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Perspective

Progress, challenges and opportunities for Red Listing☆

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ABSTRACT

Despite its recognition as an important global resource for conservation, the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species only provides assessments of extinction risk for a small and biased subset of known biodiversity. A more complete Red List can better support species-level conservation by indicating how quickly we need to act on species deemed to be priorities for conservation action.

Vascular plants represent one of the Red List knowledge gaps, with only 7% of species currently on the Red List (including in the Data Deficient and Least Concern categories). Using vascular plants as a case study we highlight how recent developments, such as changes to rules, improvements to data management systems, better assessment tools and training, can support Red List assessment activity. We also identify ongoing challenges, such as the need to support regional and national assessment initiatives, the largely voluntary nature of the Red List community, as well as the need to meet core operating costs for the Red List. Finally, we highlight how new opportunities such as automation and batch uploading can fast-track assessments, and how better monitoring of assessment growth can help assess the impact of new developments. Most of our findings are also applicable to other species-rich groups that are under-represented on the Red List.

We examine trends in plant Red Listing and conclude that the rate of new assessments has not increased in line with what would be required to reach goals like the Barometer of Life. This may result partly from a lag between recent changes and their effects, but further progress can be made by realising the opportunities outlined here and by growing the Red List community and strengthening collaboration with IUCN.

1. Introduction

The (IUCN) Red List of Threatened Species™ (hereafter the Red List) is an important global resource for conservation (Rodrigues et al., 2006). Faced with limited resources and ongoing threats (Symes et al., 2018), conservationists must prioritise their actions. Species-level prioritisation can be driven by different factors such as rarity (Ricketts et al., 2005), phylogenetic diversity (Faith, 1992) or ‘keystone’ ecological roles (Marsh et al., 2007), but incorporating extinction risk, the likelihood of extinction under prevailing conditions (Mace et al., 2008), is crucial in order that priorities reflect the urgency with which we need to act. Currently, the Red List is the most recognised global system and documents extinction risk of >96,951 species (IUCN, 2018a). However, this represents a small and a biased subset of biodiversity (Stuart et al., 2010) and it is crucial to make the Red List more representative if it is going to guide species-level prioritisation.

1.1. Gaps and bias in Red List coverage

A major shortcoming of the Red List is its biased taxonomic coverage across the species-level diversity currently known to science. Comprehensive Red List assessments have been achieved for birds, mammals and amphibians, though assessment gaps for reptiles and fish limit overall coverage for vertebrates to 68% of described species (Table 1). Invertebrates, plants and fungi, on the other hand, are largely under-assessed, with an average assessment of <3% of known

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Table 1
Progress in assessing extinction risk of major groups of organisms using the IUCN Red List system (IUCN, 2018a).

	Estimated Number of described species	Number of species evaluated	Species evaluated as % of species described	Number of species not assessed
Invertebrates	1,305,250	21,886	2	1,283,364
Plants[a]	417,801	27,514	7	390,287
Fungi & protists	52,280	81	<1	52,199
Vertebrates	69,537	47,470	68	22,067

[a] The IUCN estimate of the number of described species of plants (310,442) has been replaced here by a more recent estimate of 417,801 based on an estimated number of land plants (including vascular plants and bryophytes of 403,911) (Nic Lughadha et al., 2016), plus 6637 species of green algae (Chlorophyta) and 7253 red algae (Rhodophyta) (Guiry and Guiry, 2019).

species (IUCN, 2018a) meaning the majority of the world's species have not had their risk of extinction evaluated.

The need for both taxonomic and temporal expansion (i.e. repeat assessments to detect trends) of the Red List has been recognised (IUCN Red List Committee, 2013; Rondinini et al., 2013; Stuart et al., 2010). For groups like plants, it is hard to overstate the magnitude of the current gap in assessment coverage on the Red List - there are 390,287 plant species still to be assessed (Table 1). Using estimates of global threat status of plants (Brummitt et al., 2015) we can infer that as many as 115,291 of the Not evaluated plant species are of elevated conservation concern (i.e. in the threatened categories Critically Endangered, Endangered, Vulnerable, or Near Threatened), which is more than the estimated number of described vertebrates (Fig. 1) and more than four times the number of all plants currently assessed on the Red List. The true value could be even higher if Data Deficient species are considered likely threatened (Bland et al., 2015), and yet higher still if we consider the estimated 10–20% of currently undescribed species (Joppa et al., 2010).

Plant assessments have not accumulated on the Red List in a systematic way, they have been subject to several different types of bias. For example, assessors have prioritised species they expect to be threatened, leading to an average of ~48% of assessed species being considered threatened (Critically Endangered, Endangered or Vulnerable), when global estimates place the figure at 21% (Brummitt et al., 2015) (Fig. 2).

Other forms of bias occur when certain groups of plants are targeted for assessment, usually driven by IUCN Specialist Groups (SGs) and Red List Authorities (RLAs). The remit of SGs is promoting and delivering conservation – including producing Red List assessments – for a focal group of species. There are 38 SGs or RLAs for plants, some with a taxonomic focus (e.g. Orchid SG), some with a geographic focus (e.g. Chinese Plant SG) and some with a thematic focus (e.g. Medicinal Plant SG) (Table S1). Three of the top ten most assessed plant families over the last ten years are under the remit of taxonomic SGs or RLAs: Cactaceae (Cactus & Succulent SG), Arecaceae (Palm SG) and Orchidaceae (Orchid SG) (Fig. 3). Unsurprisingly, species within the remit of taxonomic SGs or RLAs are more likely to be assessed than expected by chance ($P < 0.001$; Table S2). However, the large number of species in families such as Orchidaceae (29,700) means that there is still a considerable shortfall in species coverage (Table S3).

The final major source of bias in plant Red List assessment is geographic. Coverage of plants on the Red List broadly reflects overall patterns of plant species richness and these are also reflected in the areas where the greatest number of not evaluated species occurs (Fig. 4).

