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A strategy for the next decade to address data deficiency in neglected biodiversity

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Abstract: Measuring progress toward international biodiversity targets requires robust information on the conservation status of species, which the International Union for Conservation of Nature (IUCN) Red List of Threatened Species provides. However, data and capacity are lacking for most hyperdiverse groups, such as invertebrates, plants, and fungi, particularly in megadiverse or high-endemism regions. Conservation policies and biodiversity strategies aimed at halting biodiversity loss by 2020 need to be adapted to tackle these information shortfalls after 2020. We devised an 8-point strategy to close existing data gaps by reviving explorative field research on the distribution, abundance, and ecology of species; linking taxonomic research more closely with conservation; improving global biodiversity databases by making the submission of spatially explicit data mandatory for scientific publications; developing a global spatial database on threats to biodiversity to facilitate IUCN Red List assessments; automating preassessments by integrating distribution data and spatial threat data; building capacity in taxonomy, ecology, and biodiversity monitoring in countries with high species richness or endemism; creating species monitoring programs for lesser-known taxa; and developing sufficient funding mechanisms to reduce reliance on voluntary efforts. Implementing these strategies in the post-2020 biodiversity framework will

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help to overcome the lack of capacity and data regarding the conservation status of biodiversity. This will require a collaborative effort among scientists, policy makers, and conservation practitioners.

Keywords: Aichi targets, biodiversity, capacity building, conservation status, Convention on Biological Diversity, indicators, IUCN Red List, monitoring

Una Estrategia para la Siguiente Década para Enfrentar la Deficiencia de Datos de la Biodiversidad Ignorada

Resumen: La medida del avance hacia los objetivos internacionales para la biodiversidad requiere información sólida sobre el estado de conservación de las especies, la cual proporciona la Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (UICN). Sin embargo, los grupos más hiperdiversos, como los invertebrados, las plantas y los hongos, carecen de datos y capacidad, particularmente en regiones megadiversas o de endemismo alto. Las políticas de conservación y las estrategias de biodiversidad dirigidas hacia el cese de la pérdida de biodiversidad para el 2020 necesitan ser adaptadas para solucionar estas insuficiencias de información para después del año 2020. Diseñamos una estrategia de ocho puntos para cerrar las brechas existentes en los datos mediante la reactivación de la investigación exploratoria en el campo sobre la distribución, abundancia y ecología de las especies; la vinculación más cercana entre la investigación taxonómica y la conservación; la mejora a las bases de datos mundiales sobre biodiversidad mediante la presentación obligatoria de datos espacialmente explícitos para las publicaciones científicas; el desarrollo de una base mundial de datos espaciales sobre las amenazas para la biodiversidad para facilitar las valoraciones de la Lista Roja de la UICN; la automatización de las preevaluaciones mediante la integración de datos de distribución y datos de amenazas espaciales; el desarrollo de la capacidad en la taxonomía, la ecología y el monitoreo de la biodiversidad en países con una gran riqueza de especies o endemismos; la creación de programas de monitoreo de especies para los taxones menos conocidos; el desarrollo de suficientes mecanismos de financiamiento para reducir la dependencia de los esfuerzos voluntarios. La implementación de estas estrategias en el marco de trabajo para la biodiversidad posterior al 2020 ayudará a superar la falta de capacidad y datos con respecto al estado de conservación de la biodiversidad. Lo anterior requerirá de un esfuerzo colaborativo entre científicos, formuladores de políticas y practicantes de la conservación.

Palabras Clave: biodiversidad, Convenio sobre la Diversidad Biológica, desarrollo de capacidad, estado de conservación, indicadores, Lista Roja UICN, monitoreo, objetivos de Aichi

摘要: 衡量全球生物多样性目标的进展需要关于物种保护状况的可靠信息, 这些信息一般由《世界自然保护联盟 (IUCN) 濒危物种红色名录》提供。然而, 对于大多数多样性高的类群, 如无脊椎动物、植物和真菌, 已有数据和相应能力都十分缺乏, 特别是在多样性或特有性很高的地区。因此, 旨在到 2020 年制止生物多样性丧失的保护政策和生物多样性战略需要做出相应调整, 以便在 2020 年后解决这些信息不足的问题。我们设计了八条战略来填补现有的数据空缺, 分别是: 重新加强对物种分布、丰度和生态的探索性野外研究; 将分类学研究与保护更紧密地结合; 强制要求在发表科学出版物时提交空间显式数据以提升全球生物多样性数据库; 建立生物多样性面临威胁的全球空间数据库以帮助《IUCN 红色名录》的评估; 通过整合分布数据和空间威胁数据来实现自动预评估; 在物种丰富度高或特有性高的国家增强分类学、生态学和生物多样性监测的能力建设; 为所知甚少的类群建立物种监测计划; 建立充分的筹资机制以减少对志愿工作的依赖。我们认为, 在 2020 年后生物多样性框架中实施这些战略, 将有助于克服生物多样性保护状况方面能力和数据匮乏的问题。这将需要科学家、政策制定者和保护实践者之间建立合作。**翻译: 胡怡思; 审校:聂永刚**

