Received: 1 December 2020 | Revised: 20 January 2021 | Accepted: 27 January 2021

DOI: 10.1111/conl.12797

Conservation Letters
A journal of the Society for Conservation Biology
Open Access
WILEY

LETTER

Women and Global South strikingly underrepresented among top-publishing ecologists

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Abstract

The global scientific community has become increasingly diverse over recent decades, but is this ongoing development also reflected among top-publishing authors and potential scientific leaders? We surveyed 13 leading journals in ecology, evolution, and conservation to investigate the diversity of the 100 top-publishing authors in each journal between 1945 and 2019. Out of 1051 individual top-publishing authors, only 11% are women. The United States, the United Kingdom, Australia, Germany, and Canada account for more than 75% of top-publishing authors, while countries of the Global South (as well as Russia, Japan, and South Korea) were strikingly underrepresented. The number of top-publishing authors who are women and/or are from the Global South is increasing only slowly over time. We outline transformative actions that scientific communities can take to enhance diversity, equity and inclusion at author, leadership, and society level. The resulting promotion of scientific innovation and productivity is essential for the development of global solutions in conservation science.

KEYWORDS

authorship, diversity, gender, global, inclusion, leadership, national bias, peer-reviewed journals, publication metrics, scientific society

1 | INTRODUCTION

The biodiversity and climate crisis, as well as related environmental issues of our time, are truly international (Bongaarts, 2019; Powers & Jetz, 2019), requiring diverse academic perspectives and leadership (Jimenez et al., 2019; Maas et al., 2019). However, these problems are addressed by scientific communities that are biased by underrepresentation of women and scientists from the Global South (Whelan & Schimel, 2019). Due to this persistent gender

and geographic bias, male scientists and research from North America and Europe continue to dominate the ecological literature, while valuable perspectives from underrepresented social groups and biodiversity-rich regions of the Global South are missing (Whelan & Schimel, 2019). Further quantifying and addressing this bias presents a much-needed process to improve diversity in ecology and conservation (Pettorelli et al., 2021). The debate on diversity, equity, and inclusion in science raises many questions, including if higher representation of minority groups observed in ecological authorship (Salerno et al., 2019; Whelan &, Schimel,2019) and early career stages (Grogan, 2019; Huang et al., 2020) is also reflected among top-publishing authors and potential scientific leaders.

If economic developments and equality measures were successful in increasing diversity and inclusion in society and academia (Di Marco et al., 2017; Falk & Hermle, 2018), we would expect more women and scientists from the Global South to be among the top-publishing authors in their fields (i.e., authors who publish the greatest number of papers). For ecologists, this would mean publishing many articles in leading journals with high impact factors in ecology and the related disciplines of evolution, ecosystems ecology, climate change biology, and conservation biology. Achieving recognition by publishing many papers in leading journals is a significant accomplishment, and academic institutions often award appointments, promotions and leadership positions based largely on high publication output in leading journals—although this is not necessarily the only or even the best indicator of scientific expertise and leadership potential (Fox & Paine, 2019; Manlove & Belou, 2018; Moher et al., 2018). Thus, if scientists from the Global South, and women globally, are underrepresented among top-publishing authors, they might continue to be underrepresented in future leadership positions. To our knowledge, this is the first comprehensive study of the identities of the top-publishing authors in ecology including their gender and geographical distribution. We present the proportion of women and scientists from the Global South among top-publishing authors in leading ecology journals, and how these proportions changed over the last decades, to discuss opportunities for enhancing diversity, equity, and inclusion in ecology.

2 | METHODS

We selected 13 leading journals in the broadly defined field of ecology for this study (Figure 1; Table S1). We selected these 13 journals by examining the list of top ecology journals based on the impact factors from the 2016 Journal Citation Reports (Hartig, 2017), including journals from the fields of ecology, evolution, conservation biology, ecosystems ecology, and climate change biology. We did not include journals in which a large proportion of articles are not scientific research articles, such as *Frontiers in Ecology and the Environment* or *Methods in Ecology and Evolution*.