1.2. Why the gaps matter

The lack of comprehensive Red List coverage for species-rich groups has precluded their inclusion in large-scale analyses of threat status and conservation actions across the globe (Boyd et al., 2008; Grenyer

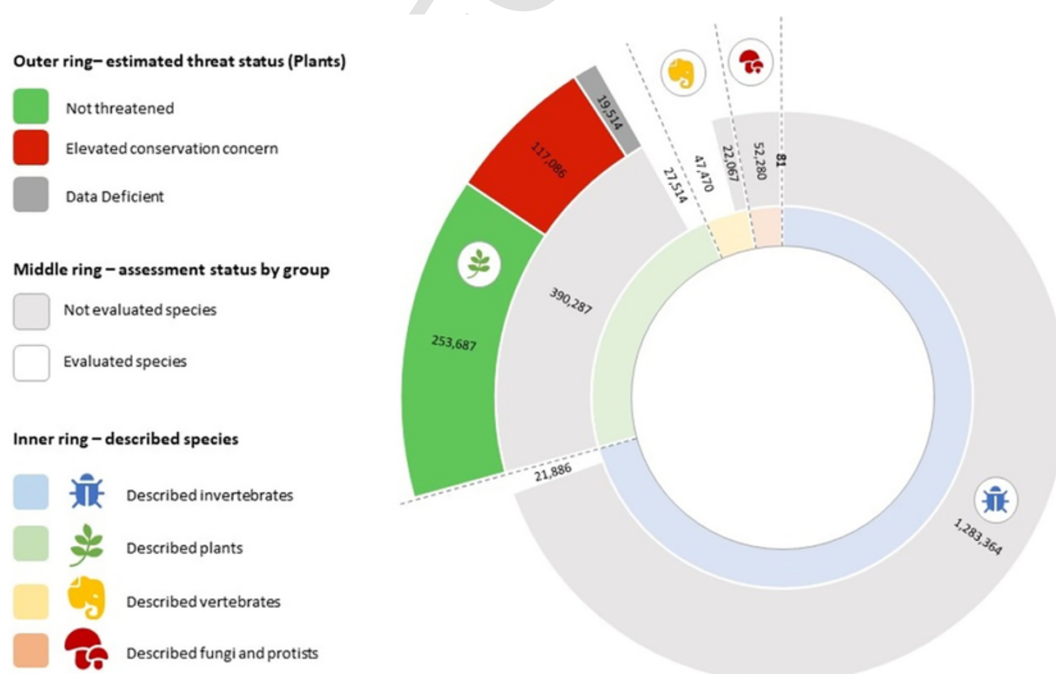

Fig. 1. Sunburst chart illustrating progress in assessing species for the IUCN Red List. The **inner ring** shows proportion of described species for major groups of organisms (Data from Table 1; IUCN, 2018a). The **middle ring** shows the breakdown of evaluated (white segments) vs. not evaluated species (grey segments). The **outer ring** shows the breakdown of not evaluated plant species by estimated threat status of Least Concern, Threatened or Data Deficient. The number of plant species of elevated conservation concern (117,086) is more than the estimated number of described vertebrates (69,537). Data on number of described species and number of evaluated species from Table 1. Estimates of proportion Least Concern, Elevated conservation concern (including Critically Endangered, Endangered, Vulnerable and Near Threatened) and Data Deficient for plants is derived from the Sampled Red List Index for Plants (Brummitt et al., 2015).

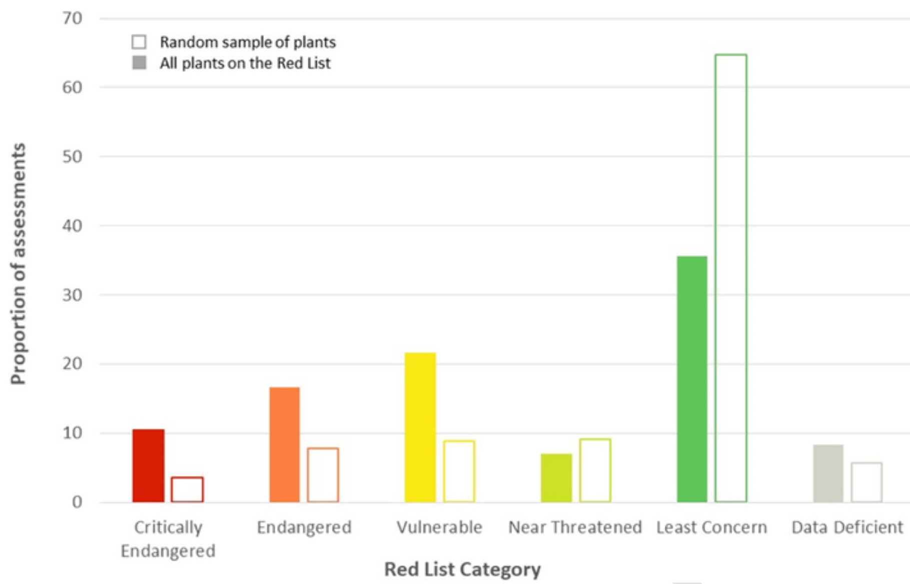

Fig. 2. Comparison of number of plant species in Red List categories for all plants on the Red List (solid bars; source: IUCN Red List 2018-2) against a random sample (hollow bars; Brummitt et al., 2015).

et al., 2006; Venter et al., 2014). It is important that non-vertebrate groups are added to such analyses because more comprehensive coverage of biodiversity can provide new insights for conservation science (Clausnitzer et al., 2009; Larsen et al., 2012; Rodrigues and Brooks, 2007). Hence, there has been a call to extend the taxonomic coverage of the Red List and develop a more complete 'Barometer of Life' by assessing 160,000 species by 2020 (Stuart et al., 2010). However, with 96,951 species assessments published since the criteria were updated in 2001 (IUCN, 2018a), this will be challenging.

The gaps in coverage are also important because the Red List has become an increasingly vital tool to support conservation through its influence in the business sector (Bennun et al., 2018). For example, Performance Standard 6 of the International Finance Corporation (IFC) specifically incorporates species categorized as Critically Endangered (CR) or Endangered (EN) on the Red List in defining Critical Habitat. Development projects must offer protection for Critical Habitat or initiate remedial action (IFC, 2012). The Red List also influences the conservation funding sector, where a threatened species on the Red List can trigger funding through initiatives such as the Mohamed Bin Zayed Conservation Fund, IUCN's own SOS fund or the Critical Ecosystem Partnership Fund. A perhaps unintended consequence of this influence is that less value is attached to species considered threatened, but not currently documented on the Red List. Failure to document threatened species on the Red List restricts our ability to influence conservation via these mechanisms.

There is also value in assessing species for the Red List even if there is insufficient information to assign a category of extinction risk: Data Deficient (DD) species are recognised as targets for research (Bland et al., 2015; Howard and Bickford, 2014) and their publication on the Red List has been shown to produce a listing effect that increases associated research output (Jarić et al., 2017).