关键词:《IUCN 红色名录》,《生物多样性公约》, 爱知目标, 保护状况, 生物多样性, 指标, 监测, 能力建设

Introduction

Current biodiversity loss is overwhelming, and the state of biodiversity continues to decline while threats increase (Tittensor et al. 2014; IPBES 2019). Global conservation policy targets, such as the Aichi Target 12 of the Convention on Biological Diversity (CBD) and UN Sustainable Development Goal 15, aimed to prevent the extinction of threatened species by 2020. However, most of these targets have not been met (Tittensor et al. 2014; IPBES 2019) and will not be met in the future without a massive effort to tackle the threats driven by human population growth and its increasing demands for natural resources. Biodiversity is distributed unevenly across the globe and across taxonomic groups (e.g., Mora et al. 2011), as are species threatened with extinction (Grenyer et al. 2006; Rodrigues et al. 2014). However, existing indicators of global biodiversity trends (e.g., Living Planet Index [WWF 2018], Red List Index [e.g., Butchart et al. 2004; Rodrigues et al. 2014], and GEO BON-Species Protection Index [GEO BON 2015]) are constrained by data that are taxonomically and geographically biased toward a relatively small, well-studied subset of the planet's biodiversity (Butchart et al. 2010; McRae et al. 2017). In particular, arthropods (e.g., crustaceans, arachnids, and insects), molluscs, and many plant taxa and fungi are some of the taxa least represented in global data sets (Troudet et al. 2017), hereafter referred to as

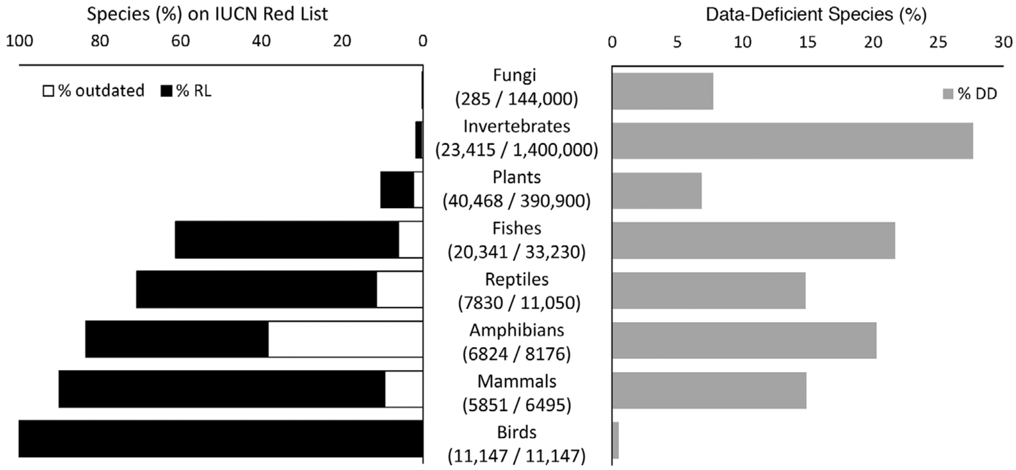

Figure 1. Percentage of species (left) assessed for the International Union for Conservation of Nature Red List of Threatened Species (RL) and percentage of assessments (right) with insufficient (data deficient) information for red-list assessments across taxonomic groups (IUCN Red List version 2020–1) (white, number of outdated [>10 years old] IUCN assessments; numbers in the center, number of species [left] on the IUCN Red List and [right] estimated number of described species).

lesser-known taxa. There is a strong need to identify both the areas and the species under most threat to facilitate conservation action for a wider range of taxonomic groups, particularly megadiverse and high-endemism regions.