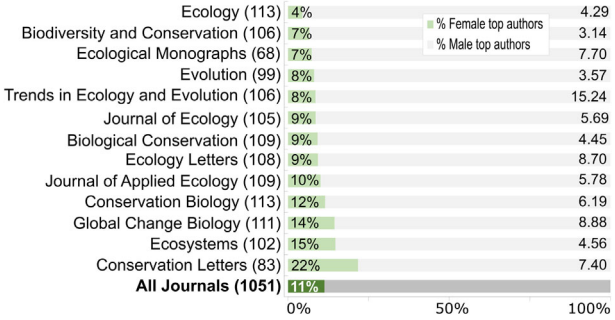

FIGURE 1 Female and male top-publishing ecologists per journal. This overview shows the relative proportions of female and male top-publishing authors (in %) in 13 leading ecology journals (*n* of individual top-publishing authors in parentheses) over the entire period of the study (1945–2019). The impact factor of each journal (2018) is provided at the right end of each bar. Of these 13 journals, 4 journals were in the field of conservation biology, 2 were in the field of evolution, and 7 were ecology journals

2.1 | Top-publishing author data extraction

We used the Web of Science to determine the 100 authors who had published the most articles in each journal, that is, the number of times their name appeared on author lists between 1945 and 2019. For each journal (Figure 1), we selected the number of top-publishing authors closest to 100 (in each journal, many authors had published the same number of articles and we selected the number of top-publishing authors that was equal or greater than 100). For author-based analyses, we considered individual top-publishing authors only once, giving a total of 1051 individual top-publishing authors out of 1332 entries. We determined country of primary affiliation using the most recent article in each journal. The country allocation is considered representative for the selected top-publishing authors, because the affiliation for authors with multiple entries was always in the same country. We also recorded the year of their earliest and latest paper in each journal for which they were a top-publishing author, and determined the position (single, first, last, or middle author) of each top-publishing author within the list of their coauthors, in each paper published in each journal. Further, we identified, for each journal, all papers that rank in the top

TABLE 1 Gender and country differences among top-publishing ecologists

Top-publishing authors	Total	F	M	%F	%M	MIN	MAJ	%MIN	%MAJ
(A) First paper of all authors (1945–2019)	1051	119	932	11.3%	88.7%	177	874	16.8%	83.2%
(B) First paper before 2000 (1945–1999)	680	62	618	9.1%	90.9%	95	585	14.0%	86.0%
(C) First paper after 2000 (2000–2019)	371	57	314	15.4%	84.6%	82	289	22.1%	77.9%
(D) First paper (15-year intervals)									
1945 to 1959	35	1	34	2.9%	97.1%	1	34	2.9%	97.1%
1960 to 1974	65	1	64	1.5%	98.5%	2	63	3.1%	96.9%
1975 to 1989	216	14	202	6.5%	93.5%	17	199	7.9%	92.1%
1990 to 2004	556	70	486	**12.6%**	87.4%	112	444	**20.1%**	79.9%
2005 to 2019	179	33	146	18.4%	81.6%	45	134	25.1%	74.9%
(E) First paper (35-year segments)									
Before 1980	143	6	137	4.2%	95.8%	5	138	3.5%	96.5%
After 1980	908	113	795	**12.4%**	87.6%	172	736	**18.9%**	81.1%

Note: The table presents the total and relative number of female and male top-publishing authors (F/M) as well as of top-publishing authors from minority and majority countries (MIN/MAJ), who published their first "top-publishing author paper" in one of the 13 journals, either over the entire period of the study (A), before 2000 (B), after 2000 (C), divided into 15-year intervals (D), or divided into 35-year intervals (E). Significant increases of women and minority countries compared to the previous time interval (based on χ^2 tests) are marked in bold.

1% by citations in a given year during the period 1945–2019 in Web of Science to investigate highly cited papers separately. We assigned authors' gender on the basis of full names and affiliations with the support of online pictures and CVs, and by direct inquiry in case of doubt. We recognize that genders are not best categorized as a strict binary, but used this gender binary to simplify analysis of the representation of women in ecology leadership.

