Received: 19 November 2024 | Revised: 20 January 2025 | Accepted: 4 February 2025

DOI: 10.1111/cobi.70051

Conservation Biology

CONTRIBUTED PAPER

Language barriers in conservation science citation networks

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Article impact statement: Increasing the visibility of non-English-language conservation articles with English abstracts can enhance their impact on global research.

Funding information
Australian Research Council Future Fellowship; The University of Queensland Research Training Program Scholarship

Abstract

Using relevant scientific evidence is crucial to effectively conserve species and ecosystems worldwide. Currently, evidence that is available only in non-English languages is severely underutilized. We examined many underutilized non-English languages in the conservation evidence literature and factors that facilitate the use of non-English-language evidence based on citation patterns of articles testing the effectiveness of conservation actions published in English and 15 non-English languages. Multivariate models incorporated explanatory variables, such as lexical distance from English, availability of an English abstract, study design complexity, conservation status of studied species, and language of citing articles. Non-English-language articles received significantly fewer English citations (i.e., citations in English-language articles) than English-language articles. Hungarian, Polish, Korean, and Russian articles were particularly undercited in English. Despite fewer English citations, many non-English-language articles had high citation rates in their own languages, indicating their value in local conservation communities. Non-English-language articles with English abstracts received more English citations. The content of the article, such as a more robust study design or assessment of threatened species, was not significantly associated with the number of English citations received. Our findings highlight the importance of increasing the visibility and recognition of non-English-language articles, especially those in currently underutilized languages, for a more comprehensive understanding of global conservation challenges. Providing a translated English abstract has the potential to increase readership of an article by increasing the accessibility to those who can understand English.

KEYWORDS
citation patterns, conservation science, evidence synthesis, evidence-based conservation, language barriers, language bias, metascience, non-English-language literature

INTRODUCTION

Conservation science intends to generate evidence that informs conservation decision-making (Wilson et al., 2016). Evidence-based conservation focuses on implementing a best-practice approach based on evidence documented in the scientific literature and other types of knowledge, such as traditional and local ecological knowledge (Gillson et al., 2019; Hosen et al., 2020; Jessen et al., 2022; Sutherland et al., 2004). The need for effective conservation intervention cannot be overstated. Seventy-three percent of monitored vertebrate populations have declined globally since 1970 (WWF, 2024), and 1 million species are threatened with extinction (Brondizio et al., 2019).

Evidence-based conservation builds on evidence synthesis—the systematic collation of relevant scientific evidence from multiple sources. However, successful evidence synthesis, and therefore successful evidence-based conservation, requires a reliable evidence base (Christie et al., 2021). Biases in the evidence collated through evidence synthesis can be detrimental to environmental outcomes because it is not always appropriate to make generalizations or apply research from one particular context to another (Christie et al., 2021; Gillson et al.,

2019). To develop a comprehensive evidence base, evidence synthesis needs to search for evidence in as many relevant sources as possible (Collaboration for Environmental Evidence, 2022).

Although the global dominance of English as the common language of science has fostered a greater capacity for global information sharing and collaboration (Di Bitetti & Ferreras, 2017), it has also led to information in other languages being undervalued and underutilized (Hannah et al., 2024; Lynch et al., 2021). Non-English-language literature encompasses over a third of all global conservation literature (Amano, González-Varo, et al., 2016), with publication rates exceeding English or increasing in many non-English languages (Chowdhury et al., 2022). Additionally, non-English-language literature is an important information source in conservation science because it provides alternative descriptions or different cultural understandings in the scientific discourse (Díaz-Reviriego et al., 2024). Non-English-language literature can also provide scientific evidence on species, regions, and ecosystems that may be otherwise undocumented in English-language literature alone (Angulo et al., 2021). Similarly, studies published in lower impact factor journals, such as much non-English-language literature, can be an important recourse in informing domestic conservation decisions (Amano, Berdejo-Espinola, et al., 2023; Choi et al., 2024). Omitting non-English-language literature from evidence synthesis can lead to bias in the resulting data sets and mislead conservation decision-making (Konno et al., 2020). Therefore, it is important to ensure that all available evidence has been collected, including evidence across multiple languages, to ensure the best possible environmental outcomes are being achieved.

Many English-language reviews with a global scope tend to only cite literature published in English (Hannah et al., 2024; Lynch et al., 2021), often based on the assumption that any important scientific information is available in English-language literature (Amano, Berdejo-Espinola, et al., 2021). If non-English-language literature is being frequently cited by English-language literature (Figure 1a), this tendency may be inconsequential. In this case, the relevant evidence is being transferred from non-English languages to English, and then to global reviews, which are often intended to inform international decision-making and conservation outcomes (Cook et al., 2013). In contrast, if non-English-language literature is not being highly cited by English-language literature (Figure 1b), there may be a divide between languages, indicating that the scientific evidence being produced in non-English languages may not be reaching global reviews. This limits its application in decision-making and conservation outcomes because the evidence base may be incomplete and biased (Christie et al., 2021). For example, non-English-language literature may not simply be inaccessible to those without relevant language skills (Hannah et al., 2024) or researchers may not consistently cite their own local-language publications when publishing in English because non-English-language literature is often considered a low-quality evidence source (Amano, Berdejo-Espinola, et al., 2021) and therefore its citation is discouraged (Lazarev & Nazarovets, 2018).

