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Myrmecology, Gender, and Geography: changing demographics of a research community over thirty years

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Abstract

Diversity is a driving force of innovation and creativity in scientific research. Therefore, supporting and maintaining diversity is a priority within academic communities. Gender is an important but understudied aspect of diversity in most scientific fields, including entomology. Women remain underrepresented in paid academic positions, despite the fact that nearly half of earned PhDs in science are awarded to women. With the goal of documenting contemporary demographic patterns and highlighting generational change in the global myrmecological community, we examined author gender ratios and publication rates over the past three decades, both globally and by country affiliation. Approximately one third of authors publishing about ants during 2008 - 2017 were women, which is similar to reported rates of their representation in other scientific fields. Over the past three decades, the total number of researchers studying ants has increased and the proportion of women authors in myrmecology has risen from 17.6% in 1987 to 27.7% in 2017. Despite this increase in representation, women publish fewer papers than men, both cumulatively and annually. This gender-specific publication gap has not diminished over the past decade. Only five women rank among the 50 authors with the greatest number of publications during the past decade. Representation of women varied among the 105 countries with which myrmecology publications were associated, and women were underrepresented in nearly all. In the 10 countries with the greatest numbers of authors and highest numbers of publications, none had a gender-ratio biased towards women. Overall, these findings describe a myrmecological community that has grown significantly over thirty years, with an increasing proportion of women. Although this trend suggests a rising generation of myrmecologists that is more gender diverse than ever before, continued lack of parity in representation of women and their productivity are areas of concern. Further examination of these issues will inform our understanding the composition of the myrmecologist community. This data-based approach is a first step toward dismantling barriers and ensuring equity for members of all genders in our next generation of researchers.

Key words: Ants, Formicidae, disparity, diversity, inclusion, equity.

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Introduction

Diversity in science: Diversity is a driving force of innovation and creativity in scientific research. The benefits of fostering diverse working collaborations, namely increased innovation and productivity, have been demonstrated across many fields, including Science, Technology, Engineering, and Mathematics (STEM) (Page 2008, Woolley & al. 2010, Moss-Racusin & al. 2012, Freeman & Huang 2014). Professional collaborations that are representative of broad cultural and social backgrounds aid in fueling creativity through challenges to established norms, exposure to novel perspectives, and exchange of information and ideas (Adams 2013, AlShebli & al. 2018). In recent years, considerable efforts have been made to facilitate greater equity and inclusion of underrepresented groups in STEM fields (Valantine & al. 2016, Hodapp & Brown 2018). Several initiatives have aimed at creating workspaces and collaborations that are more inclusive with respect to gender, race, ethnicity, nationality, socioeconomic class, and more (Fox 2008, Allen-Ramdial & Campbell 2014). However, quantitative data on diversity in research are often lacking, making it difficult to mitigate disparities. These knowledge gaps are especially pervasive in highly specialized subdisciplines, such as myrmecology, where little data on researcher demographics have been collected (but see Ramalho & al. 2020a). Here, we focus on one aspect of diversity, gender, and associated demographics of authorship among ant researchers, including publication rate and national affiliation. While we recognize that gender is non-binary, these metrics can still offer tractable measures of one aspect of diversity and equity in the global community of myrmecologists.

Women in science: Nearly half of earned PhDs in science are awarded to women, yet they remain underrepresented in paid academic positions in most scientific fields (Rossi 1965, Shen 2013, Sheltzer & Smith 2014), including entomology (Walker 2018, Wiedenmann & al. 2018). The women who occupy these positions face barriers to advancement, and they are less likely than men to be retained in research positions (Adamo 2013) and advance to prominent leadership roles (Williams & al. 2017, Berenbaum 2019). A cascade of contemporary research has consistently identified gender bias in academic activities, where women are underrepresented on editorial boards (Cho & al. 2014), as reviewers for journal articles (Walker 2018), among speakers at high-profile academic venues (Nittrouer & al. 2018), and as nominees for major awards (Lunnemann & al. 2019). Awards, when granted, are of lower value than those bestowed upon men (Ma & al. 2019). These studies are informative in identifying gender bias as a contributor to lack of parity, despite the fact that their inclusivity is limited to a binary definition of gender which fails to encompass the full spectrum of gender identity and expression (MORADI & PARENT 2013). Gender bias that manifests in inequities such as those described above may be due to explicit or implicit discrimination, differential resource allocation (Ceci & Williams 2011), or relate to life choices (Ramalho & al. 2020b), but is common across STEM fields. Additionally, the longstanding, but erroneous belief that national economic status is a principal determinant of gender equity (Gaddis & Klasen 2014) can confound efforts to support the advancement of women. Identifying barriers to the success of underrepresented STEM professionals is an essential step for supporting equity in the broader community of researchers. Publications on this topic universally highlight the need for high-resolution data on the status of gender equity to set goals for increasing parity in individual fields. In response to this need, this study assesses gender across the global myrmecological community.

Myrmecology: The field of myrmecology encompasses basic and applied research on ants, comprising many subdisciplines of the biological sciences, including taxonomy, evolution, ecology, behavior, biochemistry, physiology, and toxicology. Research on ants also intersects with other scientific fields, such as physics, mathematics, computer science, and engineering. Researchers work with ants for a variety of reasons that extend beyond the value and importance of the subjects themselves. For example, taxonomic and genomic resources on ants that are available for research make this group of arthropods one of the most tractable and diverse lineages of non-model organisms on earth. Myrmecologists, therefore, are a broad swath of researchers – here we include those who may not define themselves first and foremost as myrmecologists, but whose work nevertheless focuses on ants.

The earliest researchers credited in ant science are primarily European and American men who worked in the late 19th and early 20th centuries. Swiss researcher Auguste Forel is often referred to as the first myrmecologist, and the term "myrmecology" was coined by American entomologist William Morton Wheeler (Georgiadis & Trager 2015). However, women also made important contributions to research on ants. Although their works may be less numerous or less widely known, these scientists include such luminaries as British entomologist Lucy Evelyn Cheesman, who collected extensively in the Pacific (Touzel & Garner 2018), and American ecologist Mary Talbot, who devoted more than half of a century to studying ant ecology and behavior (Kannowski 2012). As the study of ants has expanded over the years, the global community of myrmecologists has broadened dramatically. Early scientists largely conducted research independently, an approach that starkly contrasts with modern workflows for collaborative research, which today require cooperation across countries, institutions, and scientific disciplines. This shift in *how* science is conducted, and the expanded foci of research conducted on ants, has also been accompanied by transitions in *who* studies ants.

The goal of this study was to characterize the contemporary gender diversity of the global myrmecological community and document changes in the composition of participants over time. We specifically asked 1) is the proportion of women, globally and by country, similar to those in other STEM fields?; 2) are publication rates of women equivalent to those of men?; and 3) how have these metrics changed over the past three decades? We assembled information to answer these questions from author names and affiliations associated with peer-reviewed ant-focused research articles from the past decade (published 2008 - 2017). We also retrieved data from twenty (1997) and thirty years (1987) ago to evaluate trends over time.

The authors of this study self-identify as members of some underserved groups (i.e., women, lesbian/gay/bisexual/transgender/queer (LGBTQ) individuals, people of color, first generation college students), but are aware that we do not speak for all members of the communities to which we belong and do not represent all axes of diversity. We acknowledge our individual privileges as able-bodied, educated individuals with advanced degrees, and we recognize that we cannot fully understand the experiences of all myrmecologists. We do, however, strive to be allies to and with marginalized groups in myrmecology through meaningful action to promote inclusivity. In compiling these data and making them publicly available, we aim to establish baseline data for evidence-based discussions about existing diversity among myrmecologists. Our research community has the potential to advance through increased diversity, enhancing productivity, innovation, and visibility. In order to support diversity and excellence in the next generation of myrmecologists, we must first understand who we are as a group.

