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INSIGHTS

The changing nature of collaboration in tropical ecology and conservation

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ABSTRACT

Collaboration can improve conservation initiatives through increases in article impact and by building scientific understating required for conservation practice. We investigated temporal trends in collaboration in the tropical ecology and conservation literature by examining patterns of authorship for 2271 articles published from 2000 to 2016 in *Biotropica* and the *Journal of Tropical Ecology*. Consistent with trends in other studies and scientific disciplines, we found that the number of authors per article increased from 2.6 in 2000 to 4.2 in 2015 using a generalized linear model (glm). We modeled changes in multinational collaboration in articles using a glm and found that the mean number of author-affiliated countries increased from 1.3 (±0.6 SD) to 1.7 (±0.8 SD) over time and that increases were best explained by the number of authors per article. The proportion of authors based in tropical countries increased, but the probability of tropical–extratropical collaboration did not and was best explained solely by the number of authors per article. Overall, our analyses suggest that only certain types of collaboration are increasing and that these increases coincide with a general increase in the number of authors per article. Such changes in author numbers and collaboration could be the result of increased data sharing, changes in the scope of research questions, changes in authorship criteria, or scientific migration. We encourage tropical conservation scientists continue to build collaborative ties, particularly with researchers based in underrepresented tropical countries, to ensure that tropical ecology and conservation remains inclusive and effective.

Key words: authorship; bibliometrics; collaboration; conservation ecology; publication metrics; scientometrics; tropical.

TROPICAL ECOSYSTEMS ARE OF HIGH CONSERVATION PRIORITY DUE TO their high diversity, endemism, the ecosystem services they provide, and the risks they face from climate- and land-use change (Myers *et al.* 2000, Laurance & Williamson 2001, Perez *et al.* 2016). Unfortunately, even basic data used to inform conservation efforts in the tropics, such as data on species occurrences and diversity, are often lacking (Lenoir & Svenning 2015, Feeley *et al.* 2016). Those working in tropical ecology and conservation can help to overcome these shortcomings with increased collaboration, through the diversification of their collaborative networks and the sharing of data (Palmer *et al.* 2005, Bruna 2010, Malhado *et al.* 2014).

In recent years, there has been an increase in the frequency of multiauthored publications in several scientific disciplines, including ecology, suggesting greater collaboration among scientists (Coccia & Wang 2015, Barlow *et al.* 2018). The benefits of collaboration include increased author inclusivity (Uriarte *et al.* 2007), research that is broader in scope and scale (Hampton *et al.* 2013), and even increases in citation rates or other metrics of article impact (Hampton & Parker 2011, Nomaler *et al.* 2013, Smith *et al.* 2014, Fox *et al.* 2016). Additionally, collaboration can help build the scientific capacity in remote or threatened areas and help transform conservation theory into practice by developing dissemination pathways via increased interaction between academics and non-academic communities (Sheil & Lawrence 2004, Sunderland *et al.* 2009). Finally, because conservation issues often span geopolitical boundaries (Ricketts *et al.* 2005, Joppa *et al.* 2008), conservationists are more likely to influence conservation policy when working with local scientists (Gómez-Pompa 2004, Stocks *et al.* 2008, Sunderland *et al.* 2009).

Scientific collaboration often results in peer-reviewed articles. While not completely capturing the scope or complexity of collaboration, the analysis of the authorship patterns at the article level is an established method for quantifying trends in collaboration (Gordon 1980, Newman 2004). Previous work has quantified collaboration between tropical biologists and the productivity of tropical scientists based in different countries (Stocks *et al.* 2008, Pitman *et al.* 2011, Malhado *et al.* 2014). These studies illustrate several geographic biases in the countries of affiliation among coauthors of an article and several ways to correct them, including improved collaboration. However, it is unknown whether collaboration between tropical biologists has increased over time or whether there is greater tropical-to-"extratropical" collaboration in response to the increased awareness of the benefits of collaboration. We analyzed patterns of authorship in over 2200 articles from *Biotropica* and the *Journal of Tropical Ecology* published between years 2000 and 2016 to quantify per-article changes in the number of authors and patterns of collaboration between authors based in different countries.