The exclusion of non-English-language studies is a concern in many fields and is a common approach in reducing the time needed to produce systematic reviews (Tricco et al., 2015). For example, in the health sciences, the effect size and confidence interval changed with the exclusion of non-English-language literature in a meta-analysis, although it did not alter conclusions (Nussbaumer-Streit et al., 2020). In other fields, many researchers also caution of the bias that may be introduced when overlooking data from non-English languages (Mheissen et al., 2024; Stern & Kleijnen, 2020). However, few studies to date have assessed the flow of scientific evidence on biodiversity conservation between languages, although investigating this can be a key component in understanding how language barriers impact evidence-based conservation. Cross-language citations can indicate the degree of transfer of scientific evidence between languages. Comprehension of these interactions between languages will allow stakeholders to understand which languages may be underrepresented in informing conservation decisions. For instance, it can be assumed that languages with lower rates of cross-language citations could produce information largely unknown to the international scientific community. Understanding this information flow can help reduce the resources needed to assess conservation literature in multiple languages.

Using a global database of primary studies on the effectiveness of conservation interventions, published in English and 15 non-English languages (Amano, Berdejo-Espinola et al., 2021; Sutherland et al., 2019), we examined this knowledge gap by investigating the language patterns in citation networks of conservation articles directly relevant to conservation practice across many regions globally. Our objectives were to assess the strength and direction of citational links between different languages to determine how conservation-related evidence flows among different languages, identify largely isolated languages that receive few cross-language citations, and investigate factors that influence the international visibility of non-English-language literature, as measured by the number of English-language citations. Thus, we tested the assumption that non-English-language literature does not need to be directly cited in global reviews because the information filters through by being cited in English-language literature (Figure 1a). Ultimately, the global information flow in conservation science is an important process that should ensure that non-English-language literature is being appropriately utilized.

METHODS

Database

We analyzed articles published in English and non-English languages that provide evidence of the effectiveness of conservation interventions. The database of non-English-language articles was established in Amano, Berdejo-Espinola et al., (2021) and contains 1234 scientific articles written in 16 different non-English languages. Using a discipline-wide literature

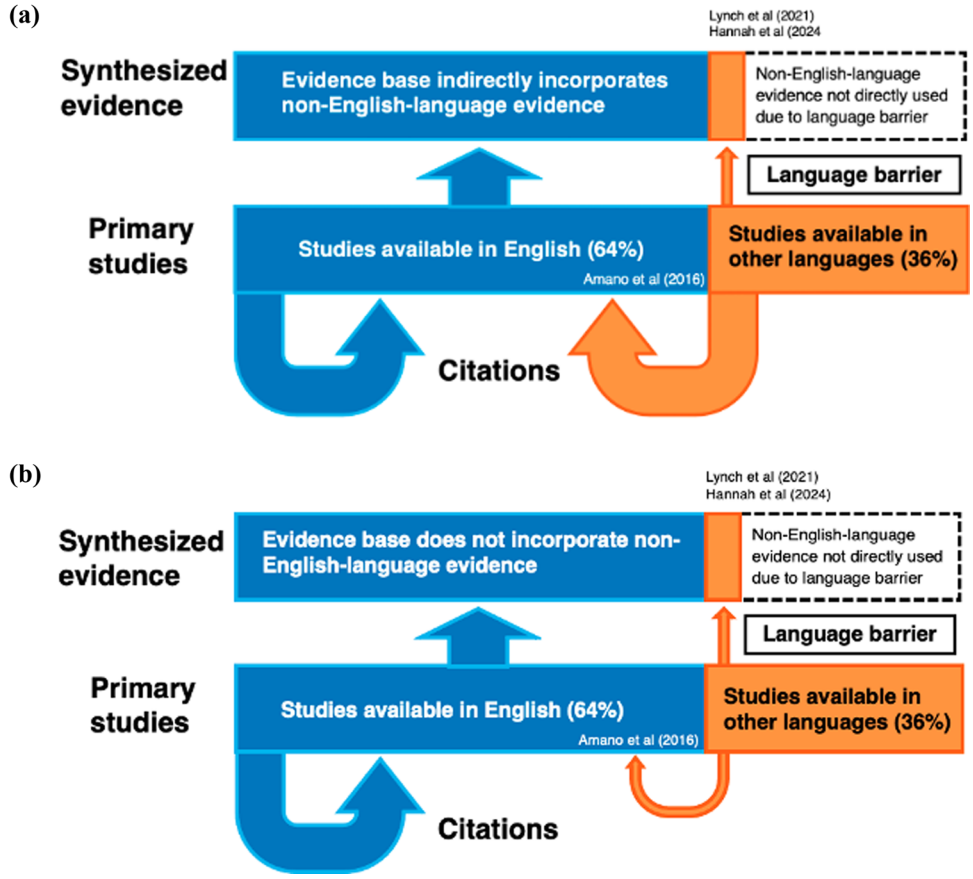

FIGURE 1 Systems wherein scientific evidence published in non-English languages is (a) widely cited in English-language studies, which are predominantly cited in reviews with a global scope, and (b) not widely cited in English-language studies, meaning this information is rarely present in evidence bases underpinning global reviews.

search method (Sutherland et al., 2019), these articles were manually screened from a range of relevant journals. Articles were included in the database if the effect was measured of an intervention that might be done to conserve biodiversity and if the effect was measured of an intervention that might be done to change human behavior for the benefit of biodiversity (details in Amano, Berdejo-Espinola et al., [2021]). Articles in Amano, Berdejo-Espinola et al., (2021) database were published from 1915 to 2020; the median year of publication was 2009. The inclusion criteria did not specifically limit articles based on species. Therefore, the database covers a wide range of species, including terrestrial and aquatic plants and animals. We utilized a subset of the articles from this database. We selected journal articles that assessed birds, mammals, and amphibians to allow for comparison among taxa ($n = 329$ total articles). These articles were published from 1963 to 2020; the median year of publication was 2009. Our database contained articles in 15 different languages: 93 articles in Japanese, 55 in German, 39 in Spanish, and 28 in Russian.