The IUCN Red List of Threatened Species (IUCN 2020) (hereafter red list) is the most comprehensive and widely used information source on the conservation status of species. Assessing the red list status of species is crucial for identifying conservation priorities (e.g., key biodiversity areas [Eken et al. 2004]), implementing effective conservation action, and measuring progress toward global conservation targets (Stuart et al. 2010; Brooks et al. 2015). Red-list assessments rely on knowledge of the taxonomy, distribution, ecology, threats, and population trends of species, together with adequate capacity to process and analyze data. However, both data and capacity are lacking for many species-rich taxa, despite their great ecological and economic importance.

If estimates of approximately 9 million eukaryote species (Mora et al. 2011) are correct, 80% of species on Earth have not been named. Furthermore, the extinction risk of most named species (ca. 94%) has not been assessed for the IUCN Red List (IUCN 2020) (Fig. 1). Only a few groups (e.g., birds, mammals, and amphibians) have >80% of their species assessed, whereas the red list includes only 0.2% of described fungi (285 species), 1.7% of described invertebrates (23,416 species [coverage is better for molluscs, freshwater crustaceans, and Odonata than other taxa]), and 10% of described plants (40,468 species). This shortfall is due to lack of human capacity, including lack of experts, funding, public awareness, and political will (Hochkirch 2016; Stephenson et al. 2017*a*). The red list assessments of >10,000 bird species involved about 2300 contributors (Rondinini et al. 2013), which greatly exceeds the number of assessors available for the more diverse but lesser-known taxa (e.g., for the ca. 50,000 species of arachnids, about 20 assessors are available [P. Cardoso, personal communication 2020]). Lack of knowledge of the distribution, population trends, and threats for many taxa is reflected in the large number of data deficient (DD) species on the red list; about 14.8% (17,154 out of 116,177) of the species are DD (IUCN 2020). For many lesser-known taxa, distribution data are often either incomplete or old (Cardoso et al. 2011), and in many cases comprise only a single locality from the type material (Bland et al. 2017). Unsurprisingly, given the high proportion of undescribed and understudied species (Hochkirch 2016), the number of DD species is particularly high (27%) among the invertebrates (Fig. 1), and even with the intent of choosing well-known species of fungi, 8% of published global red-list assessments are DD. Some species may never be assessed because either the type material has been lost, the taxonomic status is doubtful, or the provenance is unknown (Bland et al. 2017), but most DD species simply lack the necessary information to assess their conservation status. Even those species assessed as threatened still suffer from a lack of information, particularly on population trends. Of all species on the red list (51,357 species), 44% are coded as "population trend unknown," whereas 66% for invertebrates are coded as such (IUCN 2020). Consequently, research on "population size, distribution and trends" is coded as necessary for 47% of the species on the red list (54,258 species). Recent advances to develop an IUCN green status of species (formerly "green list" [Akçakaya et al. 2018]) aim to quantify species recovery and conservation success, but this will require even more precise data on species abundance and distribution. Root causes of the lack of biodiversity data collection are numerous and include financial and capacity constraints and inadequate political will (e.g., Stephenson et al. 2017*a*).

It is, therefore, crucial to prioritize and strengthen resources that facilitate red list assessments, to collect more data, and to make the existing information available as efficiently as possible (which would meet the aim of the CBD Aichi Target 19 on developing the knowledge, science base, and technologies relating to biodiversity). We devised an 8-point strategy to address these problems in a post-2020 biodiversity framework specifically for lesser-known taxa: revive explorative field research; link taxonomy information to conservation information; improve global collation of spatial biodiversity data; map spatial threat data; automate preassessments; facilitate knowledge transfer; and provide funding mechanisms to fill knowledge gaps.

Strategy to Address Data Deficiency

Revive Explorative Field Research

A lack of basic natural history information has been highlighted as the main factor hampering red list assessments (Bland et al. 2017). Most of the species-specific data needed (taxonomy, distribution, life history, ecology, threats, population status, and trends) can only be collected during effective and targeted field surveys. The acquisition of this knowledge lies in the domain of ecologists, taxonomists, and field naturalists (both professional and citizen scientists) and requires improved funding mechanisms and more specialists with species knowledge. Basic field work with a focus on faunistic, floristic, and fungal data has declined greatly during recent decades. Capacity building of this kind is particularly necessary in high-richness and -endemism regions (Schmeller et al. 2017) (see also "Facilitate Knowledge Transfer"). Traditional surveys can be complemented by new technologies, such as environmental DNA, metabarcoding, and remote sensing, but all these methods require calibration based on expert knowledge and data from the field. Understanding the reasons for data deficiency and how easy it is to overcome this data deficiency via targeted field study will help prioritize those DD species that promise high returns in terms of improvements to conservation assessments (e.g., Bland et al. 2017). Fieldwork and associated research on biodiversity is increasingly hampered by stricter controls in many countries due to different interpretations and implementation of the Nagoya Protocol on Access and Benefit-Sharing (Schindel & du Plessis 2014). We, therefore, urgently need simplified procedures for issuing research permits to qualified personnel to enable essential fieldwork.