Materials and methods

Human subjects research: This study was reviewed by the University of Florida Institutional Review Board (IRB#201902902) and approved as exempt.

Methodological limitations: The goal of this research was to identify disparities in the myrmecological community in an effort to reduce inequities. The authors openly acknowledge that the data upon which these conclusions are based cannot address all aspects of diversity. Six points in particular are possible sources of error: 1) *Diversity* is more than gender and national affiliation. Truly describing demographic trends in our community requires identifying factors that encourage, or limit, participation of all groups in myrmecology research. 2) *Gender* is not binary, and therefore the binary gender designations used in this study do not reflect the reality of gender as a spectrum. The limits of available gender designations are a result of cis-normative understanding of gender, which is mirrored in the typical perceptions (and biases) of most professional communities and career-impacting groups such as job search committees, journal editors, and peer reviewers. Self-reported gender would more accurately reflect each author's identity. 3) *Name-based gender inference* is more successful with names of European origin, in general (Santamaría & Mihaljević 2018). The greatest number of names in our dataset for which gender inference was not possible were those transliterated from non-Latin alphabets. 4) *Country affiliation* of authors is based on institutional location rather than origin of individuals. Because many researchers work abroad temporarily (e.g. graduate training, postdoctoral positions) or permanently, this metric is therefore an imperfect measure of international diversity of authors. 5) *Publication venues* included in this study are not exhaustive, and myrmecological literature can be found in many journals not indexed by Web of Science. An unintended consequence of this approach is that this dataset is English-language biased and likely favors experimental research over publications focused on taxonomy and natural history observation. 6) *Authors* in this study are treated equally, regardless of authorship position on a publication, and without regard to journal ranking. Both factors matter for professional advancement, and first and last author position usually indicate lead researcher position for the individual study and of the lab group, respectively. Future studies should consider how to address these concerns, as further enhancing the granularity of results will increase our ability to assess and promote diversity.

Data acquisition: Metadata were assembled for myrmecological literature published from 2008 to 2017 by conducting a search of the Web of Science (WoS) Core Collection database using the following search string: (*Topic* = formicid* OR myrmecol*) AND (*Year published* = 2008 - 2017) on 8 September 2018, at the University of Florida; the same criteria were used for a search of years 1997 and 1987, conducted on 8 November 2018. The authors refined the results of the search to include only peer-reviewed journal articles, reviews, and book chapters. Finally, the following data for each of the resulting reference records were downloaded: Author / Editors, Addresses, ISSN / ISBN, IDS Number, Title, Times Cited, Language, Accession Number, Source, Document Type, Keywords, Source Abbreviation, WoS Categories, Author identifiers, Conference Information, Research Areas, and Usage Count. Duplicate records were eliminated and the resulting reference records were processed, where authors were disambiguated using the "refsplitr" package (Fournier & al. 2020) with (R Core Team 2020), the platform used for all analyses described below.

A dataset was generated based on unique combinations of authors and publications, from which author and publication metrics were calculated. To focus on trends associated with the most active members of the myrmecology community, a dataset from 2008 to 2017 was generated that excluded singleton authors – defined as authors for whom only a single published paper was recovered for the examined time period. Singletons were included in 1997 and 1987 datasets because most authors in both years were associated with only a single publication.

Author gender classification: Gender was inferred for each author in the dataset as: woman, man, or unknown, using name-to-gender inference services in a three-step process, which was adopted to reduce misclassification rate as much as possible (Santamaría & Mihaljević 2018) (but see methodological limitations above). For each dataset, 1) names were assigned gender probabilities based on first names using the Genderize.io API via the "genderizeR" package in R (Wais 2016, Genderize ND). Gender classifications with a probability of 80% and above were accepted, and any assignment with probability below 80% was then 2) investigated further using *Gender.api* (Gender api 2016), which assigned gender probabilities based on first names. Gender assignments with a probability of 80% and above were accepted, and assignments with probability below 80% were investigated further by 3) manually searching for identifying pronouns in publications and online professional websites. When publications did not identify authors by first names, but cited first and middle initials only, significant effort was dedicated to identifying full names for gender inference. Authors were coded as unknown if it was not possible to infer gender as described above; the category "unknown" does not refer to non-binary individuals.

Country affiliation: For each publication record from 2008 to 2017, the author's primary institution was used to infer country affiliation and georeferenced using the "refsplitr" package in R (Fournier & al. 2020). Authors with no affiliation listed on publications and were coded as "NA". Country affiliation was not readily available for authors in 1997 and 1987 datasets. Authors in the 2008 - 2017 dataset that were affiliated with different countries on separate papers (e.g., an author changed institutions, and thus national affiliation) were included in each country's total author count. However, authors were only counted once when calculating global author totals. Proportion of women authors was determined by dividing the number of women by the total number of authors within each unit of time and geographic region. The average proportion of women authors was calculated, globally, based on countries with 10 or more authors from 2008 to 2017 (61 countries). For individual countries, average authorship proportion was calculated using data from countries that had a minimum of three publications, published during at least two separate years, as this provided more precise national authorship proportions (79 countries).

Publication numbers: To assess differences in total publication numbers between women and men, a generalized linear mixed-effects model was run using R statistical software, where total paper counts for each *unique author* were a function of gender, and random intercepts of "Years" and "Country" accounted for potential variation between years and countries, respectively. Multi-authored papers were represented in this modeling framework multiple times, once for each author. This model was also used to evaluate the singleton-excluded dataset. A multi-model approach was used, with three model derivations: one used a negative binomial error distribution (link = log), the second used a Poisson error distribution (link = log), and the third was a null model response variable set to a function of 1. All models were compared and ranked utilizing Akaike Information Criterion (AIC) scores, a framework regarded as less biased than step-wise model selection (Burnham & Anderson 2004). These three models were the final models evaluated within the AIC framework because other models with more complex random effects did not achieve model convergence despite the implementation of various model optimizers. For all statistical tests an alpha level of 0.05 was used to assess statistical significance.

GDP and population data were used to calculate per capita gross domestic product (GDP) of each country in the dataset from 2008 to 2017, providing a means of assessing author gender ratios in the context of national economic growth. National GDP (in US $) and total population data were downloaded from The World Bank Databank's World Development Indicators database (World Bank 2019). Taiwan was not included in the GDP data and was therefore removed. A mixed-effects model with a Gaussian error distribution was used to assess the relationship between per capita GDP and women authorship proportions. To assess model performance, diagnostics of fitted values compared to model residuals, fitted values to actual values, and marginal and conditional R^2 values were observed using the "MuMIn" package in R (Bartoń 2013). Average annual numbers of publications by women, men, and unknown authors from 2008 to 2017 were calculated by averaging the total number of papers associated with each unique author for each year. Visual comparisons were used to assess differences in publication rates from the 2008 - 2017 dataset with datasets from prior decades, as data from 1987 and 1997 represent discrete years rather than averages of values accumulated over a decade. All mixed effect models were run using the "lme4" package (Bates & al. 2015) and all graphics were produced using the "tidyverse" package (Wickham & al. 2019) in R.

Change over time: To assess temporal trends in the proportion of women publishing in myrmecology during 2008 - 2017, two statistical approaches were used. For both, the proportion of women and men was calculated by dividing the total number of authors per gender by the sum of all authors for a given year. First, the 2008 - 2017 data were split into two time categories (2008 - 2012 and 2013 - 2017) and compared the means of women author proportions between the time periods using a t-test in R. The normality and homogeneity of variances in the data were assessed using a Shapiro-Wilkes test in R and a Levene's test using the "car" package (Fox & al. 2007), respectively. Second, for singleton authors, a simple linear model was run in R on gender proportions of authors as a function of year and model assumptions and diagnostics were evaluated based on residual diagnostic plots. This linear model could not be applied to overall women authorship proportions because data failed to meet model assumptions.