We also used a discipline-wide literature database provided by Conservation Evidence (https://www.conservationevidence.com/) that contained 11,847 articles, predominantly written in English, but also containing a number of non-English-language papers. This database contained journal articles and theses. The inclusion criteria for this database were the same as described for the non-English-language database (Sutherland et al., 2019). Articles in this database were published from 1912 to 2022; the median year of publication was 2006. Similar to the non-English-language database, the inclusion of articles is not based on the species covered by the study, so a wide range of species are covered in this database. To allow for more manageable data extraction, a random sample of papers in the 3 taxonomic categories was taken from the Conservation Evidence database. A sample size of 171 English-language articles was determined by using the sample formula in the R package samplingbook (Manitz et al., 2021). We assumed a confidence interval of 0.15 and that 50% of the total citations would be English-language citations. Because citation patterns may vary over time, we attempted to maintain the same temporal structure as the non-English-language database in each taxonomic group (birds, mammals, amphibians). To achieve this, we performed stratified random sampling in which articles were randomly selected in decade-taxon combinations (e.g., 3 articles from 1990 to 2000 in the category birds). The articles in this sample were published from 1971 to 2019; the median publication year was 2007.

Both the Conservation Evidence and non-English-language databases already contained general metadata relating to each article, such as the title, author names, year, and journal name. The non-English-language database also contained information relating to the language of the article.

Data extraction

Each article was individually searched on Google Scholar (https://scholar.google.com.au/) by looking up either English-language or non-English-language titles (if applicable) between 9 June 2023 and 29 August 2023. If an article could not be found using Google Scholar, it was also searched using Google (https://www.google.com/) and the University of Queensland institutional library (https://www.library.uq.edu.au/). If found on these platforms, the article was searched again in Google Scholar with the DOI, the non-English-language title, or any other identifying information to obtain the citation information from the Google Scholar platform. Articles that were still unable to be located were marked as such and were excluded from the analysis ($n = 14$ articles in the non-English-language database). For the non-English-language articles, the article was assessed to determine if any English-language title or abstract was provided. Next, the number of citations received by the article was recorded based on information provided on Google Scholar. The citations were then evaluated to determine whether there were any self-citations. Self-citations were recorded if any author of the original article appears as an author of the citing article. Finally, each article that had cited the focal article was accessed individually to determine its language. The language of each citing article was determined by pasting either the title of the article or a portion of the main text into Google Translate (https://translate.google.com/) and using its language detection feature. The number of citations by language was recorded for each article.

The lexical distance between each non-English language and English was recorded using an online linguistic distance calculator from eLinguistics.net (http://elinguistics.net/) (the lower the value, the more a language was related to English). The non-English-language database also included lists of the species studied in each article. These species were cross-referenced against the International Union for Conservation of Nature (IUCN) Red List of Threatened Species 2023-1 (https://www.iucnredlist.org/) to determine the conservation status of the species studied in each article. All data extraction was performed from June to August of 2023.

Analyses

Three multivariate models were developed in R 2023.06.0+421 (R Core Team, 2019) with the full database of English and non-English-language articles. First, to assess the difference in citation numbers between English and non-English-language articles, we ran a negative binomial generalized linear model (GLM) with the number of English citations (i.e., citations by English-language articles) as the response variable and the language of articles as the explanatory variable. English was used as the reference category. Next, we ran the same GLM but with the total number of citations (i.e., citations by articles in any languages) as the response variable.

In the third analysis, we assessed the factors that explain variation in the number of citations by English-language articles. In this analysis, we used only the non-English-language database. The response variable was the number of English citations, and the explanatory variables were year of publication, availability of an English abstract (yes or no; no was the reference category), and study design (more complex or less complex; less complex was the reference category). After, before–after, and control–impact designs were categorized as being less complex and before–after control–impact and randomized control trials were categorized as more complex, following Christie et al. (2019). The IUCN status of the study species was categorized based on threat level as per the IUCN red list classification (threatened or not threatened; not threatened was the reference category). Least concern and near threatened were defined as not threatened, and vulnerable, endangered, and critically endangered were defined as threatened. We identified taxonomic group (birds, mammals, and amphibians; birds was the reference category), lexical distance of article language from English, and the total number of same-language citations received by an article.

We hypothesized that articles providing their abstracts in English and those in languages that are linguistically closer to English receive a higher number of citations from English-language article. We used other explanatory variables to control for their impacts. It was also expected that year of publication of an article is negatively associated with a higher number of English citations because older articles have more time to receive citations. We also hypothesized that non-English-language articles with a large number of same-language citations are of high importance and may thus also have a high number of English citations. We also expected articles that focus on threatened species to have a higher number of English citations due to the conservation importance of the studied species. Non-English-language articles with a more robust study design were also expected to receive a higher number of English citations because these articles may be perceived as more valid and worth citing.