1.3. *Growing the Red List – vascular plants as a case study*

Using vascular plants as a case study, in the following sections we first review recent developments in Red List assessment rules, guidelines and information management, and the tools and techniques available to support assessments. We consider what impact these changes have had on the Red List and the extent to which they are likely to contribute to filling current gaps. Secondly, we consider ongoing challenges and issues influencing growth of the Red List. Finally, we explore opportunities for future work that may provide quick wins and can stimulate activity towards addressing knowledge gaps.

1.4. *Overview of Red Listing process*

To put the following sections into context, we outline a generalised Red List assessment workflow (Fig. 5). There is no universally applied workflow, but Red Listing efforts often start with a species list, where species are either prioritised for assessment, or not (classified as Not Evaluated). This is followed by a pre-assessment stage where all available relevant data for each species are gathered. For plants this usually involves herbarium specimen data and observations ('occurrence data'), or information derived from floras or monographs. The assessment stage is where data are analysed to produce metrics that allow the Red List criteria to be applied. If insufficient data are available, a species can be classed Data Deficient (DD). If data are available to apply the criteria, and quantitative thresholds are met, a species can be assigned a threatened category: Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). If thresholds are not met, but are close, a species may be Near Threatened (NT). If a species is far from the thresholds, it can be categorized Least Concern (LC). The assessment can be a 'desktop' process (Brummitt et al., 2008), often carried out by an individual that can access specimen collection data and contact relevant experts, or it can be undertaken as part of a workshop where assessors, experts and facilitators process multiple assessments. Each assessment is then reviewed by an appropriate Red List Authority (RLA) or a delegated expert, or if no appropriate reviewer can be found, the Red List Unit. The review stage often results in feedback to the assessor(s) in an iterative process until there is agreement. Finally, assessments are submitted to the Red List Unit where they undergo consistency and quality checks before publication on the Red List.

2. Recent developments

2.1. *Automated criteria calculation and consistency checks*

Red Listing is based on quantitative criteria that categorize species according to their likelihood of extinction under prevailing conditions (IUCN, 2001; Mace et al., 2008). The criteria are underpinned by met-

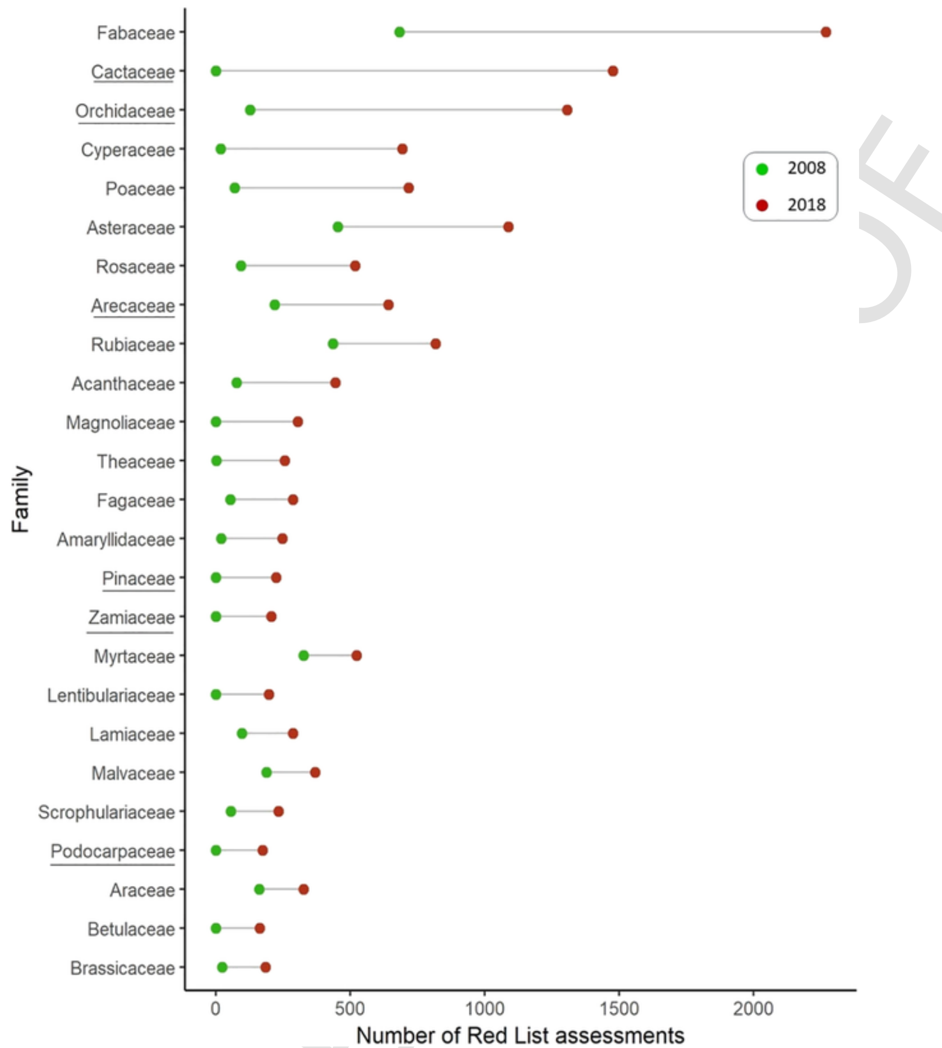

Fig. 3. Comparison of number of species per family on the 2008 version of the Red List with the current 2018 Red List. The y axis is ranked by families with the highest increase in assessments over the last ten years (2008–2018). Families under the remit of taxonomic specialist groups are underlined. There is considerable variation in the number of species in each family - a full list of families along with proportion of species assessed is provided in Table S3. A plot of the proportion of species assessed per family is shown against size of the family (number of species) in Fig. S3. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

rics relating to extinction theory, such as small or declining populations (Mace and Lande, 1991) and the existence of immediate and plausible threats. Thresholds set for these metrics determine to which category a species should be assigned (IUCN, 2001). Manual interpretation of the criteria, even by trained assessors, can sometimes result in errors that need to be resolved, either through assessment review or by IUCN Red List Unit staff, the team ultimately responsible for publication and maintenance of the Red List. Manual corrections absorb time that could be spent processing error-free assessments. To assist assessors, an automated *criteria calculator* has been built into the online Red List data management system, the Species Information Service (SIS). This automatically assigns the most appropriate category based on the data that have been entered (IUCN, 2018b).

