

Myrmecology: majority of females only within the colony

Mirmecologia: maioria das fêmeas apenas dentro da colônia

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Abstract: Diversity and inclusion in science are issues that still need to be addressed and the scientific community should act urgently to overcome disparities especially because women are still underrepresented across science, technology, engineering, and math (STEM). Information about women authoring scientific papers are important data that can help us understand if a specific field is inclusive. We focussed on the area of Myrmecology and we investigated whether first and last authorship is biased in this field. This study showed that although our research focuses on a group dominated by females (ants) in terms of authorship of papers it is still a male dominated society with no significant increases in female representation since 1990 with women representing only 35.59% of first authors and 22.90% of last authors. And despite our data showing promising trends for the last few years (2016-2018) where we see a slight increase in women as first authors however for the last author position there has still been no change. We also compared worldwide results to that of myrmecologists from Brazil, a hub of ant biological research. We conclude our study by proposing several actions that we can all do to overcome this issue and make science more equal and inclusive.

Keywords: Women in science. Diversity in science. Authorship. Gender equality.

Resumo: Diversidade e inclusão na ciência são questões que ainda precisam ser abordadas e a comunidade científica deve agir com urgência para superar as disparidades, especialmente porque mulheres ainda estão subrepresentadas nos campos da ciência, tecnologia, engenharia e matemática (STEM). Informações sobre mulheres que escrevem artigos científicos são dados importantes e podem nos ajudar a entender se um campo específico é inclusivo. Focamos na área da Mirmecologia e investigamos se a primeira e a última autoria são tendenciosas nesse campo. Este estudo mostrou que, embora a pesquisa se concentre em um grupo dominado por fêmeas (formigas), em termos de autoria de artigos científicos ainda se trata de uma sociedade dominada por homens, sem aumentos significativos na representação feminina desde 1990, com apenas 35,59% como primeiras autoras e 22,90% como últimas autoras. Apesar de os dados mostrarem tendências promissoras dos últimos anos (2016-2018), com ligeiro aumento de mulheres como primeiras autoras, para a última autoria ainda não houve mudanças. Também comparamos os resultados mundiais com os mirmecologistas do Brasil, que é um centro de referência em pesquisas com formigas. Concluímos nosso estudo propondo várias ações que todos podemos fazer para superar esse problema e tornar a ciência mais igual e inclusiva.

Palavras-chave: Mulheres na ciência. Diversidade na ciência. Autoria. Igualdade de gênero.

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BACKGROUND

Science can help us understand the world around us and improve the quality of life for humanity. With all this potential, science should be equally accessible to everyone. But it is not what several studies have shown where women are often underrepresented in the workforce and this situation is also true across science, technology, engineering, and math, called the STEM fields (Goulden *et al.*, 2011; Shen *et al.*, 2018; Ysseldyk *et al.*, 2019).

The reasons for this disparity are numerous and require further investigation to be corrected. For example, The Royal Society of Chemistry (2019) report showed that women are less likely to have articles accepted in chemistry journals than men. In addition, this gender bias also occurs in citations, where women's papers have fewer citations compared to male authors. There are several reasons that contribute to these situations. But Murray *et al.* (2018) showed that reviewers tend to favor same-sex authors. Since there is a majority of men composing the editorial members of journals, this may contribute to gender disparity.

In Latin America data has shown that women are underrepresented in ecology and zoology journals in several subfields across regions and countries of this place, with Brazil being represented with around 30% of women authorship in this area (Salerno *et al.*, 2019). Another intriguing study has shown that 49% of Brazilian scientific studies are produced by women (Elsevier, 2017), but the vast majority of national research productivity scholarship awards (an award granted by the Brazilian National Council for Scientific and Technological Development - *Conselho Nacional de Desenvolvimento Científico e Tecnológico/CNPq* - to researchers with outstanding production in areas of science) are held by men, and the small number of women that have been awarded these fellowships are in the lower ranked categories in the research ranking system (Valentova *et al.*, 2017). Furthermore, the scenario is not better

for Brazilian scientists in other fields including physics (Brito *et al.*, 2015). Although the causes of the disparities are diverse, these studies demonstrate that Brazil is far from having equality in science.

