Overcoming the gender bias in Ecology and Evolution: is the double-anonymized peer-review an effective pathway over time?

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Male researchers dominate scientific production in Science, Technology, Engineering, and Mathematics (STEM). However, potential mechanisms to avoid this gender imbalance remain poorly explored in STEM, including Ecology and Evolution areas. In the last decades, changes in the peer-review process towards double-anonymized (DA) have increased among Ecology and Evolution (EcoEvo) journals. Using comprehensive data on papers from randomly selected 20 EcoEvo journals with impact factor > 1, we tested the effect of the DA peer-review process in female-leading (i.e., first and senior authors) papers. We tested whether the representation of female-leading authors differs between double and single-anonymized (SA) peer-reviewed journals. Also, we tested whether the adoption of the DA by previously SA journals has increased the representativeness of female-leading authors over time. We found that publications led by female authors did not differ between DA and SA journals. Moreover, female-leading papers did not increase after changes from SA to DA peer-review. Tackling female underrepresentation in science is a complex task requiring many interventions but our results highlight that adopting the DA peer-review system alone could be insufficient in fostering gender equality in EcoEvo scientific publications, then academics should be aware of other efforts to address this underrepresentation. We argue that building more gender-diverse editorial boards and then adopting a triple-anonymized review process by journals (i.e., when neither authors, reviewers, or editors know the identity of each other until the first decision) could be a pathway towards achieving gender equality in EcoEvo scientific publications.

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Abstract

Male researchers dominate scientific production in Science, Technology, Engineering, and Mathematics (STEM). However, potential mechanisms to avoid this gender imbalance remain poorly explored in STEM, including Ecology and Evolution areas. In the last decades, changes in the peer-review process towards double-anonymized (DA) have increased among Ecology and Evolution (EcoEvo) journals. Using comprehensive data on papers from randomly selected 20 EcoEvo journals with impact factor > 1, we tested the effect of the DA peer-review process in female-leading (i.e., first and senior authors) papers. We tested whether the representation of female-leading authors differs between double and single-anonymized (SA) peer-reviewed journals. Also, we tested whether the adoption of the DA by previously SA journals has increased the representativeness of female-leading authors over time. We found that publications led by female authors did not differ between DA and SA journals. Moreover, female-leading papers did not increase after changes from SA to DA peer-review. Tackling female underrepresentation in science is a complex task requiring many interventions but our results highlight that adopting the DA peer-review system alone could be insufficient in fostering gender equality in EcoEvo scientific publications, then academics should be aware of other efforts to address this underrepresentation. We argue that building more gender-diverse editorial boards and then adopting a triple-anonymized review process by journals (i.e., when neither authors, reviewers, or editors know the identity of each other until the first decision) could be a pathway towards achieving gender equality in EcoEvo scientific publications.

Keywords: Gender diversity, gender equality, inclusion, triple-anonymized policy.

Introduction

Females represent half of the global population but are still underrepresented in most work fields, mainly in politics and economics (World Economic Forum, 2019). In the education field, despite recent progress (World Economic Forum, 2019), we are far from reaching equity. Females are strongly underrepresented in STEM (Science, Technology, Engineering, and Mathematics), both in graduate courses and research positions, where only 33% of researchers are women (Garcia-Holgado et al., 2020; Unesco, 2021). In biological sciences, the number of male and female students is equal in higher education degrees in European countries, the Caribbean, Latin America, and the United States (European Commission, 2019; García-Peñalvo, 2019; National Science Foundation, 2018), although there is still a gender bias in graduate school and professional positions (National Science Foundation, 2018; Unesco, 2021). In this sense, the gender gap increases with career advancement, and females are a minority in leadership positions, representing only 28% of faculty professors in life science careers in the US (National Science Foundation, 2018). Gender bias in the academic environment has multiple dimensions and causes manifested in society, home, workplace, and individuals (Leite and Diele-Viegas, 2020; Unesco, 2021). These aspects lead to reduced female participation and competitiveness in academia, especially in leadership positions (Sheltzer and Smith, 2014).

