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Research

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Females Are First Authors, Sole Authors, and Reviewers of Entomology Publications Significantly Less Often Than Males

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Abstract

Female authors and reviewers are significantly underrepresented in entomology journals, consistent with many other STEM journals. During the years 2001 through 2017, women published significantly fewer first-author and single-author articles in five ESA journals and the *Annual Review of Entomology*. Female reviewers are also significantly outnumbered by male reviewers in ESA journals. Results show that in general, female first author and reviewer proportions are rising over time but progress is slow, about 1% yearly for both authors and reviewers. There are a greater number of female authors than female reviewers, but proportions are significantly related to each other, suggesting that female authors and reviewers reinforce the presence of each other. Potential contributing factors for these results include peer review, funding levels for research, time available for research, and women's self-confidence and collaboration with other scientists.

Key words: gender difference, STEM publication, peer review, entomology

Publishing research results is a critical factor in any scientist's career development (Mendoza-Denton 2017). Publications enhance visibility (Kafer et al. 2018) and are 'frequently used as a measure of scientific merit' (Engvist and Frommen 2008). Women are persistently underrepresented in STEM disciplines (Moss-Racusin et al. 2012, Nature 2017), and this pattern extends to publication: women publish significantly fewer articles than do men (Duch et al. 2012, Lariviere et al. 2013, Bendels et al. 2018, Holman et al. 2018). This includes papers published in the flagship science journals *Nature* and *Science* (Conley and Stadmark 2012, Aakhus et al. 2018, Bendels et al. 2018, Lerchenmueller et al. 2018, Loverock and Hart 2018, Nature 2018, Overbaugh et al. 2018, Shen et al. 2018b, Berg 2019), and a wide array of specialized journals in different STEM areas, such as ecology and evolution (Bonnet et al. 2004, Symonds et al. 2006, Martin et al. 2012, West et al. 2013, Cameron et al. 2016, Bradshaw and Courchamp 2018, Edwards et al. 2018, Manlove and Belou 2018), computational biology (Bonham and Stefan 2017), mathematics (Milhaljevic-Brandt et al. 2016), engineering (Ghiasi and Sugimoto 2015), and academic medicine (Jagsi et al. 2006, Kaufman and Chevan 2011, Holliday et al. 2014, Mueller et al. 2016, Piper et al. 2016, Huryn et al. 2017, Butcher 2018, Khan et al. 2018, McDermott et al. 2018, Schwalbe and Fearon 2018, Silver et al. 2018). Women also publish fewer single-author articles than do men (Milhaljevic-Brandt et al. 2016, Zeng et al. 2016).

Because a significant component of competition for many STEM positions and promotion is publication record (Cameron 2013, Holliday et al. 2014, Allen-Hermanson 2017, Broderick and Casadevall 2017, Mendoza-Denton et al. 2017, Epstein and Lachmann 2018), any differences in publication patterns among scientists warrant investigation. A likely segue from the publication record in other disciplines is to consider how gender affects publication in entomology. To my knowledge, this is the first research paper to examine potential gender effects on publication in entomology. I show here that women were first, or lead, authors significantly less often than were men in papers published in five Entomological Society of America (ESA) journals between 2001 and 2017, and in the yearly *Annual Review of Entomology*, and that female reviewers for ESA journals are significantly underrepresented compared with male reviewers. Moreover, proportions of female first authors and female reviewers were significantly related to each other.

Materials and Methods

I assigned gender of first authors of 14,545 articles from 2001 to 2017 published in the following ESA-published journals: *Annals of the Entomological Society of America* (*Annals*; n = 2,001), *Environmental Entomology* (*Env. Entomol.*; n = 3,121), *Journal of Economic Entomology* (*JEE*; n = 4,718), *Journal of Medical*

Entomology (*JME*; *n* = 2,943), and *Journal of Insect Science* (*JIS*; *n* = 1,762).

I investigated female authorship from the perspective of lead, or first, author status only; I did not compile data on junior or last authors for this research. First author position in the biological sciences, which includes entomology, conventionally indicates that individual was responsible for most of the work, including writing the manuscript. Authorship position may be dependent on several different variables, including discipline, gender, and geography (Fox et al. 2018). To consider the possible significance of last author position in entomology, I calculated the proportion of male and female last authors of articles (*n* = 917) in the six journals for 2017 only. However, because results (20–29% females, 71–80% males) were similar to those for first authors, and because it is unclear in which journals or disciplines first author or last author position is considered the plum position, I did not continue this part of the analysis.