Although it has been shown that representation and role models are important (Lockwood, 2006), there are several fields of study that suffers from underrepresentation of women and other minorities, and entomology is not immune with salaries significantly lower for females compared to males (Reece & Hardy, 2017; Walker, 2018). Myrmecology is an active field of study within entomology, having a large number of ant scientists around the world. However, there have been no studies yet that examine female representation in myrmecology. One of the major milestones in the field of myrmecology was the publication of "The Ants" in 1990 (Hölldobler & Wilson, 1990), which won numerous awards helping spread ant knowledge worldwide and inspiring a new generation of ant scientists. Since then, significant technological advances have been made including worldwide accessibility to the internet, which has acted as a major propeller for science and data sharing. Ease of obtaining information through the emergence of online public databases like the National Center for Biotechnology Information (NCBI) is just one example of the way the internet facilitates science.

Against this backdrop, the motivation of this study is to evaluate female representation in myrmecology worldwide since 1990 by measuring the number of publications in NCBI with women as first and last authors. In addition, the study also analyzes the impact of women representation in Brazil in this century, being the first study to address the representation of women in myrmecology. Our data is alarming and points out that time alone will not resolve the situation, so direct measures are needed to overcome this bias. However, in addition to highlighting the problem, we also suggest a series of actions, personal and institutional, that can help overcome the injustices that women myrmecologists face daily and in their careers.



METHODS

We downloaded the citations for all manuscripts (8,472) associated with the word 'Formicidae' from PubMed's MEDLINE database on the Jupiter notebook (Kluyver *et al.*, 2016) and then filtered the manuscripts from the year 1990 to 2018, leaving 7,563 records. It is important to highlight that another reason we focused on 1990-2018 publications because the use of alphabetical authorship in scientific publishing has declined in the last several decades (Waltman, 2012). Since these are the two most prestigious positions of the manuscript in our field, the gender/sex of the first and last author of each paper were predicted by genderizeR package (Wais, 2016), in the R software (R Development Core Team, 2019). This R package has over 250,000 names in the database and is able to predict the gender of the name using social media data from over 79 countries and 89 languages. We only included names with 0.9 confidence in our study. Obtaining NCBI information from manuscripts is a complex task, so our data was also manually checked for confirmation of gender for those not predicted by genderizeR. A total of 5,833 manuscripts were successfully classified by gender for the first and last authors and were included in subsequent analyses.

The analyses were conducted primarily focusing on the percentage of females as the first and last author of the manuscripts. To estimate this representation across time (1990-2018), the year of publications were also considered. To assess female representation in myrmecology over the last 29 years (1990-2018) statistical analyses using the T-test in R were implemented to ascertain if there is a significant difference from the average across all years to the present. We also investigated the number of manuscripts with same sex first and last authors (female:female and male:male).

As a second part of our analyses we focused on data on Brazilian authors because this country is known worldwide for great myrmecological diversity – both number of myrmecologists and ant species biodiversity

– and has hosted a bi-annual myrmecological meeting for over 40 years. Therefore, using the same techniques described above we ask the same questions, but only for Brazilian first and last authors (414 manuscripts were successful in classifying the gender), and for a smaller number of years (2001-2018) due to difficulty in obtaining correct NCBI information for author country in older manuscripts (last century). These data also served as a comparison with the rest of the world.

RESULTS

Information from a total of 8,472 manuscripts published between 1990 and 2018 in the field of myrmecology was downloaded, of which 5,833 we could assign the gender/sex of the first and last authors. As expected, most authors in the field of myrmecology are male, with women representing only 35.59% of first authors and 22.90% of last authors. These data were also categorized by year (Figure 1A), and although there are a few atypical years with increases in female representation in both manuscript positions, our statistical analysis shows that there was no significant change between the average (first author = 29.53, last author = 20.37) across the 29 years included in our analysis and the current publication numbers (first author: $t = 1.0179$, $p\text{-value} = 0.4943$; last author: $t = 1.0187$, $p\text{-value} = 0.4941$). This indicates that since 1990, overall there have been no significant increases in female representation in myrmecology.