Efficiency is also lost towards the end of the assessment process when time is spent checking assessments for consistency, such as ensuring the minimum requirements have been met. To reduce this wasted effort, an *integrity checker* has been added to SIS that checks that the appropriate level of supporting data has been provided – see Section 2.2. The use of the *criteria calculator* and *integrity checker* will help assessors generate 'technically' correct assessments. Enforcing use of these tools is unlikely to result in a significant increase in the generation of new assessments; rather it will help to free capacity of the Red List Unit to process more assessments, and act as a training aid that can reduce assessor bias (Hayward et al., 2015).

2.2. Reduced data requirements

The comprehensive, quantitative nature of each Red List assessment both makes the Red List a valuable tool and slows its expansion. Assessors have been deterred by having to document species in much more detail than may be necessary to assign Red List Categories with reasonable confidence, resulting in potential contributors to the Red List either failing to finalise assessments or resorting to publishing them elsewhere.

Lobbying by the IUCN Plant Conservation Committee (PCC) and the IUCN SSC South African Plant Specialist Group resulted in revised guidelines on supporting information requirements for Red List assessments (IUCN, 2016). The new guidelines identified that some data are not strictly required to support assessments and these fields were therefore downgraded to optional. Further, data requirements were differentiated according to the final category (e.g. minimal data are now required to support Least Concern assessments, while a threatened rating still requires all relevant data). The new requirements split supporting data for Red List assessments into three categories:

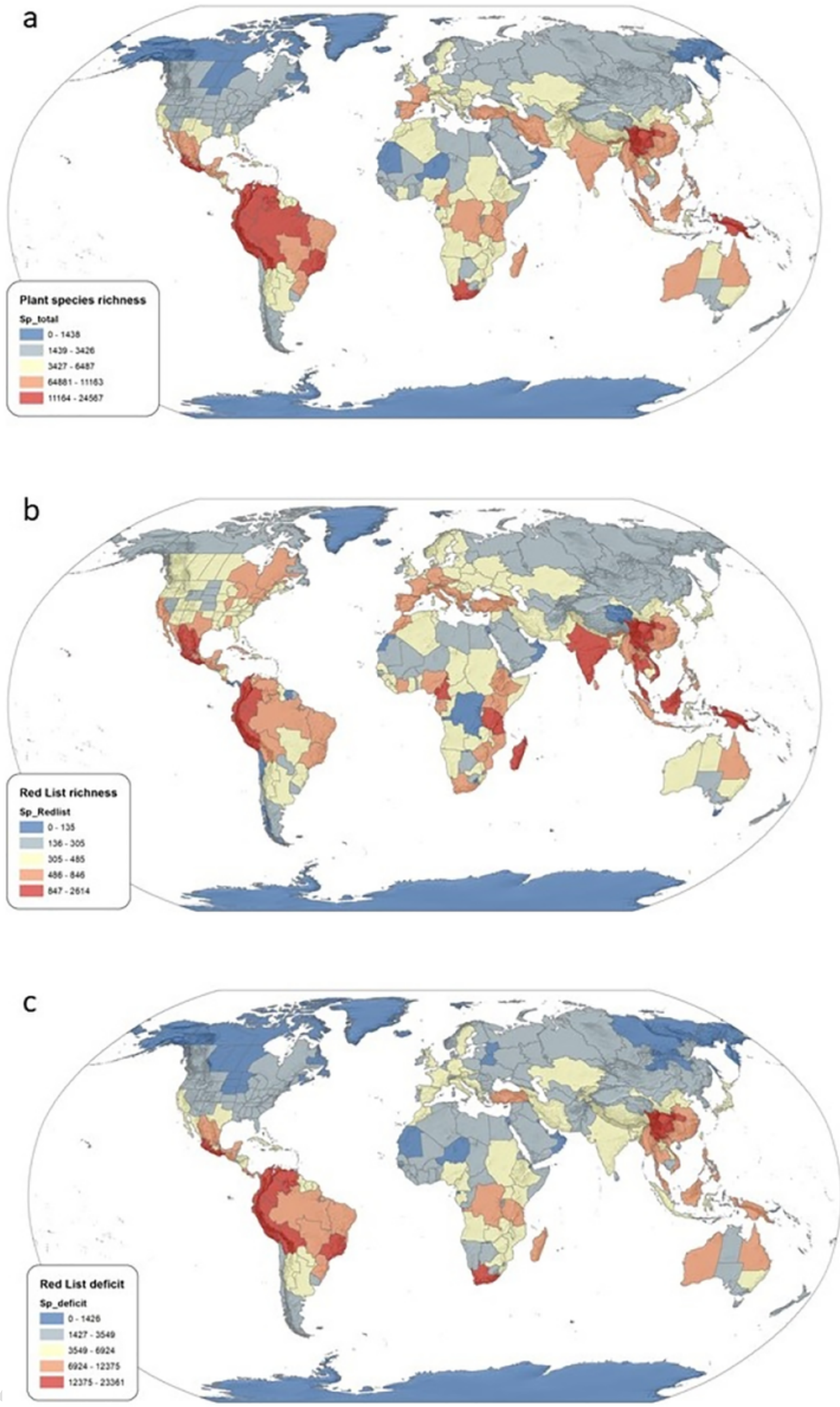

Fig. 4. (a) Plant species richness based on TDWG level 3 geographic regions (Source: Plants of the World Online), (b) Richness of plant species published on the IUCN Red List (IUCN, 2018a) and (c) Deficit of plant species Red List assessments (Red List richness subtracted from plant species richness).

1. **Required** – required for all Red List assessments or under specific conditions (e.g. plant growth form is only needed for plants).
2. **Recommended** – not mandatory, but assessors are encouraged to enter such data.
3. **Discretionary (Optional)** – includes data not essential for the Red List, but which may be recorded for analytical purposes.

Reduced data requirements for Least Concern species open up the possibility of rapidly documenting many plant species – see Section 4.2 – potentially leading to a future increase in Least Concern assessments published on the Red List.

