, and, similarly, iNaturalist requires a specific set of requirements to be fulfilled before an observation is considered to be research grade.

SCALING UP EXTINCTION RISK ASSESSMENTS OF PALMS GLOBALLY

Could we use tools, such as iNaturalist, to harness the enthusiasm and dedication of communities of existing and potential citizen scientists around the world? Doing so would help enormously to speed up data collection and enable the more rapid production of extinction risk assessments for plant groups around the world, in the face of increasing threats to the survival of species.

Palms represent an ideal taxonomic group to use as a model group for the gathering of data using citizen scientists for a number of reasons. Palms are a relatively conspicuous and recognizable plant family, and there is an active and large global community of extremely enthusiastic and knowledgeable experts on palms, including scientists, professional horticulturalists, conservation practitioners and amateur growers. Palms are relatively well studied (Dransfield *et al.*, 2008; Baker *et al.*, 2009) and substantial scientific resources are available to aid identification, e.g. field guides to different regions of the world (e.g. Henderson, Galeano & Bernal, 1995; Baker & Dransfield, 2006; Dransfield *et al.*, 2006; Henderson, 2009). A widely accepted consensus classification for a taxonomic group, as in palms, provides a relatively stable, robust classification on which citizen science projects can structure records and allow unambiguous identification of taxa.

In the same way that the global community of birdwatchers and experts have embraced citizen science projects based on birds, the same could be done with palms. iNaturalist could be promoted as a way of rapidly contributing observations and identifications, from anywhere in the world, irrespective of the degree of formal ‘expertise’. Identification tools and guides could be developed with the iNaturalist website and mobile apps to help users to identify palms themselves, prior to seeking community reviews for their identifications. Participants may wish to catalogue their sightings of species from field notebooks and photograph libraries, pinpointing geographical coordinates via maps and GoogleEarth, and uploading images. Experts with spreadsheets and databases of records (including herbarium specimens) can 'batch upload' to the iNaturalist site, and georeferences can be automatically extracted from photographs taken on a mobile device or a camera with a GPS receiver. Citizen science projects such as eBird (Sullivan *et al.*, 2009; Wood *et al.*, 2011) have shown that enormous datasets can be built up relatively quickly with some community development and time investment, and the data on palms around the world that this approach could gather would be invaluable.

Within a year of the first author setting up a 'Palms of the World' project in iNaturalist to test how the system worked, > 230 observations had been added, representing > 130 species, and 16 people had signed up, without any prompting or effort. Most of the observations have been added by existing members of the palm research community, working in Madagascar, Singapore and New Guinea. With nearly 3000 palm observations from around the world recorded on iNaturalist that have not yet been added to this project, there is already a good amount of untapped content that can be quickly incorporated from the wider iNaturalist community. The project provides a ready-to-use system into which the palm community can record observations of palms in the wild and make a direct contribution to the assessment of all palm species.

Harnessing the power of palm enthusiasts around the world, using a tool such as iNaturalist, could lead to a genuine step-change in the amount of evidence-based distribution data available for palm species. This would make the production of a global Red List assessment of the palms of the world a much more achievable goal, some 20 years after it was recognized by the IUCN Palm Specialist Group as an urgent priority (Johnson, 1996).

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