The data look promising when focused specifically at the last few years (2016-2018) for female representation as first authors, which corresponds to around 40% of the manuscripts. However, by analyzing the results of women as last authors for the same period (2016-2018), our data reveals that there have been no changes in our field for this position (Figure 1A).

Our data are even more surprising when we analyze the number of publications where the first or last authors are of the same gender (female:female or male:male). The number of manuscripts that had

women as first and last author on the same publication corresponds only to 9.90% of the manuscripts when compared to publications with both the first and the last authors are male, representing 50.58% of the total papers included in this study (Figure 1B).

When the data focused only on Brazil, the results show a slight advance compared to the worldwide data with female first authors corresponding to about 43% and last authors with 25.65%. Also, the same pattern was found with jumps in female representation in some atypical years, with women as first authors standing out in 2016 and 2017 representing about 60% of all publications. But what caught our attention was the decrease of females as the last author in recent years (Figure 2A). Our statistical analysis also showed no overall progress when comparing the average across all years (first author = 40.50, last author = 27.46) with the current year (first author: $t = 1.028$, $p\text{-value} = 0.4912$; last author: $t = 1.0213$, $p\text{-value} = 0.4933$). The combination of women as both the first and last author in Brazil also was slightly better compared to the worldwide data with 13% of manuscripts first and last authored by women, but manuscripts with men in the first and last author positions were still a large majority for 43.64% of manuscripts from Brazil (Figure 2B), confirming the trend of the world scenario.

DISCUSSION

One of the most significant years for the field of myrmecology was the year that "The Ants" was published by Hölldobler & Wilson (1990). This book has won internationally renowned awards and helped bring attention to the field of myrmecology around the world. With the advance of technology, and using data mining techniques, for the first time, we can assess the impact of female representation as first and last authors in the field of myrmecology since 1990. Our study highlights that there have been no significant changes in the last three decades, especially for women as the

last authors which is an estimate of career success in high-level positions.

Our data highlight the problem described for women in other STEM fields, which often uses the leaky pipeline metaphor (Goulden *et al.*, 2011; Ysseldyk *et al.*, 2019). The central idea is that as women advance their careers and seek higher career positions, there is a leak at every step. Multiple causal factors can contribute to and propagate this situation, such as imposter syndrome, sexism, maternity leave, the glass ceiling, sexual harassment and all this can influence a woman's decision to leave their careers in academia (Ysseldyk *et al.*, 2019).

In spite of the fact that groups with greater diversity of people can achieve better problem solving and scientific impact (Campbell *et al.*, 2013; Hong & Page, 2004), our data suggest that in myrmecology gender diversity has still not been achieved. Although our data did not access the genders of middle authors from the included manuscripts, the two most prestigious positions of the manuscript being held by more than 50% of men are not a good indicator of gender parity. Often considered the most prestige position, the last authorship in myrmecology highlights one important fact: women are in lower numbers as leading research groups in this field of study, corroborating data found in other studies highlighting that more women leave academia after graduating, after finishing their postdoctoral research, or before becoming the principal investigator of a research group (West *et al.*, 2013). In Brazil, the scenario is even more worrisome with women being underrepresented in the last author positions and decreasing in the last years while first authorship positions are increasing. In addition as Brazilian institutions and governments cut budgets for scientific research (Escobar, 2019; Magnusson *et al.*, 2018) this context may get worst in the next several years with the 'brain drain' of young researchers to other countries due to the lack of opportunities for scientists (Boggio, 2019).