2.2 | Analyses of top-publishing author data

Our analysis of gender and country differences is based on top-publishing author information that was extracted for all 1051 individual top-publishing authors. The data were examined for the entire period of the publications (1945–2019), as well as for intervals of 15 and 35 years to investigate changes over time in the number of top-publishing authors using χ^2 tests comparing each time interval with the previous time interval, starting with the second time interval (Table 1E and 1D). For these analyses, we defined "minority countries" (i.e., countries that accounted for ≤2% of all top-publishing authors), because not all minority countries are located in the Global South.

All statistical analyses were conducted in R (R Core Team, 2017). Gender effects were investigated using specified generalized linear mixed effect models ("glmer" function, "lme4" package in R), testing the potential effects of journal identity, journal age, and publication period (using binomial error distribution for gender and ensuring that data were not overdispersed). The models were compared using Akaike Information Criteria (AIC) values to identify variables with strong explanatory value (Table S2).

Country differences were investigated based on GDP per capita and population size in each country (data obtained from The World Bank, 2019) to explore differences among their proportions of top-publishing authors. For all countries, the number of top-publishing authors was standardized by country population size and regressed against mean number of top-publishing authors per country (Figure 3).

3 | RESULTS

3.1 | Gender differences

Among the 1051 top-publishing authors, only 11% were women, with women representing less than 10% of top-publishing authors in 8 of the 13 journals (Figure 1). The proportion of women among top-publishing authors has increased only slowly over time: of those who published their first paper before 2000, 9% are women, compared to 15% women among top-publishers who published after 2000 (Tables 1A–C). Considering shorter 15-year intervals (Table 1D), the proportion of women among top-publishing authors increased from 3% (1945–1959) to 18% (2005–2016). However, the proportional increase of women was significant only from time interval 1975–1989 to 1990–2004 ($p = .04$) and between the two 35-year intervals ($p < .001$), but not between all other time intervals tested with χ^2 tests (Table 1).

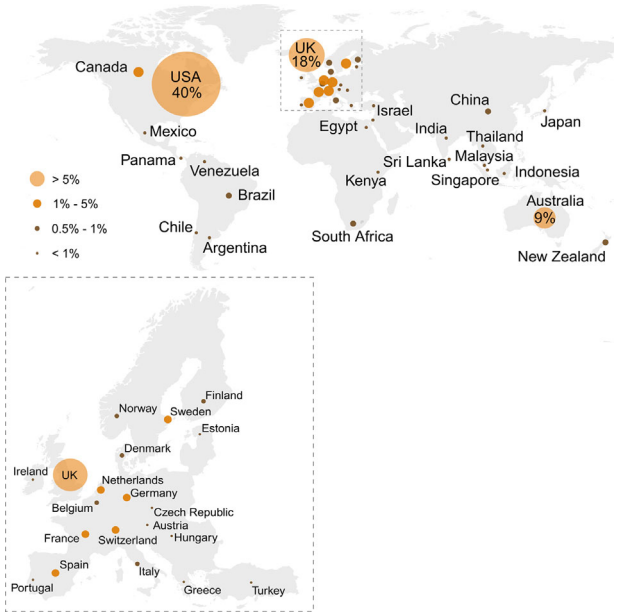

FIGURE 2 Global proportions of top-publishing ecologists. The world map shows data from 1051 top-publishing authors from 42 countries and 13 ecology journals between 1945 and 2019. The proportion of top-publishing authors is represented in proportional classes by circles of different sizes. For the three countries with the highest proportion of top-publishing authors, values are given in %. Results for Europe are shown separately (dashed rectangle) at higher resolution