Data availability: To encourage further research in this area, this dataset, including metadata used in the analyses and graphics, is available as digital supplementary material to this article, at the journal's web pages (Appendix S1).

Results

The myrmecological community has grown to be large and prolific. Our Web of Science search recovered 4817 publications from the past decade (2008 - 2017), work produced by 8106 authors from 105 countries. Singletons (i.e., authors publishing a single paper) comprised 69.7% (n = 5653) of all authors during this period. The remaining subset of authors that published two or more papers included 2453 individuals. We recovered 202 publications associated with 401 authors in 1997, ten years prior to the 2008 - 2017 dataset. Two decades earlier, in 1987, we found 59 papers associated with 96 authors (Tab. 1). Singletons were not removed from 1997 and 1987 datasets because most of these authors published only a single paper in a given year.

Women's representation: During the decade spanning 2008 - 2017, women comprised 32.9% (n = 2671) of unique authors, whereas men constituted 63.1% (n = 5120) and authors of unknown gender 3.8% (n = 314) (Tab. 1). When singleton authors were excluded from the 10-year dataset, representation of women was lower, at 29.4% (n = 721, 67.8% men, n = 1662; 2.85% unknown, n = 70). Among the decade's singletons, men were also more numerous than women: 34.5% of authors were women

Tab. 1: Authorship, by gender, of myrmecological publications in 1987, 1997, and 2008 - 2017. Table provides total paper and author numbers as well as the genders that make up these values. Publications include peer-reviewed journal articles, reviews, and book chapters.

Year(s)	Number of papers	Number of authors	% Women (number of authors)	% Men (number of authors)	% Undetermined (number of authors)
1987	59	96	16.7% (16)	78.1% (75)	5.2% (5)
1997	202	401	20.7% (83)	78.3% (314)	1.0% (4)
2008	398	993	25.8% (256)	71.7% (712)	2.5% (25)
2009	412	1066	26.8% (286)	70.8% (755)	2.4% (25)
2010	445	1205	30.5% (368)	66.5% (801)	3.0% (36)
2011	484	1280	29.7% (380)	66.6% (853)	3.7% (47)
2012	470	1198	29.1% (349)	67.5% (809)	3.3% (40)
2013	480	1334	31.0% (414)	65.4% (873)	3.5% (47)
2014	499	1364	28.6% (390)	68.1% (929)	3.3% (45)
2015	537	1603	30.9% (496)	66.4% (1065)	2.6% (42)
2016	550	1698	32.6% (554)	64.4% (1094)	2.9% (50)
2017	542	1717	30.6% (525)	66.0% (1134)	3.4% (58)
2008 - 2017 annual average	481.7	1345.8	29.6%	67.4%	3.1%
2008 - 2017 annual average Singletons excluded	781	1216	26.4% (206.8)	71.5% (556.7)	2.2% (17.1)
2008 - 2017 annual average Singletons only	565.2	565	34.0% (195)	61.6% (345.8)	4.4% (24.4)
2008 - 2017 (total)	4817	8105	32.9% (2671)	63.1% (5120)	3.8% (314)

(n = 1950), 61.2% were men (n = 3458), and 4.32% were unknown (n = 244). Of the total number of women authors, 73.0% published only a single paper during these ten years, a higher proportion than among men (67.5%; unknown = 77.7%).

The proportion of women in the myrmecology community was also calculated as an annual average: 29.6% (67.4% men, 3.1% unknown); this number was lower than the proportion of women summed across the entire decade (Tab. 1, Fig. 1, Fig. 2). The average annual proportion of women with more than one paper represented in this dataset was even lower, at 26.4% (71.5% men, 2.2% unknown). Among authors associated with only a single paper, the average annual proportion of women was 34% (61.6% men, 4.4% unknown).

Individual countries differed in author gender ratios, but men predominated in the vast majority (Appendix S1). In the ten countries with the greatest number of authors in the 2008 - 2017 decade, representation of women was highest in Mexico (35%) and Brazil (35%), and the lowest was in Japan (10%) (Fig. 3). The overall global proportion of women authors was 30.2% during the decade of 2008 - 2017; national proportions of women ranged from 4.8% (Saudi Arabia) to 83.3% (Sri Lanka). Among all nations publishing in myrmecology, some departed notably

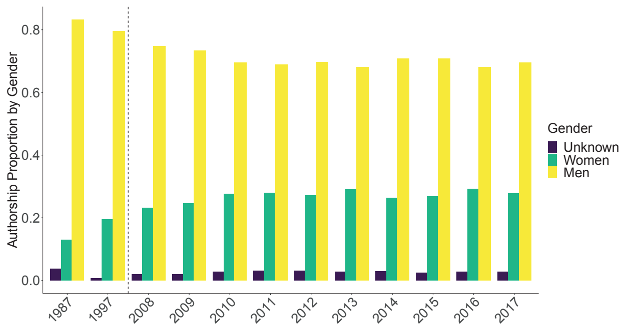

Fig. 1: Proportion of women, men, and unknown authors of publications in the field of myrmecology from 2008 to 2017, retrieved from the present study. Colors indicate gender. Dotted vertical line represents cutoff between the pre-2000 and post-2000 datasets.

from average gender ratios. Countries with very high representation of women included Sri Lanka (83.3%), Bulgaria (77.8%), and Croatia (66.7%) – all of which had small research communities of 16 or fewer authors. Argentina was the only country with a large research community where the majority of authors were women (55.0%, n = 169 total authors). By contrast, countries with poor representation of women were more common. They included