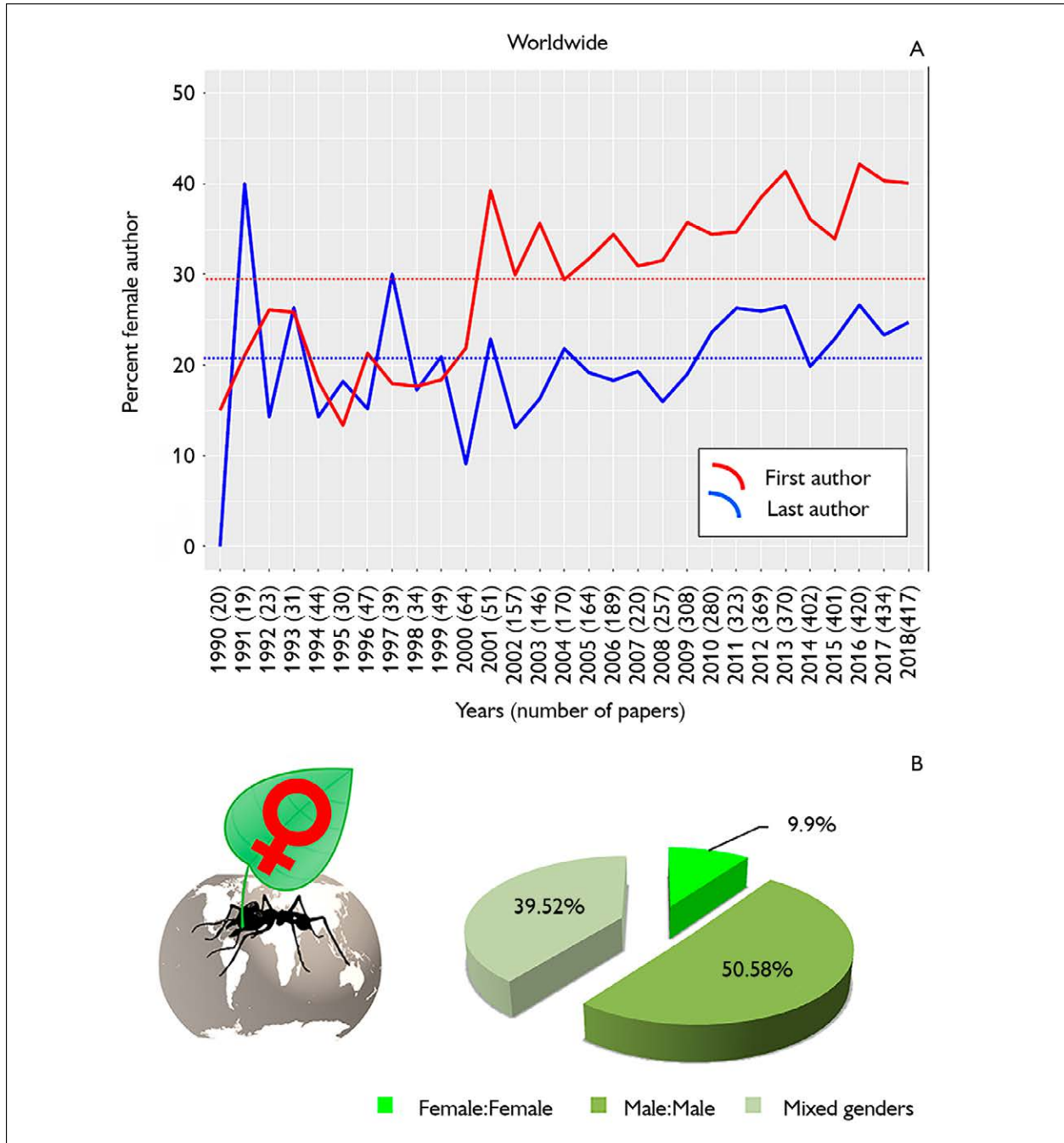


Figure 1. Worldwide representation of female authors in myrmecology publications: A) representation of females as the first or last authors of manuscripts in the field of myrmecology over the past 29 years. The x-axis indicates the years 1990-2018. The y-axis indicates the percentage of female authors. Female first authors are represented by the red line. Female last authors are indicated by the blue line. The dotted line indicates the average of all years of publication (color red represents the first author, and color blue the last author); B) worldwide representation of gender parity as both first and last author of manuscripts. Female:Female means that both the first author and the last author of the manuscript are female. Male:Male means that the first author and the last author of the manuscript is male. Mixed genders there is a combination of both genders for these positions in the manuscripts.

