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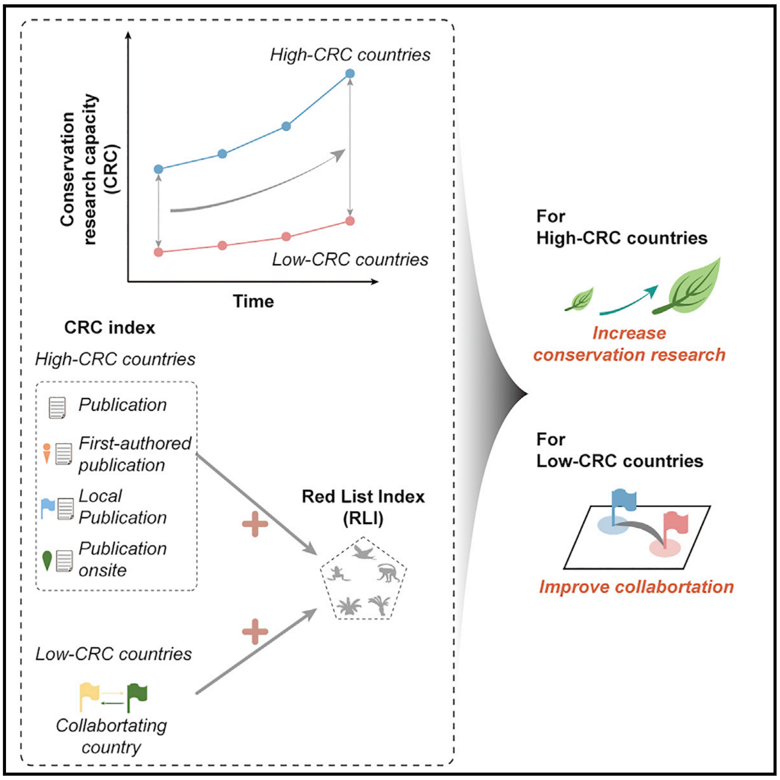
Article

Growing disparity in global conservation research capacity and its impact on biodiversity conservation

Graphical abstract



Highlights

- Conservation research capacity differs greatly among countries
- Disparity in global CRC is growing
- CRC has a positive impact on biodiversity conservation
- Different aspects of CRC are effective for countries with high and low CRC

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In brief

Although the importance of building research capacity for halting global biodiversity loss has long been highlighted, no study has yet directly evaluated the effect of conservation research capacity of countries in biodiversity conservation. We assess conservation research capacity for 193 countries, revealing a large and growing disparity among countries. Different aspects of conservation research capacity are effective in conserving biodiversity for countries with different levels of capacity. Building conservation research capacity must be a priority for all countries.

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Growing disparity in global conservation research capacity and its impact on biodiversity conservation

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SCIENCE FOR SOCIETY Global biodiversity is declining at an accelerating rate, impairing ecosystem functions that are vital to the long survival of human beings. Various actions need to be taken to halt and reverse biodiversity loss, but action thus far has been insufficient. Building conservation research capacity has long been proposed as a key means to support biodiversity conservation. However, an assessment of the status and change of conservation research capacity around the world, as well as its impact on biodiversity conservation is still lacking. Our study reveals the huge and growing disparity in conservation research capacity among countries. Of particular concern is that fact that many countries with high biodiversity have insufficient research capacity. We also find that conservation research capacity has a positive impact on biodiversity conservation, with different aspects of research capacity being effective for countries with different levels of capacity. Countries must promote their conservation research capacity, and meaningful collaboration among countries is encouraged.

SUMMARY

Building conservation research capacity (CRC), especially in developing countries, has long been proposed to halt and reverse biodiversity loss. Yet, a global evaluation of CRC and its impact on biodiversity conservation is still lacking. Here, by analyzing over 177,000 scientific papers from major conservation journals published after 2000, we derived six indicators of CRC and monitored their changes for the 193 United Nations member countries. We found that while CRC expectedly varied globally, the disparity in CRC between the top and bottom echelons grew over time. While most CRC indicators improved biodiversity conservation status (i.e., the IUCN Red List Index) in high-CRC countries, only the number of collaborating countries had a positive impact for low-CRC countries. Therefore, building CRC must be a top conservation priority, and high-CRC countries must lend greater support for low-CRC countries through meaningful collaborations and funding truly collaborative research in low-CRC developing countries.

INTRODUCTION

Biodiversity is declining at an accelerating rate,[1] with current extinction rates comparable to the five previous mass extinctions in Earth's history.[2,3] Conservation scientists and policymakers have been racing to save species from extinction and to reduce biodiversity loss since the 1990s.[4,5] While some progress has been made to halt worldwide biodiversity loss, conservation efforts, capacities, and impacts, as well as their effectiveness, have been quite uneven across the world.[6,7] To

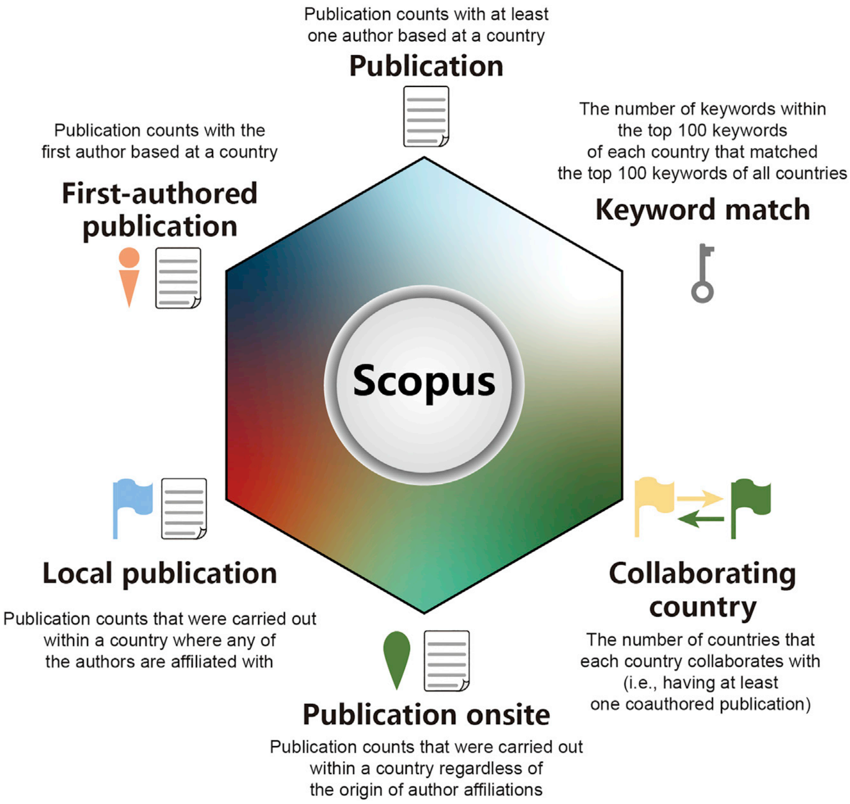

Figure 1. Indicators of conservation research capacity (CRC) of the 193 United Nations member countries

The indicators include (1) the biodiversity conservation research output in which each country's affiliated scientists participated (*publication*) and (2) played a major role (*first-authored publication*); (3) representation of research attention that each country receives domestically (*local publication*) and (4) globally (*publication onsite*); (5) level of international collaboration (*collaborating country*); and (6) assessment of the congruence of each country's research foci with global trends (*keyword match*).

achieve the 2030 Agenda for Sustainable Development and the 2050 Vision for Biodiversity, the Kunming-Montreal Global Biodiversity Framework was released in December 2022 after the 15th meeting of the Conference of the Parties (COP-15) to the Convention on Biological Diversity (CBD). In particular, Target 20 of the framework is to "strengthen capacity-building and development, access to and transfer of technology, and promote development of and access to innovation and technical and scientific cooperation, … for the conservation and sustainable use of biodiversity," especially in developing countries (https://www.cbd.int). The diverse skills, knowledge, and information required to achieve conservation goals are collectively called conservation capacity,[8] among which research capacity is one of the most critical components. Scientific research contributes to biodiversity conservation by providing information on biodiversity trends, identifying critical threats, raising public awareness, improving management of protected areas (PAs), attracting funding, and preventing poaching.[1,9–13] However, while some regional studies have evaluated the effectiveness of conservation research capacity (CRC) in species or biodiversity conservation within PAs,[10,14,15] assessments of country-level impact of CRC on biodiversity conservation status, while critical, are surprisingly lacking.