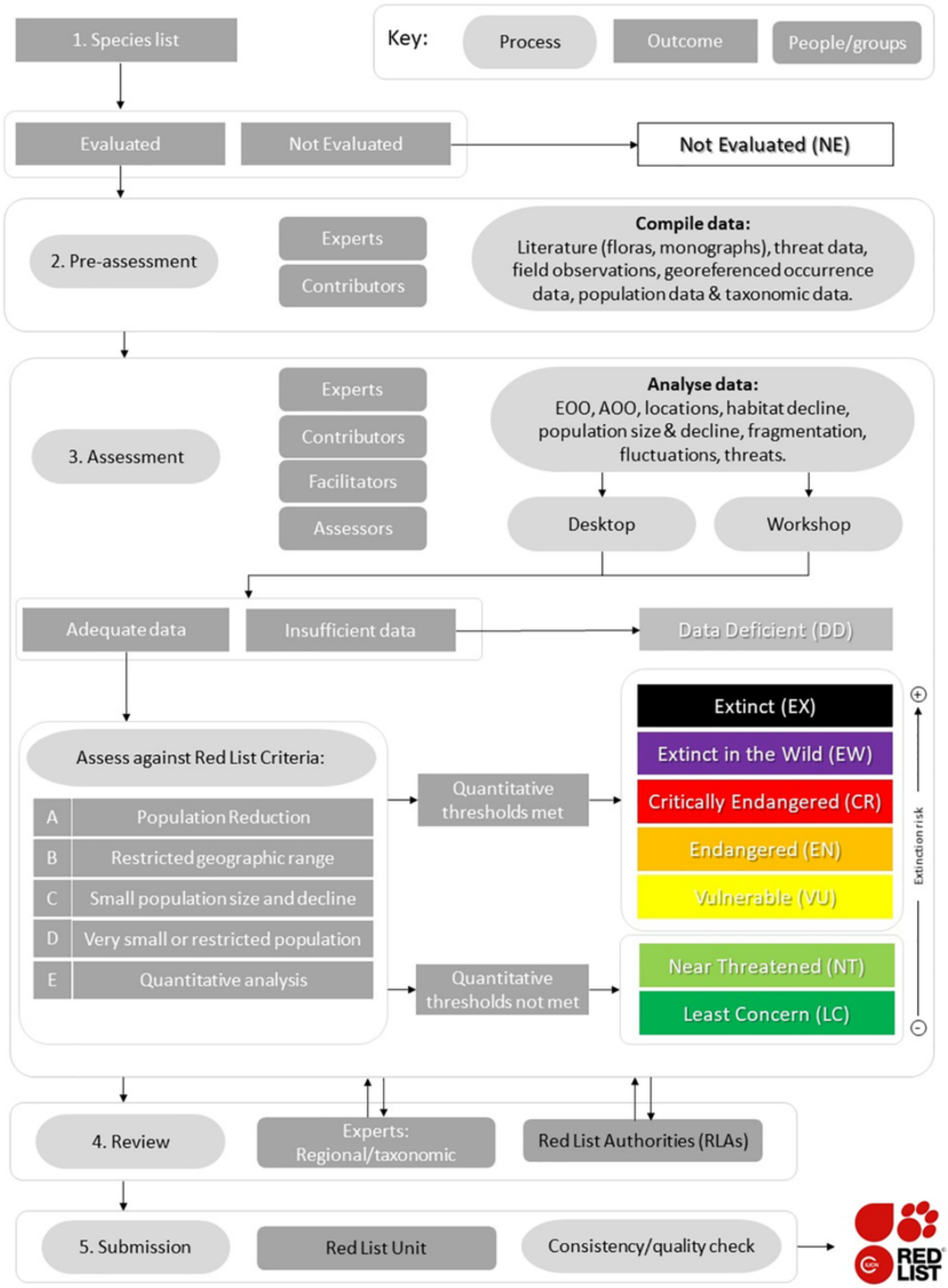

Fig. 5. Generalised Red List assessment workflow from species list to publication on the Red List. Ovals represent processes, grey and coloured rectangles are outcomes and curved rectangles are people or groups. EOO = Extent of occurrence, AOO = Area of occupancy. Arrows indicate direction of flow through different stages, including feedback. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

This revision of data-requirements highlights several important points. First, pressure from IUCN plant Specialist Groups helped make positive changes to Red Listing procedures; the Red List Committee (incorporating Red List partners) was willing to respond. Second, the changes are also helpful for other highly species-rich groups, such as fungi and invertebrates, that face similar challenges. Third, the Red List Committee should carefully consider which data are mandatory for Red Listing. New kinds of data will doubtless be required to support future Red List assessments, to document novel threats or support policy changes, but new data requirements should be clearly justified to the Red List community and tools or techniques should be developed to facilitate the generation of the new data.

2.3. Batch assessment upload with 'SIS connect'

The data management system underpinning the Red List (SIS) was developed to allow manual entry of supporting data for Red List assessments. However, supporting data needed for assessments, such as country-level distributions, taxonomic data or specimen data, often already exist in other databases. The need to manually transfer these data from one system to another limits the rate at which assessments can be added to SIS. To speed up the process, the Red List Unit developed a system to simultaneously transfer multiple assessments to SIS through a web service called 'SIS Connect' (http://connect.iucnredlist.org/). Successful transfers have been made by the Royal Botanic Gardens, Kew (via the BRAHMS database), by the New Caledonia Plant Red List Authority and by the South African National Biodiversity Institute.

2.4. Inclusion of assessments in languages other than English

Until recently the Red List only published English-language assessments, despite IUCN's position of supporting three official languages (English, French and Spanish). Because of this, regional Red Listing initiatives generating assessments in French (UICN France et al., 2013), Portuguese (Martinelli et al., 2013) and Spanish (Calderón Saenz Eduardo, 2005) have not published their results on the global Red List, or have had to undertake expensive and time-consuming translations into English beforehand. This barrier constrained the potential connectivity between regional assessment initiatives and the global Red List, especially the submission to the Red List of assessments of national endemics, which are equivalent to global scale assessments (Rodríguez, 2008).

Assessments can now be submitted in French, Spanish and Portuguese. The potential gain to the Red List in terms of growth in non-English language assessments has yet to be quantified, but with French, Spanish and Portuguese being the primary languages in seven of the top 17 megadiverse countries, each containing >5000 endemic plant species (Mittermeier and Goettsch, 1997), the majority of which are currently 'Not Evaluated', there is clearly scope for a large increase in assessments.