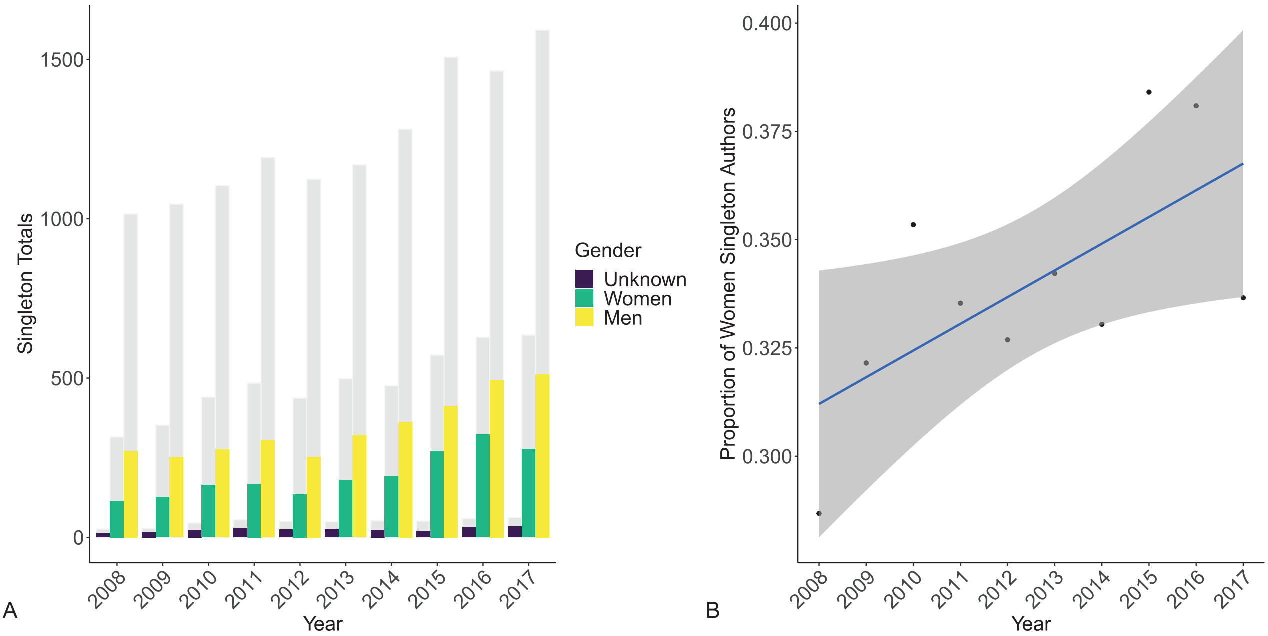

Fig. 2: Singleton authors counted by research papers in the field of myrmecology, retrieved from the present study. (A) Annual number of singleton authors, by gender, publishing in myrmecology from 2008 to 2017. Grey bars represent the total number of authors by gender and year from the total dataset. (B) Linear regression indicates a significant increase in the proportion of women authors among singletons, in relation to men, as a function of time (years).

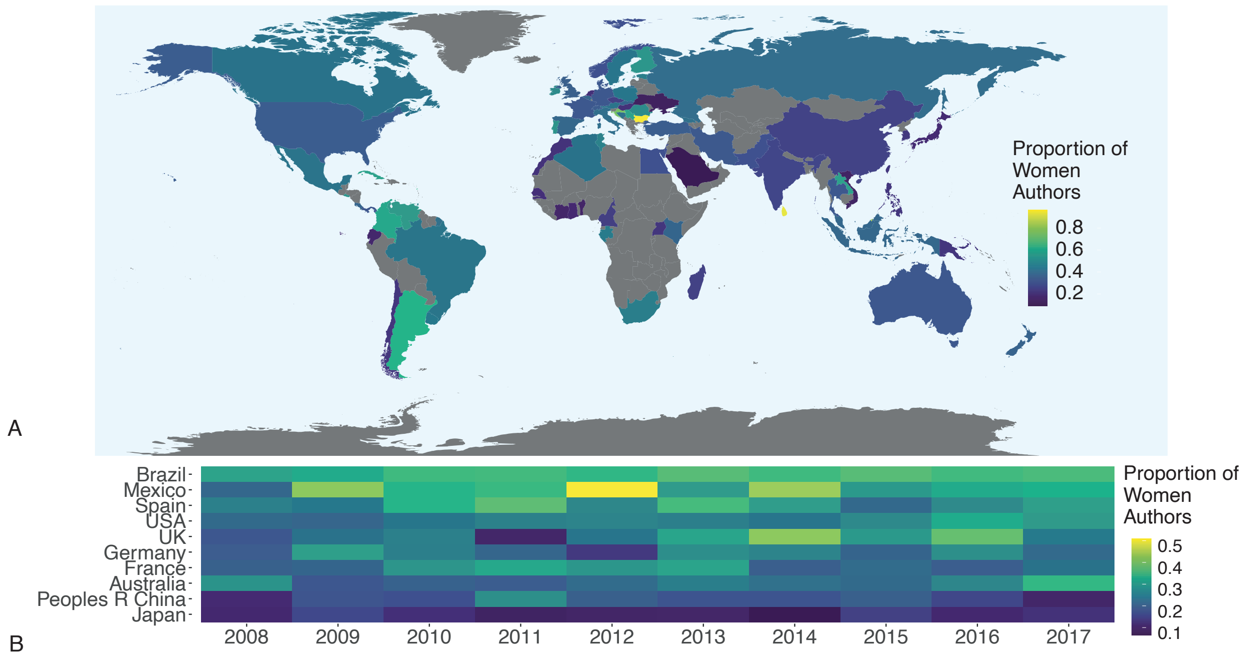

Fig. 3: Global proportion of women authors, by country, calculated with data from the 79 countries with three or more publications from 2008 to 2017, published during at least two years. (A) Global map showing annual authorship proportion of women in 79 countries, averaged across all years. Color gradient reflects the proportion of women authors. (B) Annual proportion of women authors in the ten countries with the greatest number of total authors between 2008 and 2017.

countries with small communities of 16 or fewer authors – Ukraine (12.5%), Philippines (14.3%), Uganda (15.4%) – to medium, with 20 - 50 authors – Hungary (2.0%), Saudi Arabia (4.8%), Ecuador (14.3%) – and large, with more than 300 authors – Japan (15.2%).

Influence of per-capita GDP: Per capita GDP did not significantly influence the proportion of women authors, as shown by the results of a linear mixed-effects model ($p > 0.05$, marginal R^2 value = 0.01; conditional R^2 value = 0.62). Rather, other country-specific differences

Tab. 2: Average annual number of publications per author, by gender, in 1987, 1997, and 2008 - 2017. Average values are separated by gender and standard error for each gender is provided. Total averages by decade (with and without singleton authors) are also provided. SE = standard error.

	Women		Men		Unknown	
	Average annual number of publications	SE	Average annual number of publications	SE	Average annual number of publications	SE
1987	1.06	0.06	1.45	0.10	1.00	0.00
1997	1.19	0.06	1.28	0.05	1.00	0.00
2008	1.23	0.04	1.43	0.04	1.04	0.04
2009	1.23	0.04	1.39	0.04	1.12	0.09
2010	1.19	0.03	1.38	0.04	1.25	0.15
2011	1.27	0.04	1.40	0.03	1.17	0.08
2012	1.25	0.04	1.39	0.04	1.25	0.13
2013	1.20	004	1.34	0.03	1.04	0.03
2014	1.22	0.03	1.38	0.03	1.16	0.05
2015	1.15	0.02	1.42	0.04	1.21	0.09
2016	1.13	0.02	1.34	0.03	1.18	0.06
2017	1.21	0.03	1.40	0.03	1.07	0.03
Mean 2008 - 2017 (with singletons)	1.21	0.01	1.39	0.01	1.15	0.03
Mean 2008 - 2017 (without singletons)	1.40	0.02	1.62	0.02	1.38	0.07

accounted for approximately 61% of the variance in the proportion of women.

Publication number: The number of myrmecology publications per author recovered in this dataset varied considerably during the decade ranging from 2008 to 2017. Only five women ranked in the top 50 highest-producers of peer reviewed publications (Tab. S1). One woman author was among the top ten publishers, a group that collectively authored 12.6% of all papers from 2008 to 2017, and whose individual paper counts ranged from 43 to 104 publications. The first, second and third highest-publishing women ranked 7th (n = 50), 16th (n = 36), and 37th (n = 29) in total publication counts, respectively.

Across the decade, the average annual number of publications per author was 1.21 for women, 1.39 for men, and 1.15 for unknown authors (Tab. 2, Fig. 4). When singleton authors were excluded, the average annual number of publications was higher for all authors, with 1.40 papers, on average, for women, 1.62 for men, and 1.38 for unknown authors.

Results from the mixed-effects model, which accounted for differences between years and countries, supported the finding that men published more papers than women (Tab. 3). Total paper counts for women and men differed substantially among countries ($p < 0.05$, marginal $R^2 = 0.17$, conditional $R^2 = 0.78$). Results were similar when singletons were excluded from the dataset, and the model fit did not change (marginal $R^2 = 0.17$, conditional $R^2 = 0.79$).