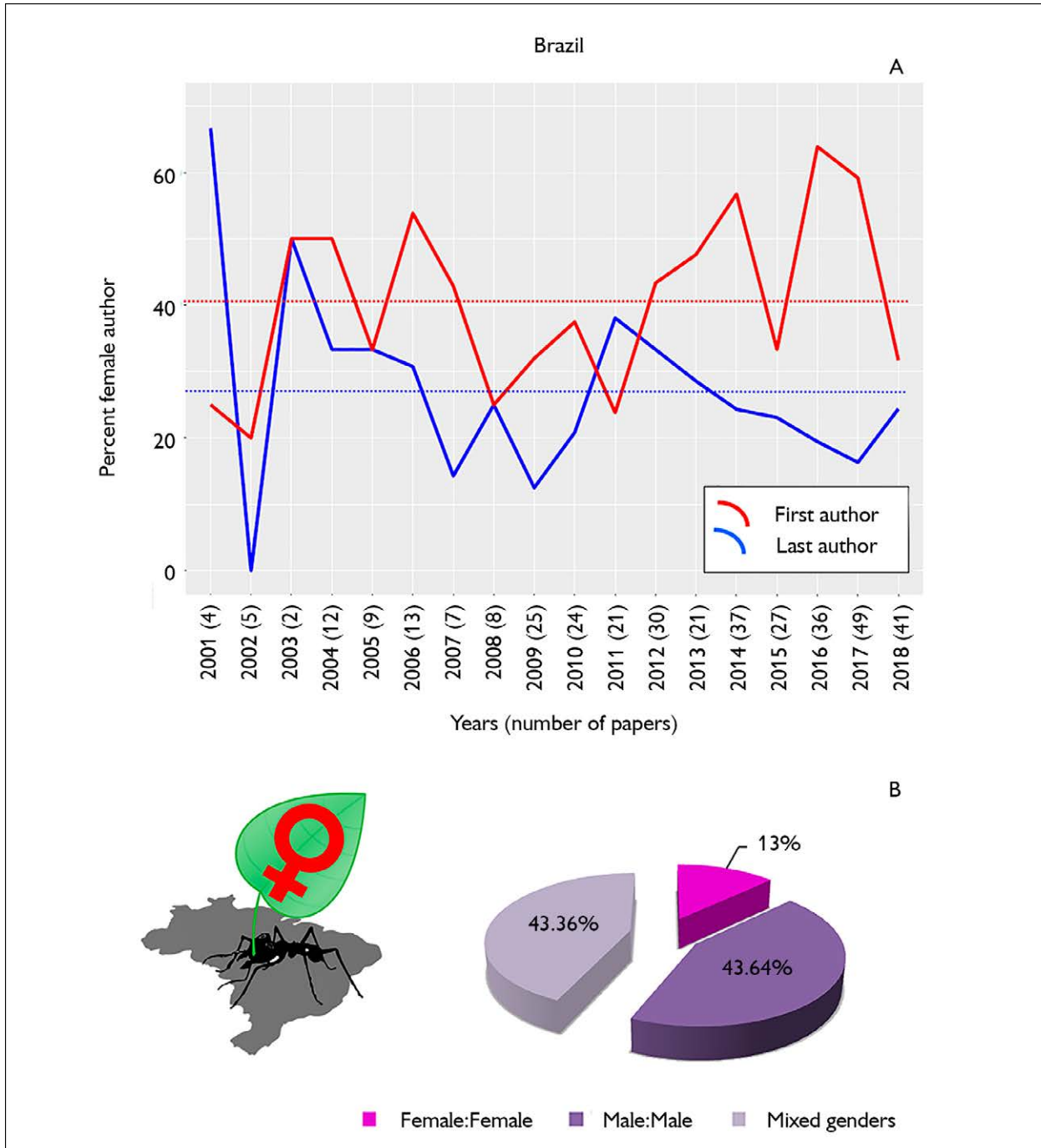


Figure 2. Brazil representation of female authors in myrmecology publications: A) representation of females as the first or last author of publications in the field of myrmecology over the past 18 years. The x-axis indicates the years 2001-2018. The y-axis indicates the percentage of female authors. Female first authors are represented by the red line. Female last authors are indicated by the blue line. The dotted line indicates the average of all years of publication (color red represents the first author, and color blue the last author); B) Brazil representation of gender parity as both first and last author of publications. Female:Female means that both the first author and the last author of the manuscript are female. Male:Male means that the first author as well as the last author of the manuscript is male. Mixed genders there is a combination of both genders for these positions in the manuscripts.

Unfortunately, this is not just a myrmecology problem. Our study corroborates other studies in several fields in the sciences in which the same trends were found with women being the minority as first and last authors (Dizney *et al.*, 2019; Martin, 2012; Shen *et al.*, 2018; West *et al.*, 2013). In the fields of ecology and zoology, the same trends were found with women occupying 35.2% and 27.9% of first and last authorship positions respectively in the year 2016 in the most prestigious journals in these fields (Salerno *et al.*, 2019).

Our data suggest that time alone will not solve this problem as has been suggested, and that we must seek active measures that minimize gender disparity, especially in the highest academic positions. Several studies have shown that everyone has some amount of implicit bias (Project Implicit, 2011), which we all have to continually and actively work to minimize. Researchers have also showed that mentors and role models are very important to increasing diversity across many fields, including science (Lockwood, 2006).

To help overcome bias in science there are many things both women and men can do, including support policy changes that limit/reduce/remove bias in your institution and at federal levels, be aware of your biases and work to overcome them, encourage and support underrepresented groups in STEM fields including women, and nominate women for awards, not only tenured faculty but also early career women. We also should ensure diversity on all admissions, hiring, promotion, and award committees. Lastly, we encourage everyone to join and support women in science or other diversity groups regardless of their gender/sex/ethnic background/etc. To reduce bias that promotes gender disparity in publications, journals should invest in bias identification training, double-blind reviews (Budden *et al.