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METHODS

We compiled a list of articles from *Biotropica* (BITR) and *The Journal of Tropical Ecology* (JTE) published from 2000 through 2015 using data from the journals' publisher-maintained Web sites (BITR: http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1744-7429, JTE: www.cambridge.org/core/journals/journal-of-tropical-ecology). We excluded society announcements, editorials, and errata. In 2006, *Biotropica* increased the number of issues published per year from four to six, so from 2006 to 2015, we sampled only the first four issues. We did this to avoid changing the proportion of articles from each journal over time. For each article, we recorded the names of all authors and the country in which the primary institution of each author was located. When authors were based in territories or protectorates, we recorded their national affiliation as the country with overseeing jurisdiction (e.g., Puerto Rico was recorded as the United States and French Guiana as France).

For each article, we calculated the number of authors and the number of unique countries in which these authors were based. We standardized author names after identifying potentially inconsistent author names (*e.g.*, the presence or absence of middle initials) with the 'agrep' function in base R (R Core Team 2018). Finally, we defined an author's country of affiliation as tropical if more than half of its landmass is within the tropical latitudes; all other countries were considered extratropical. Given that tropical climates may exist outside of tropical latitudes, this is likely a conservative estimate of tropically based authors.

We built generalized linear models (glms) to test the factors that best explained changes in the mean number of authors per article, the number of author-affiliated countries per article, and the collaboration between authors based in tropical and extratropical countries (Venables & Ripley 2002). First, we modeled the count data for the number of authors per article using year as the sole predictor variable with a Poisson distributed error structure. We modeled the number of author-represented countries present per article using a negative binomial glm with a log-link function with the MASS package (Venables & Ripley 2002) and considered the effects of year, author number, and their interaction. The number of authors per article was used as a covariate because articles with more authors are more likely to have a greater number of international coauthors. Finally, we modeled the probability of tropical–extratropical collaboration as a function of year, number of authors per article, and their interaction using a glm with a binomial error structure and logit-link function. We did so only with articles containing more than two authors, as single-authored articles are by definition non-collaborative. For each analyses, we performed model selection via Akaike information criteria (Fox 2016) to identify the model that bests fit the data. All analyses were performed using the R statistical programming language (v.3.4.4; R Core Team 2018) and visualized using the 'sjPlot' library (Lüdecke 2017).

RESULTS

The 2271 articles in our dataset (1140 from BITR and 1130 from JTE) collectively had 7525 authors based in 93 countries (Supporting Information). Over half of authors were based in one of four countries: the United States (26% of authors), Brazil (12%), Mexico (7%), and Germany (6%). In contrast, 60 countries had ≤25 authors each, collectively accounting for about 5% of all authors (Fig. S1). Sixty of the 93 countries met our criteria for classification as tropical; 37% of the authors were based in these countries.

The mean number of authors per article increased from 2.6 in 2000 to 4.2 in 2015 (Fig. 1; Table 1 & Table S2). From 2000 to 2015, there was a significant increase in the number of countries per article (from 1.3 ± 0.6 SD to 1.7 ± 0.8 SD) (Fig. S2), but the best model for the number of author-affiliated *countries* per article included solely the number of authors per article (Table 1). However, the second-best model was nearly indistinguishable from the first and included an interaction between year and number of authors per article (Table 1; Table S3; Fig 2.). According to this second model, recent years' articles with less than five authors were slightly more collaborative, while articles with greater than five authors were less collaborative through the entire period that we reviewed.

From 2000 to 2015, the percentage of articles (including single-author articles) with exclusively extratropical authors decreased from 57% to 42% (Fig. S3). Over the same time period, tropical–extratropical collaborations increased from roughly one-fifth to one-third of all publications, while the proportion of articles whose authors were entirely based in tropical countries was at most 31% (Fig. S3). The probability of tropical–extratropical collaboration rose from 25% to 35%, but this increase was not significant (Fig. S4). The probability of tropical–extratropical collaboration was best explained solely the number of authors per article (Table 1).