The variance inflation factor (VIF) was sufficiently small (<2.96, calculated with the package car in R [Fox & Weisberg, 2019]) for all explanatory variables in the models. All models were tested for goodness of fit with a likelihood ratio test against a null model.

The data used in the analysis are provided in Appendix S1. All codes used in the analysis are available at https://github.com/KHannah12/MultilingualCitations/.

RESULTS

The number of English citations among the 329 articles written in non-English languages was generally low (median = 0, range

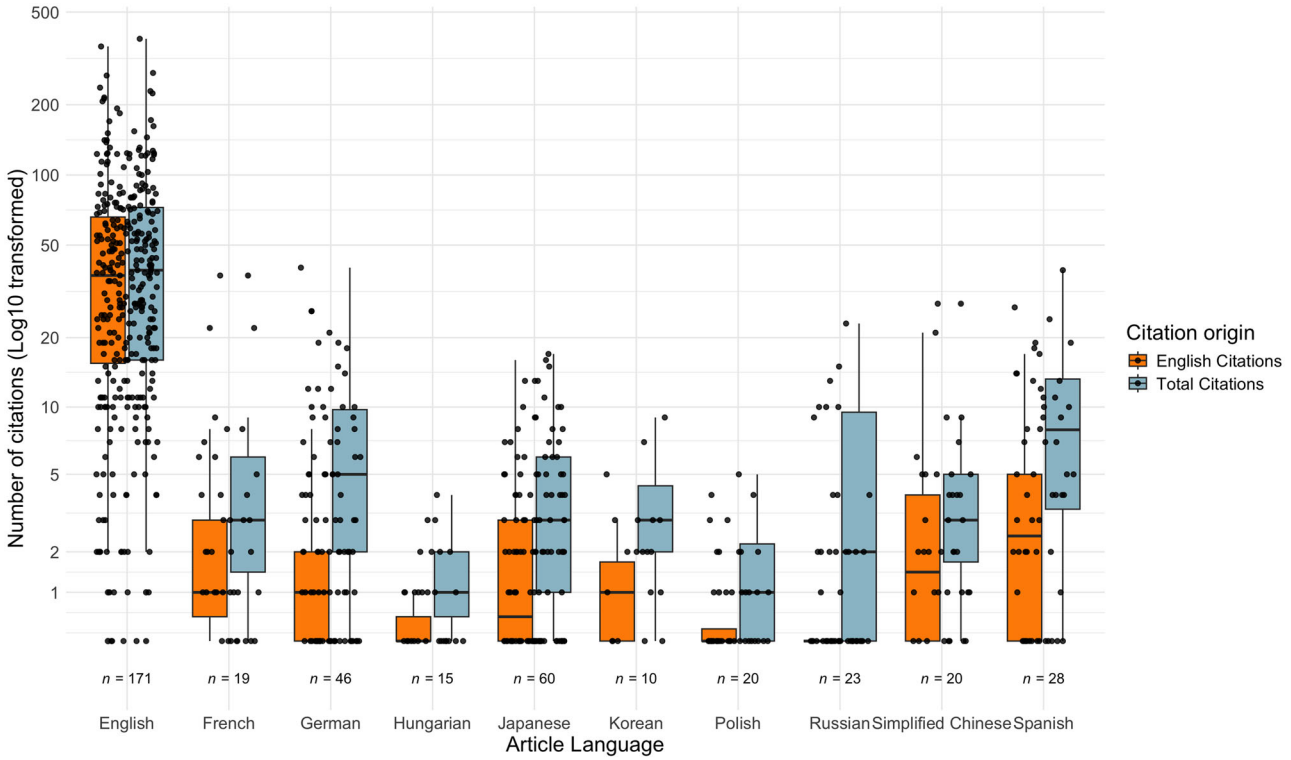

FIGURE 2 The number of English citations (citations from English-language articles) (orange) and the total number of citations (blue) received by articles written in English, French, German, Hungarian, Japanese, Korean, Polish, Russian, Simplified Chinese, and Spanish (horizontal line, median; top of bar, first quartile [Q1]; bottom of bar, third quartile [Q3]; whiskers, range of values within 1.5 times the interquartile range; dots, individual articles; *y*-axis transformed to log10).

0–26) (Figure 2). Articles in Hungarian, Polish, and Russian in particular received few English citations (range 0–2). In contrast, English-language articles received a median of 37 English citations (range 0–356), and the number of English citations was significantly lower for articles in all non-English languages compared with English-language articles (Figure 2; Appendix S2).

Although there was little difference between the number of English citations and the total number of citations for English-language articles, the total number of citations was consistently higher than the number of English citations for articles in all non-English languages (Figure 2). Most of the non-English-language citations were from the same language as the original article (Figures 3 & 4). For example, 28% ($n = 74$) of the assessed non-English-language articles contained only citations in the same language, and 47% ($n = 124$) contained over 50% of their citations in the same language. This suggests that many of the non-English-language articles were discovered more from researchers using the same language than from English. Although the total number of citations received by an article was still significantly lower for all non-English languages compared with English (Figure 2; Appendix S3), this result suggests that the extremely low number of English citations for non-English-language articles was not solely due to the lack of the importance of the study and at least partly due to the lack of visibility or lack of searching effort resulting from language barriers.