Current evidence of a global biodiversity crisis varies widely among countries and regions.[16,17] As a result, demonstrable policies and strategies in one region may not work well, if at all, elsewhere,[18] thus local scientists and scientific studies become vital.[14] Not surprisingly, local scientists are often more involved in regional conservation and hence are more influential in national policy making than outsiders.[19] Only when there are local systems of scientists can existing knowledge be applied properly, studies in their own national settings be undertaken, and new knowledge about their unique problems be generated. This will eventually contribute to increasing the global knowledge base and finding appropriate solutions.[20–22] As Maurizio Iaccarino, Secretary General of the UNESCO/ICSU, puts it "Science cannot be imported from richer countries, but must be developed locally."[23]

Unfortunately, many developing countries have too few local scientists and lack CRC to deal with pressing conservation challenges.[4,21,24] This issue was recognized in 2005 by the Society for Conservation Biology when the theme "Conservation Biology Capacity Building and Practice in a Globalized World" was adopted. Seventeen years later we seek to provide a global assessment of the status and trends of CRC to guide future capacity-building efforts.

Here, we construct six indicators of CRC status based on 177,627 publications between 2001 and 2020 from 229 conservation-related journals in the Scopus database (Figures 1 and S1). Using these indicators, we assess the status and trends of CRC during the past 20 years for all 193 United Nations member countries. We evaluate the effectiveness of CRC on biodiversity conservation, using the widely used Red List Index (RLI) (https://www.iucnredlist.org/assessment/red-list-index/) as an index of biodiversity conservation status.[25–27] RLI changes depict trends in the conservation status of species groups based only on genuine status changes in the IUCN Red List, with positive changes indicating an overall status improvement, and negative changes indicating a status deterioration. We hypothesize that our CRC indicators will have a positive effect on RLI change for all countries, after we account for other contributing variables that may also affect biodiversity conservation, such as human population and forest area.[28,29] Furthermore, we expect that the impact of CRC indicators on RLI will diverge among countries with distinct levels of CRC, analogous to the reported conditional influence of human pressure on biodiversity.[29] Our results suggest that CRC differs greatly among countries, and countries with higher CRC have a higher growth rate, indicating a growing disparity among countries in the near future. We find that most CRC indicators have a positive impact on biodiversity conservation for high-CRC countries; however, only the number of

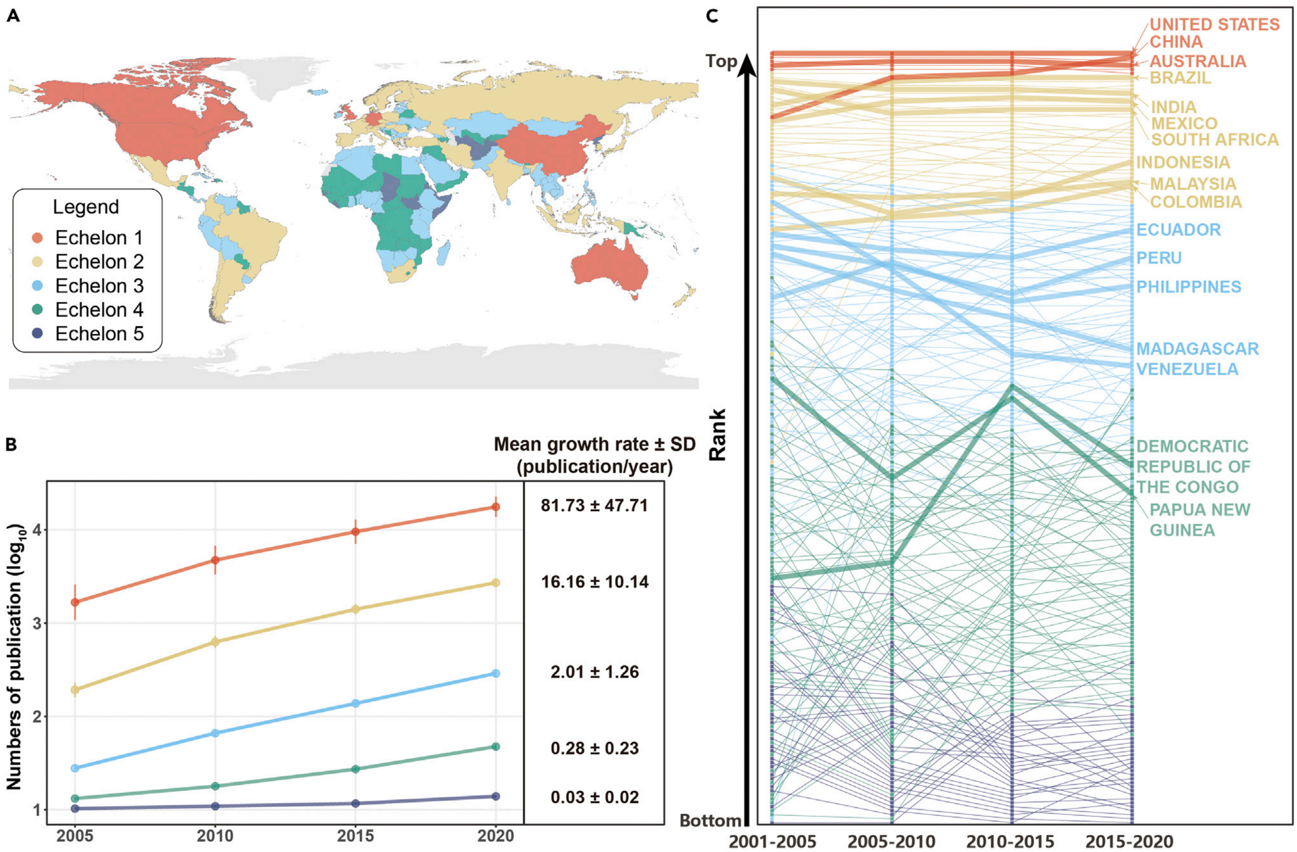

Figure 2. Status and trends of conservation research capacity indicators for all 193 countries assigned to five echelons

(A) Countries were categorized into five echelons based on the number of publications during 2001–2020, which differed from one another by one order of magnitude.

(B) Numbers of publications (log_{10} x) generally increased over 2001–2020, although growth rates varied among echelons (also see Figure S3H, error bars represent SD). Mean annual publication growth rates of countries are listed to the right of echelon lines.

(C) Based on the number of publications in each 5-year time bin, the rank of many countries in the third, fourth, and fifth echelons fluctuated extensively over 5-year time bins (e.g., some of the megadiverse countries highlighted on the figure had a distinct growth rate resulting in remarkable rank changes), while only a few countries in the first and second echelons did so. Each country's echelon is based on the overall publication data from 2001 to 2020.

collaborating countries has a positive impact for low-CRC countries. Therefore, we suggest that all countries need to promote CRC to reduce global biodiversity loss, particularly in low-CRC countries. Our study highlights the importance of building CRC in meeting challenges of global biodiversity loss, providing baseline data for making evidence-based policy.

RESULTS

Status and trends of CRC for countries

Our six CRC indicators were inter-related (all Spearman correlation rho >0.75, Table S1). However, *first-authored publication*, *local publication*, and *publication onsite* had a strong linear relationship with *publication* ($R^2 \geq 0.940$, n = 193), whereas *collaborating country* and *keyword match* had an asymptotic relationship with *publication* (Figure S2). Because *publication* is the most intuitive and easily quantifiable indicator, we used it as the basic CRC indicator to illustrate the disparity among countries.