DISCUSSION

Previous work has shown that the lead authors of most papers published in *Biotropica* and the *Journal of Tropical Ecology* from 1995 to 2004 were based in the United States, Brazil, UK, and Mexico

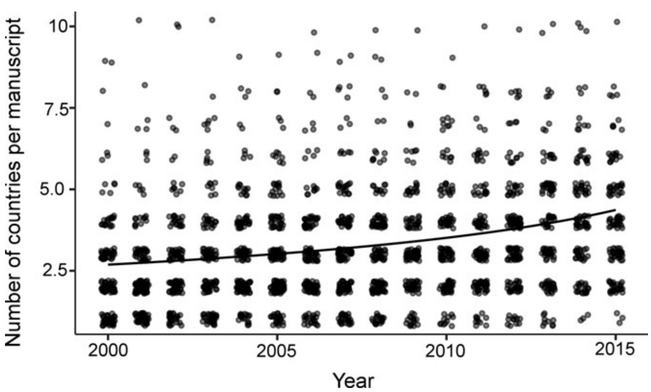

FIGURE 1. Observed number of authors per article ± standard deviation and the glm-modeled increase over time. Points offset slightly within years to illustrate the overlapping data.

TABLE 1. *Generalized linear model (glm) specifications and model selection for the three models used to investigate trends in collaboration in the tropical ecology and conservation literature (*Biotropica *and* Journal of Tropical Ecology *2000–2016).*

Response	glm specification	Residual deviance	Residual df	Delta AIC	AIC weight
Number of authors per article	**1) Year**	**2238**	**2269**	**0**	**1**
Number of countries per article	1) Year	695	2269	194	0
	2) Year * number of authors	496	2267	0	0.49
	3) Number of authors	500	2269	0	0.51
Probability of tropical-extratropical collaboration	1) Year	2398	1973	220.7	0
	2) Year * number of authors	1973	1973	3.7	0.1
	3) Year + number of authors	2177	1973	1.9	0.25
	4) Number of authors	2177	1973	0	0.65

Counts for the number of authors per article (null df = 2270, null deviance = 2394) were modeled with a Poisson glm, the number of countries per article (null df = 2270, null deviance = 709) was modeled with a negative binomial glm, and the probability of tropical–extratropical collaboration (null df = 1976, null deviance = 2405) was modeled with a binomial glm. The final models for each response variable are in bold.

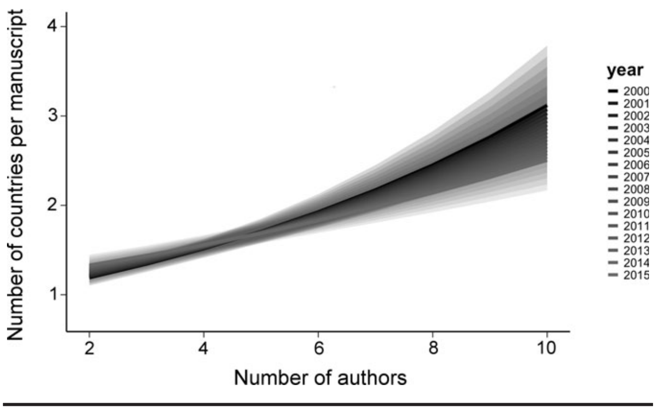

FIGURE 2. The predicted number of author-affiliated countries per article as a function of the interaction between year and number of authors per article. Line colors show the modeled interaction between the number of authors and the number of countries represented by coauthors per article by year. Shaded areas are 95% confidence intervals for the negative binomial generalized linear model (Table S3).

(Stocks *et al.* 2008). Our analyses of articles published in these journals from 2000 to 2015, which we expanded to include all authors, show that these are still the countries where the majority of authors are based. Furthermore, authors with extratropical country affiliations are nearly twice as likely as tropically based authors to be represented in these journals. Even among authors based in tropical countries, however, there were major geographic disparities—authors were concentrated among a relatively small number of countries (particularly Brazil and Mexico).