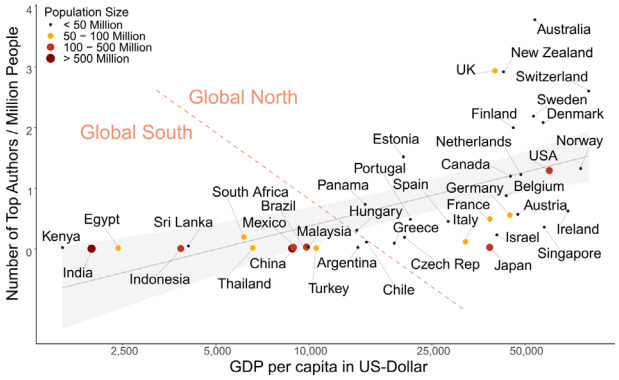

FIGURE 3 Top-publishing ecologists by GDP. The number of top-publishing authors (standardized by country population size) is shown by GDP per capita (World Bank, 2019) in the 42 top-publishing author countries. The gray area indicates values within a 95 % confidence interval above or below observed means (solid line). Differences between the Global North and South are indicated by a rough guideline (dashed line)

A comparison of generalized mixed models using AIC revealed that the proportion of female authors is not related to journal identity, journal age, or the year of first publication (Table S2), indicating that gender differences must be related to other factors.

Male top-publishing authors also published on average more papers (21.2 vs. 14.8, t-test, df = 269.86, $t = -5.16$, $p < .001$) and were top authors for more journals (1.36 vs. 1.15, t-test, df = 229.38, $t = -4.15$, $p < .001$) than female top-publishing authors. Among the 514 most highly cited papers published during this period, most of them were led by men (355, i.e., 69%). We also found that men wrote more single author papers than women (4.6% for women, 10.2% for men χ^2 test, $\chi^2 = 79.86$, df = 3, $p < .001$) but there was no significant difference for first, middle, or last position in coauthorship.

3.2 | Country differences

Of 42 countries specified as the affiliations of the top-publishing authors, three account for a disproportionately large number of top-publishing authors (Figure 2 and Table S1): the United States (40%), the United Kingdom (18%), and Australia (9%). The next seven leading countries are Canada (4%), Germany (4%), France (3%), Switzerland (2%), the Netherlands (2%), Spain (2%), and Sweden (2%). These 10 countries together account for 86% of the top-publishing authors. It is notable that the top three countries are English speaking, and all of the top 10 countries are Western countries of the Global North.

Each of the remaining 32 countries on the list of countries with top-publishing authors, including populous countries such as China, India, Japan, and Brazil had 1% or fewer of the top-publishing authors. These remaining 32 countries together account for only 13% of the top-publishing authors. None of the other 151 countries of the world (e.g., including Russia, a large part of the Global North by area) have even one name on the list of 1051 top-publishing authors.

The proportion of top-publishing authors from "minority countries" (here individual countries accounting for 2% or less of total top-publishing authors) is increasing over time, rising from 14% to 22% among scientists who published their first publication before or after 2000 (Table 1). The proportion of top-publishing authors from minority countries increased from 3% (1945–1959) to 25% (2005–2016) with an average annual growth rate of 6% (Table 1D), but these increases were only significant between the time intervals 1975–1989 and 1990–2004 ($p < .001$) and the two 35-year intervals ($p < .001$). The proportion of female top authors in the entire period (1945–2019) was 12% for majority countries and 8% for minority countries (Table S3).

We analyzed country-specific variables (i.e., economic development as a driver of scientific productivity, and population size as a source of potential authors) to explore differences among their proportions of top-publishing authors. We found that GDP per capita and population size

FIGURE 4 Recommendations to promote more diverse scientific communities at author, leadership, and society level. Based on the results of this study and literature, links between individual levels are highlighted and examples for transformative action are given

are positively correlated with the number of top-publishing authors. GDP remains correlated with number of top-publishing authors, even after standardizing the number of authors by population size ($p < .001$, $R^2 = .27$; Figure 3).

4 | DISCUSSION

4.1 | Biased top authorship

The findings of our study indicate a persistent lack of women and international diversity among top-publishing authors in ecology and its potential leadership. Our study complements existing studies on geographical and gender representation in ecology (Whelan & Schimel, 2019) through the novel and essential consideration of top-publishing authors who often gain access to leadership positions through their high publication impact (Figure 4).