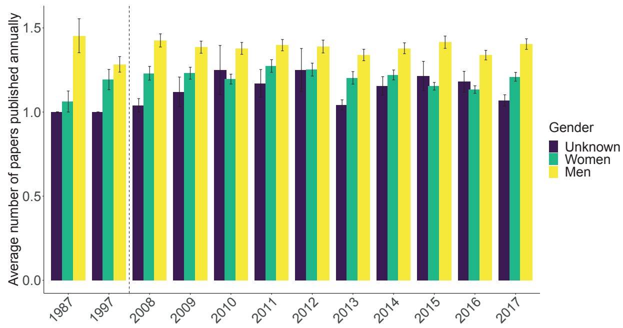

Fig. 4: Average number of papers per author, by gender, in 1987, 1997, and 2008 - 2017. Colors indicate gender and error bars represent the standard error of each average value. Dotted vertical line represents cutoff between the pre-2000 and post-2000 datasets.

The countries with the largest myrmecology communities, based on number of publishing authors from 2008 to 2017, were the USA (n = 1475), Brazil (n = 894), Germany (n = 370), Australia (n = 295), France (n = 282), Japan (n = 280), the People's Republic of China (n = 217), the United Kingdom (n = 196), Spain (n = 161), and Mexico (n = 99) (Fig. 5). In these countries, as in nearly all countries, men published more papers (n = 3498) than women

Tab. 3: Model output from a mixed-effect negative binomial model assessing total paper counts as a function of author gender with random effects of time (Year) and count incorporated in the model structure. Men had statistically higher mean paper counts than women or authors of unknown gender. SD = standard deviation; SE = standard error.

Random effect:				
Name	**Variance**	**SD**		
Country	1.247	1.117		
Year	0.012	0.109		
Fixed effects:				
Name	**Estimate**	**SE**	**z-value**	**P-value**
Intercept (Unknown)	-0.618	0.180	-3.430	<0. 001
Women	1.163	0.127	9.173	<0. 001
Men	2.085	0.125	16.739	<0.001

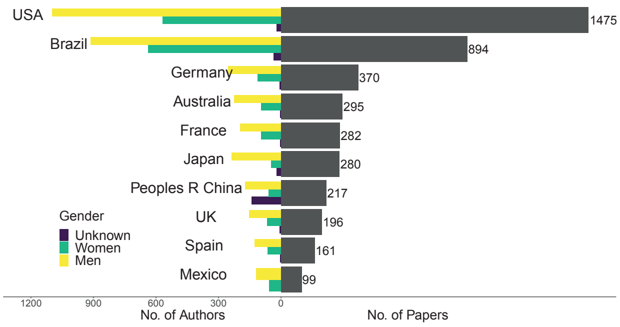

Fig. 5: The 10 countries associated with the greatest numbers of publications in myrmecology from 2008 to 2017, retrieved in the present study. Number of authors by gender (left, colors represent different genders) and total number of papers (right) are presented for each country.

(n = 1798) during the decade. The average annual number of publications per author, by gender, in these ten countries was only slightly higher than for all countries worldwide, with 1.22 (SE 0.02) papers for women, 1.41 (SE 0.01) for men, and 1.18 (SE 0.04) for unknowns. When singletons were excluded, annual publication number per author, by gender, in these ten countries increased for both men and women, with the average number of papers by men (1.65, SE 0.02) remaining higher than those authored by women (1.40, SE 0.03) and unknown authors (1.43, SE 0.01).

The average number of publications by men exceeded those by women during the 2008 - 2017 decade in nearly all nations outside of the top-ten countries (based on total number of papers). Women out-published men in only two nations, Bulgaria and Slovakia. However, both countries had fewer than ten published authors over this decade. Women did not publish more than men in any country with more than ten authors during the decade from 2008 to 2017.

Trends over time: International representation in the myrmecology literature has grown over the thirty-year time period examined in this study. While country affiliation data were not available for all publication records from 1987 and 1997 in the Web of Science database, the available data show that authors from 11 countries were represented via publications in 1987, with the greatest number of authors affiliated with the USA (13), followed by Belgium (4), France (3), and Germany (2). Authors from 40 countries were represented in 1997, with the greatest number affiliated with the USA (49), followed by France (11), and Brazil (8). Myrmecology publications from 2008 to 2017 included authors from 105 countries, with individuals in the USA, Brazil, and Germany represented in the highest numbers.

Representation of women over time: Participation by women in myrmecological research has increased globally over 30 years. Women authors represented 17% of the community in 1987 (78% men, 5% unknown) (Tab. 1). Ten years later, in 1997, representation of women was higher, at 21% (78% men, 1% unknown). The following decade, in 2008, 23% of authors were women (75% men, 2% unknown), and data from 2017 indicate that 28% of authors were women (70% men, 3% unknown). Despite this increase in women over three decades, there has been no statistically significant change in annual proportion of women over the past ten years. There was no difference in proportion of women during the first five years, 2008 - 2012, as compared to the second five years, 2013 - 2017 ($p > 0.05$, t-value ≅ 0). The proportion of women singletons, authors with a single myrmecological publication, also increased over the 30 years we examined, from 22.2% in 1987 to 33.6% in 2017. From 2008 to 2017, the proportion of women singletons increased significantly in relation to men singletons (Fig. 2) ($p < 0.05$, adjusted-$R^2 = 0.36$).

Publication number over time: The average number of indexed publications per author, overall, has not grown over 30 years. Authors published slightly more than one paper per year, on average, in 1987 (mean = 1.26 ± 0.04) and in 1997 (mean = 1.36 ± 0.08). During the decade from 2008 to 2017, the average annual number of publications per author was similar (mean = 1.33 ± 0.01).

Men out-published women during each year examined in this study. This gender-based difference in publication rate was greatest in 1987. After this time, the annual gap in publication rate was lower but no trend (decreasing or increasing) was detected (Tab. 2, Fig. 4). Publication rates in 1987 were 1.06 ± 0.06 for women, 1.45 ± 0.1 for men, and 1.00 ± 0 for unknown authors. The publication rates in 1997 were 1.19 ± 0.06 for women, 1.28 ± 0.05 for men, and 1.00 ± 0 for unknown authors. The average number of publications was higher overall in 2008, though publication rates for women (1.23 ± 0.04) were still lower than those of men (1.43 ± 0.04) (unknown: 1.04 ± 0.04). Average annual publication rates in 2017 were similar to those from 2008, where women (1.21 ± 0.03) again had lower rates of publication than men (1.40 ± 0.03) authors (unknown: 1.07 ± 0.03).

Discussion

A growing body of research on the field of workplace disparities in STEM fields has shown that gender-heterogeneous teams produce better science (Campbell & al. 2013). One of the first essential steps to overcoming structural barriers that constrain diversity in STEM is collecting and publishing data on diversity representation (Grogan 2019). These data are necessary for identifying problems within the STEM community and provide the requisite evidence-based foundation for achieving measurable goals of increased representation. Here we report on the global gender demographics of the myrmecological community by reviewing thirty years of publications, assessing which countries are active in myrmecology research, what proportion of researchers are women, the scale of the gender gap in publication rate, and how these metrics have changed over time.

The global myrmecological community has grown dramatically in thirty years, and today research on ants is conducted across the globe, in over 100 countries. More than 8000 authors published papers about ants over the past decade alone. This growth reflects an increase in international activity – historically, early myrmecologists were overwhelmingly affiliated with institutions in Europe and North America (especially USA). Now, an abundance of research also originates from institutions across Central America, South America, Australia, and Asia. Myrmecological research is also increasing in Africa and Madagascar, with much influence coming from collaborations fostered through organizations such as the E.O. Wilson Biodiversity Foundation, Gorongosa National Park, the Bibikely Biodiversity Institute, and the Madagascar Biodiversity Center to name a few. The proliferation of myrmecology research is not necessarily limited to regions with high ant richness, but likely relates to supportive scientific infrastructure and funding mechanisms.