2.5. Spatial tools support Red List automation

Spatial metrics used in the Red List criteria that were previously challenging to calculate have now become mainstream through the development of spatial tools – see Table S4 for a list. These web based tools such as *GeoCAT* (Bachman et al., 2011), or R packages such as *Red* (Cardoso, 2017), can be used to calculate spatial metrics such as extent of occurrence (EOO) and area of occupancy (AOO) and build species distribution models using occurrence data. Advantages include rapid, consistent and auditable measurements. Disadvantages include potential uncritical user acceptance of results without considering other factors, such as sampling intensity (Sheth et al., 2012), although this can be addressed with training (see Section 2.7).

2.6. Linking new species and Red List assessment publications

New plant species are described at a fairly consistent rate, with a mean of 2205 per year (1999–2017, International Plant Names Index, 2018). However, recently described species are not being assessed and published on the Red List in a timely manner, usually taking >5 years after description (Fig. 6).

Authors of species new to science often include statements on their conservation status. Journals such as *Kew Bulletin* request descriptions of new taxa to include conservation statements specifically applying the IUCN Red List categories and criteria. However, these assessments rarely reach the global Red List. Of the 1234 newly described taxa published in *Kew Bulletin* from 2003 to 2017, only 116 (9%) had assessments on the Red List 2018.2. A disincentive could be the extra effort required to transfer data to SIS and lack of perceived 'reward' for publication on the Red List if it is not considered equivalent to a scientific journal. The recent registration of the Red List with an international standard serial number (ISSN 2307-8235), development of a journal-like submission process and decision to publish Red List assessments as PDFs with digital object identifiers (DOI), and a more dynamic publication schedule, will all help to address this perception and incentivise publication on the Red List.

The connection between new species descriptions and Red List assessments can also be improved with initiatives such as the 'Species Conservation Profile' (SCP) (Cardoso et al., 2016). The profile is equivalent to a Red List assessment, minus the final category and rationale.

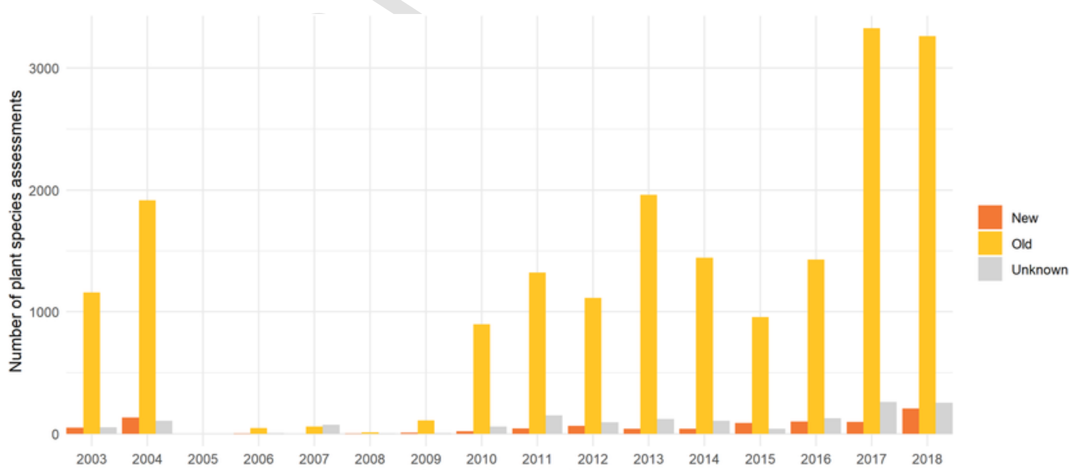

Fig. 6. Number of plant species assessments documented on the Red List for each year from 2003 to 2018, grouped by the time since the species was described. Species that were documented on the Red List within 5 years of being published are labelled as 'New' and species where >5 years had elapsed before a Red List assessment was published are labelled as 'Old'. When the year of species description could not be found or was ambiguous, it is marked as 'Unknown'. As there are often multiple updates of the Red List in a year, the latest update was used to give the annual total for that year. There were no plant Red List assessments added to the Red List in 2005. Year of species description was derived from the International Plant Name Index (IPNI) (www.ipni.org). The year 2018 is likely to underestimate the number of described species as these may not have been indexed by IPNI yet. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

It can be published through the *Biodiversity Data Journal* (BDJ) and subsequently submitted for publication on the Red List via SIS Connect. We encourage other journals that publish species descriptions to adopt this approach and strengthen links between extinction risk assessments of new species and formal publication on the Red List.

2.7. Consolidated training resources

Although formal training is not necessary in order to submit an assessment, many plant Red List contributors have been trained in applying the Red List Categories and Criteria and documenting an assessment. A shortage of plant experts trained in Red Listing could be a limiting factor for global Red Listing, and has been highlighted as a problem for regional Red Listing (Miller et al., 2007). Options for self-study have been greatly enhanced by the release of an online training course. The "Assessing Species' Extinction Risk using IUCN Red List Methodology" course, available from the 'ConservationTraining' portal https://www.conservationtraining.org, was launched in April 2014, and enrolled 2513 people by October 2016 (Caroline Pollock pers. comm.). Instructor-led training is also likely to grow the number of plant specialists contributing Red List assessments. Training should be targeted at scientists focused on areas of high plant diversity and offered in the most appropriate supported language. Training should also be followed up with a period of first-time assessment support as several sessions may be needed before assessment competency is attained (see Section 4.3 for further support tools).

Currently, it is difficult to analyse the impact of Red List training because trainees are not adequately tracked. This could be resolved with ORCID identifiers, unique 16-digit numbers that unambiguously identify researchers (Haak et al., 2012). If Red List trainees sign up for ORCID identifiers and document Red List training as a qualification, it will be possible to link trainees with assessments, and quantify the impact of training on assessment activity. If language and keywords on geographic and taxonomic interest are also documented in ORCID, then the reach of training in other languages can be monitored and potential recruits to fill Specialist Group gaps can be identified (see Section 3.3).

3. Challenges

3.1. Funding

Although the IUCN Red List is a critical conservation resource, its long-term stability could be compromised if core operating costs are not met. This has already been recognised in the Red List Strategic Plan (Result 9: The IUCN Red List is sufficiently and sustainably financed) (IUCN Red List Committee, 2013). In 2013, growing and maintaining the Red List cost US$4.7 million, plus the equivalent of US$0.5 million in volunteer time (Juffe-Bignoli et al., 2016). For a flagship product, this is small relative to IUCN's annual income of US$129 million (IUCN, 2017); Red List sustainability and growth may be at risk if funding is not prioritised to support vital infrastructure such as SIS, and to staff the Red List Unit sufficiently. Stabilising the core Red List operations, such as maintaining and developing SIS, quality control, standards development, training and support will ensure that additional funding can be wholly directed towards assessment and reassessment generation.