Conservation research capacity varied greatly among the 193 countries with many of those in Africa and Central Asia having weak CRC (Figures 2A, 2B, and S3A–E). CRC in the United States was far higher than elsewhere, with a total of 59,105 publications between 2001 and 2020. The United States and five other countries, i.e., Australia, Canada, China, Germany, and the United Kingdom, with at least 10,000 publications each, occupy the top echelon. Each echelon, which is here defined as country-scale classes of publication productivity, differed by one order of magnitude of publication number from their upper echelon. Thirty-two countries are in the second echelon (with $\geq$1,000 and <10,000 publications), 58 countries in the third echelon (with $\geq$100 and <1,000 publications), 67 countries in the fourth echelon (with $\geq$10 and <100 publications), and 30 countries in the fifth echelon (with <10 publications). Furthermore, three of the 30 countries in the bottom echelon had no publication (Table S2). While countries in the third, fourth, and fifth echelons represented ~80% of all countries, they only published ~6% of all first-authored papers. The 155 countries in the third, fourth, and fifth echelons encompass 138 developing countries (as defined by United Nations Development Program, http://hdr.undp.org/en/content/developing-regions) and 17 developed

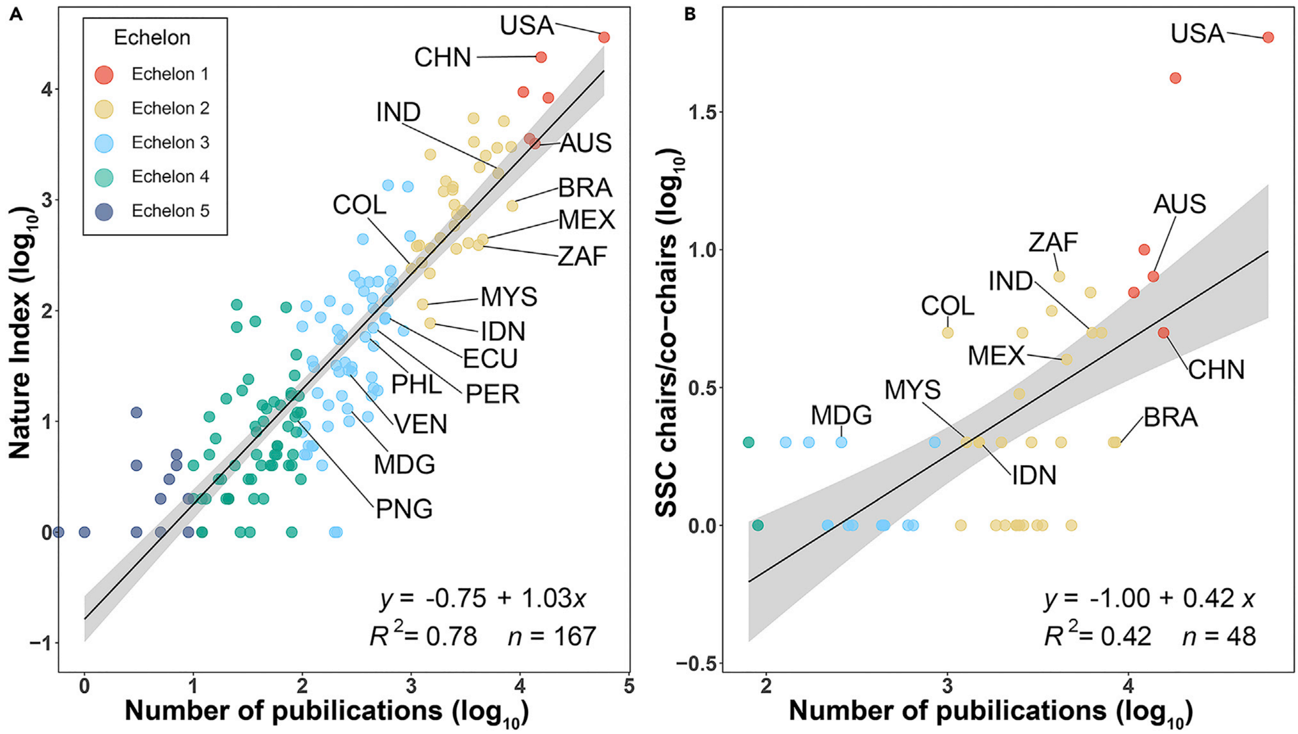

Figure 3. Validation of indicators of conservation research capacity (CRC)

(A) Relationship between overall publication counts, the basic CRC indicator in this study, and the Nature Index, with the 17 megadiverse countries marked on the figure (AUS, Australia; BRA, Brazil; CHN, China; COL, Colombia; ECU, Ecuador; IDN, Indonesia; IND, India; MDG, Madagascar; MEX, Mexico; MYS, Malaysia; PER, Peru; PHL, Philippines; PNG, Papua New Guinea; USA, United States of America; VEN, Venezuela; ZAF, South Africa). Countries below the regression line have higher research capacity related to biodiversity conservation compared with other natural sciences, i.e., devote greater research efforts to biodiversity conservation relative to natural sciences in general.

(B) Relationship between publication counts and the number of chairs/co-chairs of Specialist Groups under the IUCN Species Survival Commission (SSC). Countries above the regression line are well represented in IUCN Specialist Groups.

countries, whereas 26 out of the 38 countries in the first and second echelons are developed countries.

The average (±SD) number of local publications per threatened species differed markedly among echelons (Figure S3F), declining from 15.36 ± 10.53 for countries in the first echelon to 0.02 ± 0.02 for countries in the fifth echelon. A very similar pattern was found for publication onsite per threatened species (Figure S3G). These results indicate that CRC strength is unrelated to biodiversity measures (e.g., number of threatened species) within countries.

Not surprisingly, research output increased over the years in most countries, indicating a growing CRC (Figure 2B). However, publication growth coefficients differed significantly among echelons (Figures 2B and S3H), indicating that countries with higher research capacity had a faster growth rate. For instance, while the United States had a coefficient of 150.7, 112 countries had a coefficient lower than 1. In other words, 112 countries had a growth rate of fewer than one publication per year over the two decades. However, some countries had a distinct growth rate, which induced marked rank shifts over 5-year time bins (Figure 2C). This indicates that although disparity among echelons may widen further, it is possible for individual countries to make significant progress. However, we also noticed that most countries with marked rank changes were in the third, fourth, and fifth echelons, while the rank of countries in the first two echelons hardly changed, especially in later time bins.

Validation of the CRC indicators

Although our indicators only reflect some aspects of CRC, they clearly discriminate differences among countries based on the relationship between our basic indicator and the Nature Index (a measure of overall natural science research output in 82 high-quality journals, https://www.natureindex.com/faq),[30] or the number of chairs/co-chairs of Specialist Groups under the IUCN Species Survival Commission (a broad measure of species conservation leadership).[31] Both measures relate positively with the total number of publications (Figure 3).

The 17 megadiverse countries,[32] defined as countries hosting the highest species diversity, carry a larger burden in conserving Earth's biodiversity.[33] We found that 11 of these countries were below the regression line of the Nature Index and *publication*, indicating that they have a CRC higher than the average of countries with similar research capacity in natural sciences (Figure 3A). However, the United States and China were above the regression line, while Democratic Republic of the Congo has no Nature Index value so was not shown on the figure. Seven of the 17 megadiverse countries are well represented in IUCN Specialist Groups since they were above the regression line