According to the concept of homophily, male scientists are more likely to support, collaborate with, hire, and mentor male scientists (Brashears, 2008; Moss-Racusin et al., 2012; Sheltzer and Smith, 2014). This tendency contributes to causing a female's work underestimation (Lariviere et al., 2013; Moss-Racusin et al., 2012; Sheltzer and Smith, 2014). This gender bias also occurs in scientific publications, mainly when the first or last authors are males (Lariviere et al., 2013; West et al., 2013). Less than 40 % of biological sciences publications have females as first authors, and less than 30% have females as last (i.e., senior) authors (Bendels et al., 2018; Fox and Paine, 2019; Salerno et al., 2019). This pattern was also found in the Ecology and Evolution (hereafter: EcoEvo) field, in which females are strongly underrepresented as first, senior, and sole authors (Fox and Paine, 2019). Consequently, only 11% of top-publishing authors in EcoEvo are females (Maas et al., 2021).

Scientific journals have a central role in the research system, and authorship patterns could reveal the composition and representativeness of the active scientific community producing knowledge through research (Mauleón et al., 2013). Thus, female underrepresentation in the authorship of scientific publications could respond to implicit biases favoring males and encourage females' withdrawal from the academic community (Martin, 2012; Salerno et al., 2019; Sidhu et al., 2009). Therefore, strategies for diminishing peer bias are necessary to increase diversity, inclusion, and representativeness in scientific publications (Diele-Viegas et al., 2021). One possible solution is implementing a double-anonymized peer review process (hereafter: DA), where both author and reviewer identities are concealed. Nevertheless, most journals have a single-anonymized review process (hereafter: SA), in which only the reviewer is anonymous.

DA peer review has been proposed as an efficient strategy to reduce biases against gender, institutions, country of origin, new ideas, authors' prestige and young scientists (Mainguy et al., 2005; Smit, 2006; Stensrud and Brooks, 2005). For that, DA is perceived as a fairer peer review system (Smit, 2006). Despite that the DA system has some concerns related to the extra workload for journals and the possibility of reviewers identifying authors or institutions (Darling, 2015; Nature, 2008; Stensrud and Brooks, 2005), journals from different areas, including EcoEvo, have implemented a DA peer review process in the last decades. Different journals considered that the DA system brings more advantages by reducing biases and increasing transparency to the peer review process (Darling, 2015; Nature, 2008; Stensrud and Brooks, 2005). However, DA results to reduce gender bias in publications are ambiguous. For instance, in medicine and economics, no differences have been found between DA and SA peer review systems, as women authors have similar publication rates under both systems (Blank, 1991; Cho et al., 1998; Justice et al., 1998; Mahajan et al., 2021). Still, in computer machine science, DA has been effective in reducing gender bias (Tomkins et al., 2017). In the Ecology area, DA had a positive effect by incrementing the female authors in Ecology journals such as Behavioral Ecology (Budden et al., 2008). However, another study suggests that the increase in female authorship in Ecology journals is related to time and not to the peer-review process (Webb et al., 2008). Similarly, the Biological Conservation Journal used an SA peer review and they did not find gender bias in publication rates (Primack et al., 2009). A similar study using Ecology and Ornithology journals found no differences in female publications between DA and SA journals (Cox and Montgomerie, 2019). Although those studies showed similar female publications between DA and SA journals, those studies included less than five journals to do the analyses. Using a comprehensive dataset from 20 journals encompassing different thematic areas of Ecology and Evolution (e.g., botanic, biogeography, biological invasion, conservation, data description, entomology, environmental economics, sustainability and zoology), here investigate the impact of the DA peer-reviewing process on the gender authorship patterns of EcoEvo scientific journals. Specifically, we hypothesized that the frequency of publications with female-leading authorships is higher under a DA peer-reviewing policy when compared to the SA policy (H1). We also hypothesize that adopting the DA peer-review policy has increased the frequency of female-leading papers over time in journals that changed their peer-review process (H2).