*, 2008), and include women as reviewers and as part of their editorial boards (Murray *et al.*, 2018). It is also important to increase the visibility of women within myrmecology and STEM more generally, by supporting their careers by inviting women to present in symposiums, meetings, workshops, and other events, as a way to support her work and get people to know her research and her group or laboratory.

By doing this we are also encouraging and inspiring female undergraduates or graduates that may be present at these events (Dizney *et al.*, 2019). Another topic that we must give special attention is ethnic diversity, which is extremely important when talking about 'women in science'. There is still an abyss when we discuss the representativeness of white and black women (and indigenous women too) in the sciences, and supporting them is critical to achieving equity in the sciences (McGee & Bentley, 2017).

Family commitments and the arrival of children can also add to the pipeline leak that causes women to postpone or interrupt their careers (Adamo, 2013; Ceci *et al.*, 2009; Martinez *et al.*, 2007; Wolfinger *et al.*, 2016). Therefore, the support in the workplace by supervisors is essential for the women to feel safe and valued so she does not feel she has to give up her career or personal life. Maternity/paternity leave and flexible working hours for both parents are also critical when a new family member arrives. Often this is only seen as something that women must face and solve. Support with childcare at academic events and at work also ensures parents (especially the women) do not have to pause their careers (Ramalho *et al.*, 2020). According to the NSF & NCSES (2017) report, white men are the majority across all STEM fields. Therefore, we know that having them as allies and champions of reducing bias in science is imperative. The threat of retaliation impacts men less (Liyanarachchi & Adler, 2011) and for that reason when white men advocate for women and other underrepresented minorities, they are less likely to suffer the same retaliation. For scientists with established careers, one strategy to increase the visibility of women and other minority scientists that has been gaining support is to only agree to be a keynote or plenary speaker at events that are balancing gender equality at the event. Most importantly, the best way to be an ally and to promote the inclusion of women in science is for men to not tolerate unacceptable behavior from other men in the presence or absence of women, and to advocate that such behavior will no longer be tolerated. A summary of the actions proposed is presented in Figure 3.