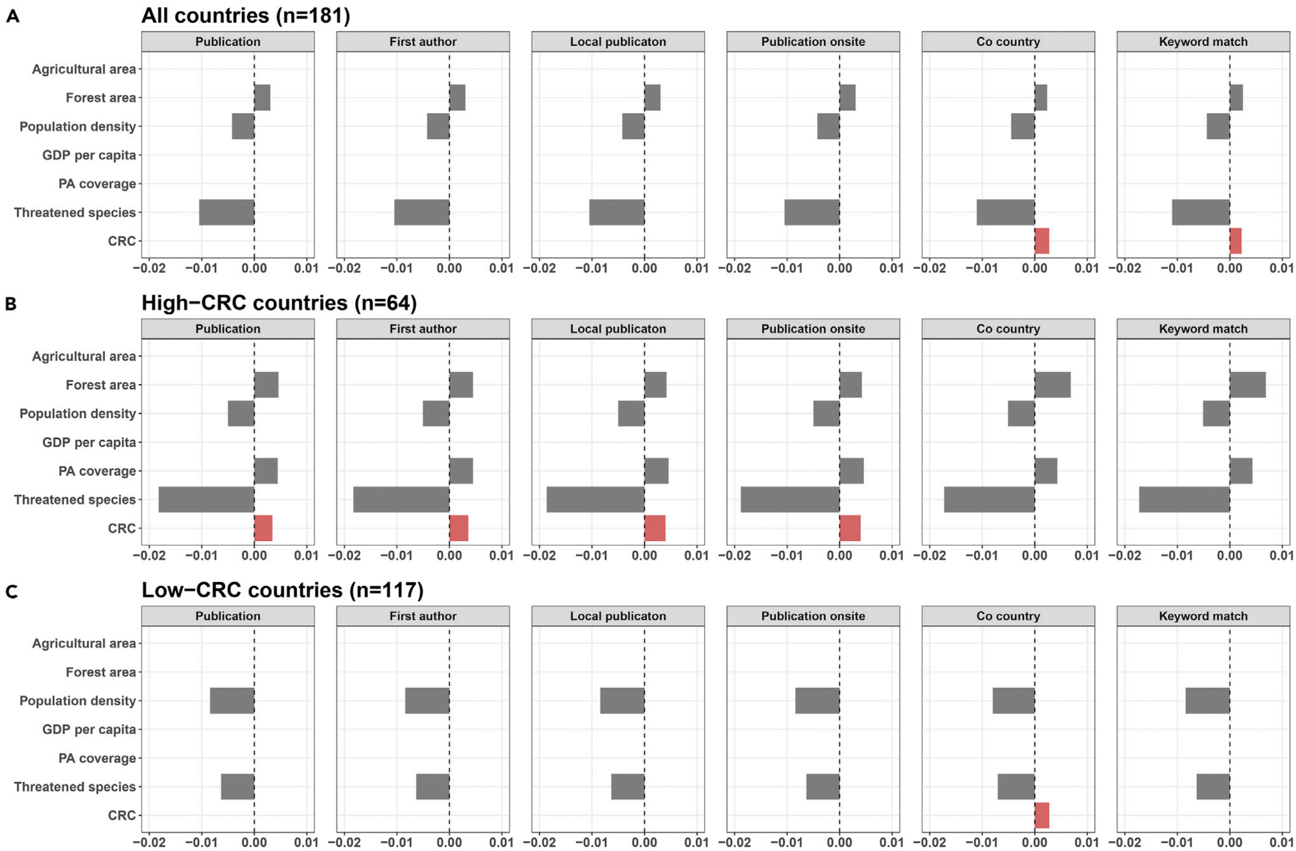

Figure 4. Contributing variables and indicators of conservation research capacity (CRC) that were included in the best-fitted models predicting country-level Red List Index (RLI) change

(A) Model results for all countries.

(B) Model results for high-CRC countries (i.e., countries with ≥300 publications).

(C) Model results for low-CRC countries (i.e., countries with <300 publications). Variables labeled on the top of each panel is the specific CRC indicator added into each model. The effects of CRC indicators are shown in red to discriminate them from other contributing variables. A Gumbel distribution was assumed for the dependent variable (RLI change) in all models. Horizontal bar lengths indicate the relative effect size of variables, and directions indicate either positive or negative effects.

(Figure 3B). China, India, and Malaysia are roughly on the regression line, whereas Brazil, the largest tropical country, is surprisingly below the regression line. The other six countries, including Ecuador, Peru, Philippines, Venezuela, Democratic Republic of Congo, and Papua New Guinea, have no chairs/co-chairs.

Effects of CRC on the RLI

RLI change was negative during 2001–2020 in most countries (mean ± SD = −0.024 ± 0.030, range: −0.182 to 0.024, n = 193), indicating an overall deterioration in species conservation status. Only 24 countries (12.4%) experienced a slightly positive RLI change, while 16 countries (8.2%) remained unchanged.

To understand the impact of CRC on RLI change, we accounted for the influences of key socioeconomic and conservation variables (e.g., human population and forest area, Table S3). Due to incomplete data, this analysis only included 181 countries, of which 64 countries with over 300 publications during 2001–2020 were broadly classified as high-CRC countries, while the other 117 countries with <300 publications as low-CRC countries. The 300 publications cutoff was robustly and rationally determined according to a sensitivity analysis, in which we tested a series of publications cutoffs (from 1,000 to 100 total publications in decrements of 100). We found that 300 publications was a suitable cutoff, as model results for high-CRC countries and low-CRC countries were stable (or insensitive) when the cutoff was set above 300, whereas model results changed when the cutoff was set below 300 (Table S4). Our multiple regression models showed that the number of threatened species and human population density had a negative effect, while per capita GDP and agricultural area had no significant effect on RLI change, regardless of CRC classes (Figure 4). Forest area had a positive impact on RLI change for all countries and high-CRC countries, while PA coverage had a positive impact on RLI change only for high-CRC countries (Figure 4).

Besides socioeconomic and conservation variables, our models indicated no consistent effects of CRC indicators on RLI change for all countries (Figure 4A). However, for high-CRC countries, all CRC indicators, except for the number of collaborating countries and keyword match, had a positive effect on RLI change (Figure 4B). Conversely, for low-CRC countries, no indicator had a significant effect on RLI change, except for the number of collaborating countries, which had a positive effect (Figure 4C). This suggests that different aspects of CRC may be effective in biodiversity conservation at different stages of CRC development.

DISCUSSION

Our study attempts to directly assess the impact of CRC of countries on biodiversity conservation. We found that CRC indicators were effective in protecting biodiversity within countries, although different aspects of CRC were effective in biodiversity conservation at different stages of CRC development.

In line with previous studies, our results showed that CRC varied greatly among countries,[34,35] and many countries appear to have insufficient CRC to conserve their biodiversity.[4,36] Our results also indicated that CRC strength was not consistent with biodiversity measures within countries.[35,37] For instance, the count of *local publication*/*publication onsite* per threatened species varied greatly among countries. The mismatch between CRC and biodiversity may hinder the achievement of global conservation goals.[37] Furthermore, the marked CRC disparity among countries will likely widen in the foreseeable future, since we found the growth rate of publications differed greatly among countries and high-CRC countries had a much higher growth rate than low-CRC countries, a discrepancy also reported in other studies.[38]

Although indicators calculated in our study only reflect some aspects of CRC, they performed well in discriminating differences among countries according to the linear relationships between our indicator and the Nature Index and number of chairs/co-chairs of IUCN Specialist Groups (Figure 3). Most of the 17 megadiverse countries were below the regression line of Nature Index and *publication*, reflecting a lean of research studies to biodiversity conservation compared with other disciplines in natural sciences. However, the United States and China were above the regression line (Figure 3A), which can be partially explained by differentiated allocation of research funding.[39] As the first and second largest world economies, these countries should assume greater responsibility in CRC building and allocate more efforts to biodiversity conservation.[31] Furthermore, countries such as the United States and Japan have high impacts on global biodiversity through global supply chains.[40] In our opinion, these high-impact countries, most of which are developed countries with high CRC, have a greater responsibility and the ability to help building CRC in resource-rich countries, which are usually tropical megadiverse developing countries with low CRC (e.g., Papua New Guinea and Democratic Republic of the Congo).[40]

Seven of the 17 megadiverse countries are well represented in IUCN Specialist Groups since they were above the regression line, while another three countries were roughly on the regression line (Figure 3B). The world's most biodiverse country (Brazil), however, is below the regression line, likely indicating a lack of senior scientists participating in international species management committees and biodiversity conservation initiatives. This is puzzling but could be generally attributed to a persistent language barrier, overall lack of research funding in both the public and private sectors, a lack of recognition of these unremunerated volunteer roles in institutional promotion or reward systems, and the rapid but still growing emergence of Brazil as a player in international conservation fora. The other six countries have no chairs/co-chairs, reflecting their relatively weaker CRC (all in the third and fourth echelons) and a conspicuous lack of IUCN chairs. Considering their extremely rich biodiversity, enhancing CRC in these countries should be a global priority for conservation funding.

Language may pose biases in the calculation of CRC indicators.[41] Although English research articles are prevalent, one-fourth to one-third of the scientific documents related to biodiversity conservation are published in languages other than English.[42,43] Ignoring these publications may induce biases in conclusions, such that research capacity for non-English-speaking countries may be underestimated.[43] We therefore used the Scopus database, which includes non-English journals. About 22% of journals in Scopus are published in languages other than English, or published in both English and local languages (https://www.elsevier.com/en-gb/solutions/scopus), which is similar to the percentage reported in a work on non-English-language studies focused to global biodiversity conservation.[43] However, the percentage of non-English journals may vary among disciplines. From the 229 journals as data source in this study (Tables S5 and S6), we downloaded 177,627 publications' reference records, among which 9,702 were non-English publications (including 22 languages). Relying on the efforts of a database to include non-English publications is an effective and convenient way to solve the language bias inherent to the conservation science literature. Further studies on the language issue require greater collaborative efforts including more researchers from non-English-speaking countries,[43] which is beyond the scope of our study.