Link Taxonomy Information to Conservation Information

Taxonomy is crucial to species awareness and conservation (Mace 2004; Thomson et al. 2018) and needs to be accelerated using modern approaches (rapid descriptions and cybertaxonomy) (Bland et al. 2017). However, taxonomy also needs closer links to conservation science. Taxonomic revisions and descriptions typically include all available records of the species treated, and modern integrative studies also provide information on ecology and threats on species, which can facilitate red listing (e.g., Borges et al. 2017*a,b*). Unpublished databases of taxonomists should be made available for improved conservation assessment of species (Marinho & Beech 2020). Future revisions and species descriptions should be required to include available information on species distributions, abundances, habitat requirements, and threats so that this information can be harvested for red-list assessments (Tapley et al. 2018). Even better, red-list assessments should be part of taxonomic descriptions and revisions, which could be reached by facilitating collaboration between taxonomists and experienced red-list assessors. Revisions of species that have already been assessed should include a statement on how the changes in taxonomy affect existing red-list assessments. In this context, it is encouraging that the *Biodiversity Data Journal* has recently established a template for publishing red-list assessments and submitting them to the IUCN Red List (Cardoso et al. 2016), although an automated way to submit these needs to be developed.

Improve Global Collation of Spatial Biodiversity Data

Online platforms, such as the Global Biodiversity Information Facility (GBIF) (www.gbif.org), are repositories for specimen and species occurrence data from museum collections, national and regional recording schemes, and citizen science projects, and their data are openly available. However, GBIF has a strong geographical bias (e.g., >266 million records from the United States, but only 9.9 million from Brazil and 1.8 million from Indonesia) and a strong taxonomic bias favoring birds and some other vertebrate and plant groups (Troudet et al. 2017). A more strategic approach to data collection is required to obtain enough information for the lesser-known taxonomic groups from understudied regions because it is unlikely that these biases will change in the near future under current efforts.

One important step forward would be for ecological, taxonomic, and evolutionary journals to make it mandatory for authors to submit spatial occurrence data to platforms or databases that feed GBIF (Meier & Dikow 2004), similar to the mandatory submission of genetic data to GenBank (Benson et al. 2011), BOLD (Ratnasingham & Hebert 2007), or other online databases. The same should apply for environmental impact assessments

(EIAs), which are a legal requirement in many countries; yet, data from EIAs are rarely shared and made publicly available. The private sector could play a major role in enhancing the availability of EIA data. These requirements to share spatial biodiversity data would lead to more comprehensive distribution information for lesser-known taxonomic groups of the kind that is crucial for assessing the red-list status of a species. It may be necessary to change legal regulations to avoid contractual obligations hampering the release of such data. Sensitive data (e.g., for species targeted by collectors) could also be hidden from the public as recommended by the IUCN (2018).

These changes may also require development of guidelines to ensure data providers are invited to be coauthors of red-list assessments or other analyses if, for example, >10% of the data used in a study are from a single provider. Many global databases, such as GBIF and Genbank, include erroneous data, including incorrect identifications, out-of-date names, and incorrect taxon localities. We recommend the development of a mechanism to validate and correct entries in GBIF by qualified experts and addition of a quality-control flag, as already happens with some citizen science platforms, such as Observation.org or iNaturalist (Pereira et al. 2017).

Map Spatial Threat Data

The IUCN Red List criteria allow one to infer population trends from habitat trends, but assessors working on lesser-known species groups in tropical countries are often based in the northern hemisphere and may lack detailed knowledge of changes in habitat trends associated with local anthropogenic impacts. Global land-cover data sets can help address this gap. The Global Forest Watch database (Hansen et al. 2013), for example, collects information on changes in forest cover that can be used to infer population trends of forest-dependent species (Li et al. 2016; Santini et al. 2019). Databases are also available for a range of other pressures on species, such as dams, wildfires, roads, pollution, and invasive species. The PREDICTS database also provides some mapping capability for human pressures and calculation of a local biodiversity intactness index; the biggest data gaps relate to insects, soil invertebrates, and fungi (Hudson et al. 2017). The use of proxy data for threats can be enhanced by creating a single threat database that uses the best-available analytical tools to offer spatially explicit information on threats to biodiversity (e.g., agricultural land-use change, deforestation, urbanization, unselective fishing, spread of invasive species, climatic extremes, wildfires, quarrying, and dams) at a fine scale. This information would greatly enhance the ability to infer population and habitat trends for lesser-known taxa required for red-list assessments and would improve assessments for those species for which lack of information on threats has led to DD status (Murray et al. 2014).