When assessing citations to all articles in each non-English language, an average of 56.8% and median of 60% of total citations (range 0–100%) were from the same language as the original article (Figures 3 & 4). Alternatively, an average of 37.8% and median of 33% of citations (range 0–100%) were from English (Figures 3 & 4). For all languages, other non-English cross-language citations (i.e., articles in languages other than their own or English) were generally very low (mean = 4.3%, median = 0%, range 0–100%). Russian clearly showed the lowest proportion of English citations, followed by Hungarian and Polish (Figure 3). These languages may be considered the most isolated, with limited sharing of their findings internationally. In contrast, French and 3 East Asian languages (Japanese, simplified Chinese, and traditional Chinese) showed a particularly high proportion of English citations overall (54%, 61%, 62%, and 67%, respectively).

As hypothesized, non-English-language articles that included an English-language abstract received a significantly higher number of English citations when controlling for other factors (Figure 5; Appendix S3). Contrary to our hypothesis, articles in languages that are more linguistically distant from English received a significantly higher number of English citations (Figure 6; Appendix S3). As expected, articles that were published in older years and had more citations from the same language also attracted a higher number of English citations (Figure 5; Appendix S3).

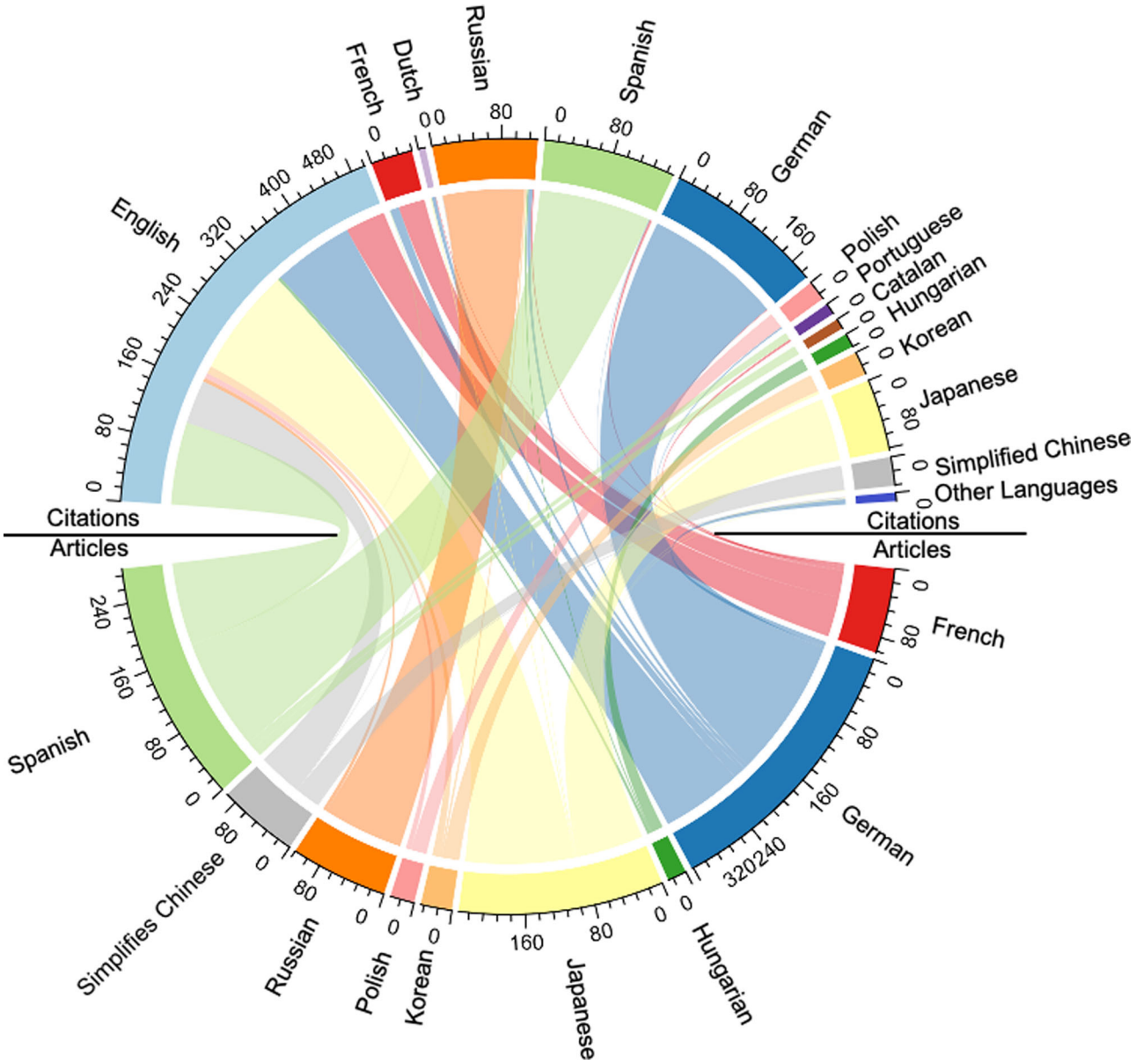

FIGURE 3 Language patterns of citations of articles in all non-English languages in our database (number of citations received in each language; languages with fewer than 10 articles excluded).