The only comprehensive evaluation to date (Juffe-Bignoli et al., 2016) revealed that philanthropy was the biggest source of Red List funding (42%), followed by governments (30%). The small (3%) contribution from the private sector can grow, and recent partnerships such as that with the Toyota Motor Company (https://www.iucn.org/content/new-iucn-toyota-partnership-expand-knowledge-threats-global-biodiversity) illustrate that large multi-nationals are willing to engage with the Red List. This commitment to tackle gaps in coverage such as for plants (http://www.kew.org/about/press-media/press-releases/toyota-supports-kew's-vital-research-threatened-plant-species) is a model that other multi-nationals can follow.

3.2. National and regional assessments for the global Red List

Many regional or national scale plant assessments have not been included in the global Red List. However, if IUCN categories and criteria have been applied and species are endemic to the region of assessment, then they are equivalent to global assessments and could be published on the Red List. A recent review of all digitally available plant conservation assessments revealed that 241,919 have been published (Bachman et al., 2017), representing 111,824 species, most of which were assessed using IUCN Red List criteria (see *ThreatSearch* to access assessment data [http://www.bgci.org/threat_search.php]). Approximately 60% of plant species are endemic to a single region (Bachman et al., 2017), indicating that a large potential source of global Red List assessments already exists. Barriers such as the need to translate (Section 2.4) and difficulties with batch transfer (Section 2.3) have now been resolved, but resources are still required to link regional assessments to the global Red List. In addition, a clear strategy is needed to engage the active community of regional assessors with the global Red List programme.

Global Red Listing of endemic plant species can be prioritised by cross-referencing regional or national assessments in *ThreatSearch* with checklists of plants in these areas. The establishment of a National Red List Working Group has also helped align national Red Listing initiatives with the IUCN Red List (Rodríguez, 2008) by focusing on training in the application of IUCN Regional Guidelines and building awareness of batch import options (Section 3.4). Good communication between the IUCN Red List Programme and regional assessors is needed to ensure value is added to national/regional assessments by publishing them on the global Red List (Miller et al., 2007).

3.3. Supporting the plant assessment champions –specialist groups and authorities

Several large, important plant families (e.g. Asteraceae, Fabaceae, Lamiaceae, Poaceae, Rubiaceae) have no SG/RLA (Table S1 and S3); these should be targets for the development of new SG/RLAs. Geographically there are gaps in SG/RLA coverage in known plant diversity hotspots such as Central America, north-western South America, West Africa, and South-East Asia including plant mega-diversity countries such as Australia, India, Papua New Guinea, Peru, Philippines, Venezuela and Ecuador (Fig. 7). Thus, many plant species fall outside the remit of any Specialist Group and steps must be taken to strategically establish more groups in these areas. The recent addition of the Indonesia RLA and Colombian SG and plans for a West African Plants RLA, a Sonoran Desert Plants SG and a Western Ghats Plant RLA, will all help address these gaps.

The SGs/RLAs are voluntary and built on goodwill. IUCN SSC should clearly specify incentives for experts to engage voluntarily with these groups, and should support those wishing to set up new groups through, for example, seed money, streamlining the application process, ensuring rapid decisions on proposals for new groups, and providing training on roles and responsibilities. Consolidating and supporting existing groups through training is also a priority.

Establishing more SGs and RLAs may mean greater overlap of jurisdiction. Although reviewing an assessment only requires one RLA, each relevant RLA should be informed of the assessment, and according to present guidelines has up to three months to review it (IUCN, 2016). This is intended to ensure robust review of Red List assessments, but could also delay the review process. To avoid bottlenecks caused by se-

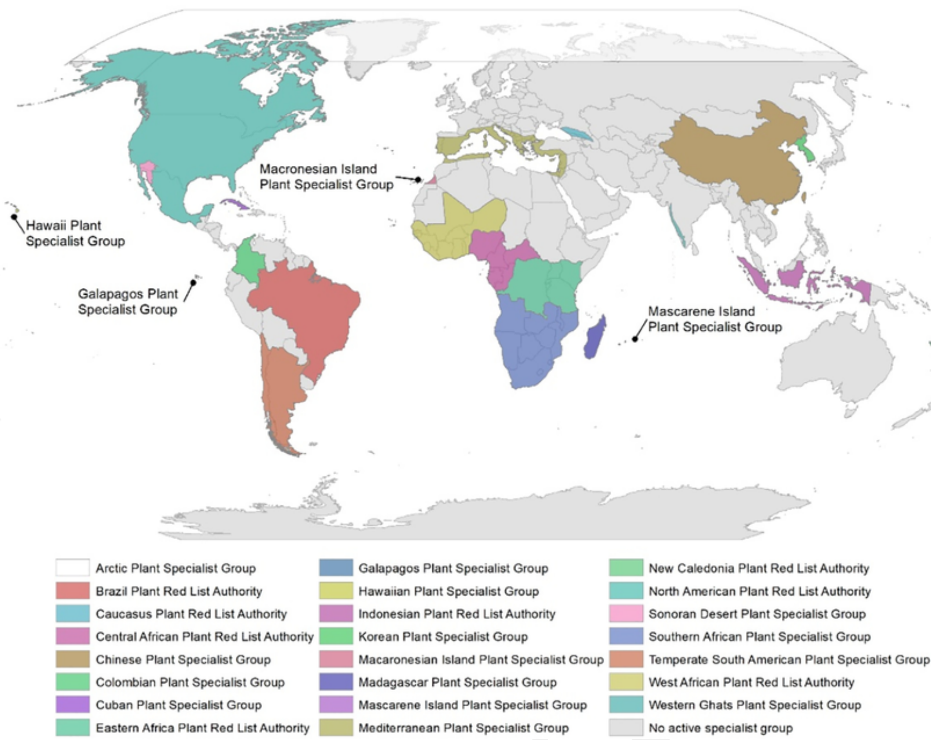

Fig. 7. Coverage of the world by plant specialist groups (and Red List Authorities) with a geographic focus. The West African, Sonoran Desert and Western Ghats Plant Specialist Groups are in preparation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

quential reviews, we encourage RLAs with overlapping remits to review assessments in parallel where possible (e.g. within one three-month period), or if they are happy to do so, to cede responsibility to the best-placed RLA. A review provided by one RLA, that has been fully addressed by assessors, should be, and typically is, sufficient for publication of an assessment.