We also found mixed evidence for whether there had been increases in international collaboration between 2000 and 2015. The increase in the number of authors per article (Fig. 1) suggested that there was indeed more collaboration. However, the per-article number of countries in which authors were based increased only slightly and was mostly due to a positive correlation with the number of authors per article. Furthermore, an increase in tropical–extratropical collaboration over time was most likely for articles with less than five authors, and despite an increase in the representation of authors based in tropical countries, the probability of tropical–extratropical collaboration did not substantially change. Our results may suggest greater collaboration and geographic diversity in the field of tropical ecology and conservation than there is in the broader community of tropical biologists. This may be because the first authors of articles in JTE and BITR are based in more countries than those of articles in general ecology or conservation journals (Stocks *et al.* 2008). It remains to be seen whether tropical–extratropical collaborations, and how they vary with author number, are similar in broader ecological journals publishing research carried out in the tropics.

Our findings are consistent with those of other studies (Coccia & Wang 2015, Logan 2016, Barlow *et al.* 2018) that have observed increases in the number of authors per article. It has been speculated that the rising number of authors per article is a consequence of 'big science' in which authors collaborate to address broad ecological questions (Gordon 1980, Hampton *et al.* 2013) that often require the compilation of large datasets (Cadotte *et al.* 2012, Hampton *et al.* 2013). It may also be due to the inclusion of previously uncredited technicians and assistants (Mammides *et al.* 2016), increased scientific specialization among scientists (Kostoff 2002, Gould 2015), and the labor-intensive work that goes into conducting ecological studies (Newman 2004, Coccia & Wang 2015). Alternatively, the increase in the number of authors per article may simply reflect changing criteria by journal editors and reviewers for what is considered a contribution that merits author attribution (Weltzin *et al.* 2006, Tscharntke *et al.* 2007, Logan 2016). It is also conceivable that increased collaboration is influenced by a change in scientist mobility (Jöns 2007, Jonkers & Tijssen 2008). All of these factors may have led to the general increase we observed in international collaboration among tropical biologists.

Our analyses are encouraging in that they suggest increases in the numbers of authors per article should result in more international and tropical–extratropical collaborations. An important caveat, however, is that multinational collaboration decreased over time for articles with more than five authors. Similarly, while the proportion of tropically based authors increased, there was no change in the probability of tropical–extratropical collaboration over time. Given that a lack of tropical–extratropical collaboration may limit the advancement conservation initiatives needed to protect tropical ecosystems *in situ* (Gómez-Pompa 2004, Ricketts *et al.* 2005, Joppa *et al.* 2008), future work should attempt to identify the mechanisms behind these patterns so that strategies to mitigate them can be developed. The same is true for other economic and geopolitical biases known to influence a country's scientific productivity (Stocks *et al.* 2008, Smith *et al.* 2014, Livingston *et al.* 2016, Espin *et al.* 2017), which also influence engagement in international collaboration. Finally, we encourage all researchers to be more proactive in developing multinational collaborations, especially with scientists in underrepresented tropical countries. Doing so will help advance conservation in tropical ecosystems and to reduce the geographic biases that remain pervasive in tropical biology.

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DATA AVAILABILITY

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.d79c4cs (Perez & Hogan 2018).

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article:

TABLE S1. A key to the country codes in Fig. S1 and accompanying designations of tropical and rare tropical countries.

TABLE S2. Model coefficients, 95% confidence interval, and coefficient probabilities for the number of author numbers per article over time as modeled using a Poisson distribution error structure glm.

TABLE S3. Model coefficients, 95% confidence interval, and probabilities for year, number of authors and their interaction as modeled using a negative-binomial generalized linear model for predicting the number of countries per article.

FIGURE S1. Ranked author abundance by country from 2000 to 2015.

FIGURE S2. The number of author-affiliated countries per article as a function of the interaction between year and number of authors per article.

FIGURE S3. Changes in the cumulative proportions of publications with varying percentages of tropical authors per year.

FIGURE S4. The probability of tropical-extratropical collaboration as a function of year as modeled with the logistic binomial glm.

APPENDIX S1. Methods.

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