Automate Preassessments

Red-list assessments are based on strict criteria, including reductions of species' populations, which can be inferred from habitat reduction (IUCN Standards & Petitions Committee 2019). Therefore, the integration of spatial data on species and threats or anthropogenic pressure can facilitate assessment of species (ter Steege et al. 2015). An automated procedure based on the known distribution of a species and existing threats within its range (see "Map Spatial Threat Data") would speed compilation of the numerous preassessments of species (e.g., Nic Lughadha et al. 2018), which could be evaluated and finalized by experts. This process would accelerate the assessment process and increase the number of lesser-known taxa on the IUCN Red List. Current approaches (e.g., Bachman et al. 2019) focus on automated assessments of least concern taxa and are solely based on distribution data due to the lack of a spatial threat database. Red-list assessments at the ecosystem level (Keith et al. 2013) would also help in the identification of complete communities at risk of extinction and inform red-list assessment at the species level.

Facilitate Knowledge Transfer

Often only a few taxonomic experts and dedicated citizen scientists have adequate knowledge to conduct red-list assessments for lesser-known taxa. As long as species knowledge resides with a few experts, who often live in species-poor countries, it will remain difficult to keep pace with the ongoing rapid loss of biodiversity. It is, therefore, vital to build capacity for taxonomic, ecological, and species monitoring in countries and regions with high species richness or endemism (Tittensor et al. 2014; Schmeller et al. 2017) by engaging more scientists and citizen scientists in local field research and conservation and by training students and government and nongovernmental organizations (NGO) staff. Conservation authorities and NGOs should employ staff with knowledge of lesser-known taxa. It is particularly important to bridge the gap between hard science and citizen science by producing print or online field guides or easy-to-use identification apps to allow the public to engage in surveys and species monitoring. Tools available to local conservation practitioners should also be improved. Automated image recognition systems (such as the apps ObsIdentify and iNaturalist Seek) work remarkably well for some lesser-known taxa, such as plants, moths, and bugs in northwestern Europe (Schermer & Hogeweg 2018), but they need constant support by species experts to calibrate the system and a high number of photos to feed the deep-learning algorithms. National capacity building in biodiversity-rich countries "should be linked to existing monitoring plans, such as those associated with national biodiversity strategies, to ensure government agencies are supported in implementing multilateral environmental agreements such as CBD" (Stephenson et al. 2017*b*). A positive example is the South African Custodians of Rare and Endangered Wildflowers (CREW) programme. Building capacity of scientists and conservation officials to conduct red-list assessments, compile conservation strategies, and implement conservation action in underrepresented countries is required.

Create Biodiversity Monitoring Programmes for Lesser-Known Taxa

Information on population trends is lacking for most species and is responsible for the absence of lesser-known species from global abundance-based biodiversity indicators, such as the Living Planet Index (McRae et al. 2017; Saha et al. 2018). Yet, this information is crucial for understanding progress toward conservation targets. Monitoring schemes are in place for only a few taxonomic groups, mainly in species-poor countries (e.g., in northwestern Europe). Recommendations often suggest the inclusion of citizen science projects to achieve monitoring goals (Tulloch et al. 2013), but this is mainly feasible for well-known taxa in species-poor countries. Invertebrates and species complexes of fungi are usually particularly difficult to identify from a photo. Monitoring a broad range of taxa provides information on ecosystem functions and services (e.g., clean water, nutrient-rich soil, erosion control, food webs, pollination, and pest control) and on broader ecosystem functioning (e.g., using aquatic invertebrates as indicators of freshwater quality) and offers the potential to monitor a larger proportion of biodiversity (Cardoso & Leather 2019). To set up appropriate monitoring systems, monitoring programs need to be optimized and harmonized to provide maximum information with minimum effort (Schmeller et al. 2015) and to ensure that data are stored, shared openly, and fed into national and global databases to facilitate their use in decision making (e.g., Borges et al. 2018). Although it will be impossible to include all species in monitoring programmes, those that target indicator communities or groups, taxa of local, national or global policy relevance, and highly threatened taxa in all the major biomes would promote maximum data acquisition with minimum effort. This approach would allow the evaluation of conservation success through the use of threatened species as sentinels for biodiversity in general.