3.4. Primary data

Botanical collections rarely incorporate demographic data, which is problematic because population size and population decline are core elements of the Red List criteria (IUCN, 2001). A single specimen collection could represent a single individual or thousands of individuals, which translates to plausible Red List categories of Critically Endangered to Least Concern. Gathering demographic data can be time-consuming and expensive, but mainstreaming population size estimation into field work will expand the options for plant Red List assessors and will lead to more robust assessments.

4. Opportunities

4.1. Automated documentation of least concern species

The manual nature of species assessment is a major factor limiting growth of the Red List, but automation is possible. Reduced data requirements (Section 2.2) and batch assessment transfer options (Section 2.3) have opened the possibility of scaling-up documentation of Least Concern assessments. Many required fields for Least Concern assessments, such as taxonomy, countries of occurrence and plant growth form, already exist in databases. We developed a tool using freely accessible data on plants to rapidly generate required data for LC assessments, including spatial points (https://XXXX.shinyapps.io/plantdash/). Crucially the assessor needs to determine which species should be assigned the LC category.

4.2. Prioritisation

Rapid, automatically generated assessments can save time and reduce costs for future assessments, but only if the species likely to be Least Concern are known. From a representative sample, we can infer that ~65% of plant species (~200,000) are likely to be Least Concern (Brummitt et al., 2015), but we don't know which. Species can be assigned a likely category using predictive models based on coarse geographic data (Darrah et al., 2017), occurrence data from herbarium specimens (Krupnick et al., 2009), climate data (Moat et al., 2018) and traits (Saatkamp et al., 2018). These approaches can reach high levels of accuracy (>96%) in predicting non-threatened species (Nic Lughadha et al., 2018).

4.3. Advancing techniques to assess threatened species

Threatened and Near Threatened plants also need to be rapidly and robustly assessed to fill Red List knowledge gaps, but have greater data requirements than LC assessments. Using remotely sensed (or Earth Observation) data can speed up the process. Such data may currently be underutilised (Turner et al., 2015), and insufficiently complete, available, up-to-date, repeated or accurate for use in threat assessments (Joppa et al., 2016), but Earth Observation data on forest loss have been used successfully to infer population declines for Red List assessment (Buchanan et al., 2008; Tracewski et al., 2016). Inference of population declines for use in Red List assessments can also be achieved by applying statistical techniques to opportunistic occurrence data (Maes et al., 2015), provided that appropriate methods are used (Isaac et al., 2014).

The Red Listing process can also be improved with existing tools (Table S4). Online consultation via web-based *fora* has proven a more cost-effective approach to Red List assessments than in-person workshops (Rondinini et al., 2013). A web-based community approach could also help transfer Red List assessment knowledge from experienced to less-experienced assessors via social Q&A platforms, such as those hosted by Stack Exchange [https://stackexchange.com]. New techniques such as chatbots could provide automated support. Sharing knowledge in a way that is open to all should yield higher quality assessments and more efficient transfer to the Red List, as well as alleviating pressure on the Red List Unit as the main information resource for assessors.

4.4. Monitoring progress

What is the evidence that the actions already undertaken, or proposed in this review, can benefit the plant Red List? It is hard to tease apart the overlapping impact of different interventions. To monitor the envisaged growth, we developed a data dashboard that will be updated as the Red List is updated: https://XXXX.shinyapps.io/plantdash. The dashboard tracks where we expect growth in species assessments to occur such as Least Concern species, newly described species, endemic species, species assessed in a non-English language, and species within the remit of specialist groups such as trees.

Monitoring is already revealing areas of progress, for example, 509 assessments have been published on the Red List via the batch transfer SIS Connect system and 915 more are in the pre-publication processing stage (pers. comm. Craig Hilton-Taylor, 2018). Growth in SIS Connect use can be monitored to evaluate the benefit of this kind of technical development to the Red Listing process. If the rate of Red Listing does not increase, potential reasons should be investigated, such as insufficient capacity of the Red List Unit to process SIS Connect assessments, quality of documentation on the system or lack of awareness of its capabilities amongst the Red List community.

Growth in the use of assessments in languages other than English is already apparent with 20 plant assessments from Brazil, written in Portuguese, successfully published on the Red List in 2016. The most recent Red List updates include 57 assessments in French and two in Spanish (Castilian).

To date there have been 9 SCP papers published by BDJ, covering 195 taxa. Encouragingly, these include Red List knowledge gap groups such as Plantae, Aranae, Lepidoptera and Coleoptera. However, technical issues still need to be resolved and so far no SCPs have been transferred via the SIS Connect system (pers. comm. Craig Hilton-Taylor, 2018). If these issues can be overcome, other journals publishing new plant species descriptions can adopt similar strategies and utilise SIS Connect to help populate the Red List.

Progress is likely to result from a combination of factors that collectively will have impact, rather like the stabilization 'wedges' proposed for moving from business-as-usual to a stable emissions scenario in response to climate change (Pacala and Socolow, 2004).

5. Conclusion

We have demonstrated that although positive steps have been taken to grow the Red List of vascular plants, the rate of new assessments has yet to achieve levels that would be needed to reach goals set out in like the Barometer of Life, such as a 10-fold increase in annual assessment output. This may be due to a lag after new opportunities have been available, such as extending assessment language options, and as new methods are adopted, such as batch assessment upload.

In the drive to grow the Red List further, we have highlighted how several possible quick wins could be achieved (e.g. automation of Least Concern assessments), as well as key investment needs for future growth of the Red List (e.g. training and capacity building and supporting core operating costs of the Red List). Most of our findings are also applicable to other species-rich groups, that are under-represented on the Red List, although these will bring unique challenges (Cardoso et al., 2011).

We hope to stimulate further discussion on the challenge of expanding the Red List in a strategic and cost-effective way that remains scientifically robust. In an era of intensifying threats, it is urgent that we work towards as complete a Red List as possible, to support species conservation. Success in this endeavour will be a product of the ongoing and strengthening collaboration between IUCN and the Red List assessment community.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2019.03.002.

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