Top-publishing authors and academic leaders shape ecology, conservation, and evolution, but show strong patterns of biased representation. Our results support findings on institutional and inclusion biases, leading to unbalanced top-authorship and potential scientific leadership (AlShebli et al., 2018; Grogan, 2019). Female scientists, as

well as many populous countries with large numbers of universities and scientists, such as China, Japan, Brazil, and India, have surprisingly few top-publishing authors. Some large, populous countries are not on the list at all. This geographic bias in the list of top-publishing authors suggests that the scientific establishment may be missing essential perspectives (Maas et al., 2019) to sufficiently address the global biodiversity and environment crisis (Nielsen et al., 2017; Nuñez et al., 2019). We argue that the scientific community, specifically research institutions, scientific societies, and scientific journals need to take strong transformative actions to address this problem (Figure 4). While many of the causes of these biases are difficult to change (e.g., geopolitical and economic insecurity), numerous advances could be achieved by actions like recruiting and inviting underrepresented scientists as editors, authors, and collaborators (Campos-Arceiz et al., 2018; Espin et al., 2017; Pettorelli et al., 2021; Primack et al., 2019). Scientific institutions and societies can immediately improve their guidelines for good scientific practice with these existing possibilities for enhancing diversity, equity and inclusion by making such demands mandatory.

Our data show that these gender and geographic gaps are closing over time, but only slowly. For example, women accounted for only 3% of the top-publishing ecologists between 1945 and 1959, but account for 18% among recent top-publishing ecologists. Even with this increase, women are clearly underrepresented relative to the proportion of women in the general population (United Nations, 2019) or in academia (Howe-Walsh & Turnbull, 2016). For example, in the United States, women make up the majority of ecology graduate students (56%), newly hired tenure track faculty members (59%), and a third of tenure-track biology faculty members (29%) (Whelan & Schimel, 2019). The proportion of women among recent top-publishing authors in ecology (18%) is only half the proportion of women first authors (Whelan & Schimel, 2019) for the five journals of the Ecological Society of America (36%). This proportion of women first authors is similar to the proportion of first authors in the 13 ecology journals included in our study (Figure S1): of 2600 papers taken randomly from the 13 journals (100 for each journal in 2008 and 2018), women were first authors of 34% of the articles. For some journals, women first-authored between 40% and 50% of papers. And yet women still only constitute 18% of the recent top-publishing authors. This suggests that women do contribute to scientific research but that they meet a strong and specific obstacle to join the group of top-publishing authors.

Similar to gender, the international imbalance in ecology is also changing slowly (Mammides et al., 2016), with the proportion of top-publishing authors from the Global South (as well as Japan and China) increasing over time. Even so, the recent proportion of top-publishing authors from the Global South (25%) is strikingly low compared to their percentage of the global population (> 80%; Solarz & Wojtaszczyk, 2015). Country differences related to per capita GDP and population size may be due to the fact that larger or wealthier countries are economically more able to support more scientists. These are issues that are beyond the scope of scientific societies, though they should be aware of them. These and related questions concerning the differences between Global South and North, as well as the consideration of more diverse genders and backgrounds, deserve more attention in scientific research and self-evaluation. The international scientific community cannot afford to neglect such large proportions of the world population and geographical area in scientific leadership and decision-making.

4.2 | Qualitative and inclusive leadership

Academic leadership is often appointed and promoted based on high publication output in leading scientific journals (e.g., Moher et al., 2018; Potvin et al., 2018). This puts careers of scientists from underrepresented groups, who contribute to academic and society-relevant tasks that are not considered in the career advancement, at particular risk (Jimenez et al., 2019; Maas et al., 2020; O'Brien et al., 2019). For example, women are often burdened with more family responsibilities and professional teaching and administration tasks than their male colleagues (Maxwell et al., 2019), and receive less recognition in and access to male-dominated work environments (Sheltzer & Smith, 2014). Accessibility plays an important role for scientists from the Global South, for example because language barriers severely limit international authorship (Nuñez et al., 2019), as well as many other barriers limiting access to information and opportunities. Consequently, women and scientists from the Global South have greater difficulties achieving high levels of scientific productivity and leadership positions (Ceci, 2018; Chapple & Ziebland, 2018; Di Marco et al., 2017; Nuñez et al., 2019).