Proportion of women: Women are undeniably underrepresented in myrmecology, worldwide, and annually comprise only 29.6% of actively publishing individuals. This number is consistent with the findings of Ramalho & al. (2020a) that women in myrmecology are underrepresented as first and last authors. Underrepresentation of women in global workforce engagement has been documented at similar rates (29.3% women) (UNESCO 2019), and comparable trends are observed in other life science fields. For example, participation of women in myrmecology is lower than in health and medical specializations, which tend to have high representation of women, but higher than in historically men-dominated fields of science such as physics and computational biology (Bonham & Stefan 2017, Holman & al. 2018).

Myrmecology is not unique in its lack of gender parity. Many scientific fields lack representation of women, especially in senior positions (Handelsman & al. 2005). First and last author positions often denote relative prestige, serving as indicators of career success (Ramalho & al. 2020a). Rather than author position, we examined publication rates. We used authors' publication numbers over a ten year span as a proxy for establishment in the field of myrmecology, with two or more publications indicating an authors' seniority in comparison to those with only one publication. By this conservative metric, the proportion of women authors publishing multiple papers (26.4%) was much lower than across the community overall (34.0%) during 2008 - 2017. These results echo previous research documenting lower publication rates among women authors in STEM than for men (Duch & al. 2012, Larivière & al. 2013, Bendels & al. 2018) and further bolster findings of significant underrepresentation of women authors in entomology journals (Walker 2019, Ramalho & al. 2020a).

Singletons, authors that published a single paper in myrmecology during the past decade, comprised 70% of total authors. Men outnumbered women in this group, just as men predominate in myrmecology overall. However, a greater proportion of women than men were singletons. Although it is beyond the scope of this study to evaluate the determinants of single-paper authorship, the sheer number of singleton authors in myrmecology demands attention. Who are these singleton authors? They may include early-career researchers embarking on a lifetime of myrmecological study, late career researchers with low publication rates, established researchers that publish infrequently on ants, and non-myrmecologist collaborators of established authors. Some are undoubtedly short-term technicians and authors who published once in myrmecology and then turned their talents elsewhere. Could some proportion of these authors have found productive careers in myrmecology? Can we reduce attrition rates by broadening the appeal of myrmecology? Can we attract and retain more talent to our field? To answer these questions and improve the recruitment and retention pipeline for myrmecology careers, we must be willing to acknowledge deficiencies in our own communities and commit to addressing them.

Around the world, we found gender disparities to be common in nearly all countries where myrmecology research is conducted; women outnumber men in vanishingly few research communities. In the ten countries with the greatest number of authors publishing in myrmecology, the highest average annual percentage of women did not surpass 35%. Even Mexico, the country closest to achieving gender parity (women reached 50% of authors in one year), did not regularly have equal numbers of women and men. These results highlight the importance of evaluating data at fine scale. For example, in the USA, the proportion of women myrmecologists was 33.6% when evaluated using data summed across a decade – a figure similar to reported rates among academic entomologists (33% women), but lower than among entomologists employed by the US government (37% women) (Walker 2018). However, the average *annual* proportion of women authors in the USA was much lower, at 25%.

Many factors contribute to gender inequity, but our results suggest that high national GDP was not correlated with gender parity in myrmecology, a result consistent with current socio-economic theory (Gaddis & Klasen 2014). Rather, sociocultural factors, including domestic support for STEM research, are likely to have the greatest influence in supporting women myrmecologists. The countries with particularly high, or low, proportions of women authors also have gender ratios comparable to those in the national STEM workforce (UNESCO 2019) – a pattern that holds true for large and small countries, and across nations with high and low numbers of publishing myrmecologists. Although higher GDP did not correlate with the proportion of women authors in this study, increasing participation of women is considered a key factor in increasing the wealth of nations, both large and small (Hamilton & al. 2018).

Publication numbers: The paucity of women authors among the top-publishing professionals in myrmecology is sobering. Only five women were among the 50 most prolific publishers of the past decade. While this is in part a by-product of historical gender inequities in academia, it also reflects a lack of diversity among senior researchers today. One unfortunate consequence of homogeneity of senior leadership is the lack of representative diversity in mentorship, which poses a challenge to increasing diversity in the recruitment pipeline and affects critical points in professional onboarding ranging from advertising training opportunities to hiring for permanent positions (Smith & Erb 1986). Avenues to success can also be affected by issues of inclusion, such as networks of co-authorship. For example, senior authors who are men are more likely than women to co-author papers with other men in the fields of ecology and evolutionary biology (Frances & al. 2020).

Publication rates are a metric of research dissemination used to evaluate academic success and affect hiring and promotion decisions. In myrmecology, women published less, on average, than men did over the past decade, a trend mirroring widespread gender disparities in advancement across STEM fields (Larivière & al. 2013, Bendels & al. 2018). Among authors who published more than once in the past decade, a man published 1.36 papers for every paper produced by a woman, on average. This disparity in productivity is another broad indicator that women researchers have not achieved senior-level positions in STEM fields at the same rate as men (Handelsman & al. 2005). The pattern of men out-publishing women authors was consistent across countries regardless of factors such as GDP, size of the national myrmecology community, and proportion of women overall. Another success metric – not evaluated here but influential to advancement – is impact, that is, article citations. Other STEM disciplines have documented that articles with women as first and / or last authors are cited less frequently than papers authored by men (Bendels & al. 2018). This measure deserves examination in the myrmecological community to provide insight into gender differences in visibility and influence in the field.

Trends over time: The overall number and proportion of women publishing in myrmecology today represents a significant increase in participation by women compared to thirty years ago. The uptick in research activity and diversification of national affiliations is good news for the field of myrmecology, as international collaborations generate more citations of published work (Smith & al. 2014), and can foster diversity of the science itself (Stocks & al. 2008). Although these numbers suggest positive diversity trends, gender ratios have only inched towards equity in myrmecology, where the proportion of authorship by women has not risen over the past ten years. This finding parallels that of Ramalho & al. (2020a), who also found no increase in the number of women senior authors (i.e., first or last author position) in myrmecology over the past ten years. Likewise, although the number of peer-reviewed papers published by women has increased, we found that women in myrmecology still publish at a lower rate than men, that the number of women singleton authors increased over the past ten years, and that the publication gap has not budged in over twenty years. These trends echo other findings from gender research in STEM fields showing that increases in participation of women are accompanied by increases in gender differences in both productivity and impact (Huang & al. 2020).

The future of the myrmecology community: The results of this study describe myrmecology researchers as a growing, increasingly international community with greater diversity and more women researchers than ever before. This is good news for a relatively small scientific specialty as heterogeneity in the workforce can lead to greater innovation and creativity (Adams 2013). However, benefits of this diversity can only be realized when all community members are appropriately supported (Nielsen & al. 2017). The subdiscipline of myrmecology is not exceptional in having limited diversity and pronounced gender disparities, but as a socially cohesive community, it does have the potential to be exceptional in overcoming these limitations. To date, the myrmecological community has yet to address barriers that have prevented, and continue to limit, full participation by women (Etzkowitz & al. 1994). Providing these data are a first step towards equity in this community, especially considering the need for education and mentorship of future leaders (Holman & al. 2018) and recruitment of diverse science and ant enthusiasts from the earliest ages (Good & al. 2010, Bian & al. 2017).