Our results indicate that the number of threatened species, human population density, and forest area had significant impacts on RLI change for all countries (Figure 4). It is not surprising that the number of threatened species was the most influential variable in determining RLI change, since the RLI score is calculated from status change of threatened species and the status of most species apparently deteriorated globally over the past 2 decades.[27,28] Human population density also had a negative impact on RLI change, a similar finding to those revealed by several other studies.[29,44,45] Larger human populations inevitably escalate demands for raw materials and energy extracted from nature, so that transformative change becomes critical in mitigating the multifaceted conflicts between human demands and biodiversity conservation.[46] Forests provide essential habitats for a major fraction of terrestrial biodiversity. Hence, it is reasonable to find that forest area had a positive effect on RLI change for all countries, which is consistent with findings from previous analyses showing that deforestation elevates extinction risk.[47,48]

The establishment of PAs is considered one of the most effective conservation interventions for global biodiversity conservation.[49] Yet we found that PA coverage had a positive impact on RLI change only for high-CRC countries, but not for low-CRC countries (Figure 4). This may be because PA coverage is lower in low-CRC countries than in high-CRC countries (15.2 ± 12.2 versus 19.5 ± 10.5, $W = 4695.5$, $p = 0.005$, Table S7), which precludes PA effectiveness in reducing biodiversity loss.

Nevertheless, 15.2% is not much lower than the CBD Aichi Target 11 set in 2010 of protecting 17% of all terrestrial habitats. The second possibility is that land set-asides in low-CRC countries may not be under effective management.[50] Many "paper parks" in developing countries fail to effectively protect biodiversity because they are severely underfunded and understaffed, and lack essential infrastructure.[49] Enhancing PA management should thus be given a higher priority than creating new PAs in low-CRC countries.

Agricultural land and per capita GDP did not significantly affect RLI change, regardless of CRC classes (Figure 4). Although agricultural lands can provide habitat for many species,[51] their expansion typically occurs with the concurrent shrinkage of natural habitats that harbor many threatened species.[52–54] These converse effects may dilute the effectiveness of agricultural land in RLI change. Per capita GDP does not necessarily explain the spatial pattern of RLI change.[28] Considering the effectiveness of increasing conservation spending in reducing biodiversity loss,[29] our results imply that the biodiversity conservation expenditure of wealthy countries within their own boundaries has been disproportionately low for their GDP. This suggests the need for more effective conservation spending, especially from wealthier countries.

Our results showed that when controlling other socioeconomic and conservation variables, CRC positively contributed to biodiversity conservation within countries, although different aspects of CRC behave differently for countries under different CRC levels (Figure 4). Here, we focus on displaying the positive impact of CRC on biodiversity conservation, but this is by no means saying that other variables are unimportant. Change in biodiversity status is a consequence of all these variables and their impacts may surpass the impact of CRC. Therefore, it is possible that the number of scientific publications worldwide increases year after year, while the status of biodiversity continues to deteriorate. To conserve biodiversity effectively, all the variables must be considered and improved. Building CRC across the world is a key option to enhance global biodiversity conservation.

To achieve the 2030 Agenda for Sustainable Development and the 2050 Vision for Biodiversity, our assessment calls for multifaceted endeavors to enhance CRC for all countries. For high-CRC countries, more conservation research should be encouraged. On the other hand, low-CRC countries would benefit directly from stronger international collaboration networks and more capacity building. Our models showed that onsite publications did not have a significant impact on RLI change for low-CRC countries. This suggests that planning and conducting studies in these countries without involving local scientists will be less effective[55] (Figure 4C). Therefore, so-called "helicopter" or "parachute" studies, which typically leave a legacy of little or no local capacity development, should be replaced by stronger long-term collaborative ventures with habitat-country researchers.[55]

Building the world's capacity to conduct effective conservation research and protect biodiversity must be a globally shared responsibility.[56] We argue that international conservation funds (e.g., Global Environment Facility, https://www.thegef.org/) should represent opportunities to garner strong support for initiating CRC development in low-CRC countries, particularly through the awarding of collaborative research grant rather than *de facto* debt for swaps.[55,57]

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for resources should be directed to and will be fulfilled by the lead contact, Peng-Fei Fan (fanpf@mail.sysu.edu.cn).

Materials availability

This study did not generate new unique materials.

Data and code availability

All the source data used in this paper are derived from the cited references or databases. The data supporting the findings of this study are provided in the supplemental information (supplemental figures), or deposited at figshare (supplemental tables and all original code): https://doi.org/10.6084/m9.figshare.21723476. Any additional information required for reanalyzing the data reported in this paper is available from the lead contact upon request.

Indicators of CRC

We rely on publication databases to determine major conservation journals. We generated a list of conservation journals from two databases, i.e., the Scopus (https://www.scopus.com) and the Web of Science (WOS, https://apps.webofknowledge.com) Core Collection, including all journals listed in the subject area of "Nature and Landscape Conservation" in Scopus and in the category of "Biodiversity Conservation" in the WOS. We collected publications from all these journals during 2001–2020, including articles, reviews, letters, and data papers. As we focused on contemporary biodiversity conservation, we excluded publications from two journals that mainly concern paleobiology (i.e., *Palaeobiodiversity and Palaeoenvironments*, and *Paleobiology*). We also excluded publications without clear author information. This allowed us to export the full reference records of publications from 229 journals (Table S6) in the Scopus database to form a local database for further processing, since Scopus includes publications from all these journals, while the WOS does not. A total of 177,627 publications were retained for analyses, including 9,702 non-English publications (although such publications have abstracts and titles in English in addition to local languages, Table S5).

We extracted information from the title, author(s), affiliation(s), publication year, abstract, and keywords of each paper's reference record, using the "bibliometrix" package (v 4.0.0)[58] in R (v 4.2.2).[59] Based on this information, we constructed six inter-related indicators to represent different aspects of CRC (Figure S1). Because we intended to evaluate capacity for each country, our first step was to assign each publication to one or more countries considering all the 193 United Nations member countries (https://www.un.org/en/about-us/member-states). Several countries, e.g., the United Kingdom and France, have overseas territories, but there is no single and consistent source for this information. In addition, some overseas territories are disputed and claimed by more than one country. To remain neutral on political disputes and because of a lack of authoritative source, we did not include overseas territories when calculating the CRC indicators for the 193 sovereign countries. Following methods used to calculate the Nature Index, we summed the count of publications for each country, which means each country would be given a "1" when a publication had at least one author based at that country. Similarly, we summed the count of first-authored publications, which means one country would be given a "1" only when the first author was based at that country. When a first author was affiliated to more than one country, the publication was assigned to the county of first affiliation. The indicator "*publication*" reflects the total number of studies that each country's affiliated scientists participated in, whereas "*first-authored publication*" represents studies in which each country's affiliated scientists played a major role. We also summed the number of "*corresponding-authored publication*" for each country. However, this indicator was not used in the following analyses because it had a very strong linear relationship with "*first-authored publication*" (corresponding-authored = 0.997 × first-authored − 8.966, R^2 = 0.999).

We determined countries where the study had been conducted for each publication by extracting all country information that appeared in the title, abstract, or keywords of each publication. Extraction rules were developed and adjusted using 1,000 randomly selected publications, for which we identified study locations manually. We then generated 200 randomly selected publications and tested the extraction accuracy. Accuracy for the set of publications was 90%, which we considered as acceptable. We noted that many publications do not have research location (e.g., some review articles), or informed their research location only in the main text. Therefore, research location of about 33.2% of all publications could not be directly extracted from the title, abstract, or keywords and these publications were excluded when calculating the "*local publication*" indicator. The *local publication* indicator was calculated as the number of publications derived from studies that were carried out within a country with at least one author affiliation. *Local publication* represents research attention that each country's biodiversity conservation receives from local scientists. We also calculated the "*publication onsite*" indicator as the number of publications for which research had been carried out in a country even if none of the authors were affiliated to that country, to represent the total biodiversity conservation research attention that each country receives.

We calculated the "*collaborating country*" indicator as the number of countries that each country collaborated with, representing the level of international collaboration. We defined collaboration as having published at least one paper collaboratively. We identified the top-100 keywords for each country and all countries. We then calculated the indicator of "*keyword match*," defined as the number of keywords in each country's top-100 that matched the top-100 keywords of all countries. Keywords thus reflects the congruence of each country's research foci with those of global trends.