Provide Funding Mechanisms to Fill Knowledge Gaps

The above strategic steps do not receive sufficient financial support. Indeed, even a database with the standing of the IUCN Red List relies largely on voluntary input (Rondinini et al. 2013; Hochkirch 2016; Juffe-Bignoli et al. 2016). Research funding agencies tend to focus on hypothesis-driven fundamental research, whereas conservation funding agencies prefer to invest in practical conservation action on the ground (Hochkirch 2017). The need for conservation assessment funding is particularly evident for species-rich but lesser-known taxa because conservation interventions are only possible with detailed knowledge of species and sufficient capacity for conservation action. Thus, there is a need to establish independent funding mechanisms for the complete process of data acquisition, data provision, red-list assessments, red-list governance, and implementation of conservation actions. The private sector, especially companies investing in extractives, could also contribute resources and data to this end. Positive examples already exist, such as the International Finance Corporation critical habitat concept (Brauneder et al. 2018).

Indicators

Clear targets regarding these strategy points should be included in the CBD post-2020 process, and they need to be accompanied by measurable and relevant indicators (Mace et al. 2018). The IUCN Red List provides the best database to measure general progress regarding knowledge of the conservation status of species, including total number of red-list assessments for lesser-known taxa and the relative proportion of DD species and the proportion of species with known population trends. Ultimately, it will be important to reverse negative trends and increase the number of species with stable or increasing population trends or improving red-list status. This general conservation success can also be measured with the green-list approach (Akçakaya et al. 2018).

To measure progress toward the 8 points more specifically, we propose the following indicators: availability of funding mechanisms for explorative field research; average number and proportion of taxonomic publications in which minimum data useful for red-list assessments are included; number of scientific journals that make spatial data submission to global biodiversity databases mandatory; number of open-access spatially explicit threat databases; number of red-list assessments that are based on automated preassessments; number of experts on lesser-known taxa in developing countries; number of monitoring programmes for lesser-known taxa by country; and availability of funding mechanisms to facilitate red-list assessments.

Conclusions

Current knowledge of the conservation status of biodiversity on Earth is insufficient to inform or monitor delivery of global conservation targets. To make progress toward post-2020 biodiversity targets measurable, there is a clear need for a cooperative effort by scientists, policy makers, and conservation practitioners to overcome the chronic lack of capacity and data through development of better tools to collect and curate information that will allow inclusion of ecologically important, understudied species-rich taxonomic groups in conservation actions. The IUCN, and its strong network of voluntary experts around the world, is probably in the best position to guide such efforts. There is sufficient evidence of the positive effects of conservation efforts on the fate of threatened species (Hoffmann et al. 2010), but time to minimize extinctions is running out.

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Literature Cited

Akçakaya HR, et al. 2018. Quantifying species recovery and conservation success to develop an IUCN Green List of Species. Conservation Biology **32:**1128–1138.

Bachman S, Walker BE, Barrios S, Copeland A, Moat J. 2019. Rapid least concern: towards automating red list assessments. Biodiversity Data Journal **8:**e47018.

Benson DA, Karsch-Mizrachi I, Lipman DJ, Ostell J, Sayers EW. 2011. GenBank. Nucleic Acid Research **39:**D32–D37.

Bland LM, Bielby J, Kearney S, Orme CDL, Watson JEM, Collen B. 2017. Toward reassessing data-deficient species. Conservation Biology **31:**531–539.

Borges PAV, Amorim IR, Terzopoulou S, Rigal F, Emerson B, Serrano ARM. 2017*a*. Cryptic diversity in Azorean beetle genus *Tarphius* Erichson, 1845 (Coleoptera: zopheridae): an integrative taxonomic approach with description of four new species. Zootaxa **4236:**401–449.

Borges PAV, Lamelas-López L, Amorim IR, Danielczak A, Nunes R, Serrano ARM, Boeiro M, Rego C, Hochkirch A, Vieira V. 2017*b*. Conservation status of the forest beetles (Insecta, Coleoptera) from Azores, Portugal. Biodiversity Data Journal **5:**e14557.

Borges PAV, et al. 2018. A global island monitoring scheme (GIMS) for the long-term coordinated survey and monitoring of forest biota across islands. Biodiversity and Conservation **27:**2567–2586.

Brauneder KM, et al. 2018. Global screening for critical habitat in the terrestrial realm. PLOS One **13:**e0193102. https://doi.org/10.1371/journal.pone.0193102.