Why are we no closer to parity in myrmecology, in number of women researchers and their productivity, than we were ten years ago? One hopeful explanation may be found in the high proportion of women authors of single papers over the past decade: women researchers may be overrepresented as early career scientists. If even a fraction of these authors are embarking upon a productive career path in myrmecology, they may well usher in a change in gender ratios from what we present here. Retaining and supporting more women through sequential educational and career stages are instrumental to achieving gender parity. Incoming women scientists will have to contend with the legacy effect of women being grossly underrepresented in senior positions that are linked with high publication output and pervasive gender bias, associations that have been documented within academia at all levels (Roper 2019). While overt sexism may no longer be tolerated, women are more likely than men to be passed over for promotions (Gumpertz & al. 2017) or not fairly judged for their research output (Budden & al. 2008). Gender parity will not be achieved by waiting for women myrmecologists to trickle in; rather, making workplace culture more supportive of professional women is the primary determinant of workforce diversity (Grogan 2019).

Promoting a rising generation of researchers that is more diverse than its antecedents requires supporting best practices that lead to successful outcomes for all. This includes combating high attrition rates for women and other minority groups (Xu 2008), supporting advancement through different career stages and levels of leadership in science (Gumpertz & al. 2017), and improving search and hiring practices to minimize unintentional biases (Ceci & Williams 2015, Smith & al. 2015). The success of double-blind review of publications and grants in increasing diversity (Budden & al. 2008) demonstrates that changes in practice can make a dramatic difference. As Ramalho & al. (2020a) emphasize, gender equity can be supported in many ways, from increasing the international representation of women and other genders at conferences and workshops, as reviewers, and on editorial boards (Smith & Erb 1986, Larivière & al. 2013, Espin & al. 2017, Walker 2019), to advocacy through social media and outreach (Jackson & Spencer 2017). Within the life sciences, proactive communication to diverse audiences, engagement of young scholars, and recruitment with diversity in mind are becoming standard practice in efforts to do better (Hansen & al. 2018, Berenbaum 2019). If the field of myrmecology is to have a vibrant future, improving diversity must be regarded as a necessity for us all.

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References

Adamo, S.A. 2013: Attrition of women in the biological sciences: workload, motherhood, and other explanations revisited. – BioScience 63: 43-48.

Adams, J. 2013: Collaborations: the fourth age of research. – Nature 497: 557.

Allen-Ramdial, S.-A.A. & Campbell, A.G. 2014: Reimagining the pipeline: advancing STEM diversity, persistence, and success. – BioScience 64: 612-618.

AlShebli, B.K., Rahwan, T. & Woon, W.L. 2018: The preeminence of ethnic diversity in scientific collaboration. – Nature Communications 9: art. 5163.

Bates, D., Mächler, M., Bolker, B. & Walker, S. 2015: Fitting linear mixed-effects models using lme4. – Journal of Statistical Software 67: 1-48.

Bendels, M.H., Müller, R., Brueggmann, D. & Groneberg, D.A. 2018: Gender disparities in high-quality research revealed by Nature Index journals. – Public Library of Science One 13: art. e0189136.

Berenbaum, M.R. 2019: Speaking of gender bias. – Proceedings of the National Academy of Sciences of the United States of America 116: 8086-8088.

Bian, L., Leslie, S.-J. & Cimpian, A. 2017: Gender stereotypes about intellectual ability emerge early and influence children's interests. – Science 355: 389-391.

Bonham, K.S. & Stefan, M.I. 2017: Women are underrepresented in computational biology: an analysis of the scholarly literature in biology, computer science and computational biology. – Public Library of Science Computational Biology 13: art. e1005134.

Budden, A.E., Tregenza, T., Aarssen, L.W., Koricheva, J., Leimu, R. & Lortie, C.J. 2008: Double-blind review favours increased representation of female authors. – Trends in Ecology & Evolution 23: 4-6.

Burnham, K.P. & Anderson, D.R. 2004: Multimodel inference: understanding AIC and BIC in model selection. – Sociological Methods & Research 33: 261-304.

Campbell, L.G., Mehtani, S., Dozier, M.E. & Rinehart, J. 2013: Gender-heterogeneous working groups produce higher quality science. – Public Library of Science One 8: art. e79147.

Ceci, S.J. & Williams, W.M. 2011: Understanding current causes of women's underrepresentation in science. – Proceedings of the National Academy of Sciences of the United States of America 108: 3157-3162.

Ceci, S.J. & Williams, W.M. 2015: Women have substantial advantage in STEM faculty hiring, except when competing against more-accomplished men. – Frontiers in Psychology 6: art. 1532.

Cho, A.H., Johnson, S.A., Schuman, C.E., Adler, J.M., Gonzalez, O., Graves, S.J., Huebner, J.R., Marchant, D.B., Rifai, S.W. & Skinner, I. 2014: Women are underrepresented on the editorial boards of journals in environmental biology and natural resource management. – PeerJ 2: art. e542.

Duch, J., Zeng, X.H.T., Sales-Pardo, M., Radicchi, F., Otis, S., Woodruff, T.K. & Amaral, L.A.N. 2012: The possible role of resource requirements and academic career-choice risk on gender differences in publication rate and impact. – Public Library of Science One 7: art. e51332.

Espin, J., Palmas, S., Carrasco-Rueda, F., Riemer, K., Allen, P.E., Berkebile, N., Hecht, K.A., Kastner-Wilcox, K., Núñez-Regueiro, M.M. & Prince, C. 2017: A persistent lack of international representation on editorial boards in environmental biology. – Public Library of Science Biology 15: art. e2002760.

Etzkowitz, H., Kemelgor, C., Neuschatz, M., Uzzi, B. & Alonzo, J. 1994: The paradox of critical mass for women in science. – Science 266: 51-54.

Fournier, A.M.V., Boone, M.E., Stevens, F.R. & Bruna, E.M. 2020: refsplitr: author name disambiguation, author georeferencing, and mapping of coauthorship networks with Web of Science data. – The Journal of Open Source Software 5: art. 2028.

Fox, J., Friendly, G.G., Graves, S., Heiberger, R., Monette, G., Nilsson, H., Ripley, B., Weisberg, S., Fox, M.J. & Suggests, M. 2007: The car package. – R Foundation for Statistical Computing, <https://cran.r-project.org/web/packages/car/index.html>, retrieved on 12 January 2020.

Fox, M.F. 2008: Institutional transformation and the advancement of women faculty: the case of academic science and engineering. In: Smart, J.C. (Ed.): Higher education. – Springer, Dordrecht, Netherlands, pp. 73-103.

Frances, D.N., Fitzpatrick, C.R., Koprivnikar, J. & McCauley, S.J. 2020: Effects of inferred gender on patterns of co-authorship in ecology and evolutionary biology publications. – The Bulletin of the Ecological Society of America: art. e01705.

Freeman, R.B. & Huang, W. 2014: Collaboration: strength in diversity. – Nature 513: 305.

Gaddis, I. & Klasen, S. 2014: Economic development, structural change, and women's labor force participation. – Journal of Population Economics 27: 639-681.

Gender api 2016: Gender API – infer gender from names. – <https://gender-api.com>, retrieved on 1 May 2019.

Genderize nd: Gender prediction based on first names. – <http://genderize.io>, retrieved on 10 September, 2018.

Georgiadis, C. & Trager, J. 2015: Myrmecology: Is it the correct term? – Parnassiana Archives 3: 7-10.

Good, J.J., Woodzicka, J.A. & Wingfield, L.C. 2010: The effects of gender stereotypic and counter-stereotypic textbook images on science performance. – The Journal of Social Psychology 150: 132-147.

Grogan, K.E. 2019: How the entire scientific community can confront gender bias in the workplace. – Nature Ecology and Evolution 3: 3-6.

Gumpertz, M., Durodoye, R., Griffith, E. & Wilson, A. 2017: Retention and promotion of women and underrepresented minority faculty in science and engineering at four large land grant institutions. – Public Library of Science One 12: art. e0187285.