Material & Methods

Journal selection and peer-review information

We selected scientific journals listed in the Journal Citation Reports 2020 of the Web of Science database (WoS) that were classified as "Ecology and Evolution", "Ecology", "Evolution", and "Evolutionary Biology". We restricted our search for journals with the 2020 impact factor (IF) equal to or higher than one. From the 142 journals recovered by our search, we then selected journals that included the following words in their scope: "Ecology and Evolution", "Ecology", "Evolution", and "Evolutionary Biology". This preliminary search resulted in 135 selected journals (Supplemental Information in Appendix S1). However, as we obtained 10 DA journals, we then randomly selected 10 SA journals using the function “sample” from the R package, resulting in 20 analyzed journals (Table 1). Among journals presenting the double-anonymized peer-review policy, four had always used the DA peer-review, and six had changed their policy from SA to DA in a specific year (see table 1). All analyses were carried out in R (R Core Team, 2019).

The definition of the peer-review policies adopted by journals as double or single-anonymized was made by checking their websites' information. When this information was unavailable on the journals' website, we emailed the editorial office or editor-in-chief. For DA journals, we also gathered information on when this peer-review system was implemented. We kept only journals with at least five years of DA system so that the possible effects of this change could be discernible.

We restricted the data gathering papers published in the first issue of each evaluated year. We considered the period between 2016-2020 for SA (i.e., journals that always have been single-anonymized) and DA (i.e., journals that always have been double-anonymized) peer-reviewed EcoEvo journals (Table 1). For those journals that changed their peer-reviewing from SA to DA through time (hereafter: switched-review journals), we selected manuscripts of the first-year issues from five years previous to the switch to DA peer-review process (i.e., pre) and five years after this change (i.e., post).

Extracting "pre" and "post" DA adoption data allowed the evaluation of whether adopting a DA peer-review policy by EcoEvo journals has increased the representativeness of female researchers as leading (first or senior) authors over time in these journals. For these switched-review journals, the first-year issues encompassed 1996-2020 (Table 1). We excluded editorial papers to avoid potential biases since most authors of these categories are the journals' editors or authors previously invited. All other paper categories submitted to the peer-review process were considered in the analyses (e.g., commentary, data paper, forum, review).

Data

We obtained information about the first and last (senior) author's names (i.e., leading authors), the number of authors and the author's country affiliation from each evaluated paper. This data was scraped from the websites of the EcoEvo journals using the *rvest* R package (Wickham and Wickham, 2016). We manually classified the leading authors as male or female by performing exhaustive searches of the author names on publicly available individual web pages and social media (i.e., *ResearchGate* and *Twitter*), scientific platforms such as *Scopus* and *Google Scholar*, and institutional databases that included gender pronouns or a photograph of the individual that suggests their gender.

Statistical analysis

To assess the impact of the DA peer-reviewing process on the number of female-leading papers, we ran four generalized linear mixed-effect models (GLMMs) using the binomial family and logit link function (Bolker et al., 2009). To test whether t the frequency of publications with female-leading authorships is higher under a DA peer-reviewing policy when compared to SA policy (H1), we fitted two GLMMs in which we considered the gender (0/1; male and female, respectively) of the first author (one model) or the senior author (second model) of each paper as the response variable and peer-review policy (DA or SA), number of authors and year of publication as explanatory variables. To test whether We also hypothesize that adopting the DA peer-review policy has increased the frequency of female-leading papers over time in journals that changed their peer-review process (H2), we also fitted other GLMMs models. For these models, we only considered the data for the six selected journals that have changed the peer-review policy over time (i.e., switched-review journals, see Table 1). The gender of the first (one model) or the senior author (second model) was considered the response variable and the publication period ("pre" or "post" - regarding the peer-review policy change event in which each paper was published), number of authors and year of publication as the explanatory variables. Because time (year of publication) and the number of authors may affect the female authorship patterns (Webb et al., 2008; West et al., 2013) we used them as covariables in all models. As geographic and journal idiosyncrasies directly impact gender bias in science, especially in the EcoEvo (Maas et al., 2021), we also included the country filiation of leading authors and journals' names as random factors terms (varying intercepts) in all four of the models. We performed the GLMMs using the “glmer” function from the “lme4” package (Bates et al., 2012).