Brooks TM, Butchart SH, Cox NA, Heath M, Hilton-Taylor C, Hoffmann M, Kingston N, Rodríguez JP, Stuart SN, Smart J. 2015. Harnessing biodiversity and conservation knowledge products to track the Aichi targets and sustainable development goals. Biodiversity **16:**157–174.

Butchart SHM, Stattersfield AJ, Bennun LA, Shutes SM, Akçakaya HR, Baillie JEM, Stuart SN, Hilton-Taylor C, Mace GM. 2004. Measuring global trends in the status of biodiversity: red list indices for birds. PLOS Biology **2:**e383.

Butchart SHM, et al. 2010. Global biodiversity: indicators of recent declines. Science **328:**1164–1168.

Cardoso P, Erwin TL, Borges PAV, New TR. 2011. The seven impediments in invertebrate conservation and how to overcome them. Biological Conservation **144:**2647–2655.

Cardoso P, Leather S. 2019. Predicting a global insect apocalypse. Insect Conservation and Diversity **12:**263–267.

Cardoso P, Stoev P, Georgiev T, Senderov V, Penev L. 2016. Species conservation profiles compliant with the IUCN Red List of threatened species. Biodiversity Data Journal **4:**e10356.

Eken G, et al. 2004. Key biodiversity areas as site conservation targets. BioScience **54:**1110–1118.

GEO BON. 2015. Global biodiversity change indicators. Version 1.2. Group on Earth Observations Biodiversity Observation Network Secretariat. Leipzig. Available from https://conbio.onlinelibrary.wiley.com/pb-assets/assets/15231739/Author%20Style%20Guide%20feb2019-1551741575403.pdf (accessed June 2020).

Grenyer R, et al. 2006. Global distribution and conservation of rare and threatened vertebrates. Nature **444:**93–96.

Hansen MC, et al. 2013. High-resolution global maps of 21st-century forest cover change. Science **342:**850–853.

Hochkirch A. 2016. The insect crisis we can't ignore. Nature **359:**141.

Hochkirch A. 2017. The invertebrate conservation challenge. IUCN SSC Quarterly Report 06/2017: 22–23.

Hoffmann M, et al. 2010. The impact of conservation on the status of the world's vertebrates. Science **330:**1503–1509.

Hudson LN, et al. 2017. The database of the PREDICTS (Projecting responses of ecological diversity in changing terrestrial systems) project. Ecology and Evolution **7:**145–188.

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany.

IUCN (International Union for the Conservation of Nature). 2018. Mapping standards and data quality for the IUCN Red List categories and criteria – version 1.16. IUCN, Gland, Switzerland. Available from https://nc.iucnredlist.org/redlist/resources/files/1539098236-Mapping_Standards_Version_1.16_2018.pdf (accessed June 2020).

IUCN (International Union for the Conservation of Nature). 2020. The IUCN Red List of threatened species v. 2019-3. IUCN, Gland, Switzerland. Available from www.iucnredlist.org (accessed March 2020).

IUCN ((International Union for the Conservation of Nature) Standards and Petitions Committee. 2019. Guidelines for using the IUCN Red List categories and criteria. Version 14. IUCN, Gland, Switzerland. Available from http://www.iucnredlist.org/documents/RedListGuidelines.pdf (accessed March 2020).

Juffe-Bignoli D, et al. 2016. Assessing the cost of global biodiversity and conservation knowledge. PLOS One **11:**e0160640. https://doi.org/10.1371/journal.pone.0160640.

Keith DA, et al. 2013. Scientific foundations for an IUCN Red List of ecosystems. PLOS One **8:**e62111. https://doi.org/10.1371/journal.pone.0062111.

Li BV, Hughes AC, Jenkins CN, Ocampo-Penuela N, Pimm SL. 2016. Remotely sensed data informs red list evaluations and conservation priorities in Southeast Asia. PLOS One **11:**e0160566. https://doi.org/10.1371/journal.pone.0160566.

Mace GM. 2004. The role of taxonomy in species conservation. Philosophical Transactions of the Royal Society London B **359:**711–719.

Mace GM, Barrett M, Burgess ND, Cornell SE, Freeman R, Grooten M, Purvis A. 2018. Aiming higher to bend the curve of biodiversity loss. Nature Sustainability **1:**448–451.

Marinho LC, Beech E. 2020. How phantom databases could contribute to conservation assessments. Science of Nature **107:**21.