The most intuitive indicator and the easiest to obtain was *publication*, which was considered our base indicator and examined in relation to other indicators (Figure S2, Table S1). Based on the *publication* indicator, we divided the 193 countries into five echelons, each of which distinguished from the upper echelon by one order of magnitude. We then mapped all echelons on a world map. We compared all CRC indicators other than *publication* among echelons, using a Kruskal-Wallis test with a post hoc Conover's all-pairs comparison test.

To assess whether conservation research occurs where it is most needed, i.e., regions with disproportionately high biodiversity,[37,60] we used the number of globally threatened species (i.e., species listed as VU, EN, and CR in the IUCN Red List) within a country as a proxy of conservation needs and calculated the number of *local publication* and *publication onsite* per threatened species within each country. We compared the two indicators among country echelons to reveal the degree to which conservation needs are fulfilled.

We summed the count of publications in each year for every country and conducted linear regression analysis on the annual numbers of publications. Regression coefficients reveal the growth rate of publications, i.e., coefficient = 1 indicates that the country has one more publication in Year_1 compared with Year_0. We compared coefficients among echelons using the same tests mentioned above. We divided the 20 years into four 5-year bins, and ranked every country based on their total number of publications within each time bin.

Validation of the CRC indicators

To validate our CRC indicators, we conducted linear regressions between *publication* and two indices from other independent sources—the Nature Index (https://www.natureindex.com) and a count of chairs/co-chairs of Specialist Groups under the IUCN Species Survival Commission. The Nature Index is "an indicator of global high-quality research output" calculated from 82 high-quality journals across major natural science disciplines (including physical sciences, chemistry, life sciences, and Earth and environmental sciences). This index provides a general indication of research capacity in natural sciences for all countries.[30] We expected a positive linear relationship between the Nature Index and the *publication* indicator. The latest Nature Index-count (2020–2021) was downloaded from its website (https://www.natureindex.com/country-outputs/generate/All/global/All/score).

The chairs/co-chairs of IUCN Specialist Groups are usually senior scientists in each specialism, such that country counts of chairs/co-chairs can represent a higher level of CRC.[31] We expected a positive linear relationship between the count of chairs/co-chairs within a country and the *publication* indicator. We collated data on chairs/co-chairs of all 157 Specialist Groups (https://www.iucn.org/commissions/ssc-groups), which were summed for each country.

Megadiverse countries have disproportionately high biodiversity[32] and are burdened with a large responsibility to conserve biodiversity.[33] We marked the 17 megadiverse countries[61] on the regression plots to illustrate whether these countries host a commensurate CRC in conserving their biodiversity. Although France may be considered as a megadiverse country (largely due to the high biodiversity in its overseas territories),[61] we did not include it as such since we excluded overseas territories when calculating CRC indicators. A country below the regression line of the Nature Index and *publication* indicates that it has a higher CRC than the overall research capacity in natural sciences, reflecting a lean of research studies to biodiversity conservation comparing with other disciplines in natural sciences. On the other hand, a country below the Species Survival Commission (SSC) chairs/co-chairs $\sim$ publication regression line indicates that it is not well represented in IUCN Specialist Groups, reflecting a lack of senior scientists in biodiversity conservation within that country.

The effects of CRC on biodiversity conservation

We used the RLI as an indicator of biodiversity conservation status for each country.[27] Although there are a handful of indicators for the state of biodiversity,[1] e.g., the RLI, Living Planet Index (LPI), Wild Bird Index (WBI), and coral reef condition, many of them are not sufficiently representative taxonomically (e.g., WBI) or spatially (e.g., LPI). RLI is a useful, standardized, and easily attainable index with sufficient spatial (country-level RLI can be readily downloaded from the IUCN Red List website, https://www.iucnredlist.org/assessment/red-list-index/), temporal (yearly data during 2001–2020 are available), and taxonomical resolutions (including five taxa—mammals, birds, amphibians, reef-forming corals, and cycads). RLI has been used in many national to global scale studies.[27,28,62,63] Change of RLI shows trends in the status of species based only on genuine status changes in the IUCN Red List. RLI values that were calculated from all five taxa that are distributed within each country were downloaded from the IUCN Red List website. We then calculated the RLI difference between 2001 and 2020 for each country. Positive and negative changes indicate that the overall status had either improved or deteriorated in the past 20 years, respectively.

RLI changes are influenced by many factors, e.g., conservation spending, human population, and agricultural expansion.[28,29,64] We considered a set of 14 variables in modeling RLI change (Table S3). We only used "Rule of Law" as a representative of the six dimensions of governance of any country, because it was significantly correlated with all other indicators (Spearman correlation rho >0.81). All 14 variables were z-standardized to place their effect sizes on a common scale,[29] using the package "clusterSim"[65] in R. Besides these 14 variables, we also added CRC indicators into the model. Since most CRC indicators were correlated but not necessarily in a linear manner (Figure S2, Table S1), we tested all indicators by adding only one indicator each time. We tested for collinearity between all variables (both the 14 variables considered and CRC) before running models and removed those with a Spearman rho $\geq$0.75 (Table S8). Therefore, we only retained six of the 14 variables (i.e., number of threatened species, forest area, agricultural area, PA coverage, per capita GDP, and population density), plus one CRC indicator in modeling procedures.

Since RLI change had a left-skewed distribution, for which a generalized linear model (GLM) framework is of limited use, we applied a more generalized modeling framework – Generalized Additive Models for Location, Scale, and Shape (GAMLSS), using the package "gamlss,"[66] where we assumed a Gumbel distribution for RLI change. To keep results easily interpretable, we tested for linear relationships between RLI change and the explanatory variables. We also assumed homogeneity in the dispersion so that only the mean was modeled and employed the "RS" algorithm to fit models. We applied a stepwise model selection procedure to acquire the best-fitted model based on AIC values.[66]

Because CRC indicators varied greatly among countries, we expected that indicators may have different impacts on RLI change among countries with very different CRC. Therefore, we divided countries into classes with stronger and weaker CRC. To avoid dividing countries into two classes arbitrarily, we conducted a cutoff sensitivity analysis by using a series of publications cutoffs (from 1,000 to 100 total publications in decrements of 100). We found that 300 publications was a suitable cutoff, as model results for high-CRC countries and low-CRC countries were stable (or insensitive) when the cutoff was set above 300, whereas model results changed when the cutoff was set below 300 (Table S4). We therefore divided the 193 countries into high-CRC countries (with $\geq$300 total publications) and low-CRC countries (with <300 publications).

We then conducted similar modeling procedures for these two classes to assess the impact of explanatory variables on RLI change, respectively, using the same set of explanatory variables as for all countries.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2023.01.003.

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AUTHOR CONTRIBUTIONS

P.F.F. conceived the original idea and led the project. P.F.F., T.M.L., L.Z., and L.Y. designed the study. L.Y. led data collection and preparation. L.Z. led the analysis and interpretation of the results. L.Y. and T.M.L. designed the figures. P.F.F. and L.Z. led the writing of this paper. C.A.C, C.A.P., and T.M.L. substantively revised the paper.

DECLARATION OF INTERESTS

The authors declare no competing interests.

INCLUSION AND DIVERSITY

We support inclusive, diverse, and equitable conduct of research.