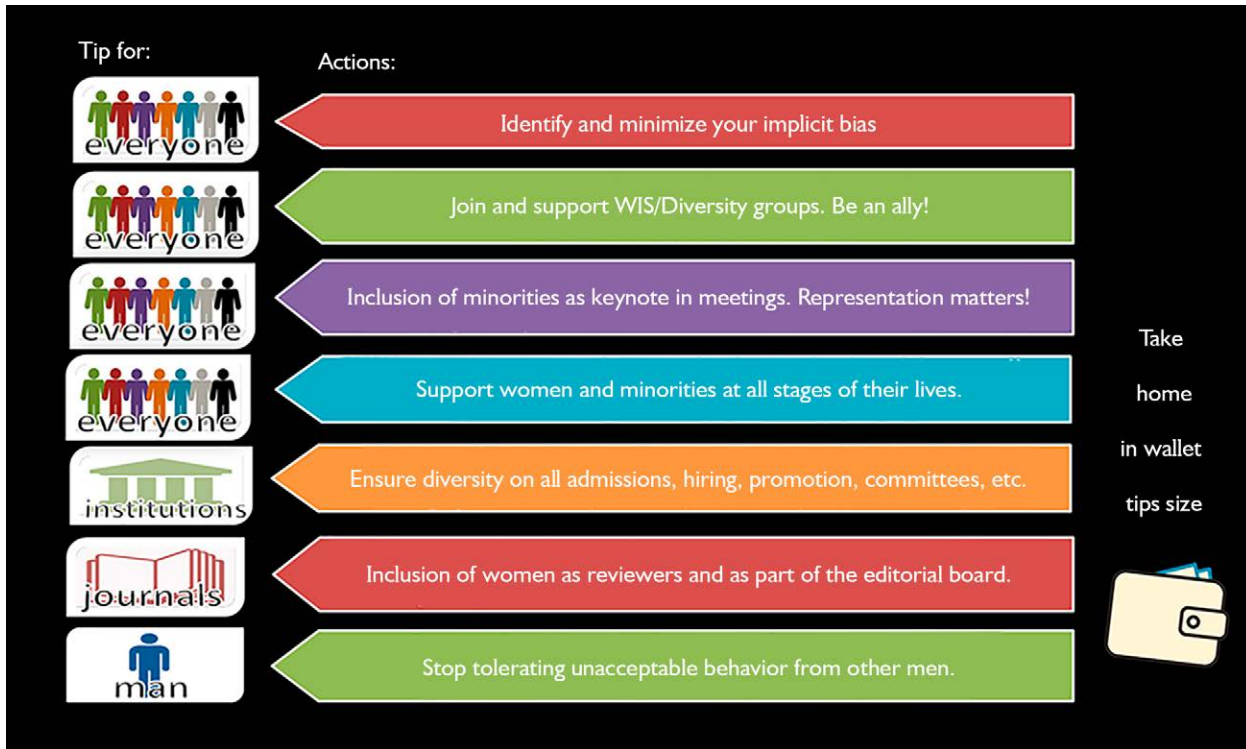


Figure 3. Summary of proposed actions to make science more diverse and inclusive.

CONCLUSION

For the first time, we have assessed whether there is gender parity within myrmecology, and our results show that we still have a long way to go to achieve equality. In addition, our study shows that time alone will not solve the problem and so we have listed several measures needed to make our field of study more inclusive.

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