Results

We obtained 2,622 papers from the 20 randomly selected EcoEvo journals (Table 1). After excluding the editorials (N = 41), our dataset resulted in 2,581 analysed papers (Supplemental Information in Appendix S1). We classified all leading authors (first and senior authors; N = 4,556) as male or female. We found only two self-declared transgender individuals. We classified these people according to the pronoun used on the website of their institutions. Males led the majority of papers in EcoEvo journals. Only 38.5% of the first and 25% of the senior authors were women. We observed higher female-leading publications in DA (34%) than in SA journals (31%). On evaluating separately, the female-leading between switched-review (before DA and after DA), always SA, and always DA, we noticed a higher frequency of females in journals that always adopted DA (44.25 for first and 30.52 for senior authors; Figure 1). Additionally, female-leading papers were more observed after adopting the DA policy in switched-review journals (see Figure 1). However, these higher frequencies in female-leading papers were not explained by peer-review policies.

We did not find a significant difference between DA and SA peer-review policies concerning women publications as first or senior authors (Tables 2 and 3, respectively). Also, we did not find a significant difference between the "pre" and "post" periods in journals that changed the peer-review policy from SA to DA regarding both first and senior gender authorship (Supplementary Data, Tables S1 and S2).

Discussion

Using a comprehensive dataset of 2,581 papers from 20 journals encompassing different thematic areas of Ecology and Evolution (e.g., botanic, biogeography, biological invasion, conservation, data description, entomology, environmental economics, sustainability and zoology), we showed that despite the increasing efforts to avoid gender imbalance in science, it is still pervasive in the EcoEvo field. We found that females were not more likely to publish in DA peer-reviewed journals (H1) and adopting the DA peer-review policy did not increase the representativeness of female researchers as first or senior authors over time in EcoEvo journals (H2).

Although submitted papers with female authorships are sent to peer review at similar rates to articles with male authorships (Fox and Paine, 2019), female scientists are the minority in biological science publications, including EcoEvo journals, representing less than 30% of first and senior authorships (Bendels et al., 2018; Fox and Paine, 2019; Salerno et al., 2019). Adopting a DA peer-review process is usually considered a possible solution to reduce the gender gap in academic publications (Budden et al., 2008). However, our results showed that this policy alone is not reducing the gender gap in EcoEvo journals. Similar results were found in journals within Ecology Behavioral scope (i.e., Ecology Behavioral, Ecology and Sociobiology, The Auk and The Ibis (Cox and Montgomerie, 2019), where DA peer-reviews also showed insufficient to reduce the gender gap in authorships (Cox and Montgomerie, 2019). Such results indicate that conscious and unconscious gender biases are still pervasive in the peer-review process, which may be related to the gender bias in editorial boards of EcoEvo journals (Liévano-Latorre et al., 2020). Female editors represent less than 30% of editorial boards of ecology and conservation journals (Cho et al., 2014; Liévano-Latorre et al., 2020; Sperotto et al., 2021). As male scientists support other male scientists (Moss-Racusin et al., 2012), editors could bias the peer review process by rejecting submitted papers with female authorships (Brodie et al., 2021). Hence, the adoption of the DA review system alone could be insufficient in fostering gender equality in scientific publications. In this sense, before adopting the DA peer-review policy, the first step to promoting gender equality in EcoEvo publications is promoting gender-equitableness in these editorial boards (Liévano-Latorre et al., 2020). In addition, a triple-anonymized peer-review process, in which neither authors, reviewers or editors know each other's identity until the first decision is made (Brodie et al., 2021), could be a more plausible alternative to SA or DA. Recent works have argued that the implementation of triple-anonymized review by scientific journals might be an effective way to create a fairer system for underrepresented female scientists, leading to a more equitable academic publishing forum (Brodie et al., 2021; Conklin and Singh, 2022).