Quantitative career metrics that emphasize the number of published papers ignore the significant handicaps faced by underrepresented groups and can create implicit biases in the scientific community (Fox & Paine, 2019; Van den Besselaar & Sandström, 2017). Thus, their importance for academic career advancement and scientific leadership is often questioned (Astegiano et al., 2019; Seppelt et al., 2018), whereas more nuanced, qualitative evaluation criteria to assess contributions of research to scientific progress and social benefits are increasingly demanded (Fox & Paine, 2019; Moher et al., 2018).

For example, an increasing number of scientific funding bodies (such as the U.S. National Science Foundation and the German Research Foundation) only allow scientists to list their 10 most relevant publications, and provide opportunities to list research products other than publications (Lamb et al., 2018). Measurements of the quality of papers could include comparisons with the average number of citations in a given field, country, or language (Tian et al., 2016). Such advanced measures should be complemented by increased consideration of alternative metrics or "altmetrics" that measure broader engagements with research outputs including views, downloads, and diffusion in social media (Lamb et al., 2018). Of course, any attempt to implement such an alternative system should evaluate whether it actually achieves its stated goals of enhancing diversity in scientific communities.

Our results show that authors from certain countries tend to dominate publishing in journals associated with country-specific societies or networks (e.g., U.S. scientists in *Ecology* and U.K. scientists in the *Journal of Applied Ecology*). This suggests that there may be self-reinforcing networks within countries that enhance the publication rates and careers of certain individual scientists and indirectly exclude others if no alternative measures are applied. Society leaderships and scientists involved in these networks should make a greater effort to be more inclusive in bringing a more diverse group of authors into such publishing groups, as well as in the creation and advertising of training opportunities to promote inclusion. Diverse and inclusive scientific communities are more productive, innovative, and impactful (Jimenez et al., 2019), and limiting factors for inclusion need to be urgently addressed by academic authors, leaders, and societies (Figure 4).

4.3 | Conclusion

Lists of top-publishing authors in ecology, evolution, and conservation science are still biased by underrepresentation of women and scientists from the Global South, reducing the diversity of academic leadership in these fields. By having diverse leaders with different perspectives, we can better resolve international environmental problems such as the effects of global climate change and biodiversity loss and provide role models for the next generation of ecologists. We thus encourage the international scientific community, especially those in leadership positions, to proactively promote diversity and inclusion in disciplines such as ecology and conservation (Maas et al., 2020). Many opportunities for increasing representation of women and scientists from the Global South are straightforward and therefore should be implemented immediately in scientific best practice, accompanied by measures that promote awareness and further evaluation of inequality in scientific careers.

ACKNOWLEDGMENTS

We kindly thank Danielle Descoteaux, Anne Toomey, Pamela Templer, Abe Miller-Rushing, as well as Edward Game, and two anonymous reviewers for providing comments on an earlier version of the manuscript. Open access funding was provided by the University of Vienna.

AUTHOR CONTRIBUTIONS

All authors have made a substantial contribution to the article, including study design (BM, VD and RP), data collection (BM, VD, RP, LS and LG), data analysis (BM, VD and LS), as well as writing and revising the manuscript (BM with support from all coauthors). All approved the final version for submission.

ETHICS STATEMENT

Ethics approval was not required for this study and no ethical restrictions apply because the data from top-publishing authors were obtained from public databases and are presented in anonymous form.

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Maas B, Pakeman RJ, Godet L, Smith L, Devictor V, Primack R. Women and Global South strikingly underrepresented among top-publishing ecologists. *Conservation Letters*. 2021;*14*:e12797.
https://doi.org/10.1111/conl.12797