We found that 91% of citations for all articles in the English-language database were from English-language articles (Appendix S4). Out of the non-English-language citations, the highest number of citations was from Spanish articles, followed by German and Portuguese, although these languages accounted for only small percentages (1.73%, 0.66%, and 0.65%, respectively) due to the overwhelming dominance of English citations. A total of 24.86% (n = 43) of articles only contained English-language citations. Only 10 English-language articles in our sample had an abstract that was translated into another language. Abstracts were found to have been translated into only Spanish (n = 8) or French (n = 2).

DISCUSSION

Our study found that non-English-language literature received significantly fewer citations than English-language literature and fewer citations from English-language articles. Our results also revealed that the total number of citations was consistently higher than the number of English citations in all non-English languages, meaning that citations to non-English-language articles were primarily from the same language. This suggests that the limited number of citations from English-language articles must have been at least partly due to the effects of language barriers, wherein these articles were overlooked or inaccessible due to their language (Amano, González-Varo, et al., 2016; Hannah et al., 2024).

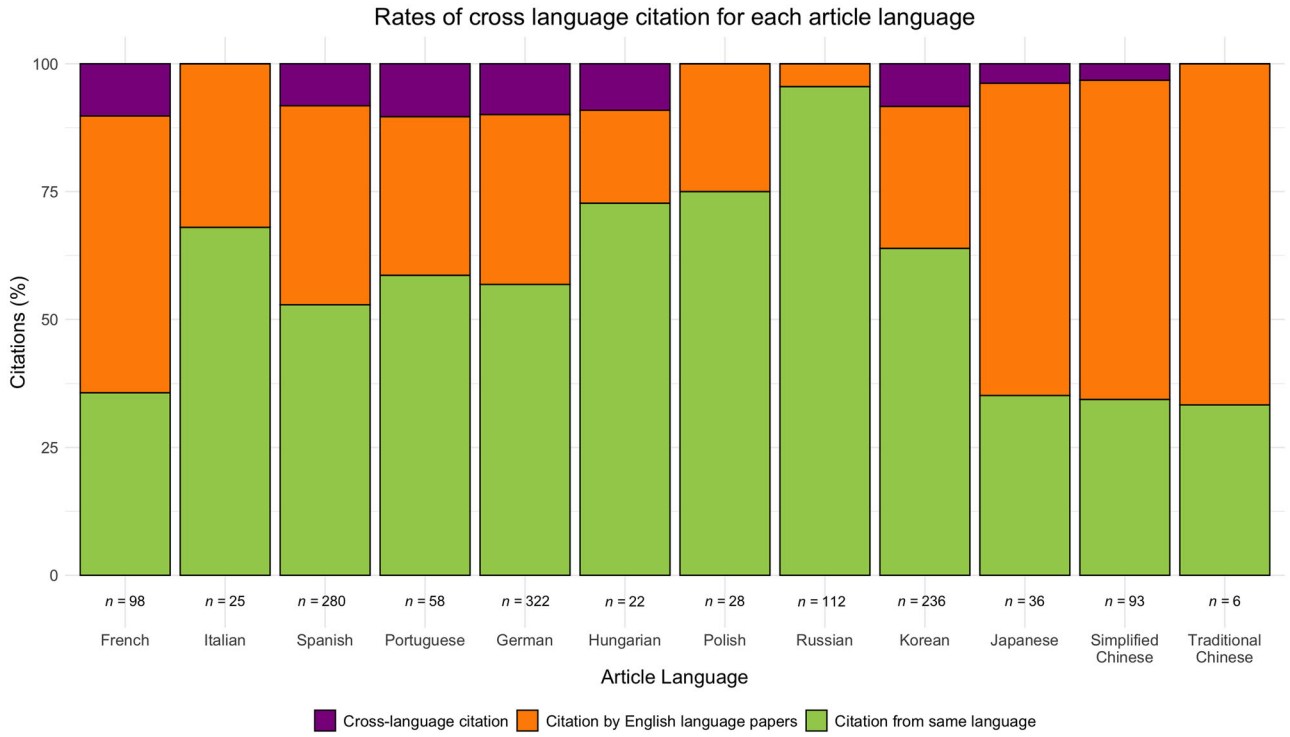

FIGURE 4 Percentage of total citations received by a non-English-language article in the same language as the article (green), in English (orange), and in another non-English language (purple) (*n*, number of citations received by articles in each language).

There were several isolated languages for which English-language citations were notably rare, including Hungarian, Polish, Korean, and Russian (Figure 3). This suggests that scientific evidence being produced in those languages may not reach a broader audience, such as researchers, policy makers, and conservation practitioners in different regions, despite the relevance or importance of the science. Russian, for example, was the most isolated language in our database, with an average of 94.8% of citations being in the same language. Russia is known to have high scientific output (Mokhnacheva & Tsvetkova, 2019); however, this information is rarely used internationally. Russian-language articles may also be particularly important in conservation due to the country's vast and unique landmass, which is home to a number of rare endemic species as well as migratory species (Kirpotin et al., 2021). These articles may provide essential insights into these species and ecosystems and thus contribute to conservation efforts and global understanding. However, due to the isolation of the Russian-language articles, much of this information remains underutilized by the international community. Although the database of non-English-language articles we used covers the top 16 non-English languages in terms of scientific publications (Amano, González-Varo, et al., 2016), our study was limited by the relatively small sample size for some languages and because we cannot dismiss the possibility that there are other languages in which important evidence for conservation is published yet rarely used internationally. A larger sample size would allow for more robust conclusions to be drawn for a greater number of languages.