The underrepresentation of women in leadership positions also emerges as a potential explanation for the minority of women as leading authors in scientific papers. Even considering that female participation in STEM and specifically in biological sciences has been increasing in the last years, females are still underrepresented in senior positions (European Commission, 2019; National Science Foundation, 2018). Major drivers of female underrepresentation in academic spaces include unconscious biases about women’s abilities, harassment, discrimination, and homophily (Diele-Viegas et al., 2021; Greider et al., 2019). Hence, female scientists receive less support in academia and harsher reviews in scientific publications, which, together with recurrent sexual and moral gender-based harassment, prevents the retention and advancement of females in STEM careers (Diele-Viegas et al., 2021; Greider et al., 2019; Leaper and Starr, 2019).

White male cis-gender researchers from Global North still dominate the ecology area (Nuñez et al., 2021) and STEM as a whole contributing to the lack of diversity in the academic environment (Maas et al., 2021). Meanwhile, underrepresented researchers (e.g., women, people of colour, and LGBTQIA+ researchers) have different barriers to keeping and advancing in a scientific career. For instance, female researchers from Latin American countries deal with the intersection of sexism, colonialism, and even racism (Bernal et al., 2019; Valenzuela-Toro and Viglino, 2021). Female Latin American scientists develop their careers in countries that invest less in STEM and present a culture that highlights male pride (Bernal et al., 2019; Valenzuela-Toro and Viglino, 2021), besides hampering literature access and present language barriers (Valenzuela-Toro and Viglino, 2021).

Besides structural challenges female researchers face in the academic environment, the COVID-19 outbreak added extra barriers to their maintenance in STEM fields in the last two years. The pandemic has negatively affected the productivity, networking, community building and well-being of women in STEM, especially mothers (Langin, 2021; Myers et al., 2020). The pandemic occasioned disrupted collaborations and pauses in career progressions of female scientists, as they face challenges of remote work conflicting with caregiving responsibilities (Myers et al., 2020; Staniscuaski et al., 2020). Consequently, female scientists have been more isolated, losing contacts and publication chances, affecting their job stability and funding (Gabster et al., 2020; Myers et al., 2020).

Conclusions

Our results highlight that adopting the DA peer-review system alone could be insufficient in fostering gender equality in EcoEvo academic publications. Thus, we suggest the application of means to increase female representation on editorial boards and a change from DA to a triple-anonymized review process to reduce female underrepresentation in academic publications. Ecologists and evolutionists understand how diversity (expressed in diverse facets such as functional, genetic, phylogenetic, and taxonomic) is important to ecosystems' resilience in facing environmental changes. The question that remains is: why is it so difficult to promote and maintain this "diversity" in addition to equity and inclusion in the academic environment? We thus argue that all academic levels must be engaged in promoting solutions to gender bias. All scientists, mentors, and research centers could promote a fair and equal academic environment by fostering diversity, inclusion, and affirmative measures, such as scholarships and research funding (Diele-Viegas et al., 2021; Maas et al., 2021). Furthermore, reforms in the education system, mentoring and academic publishing are needed to reach equality in science (Holman et al., 2018). For instance, creating new evaluation metrics and implementing inclusive policies, such as encouraging gender equality in the editorial boards, could reduce the gender gap in STEM fields (Diele-Viegas et al., 2021; Liévano-Latorre et al., 2020; Sperotto et al., 2021).

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ADDITIONAL INFORMATION AND DECLARATIONS

Data Availability

All data used in this study are available as Supplemental Information in Appendix S1.

Competing Interests

The authors declare no competing financial interests.

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TABLES

Table 1 The 20 randomly selected EcoEvo journals for the present study. The dashes refer to non-collectable data, such as journals that are DA and SA from the beginning.