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REFERENCES

1. Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., et al. (2010). Global biodiversity: indicators of recent declines. Science *328*, 1164–1168. https://doi.org/10.1126/science.1187512.
2. Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O.U., Swartz, B., Quental, T.B., Marshall, C., McGuire, J.L., Lindsey, E.L., Maguire, K.C., et al. (2011). Has the Earth's sixth mass extinction already arrived? Nature *471*, 51–57. https://doi.org/10.1038/nature09678.
3. Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T.M., Gittleman, J.L., Joppa, L.N., Raven, P.H., Roberts, C.M., and Sexton, J.O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science *344*, 1246752. https://doi.org/10.1126/science.1246752.
4. Rands, M.R.W., Adams, W.M., Bennun, L., Butchart, S.H.M., Clements, A., Coomes, D., Entwistle, A., Hodge, I., Kapos, V., Scharlemann, J.P.W., et al. (2010). Biodiversity conservation: challenges beyond 2010. Science *329*, 1298–1303. https://doi.org/10.1126/science.1189138.
5. Chandra, A., and Idrisova, A. (2011). Convention on Biological Diversity: a review of national challenges and opportunities for implementation. Biodivers. Conserv. *20*, 3295–3316. https://doi.org/10.1007/s10531-011-0141-x.
6. Amano, T., and Sutherland, W.J. (2013). Four barriers to the global understanding of biodiversity conservation: wealth, language, geographical location and security. Proc. Biol. Sci. *280*, 20122649. https://doi.org/10.1098/rspb.2012.2649.
7. Baynham-Herd, Z., Amano, T., Sutherland, W.J., and Donald, P.F. (2018). Governance explains variation in national responses to the biodiversity crisis. Environ. Conserv. *45*, 407–418. https://doi.org/10.1017/S037689291700056X.
8. O'Connell, M.J., Nasirwa, O., Carter, M., Farmer, K.H., Appleton, M., Arinaitwe, J., Bhanderi, P., Chimwaza, G., Copsey, J., Dodoo, J., et al. (2019). Capacity building for conservation: problems and potential solutions for sub-Saharan Africa. Oryx *53*, 273–283. https://doi.org/10.1017/S0030605317000291.
9. Chapman, C.A., and Peres, C.A. (2001). Primate conservation in the new millennium: the role of scientists. Evol. Anthropol. *10*, 16–33. https://doi.org/10.1002/1520-6505(2001)10:1<16::AID-EVAN1010>3.0.CO;2-O.
10. Pusey, A.E., Pintea, L., Wilson, M.L., Kamenya, S., and Goodall, J. (2007). The contribution of long-term research at Gombe National Park to chimpanzee conservation. Conserv. Biol. *21*, 623–634. https://doi.org/10.1111/j.1523-1739.2007.00704.x.
11. Piel, A.K., Lenoel, A., Johnson, C., and Stewart, F.A. (2015). Deterring poaching in western Tanzania: the presence of wildlife researchers. Glob. Ecol. Conserv. *3*, 188–199. https://doi.org/10.1016/j.gecco.2014.11.014.
12. Chapman, C.A., Corriveau, A., Schoof, V.A.M., Twinomugisha, D., and Valenta, K. (2017). Long-term simian research sites: significance for theory and conservation. J. Mammal. *98*, 652–660. https://doi.org/10.1093/jmammal/gyw157.
13. Thompson, M.E., Muller, M.N., Machanda, Z.P., Otali, E., and Wrangham, R.W. (2020). The Kibale Chimpanzee Project: over thirty years of research, conservation, and change. Biol. Conserv. *252*, 108857. https://doi.org/10.1016/j.biocon.2020.108857.
14. Hu, Y., Luo, Z., Chapman, C.A., Pimm, S.L., Turvey, S.T., Lawes, M.J., Peres, C.A., Lee, T.M., and Fan, P. (2019). Regional scientific research benefits threatened-species conservation. Natl. Sci. Rev. *6*, 1076–1079. https://doi.org/10.1093/nsr/nwz090.
15. Zhang, L., Turvey, S.T., Chapman, C., and Fan, P. (2021). Effects of protected areas on survival of threatened gibbons in China. Conserv. Biol. *35*, 1288–1298. https://doi.org/10.1111/cobi.13664.
16. Common, M.S., and Norton, T.W. (1992). Biodiversity: its conservation in Australia. Ambio *21*, 258–265. https://www.jstor.org/stable/4313936.
17. Mitchley, J., Price, M.F., and Tzanopoulos, J. (2006). Integrated futures for Europe's mountain regions: reconciling biodiversity conservation and human livelihoods. J. Mt. Sci. *3*, 276–286. https://doi.org/10.1007/s11629-006-0276-5.
18. Cazalis, V., Princé, K., Mihoub, J.-B., Kelly, J., Butchart, S.H.M., and Rodrigues, A.S.L. (2020). Effectiveness of protected areas in conserving tropical forest birds. Nat. Commun. *11*, 4461. https://doi.org/10.1038/s41467-020-18230-0.
19. van Wilgen, B.W., Boshoff, N., Smit, I.P.J., Solano-Fernandez, S., and van der Walt, L. (2016). A bibliometric analysis to illustrate the role of an embedded research capability in South African National Parks. Scientometrics *107*, 185–212. https://doi.org/10.1007/s11192-016-1879-4.
20. Nchinda, T.C. (2002). Research capacity strengthening in the South. Soc. Sci. Med. *54*, 1699–1711. https://doi.org/10.1016/S0277-9536(01)00338-0.
21. Rodríguez, J.P., Simonetti, J.A., Premoli, A., and Marini, M.Â. (2005). Conservation in Austral and Neotropical America: building scientific capacity equal to the challenges. Conserv. Biol. *19*, 969–972. https://doi.org/10.1111/j.1523-1739.2005.00555.x.
22. Franco, M., Cooper, R., and Orduñez, P. (2006). Making sure public health policies work. Science *311*, 1098. https://doi.org/10.1126/science.311.5764.1098b.
23. Iaccarino, M. (2004). Mastering science in the South. EMBO Rep. *5*, 437–441. https://doi.org/10.1038/sj.embor.7400159.
24. Rodríguez, J.P., Rodríguez-Clark, K.M., Oliveira-Miranda, M.A., Good, T., and Grajal, A. (2006). Professional capacity building: the missing agenda in conservation priority setting. Conserv. Biol. *20*, 1340. https://doi.org/10.1111/j.1523-1739.2006.00535_1.x.

25. Butchart, S.H.M., Stattersfield, A.J., Baillie, J., Bennun, L.A., Stuart, S.N., Akçakaya, H.R., Hilton-Taylor, C., and Mace, G.M. (2005). Using red list indices to measure progress towards the 2010 target and beyond. Philos. Trans. R. Soc. Lond. B Biol. Sci. *360*, 255–268. https://doi.org/10.1098/rstb.2004.1583.

26. Butchart, S.H.M., Akcakaya, H.R., Kennedy, E., and Hilton-Taylor, C. (2006). Biodiversity indicators based on trends in conservation status: strengths of the IUCN Red List Index. Conserv. Biol. *20*, 579–581. https://doi.org/10.1111/j.1523-1739.2006.00410.x.

27. Butchart, S.H.M., Resit Akçakaya, H., Chanson, J., Baillie, J.E.M., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N., and Hilton-Taylor, C. (2007). Improvements to the red list index. PLoS One *2*, e140. https://doi.org/10.1371/journal.pone.0000140.

28. Rodrigues, A.S.L., Brooks, T.M., Butchart, S.H.M., Chanson, J., Cox, N., Hoffmann, M., and Stuart, S.N. (2014). Spatially explicit trends in the global conservation status of vertebrates. PLoS One *9*, e113934. https://doi.org/10.1371/journal.pone.0113934.

29. Waldron, A., Miller, D.C., Redding, D., Mooers, A., Kuhn, T.S., Nibbelink, N., Roberts, J.T., Tobias, J.A., and Gittleman, J.L. (2017). Reductions in global biodiversity loss predicted from conservation spending. Nature *551*, 364–367. https://doi.org/10.1038/nature24295.

30. Nature (2014). Introducing the index. Nature *515*, S52–S53. https://doi.org/10.1038/515S52a.

31. Fan, P.-F., Yang, L., Liu, Y., and Lee, T.M. (2020). Build up conservation research capacity in China for biodiversity governance. Nat. Ecol. Evol. *4*, 1162–1167. https://doi.org/10.1038/s41559-020-1253-z.

32. Mittermeier, R.A., Mittermeier, C.G., and Gil, P.R. (1997). Megadiversity (Earth's Biologically Wealthiest Nations).

33. Seidl, A., Mulungu, K., Arlaud, M., van den Heuvel, O., and Riva, M. (2021). The effectiveness of national biodiversity investments to protect the wealth of nature. Nat. Ecol. Evol. *5*, 530–539. https://doi.org/10.1038/s41559-020-01372-1.

34. Liu, X., Zhang, L., and Hong, S. (2011). Global biodiversity research during 1900–2009: a bibliometric analysis. Biodivers. Conserv. *20*, 807–826. https://doi.org/10.1007/s10531-010-9981-z.