Having an English-language abstract was positively associated with the number of English citations in non-English-language articles (Figure 5; Appendix S3). Although there may be other confounding factors (e.g., non-English-language articles indexed on a well-known literature search system may be more likely to have English-language abstracts), this suggests that providing an English-language abstract in a non-English-language article can increase its international visibility, potentially increasing its impact. Our results showed that non-English-language articles with a more robust study design or those assessing species of greater conservation concern did not necessarily receive more English citations. This may indicate that scientific rigor and global importance are not necessarily the key elements in gaining article attention; instead, language-related visibility and accessibility may be crucial. Many of the non-English-language articles we assessed adopted robust study designs to test the effectiveness of conservation actions for threatened species (Amano, Berdejo-Espinola et al., 2021), some of which may not have been fully utilized in conservation simply due to language barriers. For example, the study by Shizhou et al. (2013), a randomized control trial investigating the critically endangered South China Tiger, had only 3 citations.

Contrary to our hypothesis, the number of English citations was higher in articles written in languages that are more linguistically distant from English. This may indicate that languages that are further from English, such as Japanese, simplified Chinese, and traditional Chinese, may have greater recognition by international and domestic communities as important sources of evidence for informing conservation science. Japanese had

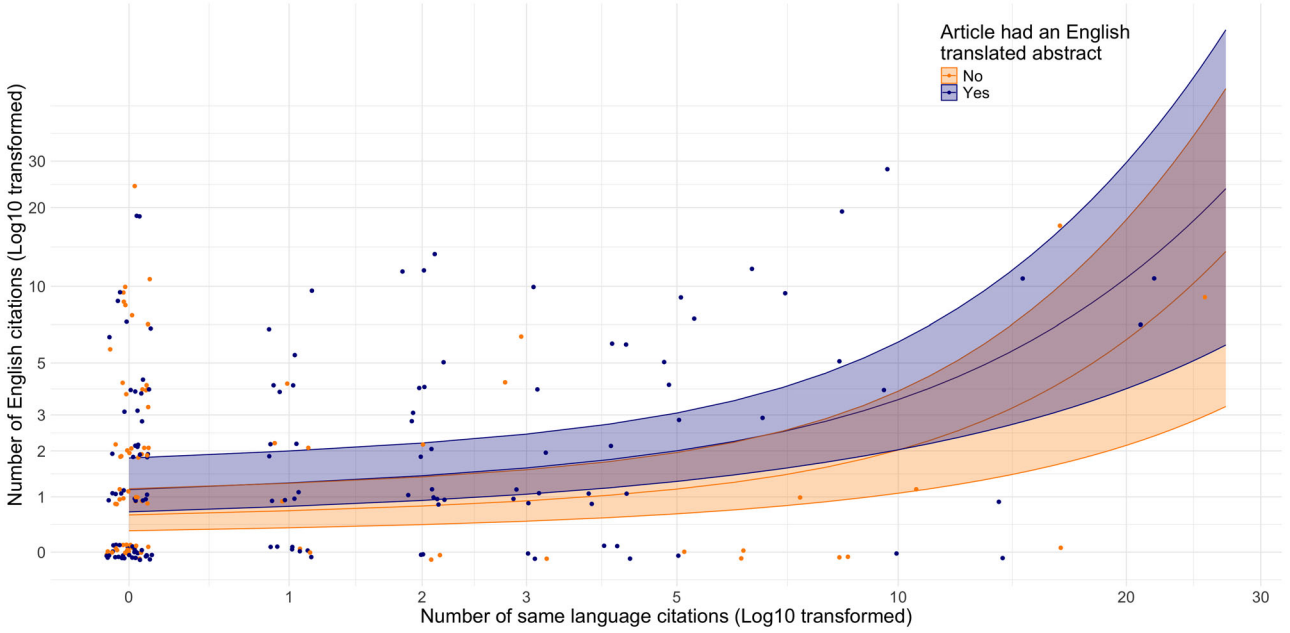

FIGURE 5 Relationship between the number of same-language citations of a conservation article (citations from articles of the same language as the cited article) and the number of English-language citations (citations from English-language articles) received by non-English-language articles with (blue, $n = 140$) and without (orange, $n = 79$) an English-language abstract (regression lines, based on fitted negative binomial generalized linear model [Appendix S3]; shading, 95% confidence intervals; jittering used to show all data points).