Journal	Impact Factor (2020)	Peer-review policy	Year of double-anonymized review adoption	First-year issues' period
Ecology and Society	3.890	Double-anonymized	-	2016-2020
Avian Conservation and Ecology	2.541	Double-anonymized	-	2016-2020
Ecosystem Health and Sustainability	2.315	Double-anonymized	-	2016-2020
Bioinvasions Records	1.504	Double-anonymized	-	2016-2020
Journal of Applied Ecology	5.840	Single-anonymized	-	2016-2020
Journal of Animal Ecology	4.554	Single-anonymized	-	2016-2020
Ecological Economics	4.482	Single-anonymized	-	2016-2020
Journal of Biogeography	3.723	Single-anonymized	-	2016-2020
Zoologica Scripta	2.603	Single-anonymized	-	2016-2020
EvoDevo	2.146	Single-anonymized	-	2016-2020
Biological Journal of the Linnean Society	1.961	Single-anonymized	-	2016-2020
Journal of Plant Ecology	1.833	Single-anonymized	-	2016-2020
Biodiversity Data Journal	1.331	Single-anonymized	-	2016-2020
Entomological Science	1.074	Single-anonymized	-	2016-2020
Conservation Biology	5.405	Switched-review*	2014	2009-2018
The American Naturalist	3.744	Switched-review	2015	2010-2019
Mammal Review	2.804	Switched-review	2009	2004-2013
Behavioral Ecology	2.761	Switched-review	2001	1996-2005

Animal Behavior	2.689	Switched-review	2009	2004-2013
Plant Ecology & Diversity	1.196	Switched-review	2008	2003-2012

*Switched-review: Switched-review: journals that changed their review model from single-anonymized to double-anonymized through time.

Table 2 Generalized Linear Mixed Model (GLMM) results for 2051 papers from 20 Ecology and Evolution scientific journals with gender (male and female; i.e., 0 and 1, respectively) of the first author as the dependent variable and peer-review policy, i.e. double-anonymized (DA) or single-anonymized (SA), as the independent variable. We also included the year of publication and the number of authors as covariates, whereas authors' country affiliation and journal as random factors in the model. Significant *P* values are in bold.

Model	**Estimate**	**SE**	**Z**	**P-value**
Intercept	-0.52311	0.129	-4.048	**5.16e-05**
Single-Anonymized peer-review	-0.0491	0.161	-0.303	0.761
Year of publication	0.133	0.076	1.752	0.079
Number of authors	-0.019	0.048	-0.392	0.695

Table 3 Generalized Linear Mixed Model (GLMM) result for 1,874 papers from 20 Ecology and Evolution scientific journals with gender (male and female; i.e., 0 and 1, respectively) of the senior author as the dependent variable and peer-review policy, i.e. double-anonymized (DA) or single-anonymized (SA), as the independent variable. We also included the year of publication and the number of authors as covariates, whereas authors' country affiliation and journal as random factors in the model. Significant *P* values are in bold.

Model	**Estimate**	**SE**	**Z**	**P-value**
Intercept	-0.979	0.105	-9.270	**<2e-16**
Single-Anonymized peer-review	-0.245	0.132	-1.852	0.064
Year of publication	0.144	0.068	2.099	**0.035**
Number of authors	-0.005	0.055	-0.096	0.923