McRae L, Deinet S, Freeman R. 2017. The diversity-weighted living planet index: controlling for taxonomic bias in a global biodiversity indicator. PLOS One **12:**e0169156. https://doi.org/10.1371/journal.pone.0169156.

Meier R, Dikow R. 2004. Significance of specimen databases from taxonomic revisions for estimating and mapping the global species diversity of invertebrates and repatriating reliable specimen data. Conservation Biology **18:**478–488.

Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B. 2011. How many species are there on earth and in the ocean. PLOS Biology **9:**e1001127.

Murray KA, Verde Arregoitia LD, Davidson A, Di Marco M, Di Fonzo MMI. 2014. Threat to the point: improving the value of comparative extinction risk analysis for conservation action. Global Change Biology **20:**483–494.

Nic Lughadha E, et al. 2018. The use and misuse of herbarium specimens in evaluating plant extinction risks. Philosophical Transactions of the Royal Society B **374:**20170402.

Pereira HM, et al. 2017. Monitoring essential biodiversity variables at the species level. Pages 79–105 in Walters M, Sholes RJ, editors. The GEO handbook on biodiversity observation networks. Springer Open, Cham, Switzerland.

Ratnasingham S, Hebert PDN. 2007. BOLD: the barcode of life data system. Molecular Ecology Notes **7:**355–364.

Rodrigues ASL, Brooks TM, Butchart SHM, Chanson J, Cox N, Hoffmann M, Stuart SN. 2014. Spatially explicit trends in the global conservation status of vertebrates. PLOS One **9:**e0113934. https://doi.org/10.1371/journal.pone.0113934.

Rondinini C, Di Marco M, Visconti P, Butchart SHM, Boitani L. 2013. Update or outdate: long-term viability of the IUCN Red List. Conservation Letters **7:**126–130.

Saha A, McRae L, Dodd CK, Gadsden H, Hare KM, Lukoschek V, Böhm M. 2018. Tracking global population trends: population time-series data and a Living Planet Index for reptiles. Journal of Herpetology **52:**259–268.

Santini L, Butchart SHM, Rondinini C, Benítez-López A, Hilbers JP, Schipper AM, Cengic M, Tobias JA, Huijbregts MAJ. 2019. Applying habitat and population-density models to land-cover time series to inform IUCN Red List assessments. Conservation Biology **33:**1084–1093.

Schermer M, Hogeweg L. 2018. Supporting citizen scientists with automatic species identification using deep learning image recognition models. Biodiversity Information Science and Standards **2:**e25268.

Schindel DE, du Plessis P. 2014. Reap the benefits of the Nagoya Protocol. Nature **515:**37.

Schmeller DS, et al. 2015. Towards a global terrestrial species monitoring program. Journal for Nature Conservation **25:**51–57.

Schmeller DS, et al. 2017. Building capacity in biodiversity monitoring at the global scale. Biodiversity and Conservation **26:**2765–2790.

Stephenson PJ, et al. 2017*a*. Unblocking the flow of biodiversity data for decision-making in Africa. Biological Conservation **213:**335–340.

Stephenson PJ, et al. 2017*b*. Priorities for big biodiversity data. Frontiers in Ecology and the Environment **15:**124–125.

Stuart S, Wilson EO, McNeely JA, Mittermeier RA, Rodríguez JP. 2010. The barometer of life. Science **328:**177.

Tapley B, Michaels CJ, Gumbs R, Böhm M, Luedtke J, Pearce-Kelly P, Rowley JJL. 2018. The disparity between species description and conservation assessment: a case study in taxa with high rates of species discovery. Biological Conservation **220:**209–214.

ter Steege H, et al. 2015. Estimating the global conservation status of more than 15,000 Amazonian tree species. Science Advances **1:**e1500936.

Thomson SA, et al. 2018. Taxonomy based on science is necessary for global conservation. PLOS Biology **16:**e2005075.

Tittensor DP, et al. 2014. A mid-term analysis of progress toward international biodiversity targets. Science **346:**241–244.

Troudet J, Grandcolas P, Blin A, Vignes-Lebbe R, Legendre F. 2017. Taxonomic bias in biodiversity data and societal preferences. Scientific Reports **7:**9132.

Tulloch AIT, Possingham H, Joseph LN, Szabo J, Martin TG. 2013. Realising the full potential of citizen science monitoring programs. Biological Conservation **165:**128–138.

WWF (World Wildlife Fund). 2018. Living planet report – 2018: aiming higher. WWF, Gland, Switzerland.