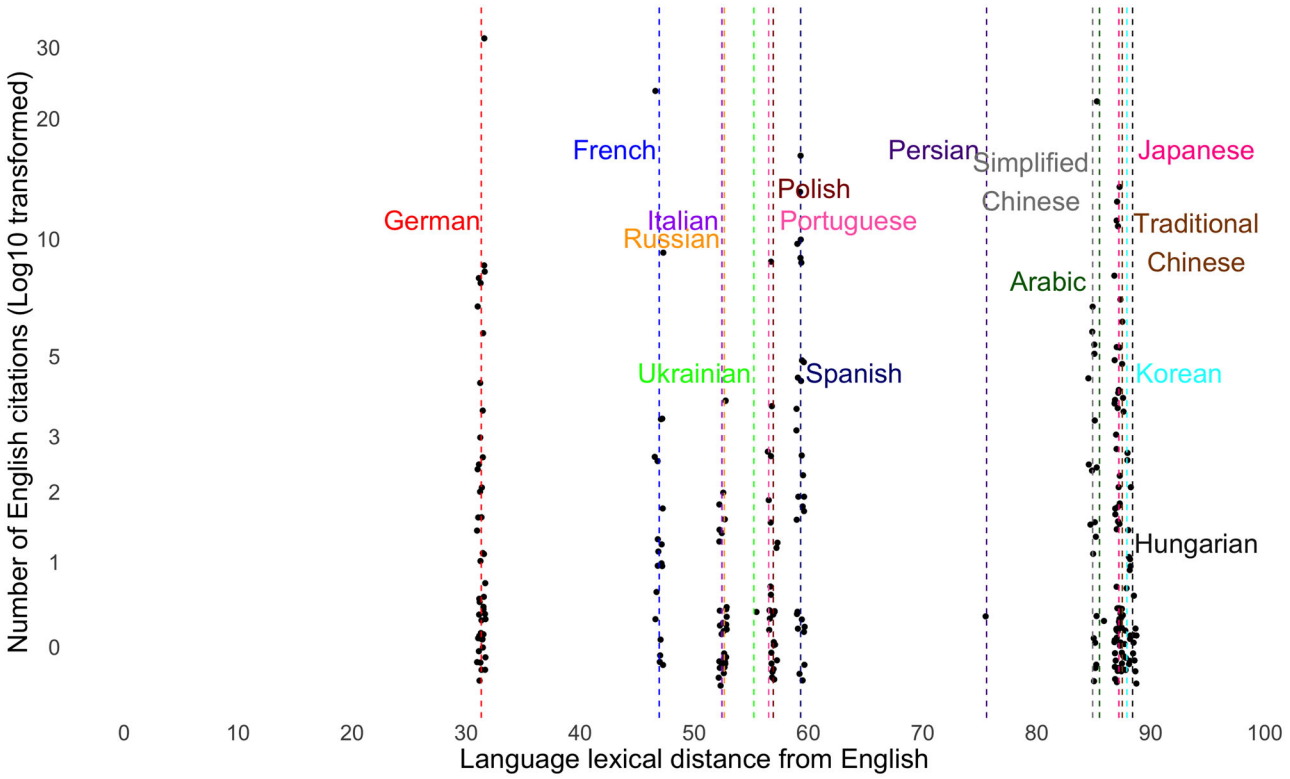

FIGURE 6 Relationship between the linguistic distance from English of the language of a non-English-language article and the number of English-language citations received by the article (jittering used to show all points).

the largest number of papers in our database (60), sourced from 12 different journals. These journals and articles seemed to be recognized as an important source of evidence domestically and internationally.

Sharing scientific information across languages is key to gaining a comprehensive understanding of conservation challenges and performing conservation actions based on relevant and robust evidence. Incorporating greater diversity in the language of sources can reduce bias (Konno et al., 2020) and offer unique perspectives and regional and local knowledge (Amano, Berdejo-Espinola et al., 2021). For example, regions with rich biodiversity but limited resources for research are often underrepresented in conservation science, leading to an incomplete understanding of ecosystems, hindering effective conservation strategies (Amano, Lamming, et al., 2016; Wilson et al., 2016). Language gaps further compound the issue because English is not widely spoken in many of the regions with rich biodiversity and research published in languages other than English there often struggle to reach a global audience (Di Bitetti & Ferreras, 2017). Similarly, information needs to flow between different non-English languages to avoid wasted resources and incomplete understandings (Buxton et al., 2020). If cross-language citations are rare, the research produced in a language may lack these alternative viewpoints, risking the formation of echo chambers. Sometimes research may apply only to a small area or locally relevant topic, but reliance on same-language citations can limit the global impact and interrupt the exchange of knowledge.

Our results suggest that providing English-language abstracts of non-English-language articles may increase the visibility and use of the articles. However, simply recommending that authors publishing in non-English languages include English-language abstracts may further burden those whose first language is not English; these authors already face significant time and resource costs (Amano, Ramírez-Castañeda et al., 2023). A potential solution could be the implementation of machine translation technologies. Although the quality of machine translation is still not perfect and varies between languages (Esperança-Rodier & Frankowski, 2021; Mohamed et al., 2024; Moneus & Sahari, 2024), publishers, journals, and literature search systems should start considering its implementation on their platforms to increase the reach of scientific publications. These measures are especially important when it comes to publications in more isolated languages, such as Russian, Korean, Polish, and Hungarian, in which there are a limited number of English citations.

Conservation science, being a discipline with global application, benefits from a diverse range of perspectives, methodologies, and findings. Although it can be difficult to assess information in multiple languages, research teams should endeavor to proactively search and include evidence that is available only in non-English languages to ensure that all relevant evidence is considered. Ultimately, the integration of multilingual information into conservation science can benefit both the scientific community and the natural world.

ACKNOWLEDGMENTS

This work was supported by the Australian Research Council Future Fellowship FT180100354 and The University of Queensland Research Training Program Scholarship.

Open access publishing facilitated by The University of Queensland, as part of the Wiley - The University of Queensland agreement via the Council of Australian University Librarians.

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How to cite this article: Hannah, K., Fuller, R. A., Smith, R. K., Sutherland, W. J., & Amano, T. (2025). Language barriers in conservation science citation networks. *Conservation Biology*, e70051. https://doi.org/10.1111/cobi.70051