Hamilton, K., Wodon, Q. & Barrot, D. 2018: Human capital and the wealth of nations: global estimates and trends. In: Lange, G.-M., Wodon, Q. & Carey, K. (Eds.): The changing wealth of nations 2018: building a sustainable future. –World Bank Group, Washington, DC, pp. 115-133.

Handelsman, J., Cantor, N., Carnes, M., Denton, D., Fine, E., Grosz, B., Hinshaw, V., Marrett, C., Rosser, S. & Shalala, D. 2005: More women in science. – Science 309: 1190-1191.

Hansen, W.D., Scholl, J.P., Sorensen, A.E., Fisher, K.E., Klassen, J.A., Calle, L., Kandlikar, G.S., Kortessis, N., Kucera, D.C. & Marias, D.E. 2018: How do we ensure the future of our discipline is vibrant? Student reflections on careers and culture of ecology. – Ecosphere 9: art. e02099.

Hodapp, T. & Brown, E. 2018: Making physics more inclusive. – Nature 557: 629-632.

Holman, L., Stuart-Fox, D. & Hauser, C.E. 2018: The gender gap in science: how long until women are equally represented? – Public Library of Science Biology 16: art. e2004956.

Huang, J., Gates, A.J., Sinatra, R. & Barabási, A.-L. 2020: Historical comparison of gender inequality in scientific careers across countries and disciplines. – Proceedings of the National Academy of Sciences of the United States of America 117: 4609-4616.

Jackson, M.D. & Spencer, S. 2017: Engaging for a good cause: Sophia's story and why #BugsR4Girls. – Annals of the Entomological Society of America 110: 439-448.

Kannowski, P.B. 2012: A myrmecologist's life: an appreciation of Mary Talbot (with photos). In: Talbot, M. (Ed.): The natural history of the ants of Michigan's E.S. George Reserve: a 26-year study. – Miscellaneous Publications No. 202. Museum of Zoology, University of Michigan, Ann Arbor, MI, pp. 211-215.

Larivière, V., Ni, C., Gingras, Y., Cronin, B. & Sugimoto, C.R. 2013: Bibliometrics: global gender disparities in science. – Nature 504: 211.

Lunnemann, P., Jensen, M.H. & Jauffred, L. 2019: Gender bias in Nobel prizes. – Palgrave Communications 5: art. 46.

Ma, Y., Oliveira, D.F., Woodruff, T.K. & Uzzi, B. 2019: Women who win prizes get less money and prestige. – Nature 565: 287-288.

Moss-Racusin, C.A., Dovidio, J.F., Brescoll, V.L., Graham, M.J. & Handelsman, J. 2012: Science faculty's subtle gender biases favor male students. – Proceedings of the National Academy of Sciences of the United States of America 109: 16474-16479.

Nielsen, M.W., Alegria, S., Börjeson, L., Etzkowitz, H., Falk-Krzesinski, H.J., Joshi, A., Leahey, E., Smith-Doerr, L., Woolley, A.W. & Schiebinger, L. 2017: Opinion: Gender diversity leads to better science. – Proceedings of the National Academy of Sciences of the United States of America 114: 1740-1742.

Nittrouer, C.L., Hebl, M.R., Ashburn-Nardo, L., Trump-Steele, R.C., Lane, D.M. & Valian, V. 2018: Gender disparities in colloquium speakers at top universities. – Proceedings of the National Academy of Sciences of the United States of America 115: 104-108.

Page, S.E. 2008: The difference: how the power of diversity creates better groups, firms, schools, and societies – new edition. – Princeton University Press, Princeton, NJ, 456 pp.

R Core Team 2020: R: A language and environment for statistical computing. – <https://www.R-project.org>, retrieved on 10 September 2018.

Ramalho, M., Martins, C. & Moreau, C.S. 2020a: Myrmecology: majority of females only within the colony. – Boletim do Museu Paraense Emílio Goeldi-Ciências Naturais 15: 17-26.

Ramalho, M.d.O., Decio, P., de Albuquerque, E.Z. & Esteves, F. 2020b: Parenting in the field of myrmecology: career challenges in the 21st century. – Boletim do Museu Paraense Emílio Goeldi-Ciências Naturais 15: 27-37.

Roper, R.L. 2019: Does gender bias still affect women in science? – Microbiology and Molecular Biology Reviews 83: art. e00018-00019.

Rossi, A.S. 1965: Women in science: why so few?: Social and psychological influences restrict women's choice and pursuit of careers in science. – Science 148: 1196-1202.

Santamaría, L. & Mihaljević, H. 2018: Comparison and benchmark of name-to-gender inference services. – PeerJ Computer Science 4: art. e156.

Sheltzer, J.M. & Smith, J.C. 2014: Elite male faculty in the life sciences employ fewer women. – Proceedings of the National Academy of Sciences of the United States of America 111: 10107-10112.

Shen, H. 2013: Mind the gender gap. – Nature 495: 22.

Smith, J.L., Handley, I.M., Zale, A.V., Rushing, S. & Potvin, M.A. 2015: Now hiring! Empirically testing a three-step intervention to increase faculty gender diversity in STEM. – BioScience 65: 1084-1087.

Smith, M.J., Weinberger, C., Bruna, E.M. & Allesina, S. 2014: The scientific impact of nations: journal placement and citation performance. – Public Library of Science One 9: art. e109195.

Smith, W.S. & Erb, T.O. 1986: Effect of women science career role models on early adolescents' attitudes toward scientists and women in science. – Journal of Research in Science Teaching 23: 667-676.

Stocks, G., Seales, L., Paniagua, F., Maehr, E. & Bruna, E.M. 2008: The geographical and institutional distribution of ecological research in the tropics. – Biotropica 40: 397-404.

Touzel, G. & Garner, B. 2018: The person herself is not interesting: Lucy Evelyn Cheesman's life dedicated to the faunistic exploration of the southwest Pacific. – Collections 14: 497-531.

Valantine, H.A., Lund, P.K. & Gammie, A.E. 2016: From the NIH: A systems approach to increasing the diversity of the biomedical research workforce. – CBE Life Sciences Education 15: art. fe4.

Wais, K. 2016: Gender prediction methods based on first names with genderizeR. – The R Journal 8: 17-37.

Walker, K.A. 2018: Gender gap in professional entomology: women are underrepresented in academia and the US government. – Annals of the Entomological Society of America 111: 355-362.

Walker, K.A. 2019: Females are first authors, sole authors, and reviewers of entomology publications significantly less often than males. – Annals of the Entomological Society of America 113: 193-201.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L., François, R., Grolemund, G., Hayes, A., Henry, L. & Hester, J. 2019: Welcome to the Tidyverse. – The Journal of Open Source Software 4: art. 1686.

Wiedenmann, R., Matthews, K., Sutton, D. & Raghu, S. 2018: Analyzing ESA's membership using life tables and modeling: who we were, who we are, and who we may become. – American Entomologist 64: 176-185.

Williams, W.M., Mahajan, A., Thoemmes, F., Barnett, S.M., Vermeylen, F., Cash, B.M. & Ceci, S.J. 2017: Does gender of administrator matter? National study explores US University administrators' attitudes about retaining women professors in STEM. – Frontiers in Psychology 8: art. 700.

Woolley, A.W., Chabris, C.F., Pentland, A., Hashmi, N. & Malone, T.W. 2010: Evidence for a collective intelligence factor in the performance of human groups. – Science 330: 686-688.

Xu, Y.J. 2008: Gender disparity in STEM disciplines: a study of faculty attrition and turnover intentions. – Research in Higher Education 49: 607-624.