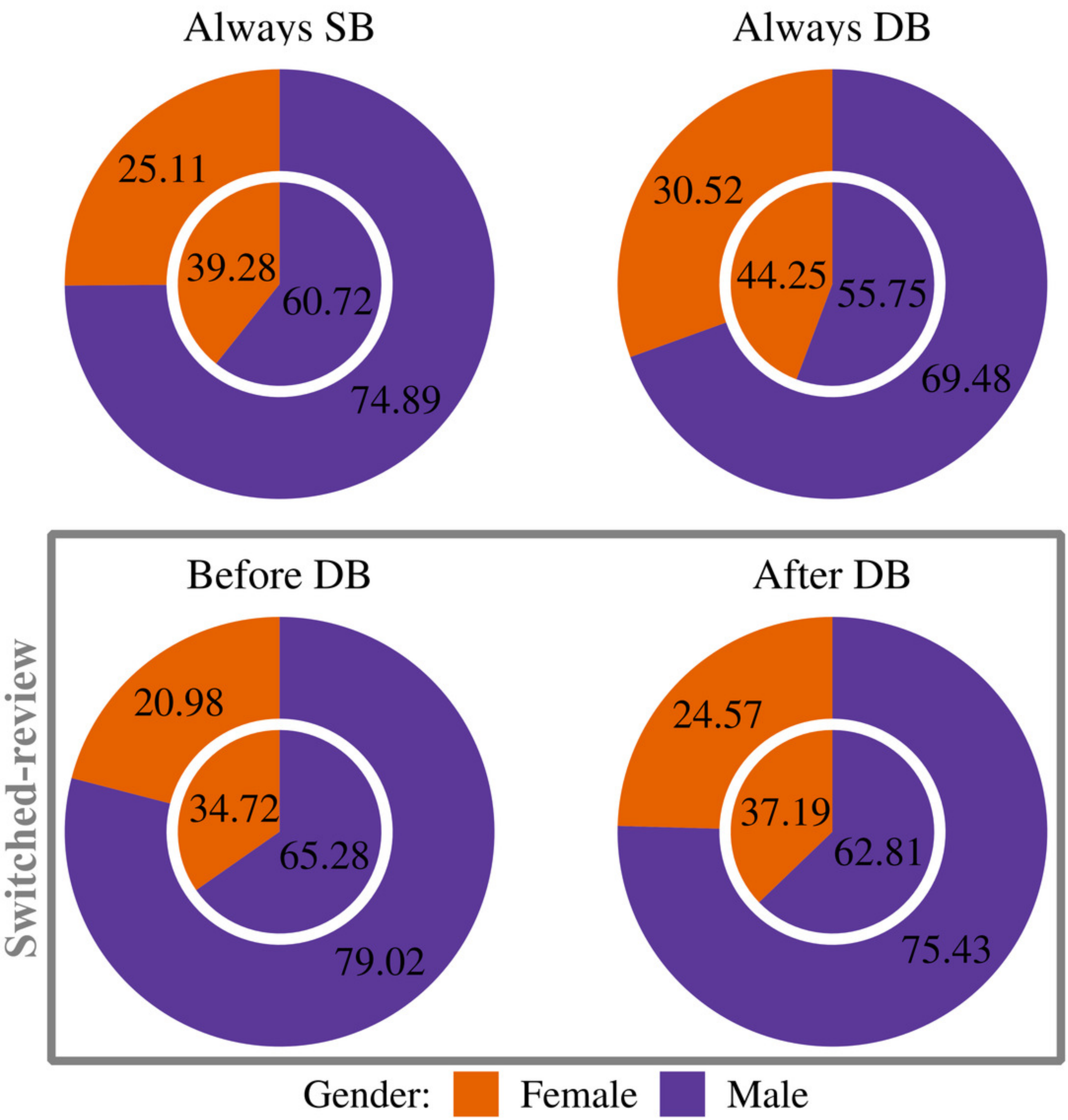
FIGURES

Figure 1. Frequencies of female (orange) and male (purple) researchers to each peer-review policy in the 20 EcoEvo journals analysed. Inner circles represent the first author and outer circles represent the senior author.

Figure 1

Frequencies of female (orange) and male (purple) researchers to each peer-review policy in the 20 EcoEvo journals analysed.

Inner circles represent the first author and outer circles represent the senior author.


Always SB
25.11
39.28
60.72
74.89
Always DB
30.52
44.25
55.75
69.48
Switched-review
Before DB
20.98
34.72
65.28
79.02
After DB
24.57
37.19
62.81
75.43
Gender: Female Male