35. Di Marco, M., Chapman, S., Althor, G., Kearney, S., Besancon, C., Butt, N., Maina, J.M., Possingham, H.P., Rogalla von Bieberstein, K., Venter, O., and Watson, J.E. (2017). Changing trends and persisting biases in three decades of conservation science. Glob. Ecol. Conserv. *10*, 32–42. https://doi.org/10.1016/j.gecco.2017.01.008.

36. Cresswell, W. (2018). The continuing lack of ornithological research capacity in almost all of West Africa. Ostrich *89*, 123–129. https://doi.org/10.2989/00306525.2017.1388301.

37. Wilson, K.A., Auerbach, N.A., Sam, K., Magini, A.G., Moss, A.S.L., Langhans, S.D., Budiharta, S., Terzano, D., and Meijaard, E. (2016). Conservation research is not happening where it is most needed. PLoS Biol. *14*, e1002413. https://doi.org/10.1371/journal.pbio.1002413.

38. Vallès, H., Labaude, S., Bezault, E., Browne, D., Deacon, A., Guppy, R., Pujadas Clavel, A., and Cézilly, F. (2021). Low contribution of Caribbean-based researchers to academic publications on biodiversity conservation in the insular Caribbean. Perspect. Ecol. Conserv. *19*, 443–453. https://doi.org/10.1016/j.pecon.2021.07.006.

39. Wu, J. (2015). Distributions of scientific funding across universities and research disciplines. J. Inf. *9*, 183–196. https://doi.org/10.1016/j.joi.2014.12.007.

40. Moran, D., and Kanemoto, K. (2017). Identifying species threat hotspots from global supply chains. Nat. Ecol. Evol. *1*, 23–25. https://doi.org/10.1038/s41559-016-0023.

41. Konno, K., Akasaka, M., Koshida, C., Katayama, N., Osada, N., Spake, R., and Amano, T. (2020). Ignoring non-English-language studies may bias ecological meta-analyses. Ecol. Evol. *10*, 6373–6384. https://doi.org/10.1002/ece3.6368.

42. Amano, T., González-Varo, J.P., and Sutherland, W.J. (2016). Languages are still a major barrier to global science. PLoS Biol. *14*, e2000933. https://doi.org/10.1371/journal.pbio.2000933.

43. Amano, T., Berdejo-Espinola, V., Christie, A.P., Willott, K., Akasaka, M., Báldi, A., Berthinussen, A., Bertolino, S., Bladon, A.J., Chen, M., et al. (2021). Tapping into non-English-language science for the conservation of global biodiversity. PLoS Biol. *19*, e3001296. https://doi.org/10.1371/journal.pbio.3001296.

44. McKee, J.K., Sciulli, P.W., Fooce, C., and Waite, T.A. (2004). Forecasting global biodiversity threats associated with human population growth. Biol. Conserv. *115*, 161–164. https://doi.org/10.1016/S0006-3207(03)00099-5.

45. Cardillo, M., Purvis, A., Sechrest, W., Gittleman, J.L., Bielby, J., and Mace, G.M. (2004). Human population density and extinction risk in the world's carnivores. PLoS Biol. *2*, e197. https://doi.org/10.1371/journal.pbio.0020197.

46. Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., et al. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science *366*, eaax3100. https://doi.org/10.1126/science.aax3100.

47. Tracewski, Ł., Butchart, S.H.M., Di Marco, M., Ficetola, G.F., Rondinini, C., Symes, A., Wheatley, H., Beresford, A.E., and Buchanan, G.M. (2016). Toward quantification of the impact of 21st-century deforestation on the extinction risk of terrestrial vertebrates. Conserv. Biol. *30*, 1070–1079. https://doi.org/10.1111/cobi.12715.

48. Betts, M.G., Wolf, C., Ripple, W.J., Phalan, B., Millers, K.A., Duarte, A., Butchart, S.H.M., and Levi, T. (2017). Global forest loss disproportionately erodes biodiversity in intact landscapes. Nature *547*, 441–444. https://doi.org/10.1038/nature23285.

49. Watson, J.E.M., Dudley, N., Segan, D.B., and Hockings, M. (2014). The performance and potential of protected areas. Nature *515*, 67–73. https://doi.org/10.1038/nature13947.

50. Leverington, F., Costa, K.L., Pavese, H., Lisle, A., and Hockings, M. (2010). A global analysis of protected area management effectiveness. Environ. Manage. *46*, 685–698. https://doi.org/10.1007/s00267-010-9564-5.

51. Li, L., Hu, R., Huang, J., Bürgi, M., Zhu, Z., Zhong, J., and Lü, Z. (2020). A farmland biodiversity strategy is needed for China. Nat. Ecol. Evol. *4*, 772–774. https://doi.org/10.1038/s41559-020-1161-2.

52. Martinuzzi, S., Withey, J.C., Pidgeon, A.M., Plantinga, A.J., McKerrow, A.J., Williams, S.G., Helmers, D.P., and Radeloff, V.C. (2015). Future land-use scenarios and the loss of wildlife habitats in the southeastern United States. Ecol. Appl. *25*, 160–171. https://doi.org/10.1890/13-2078.1.

53. Kehoe, L., Romero-Muñoz, A., Polaina, E., Estes, L., Kreft, H., and Kuemmerle, T. (2017). Biodiversity at risk under future cropland expansion and intensification. Nat. Ecol. Evol. *1*, 1129–1135. https://doi.org/10.1038/s41559-017-0234-3.

54. Molotoks, A., Stehfest, E., Doelman, J., Albanito, F., Fitton, N., Dawson, T.P., and Smith, P. (2018). Global projections of future cropland expansion to 2050 and direct impacts on biodiversity and carbon storage. Glob. Chang. Biol. *24*, 5895–5908. https://doi.org/10.1111/gcb.14459.

55. Hobaiter, C., Akankwasa, J.W., Muhumuza, G., Uwimbabazi, M., and Koné, I. (2021). The importance of local specialists in science: where are the local researchers in primatology? Curr. Biol. *31*, R1367–R1369. https://doi.org/10.1016/j.cub.2021.09.034.

56. Sreenivasan, K.R. (2004). Science in the South. Science *306*, 1259. https://doi.org/10.1126/science.1106992.

57. (2021). The answer to the biodiversity crisis is not more debt. Nature *598*, 539–540. https://doi.org/10.1038/d41586-021-02891-y.

58. Aria, M., and Cuccurullo, C. (2017). bibliometrix: an R-tool for comprehensive science mapping analysis. J. Inf. *11*, 959–975. https://doi.org/10.1016/j.joi.2017.08.007.

59. R Core Team (2016). R: A Language and Environment for Statistical Computing.

60. Tydecks, L., Jeschke, J.M., Wolf, M., Singer, G., and Tockner, K. (2018). Spatial and topical imbalances in biodiversity research. PLoS One *13*, e0199327. https://doi.org/10.1371/journal.pone.0199327.

61. Scarano, F.R., Fornero Aguiar, A.C., Mittermeier, R.A., and Rylands, A.B. (2021). Megadiversity. In Reference Module in Life Sciences (Elsevier). https://doi.org/10.1016/B978-0-12-822562-2.00013-X.

62. Szabo, J.K., Butchart, S.H., Possingham, H.P., and Garnett, S.T. (2012). Adapting global biodiversity indicators to the national scale: a Red List Index for Australian birds. Biol. Conserv. *148*, 61–68. https://doi.org/10.1016/j.biocon.2012.01.062.

63. Juslén, A., Hyvärinen, E., and Virtanen, L.K. (2013). Application of the Red-List Index at a national level for multiple species groups. Conserv. Biol. *27*, 398–406. https://doi.org/10.1111/cobi.12016.

64. Olah, G., Butchart, S.H.M., Symes, A., Guzmán, I.M., Cunningham, R., Brightsmith, D.J., and Heinsohn, R. (2016). Ecological and socio-economic factors affecting extinction risk in parrots. Biodivers. Conserv. *25*, 205–223. https://doi.org/10.1007/s10531-015-1036-z.

65. Walesiak, M., and Dudek, A. (2020). The choice of variable normalization method in cluster analysis. In Education Excellence and Innovation Management: A 2025 Vision to Sustain Economic Development During Global Challenges (International Business Information Management Association (IBIMA)), pp. 325–340.

66. Rigby, R.A., and Stasinopoulos, D.M. (2005). Generalized additive models for location, scale and shape. J. Royal Statistical Soc. C *54*, 507–554. https://doi.org/10.1111/j.1467-9876.2005.00510.x.