Gender was determined on the basis of first name of authors or, in the case of authors using only initials or for first names not easily assessed as male or female, by searching for information on the internet such as listed place of employment, or on websites such as LinkedIn or ResearchGate. In a small number of cases (<10% on average for all journals), gender could not be determined, so those data were not used in the analysis. For comparison with share of female authors in a review-based journal, I used the same procedure to determine gender for first authors of articles published in the *Annual Review of Entomology* (*Annual Review*) for the same time period (*n* = 452). For simplicity, I refer to the journals by abbreviations hereafter. Within this database, I compiled data on single-author publications (*n* = 761) by gender and analyzed these data separately and as part of the master database.

Lists of reviewers for the five ESA journals were examined, and gender assigned for the periods 2001 through 2017. Reviewer lists were published on an irregular basis for the journals: *Annals* (2001, 2008–2017); *Env. Entomol.* (2003, 2007–2010, 2013–2017); *JEE* (2003–2004, 2006, 2008–2010, 2014–2015); *JME* (2003–2004, 2006, 2008–2010, 2015); and *JIS* (2015, 2017).

Statistics

To test for gender differences in first authors and reviewers, I used χ^2 tests compared with null hypotheses of gender ratios of the entomology doctorates awarded that year (Walker 2018). Data from ESA journals were pooled for each year for the comparison, with separate tests for the *Annual Review*. Data for individual years in each journal were also analyzed, but as they were similar to the pooled data, only the pooled data were used. To test for differences in female proportion of first authors between journals, I used analysis of variance, followed by *t*-tests to separate means. The same procedure was used to test for differences in female reviewers between journals.

In the analysis of single-authored papers, I used *t*-tests to compare proportion of male-authored papers to proportion of female-authored papers, and regression to test for effects of time.

Regression was used to examine the relationship between time and proportion of first female authors and proportion of female reviewers, as well as proportion of female authors and female reviewers. Slope of line was used to determine yearly change in first author and reviewer proportions.

Results

Females Were First Authors of Published Articles Significantly Less Often Than Males

In every year from 2001 to 2017, in the five ESA journals, males were first authors of significantly more papers than were females (Fig. 1, Table 1). Males were also first authors of more papers than females for the *Annual Review* for during the 17-year period, and significantly so for 11 of those years (Table 2).

Female first author proportion varied between journals significantly ($F = 5.63$, df = 101, $P < 0.001$). Mean female first author proportion was not significantly different for *Annals* (0.285 ± 0.07), *Env. Entomol.* (0.295 ± 0.013), *JME* (0.305 ± 0.014), and *JIS* (0.263 ± 0.022), but *Annals*, *Env. Entomol.*, and *JME* mean proportions were significantly different than *JEE* mean female first author proportion (0.244 ± 0.01). *JIS* mean proportion did not differ significantly from *JEE* mean proportion. Mean female first author publication was significantly lower in the *Annual Review* than in any of the other journals (0.202 ± 0.017; Fig. 1).

Female First Authorship Has Increased Significantly Over Time for Four of the Six Journals

In four of the six journals, female first authorship increased during the period 2001 to 2017: for *Annals*, 1.1 % per year ($F = 24.816$, df = 1, $P < 0.001$); for *Env. Entomol.*, 0.9% per year ($F = 35.127$, df = 1, $P < 0.001$); for *JME*, 0.8% per year ($F = 15.970$, df=1, $P < 0.001$), and *JIS*, 1.2% per year ($F = 10.533$, df = 1, $P = 0.005$) (Fig. 1). Comparatively, increases in female first authorship over time were not significant for *JEE* (0.4% per year; $F = 4.145$, df=1, $P = 0.059$) or for the *Annual Review* (0. 2% per year; $F = 0.27$, df=1, $P = 0.605$) (Fig. 1).

More Single-Author Papers Were Written by Males Than by Females; Rate of Male Single-Author Papers Has Declined in Five of the Six Journals, Whereas Rate of Female Single-Author Papers Has Not Changed Over Time

In all journals, males published significantly more single-authored papers than did females: for *Annals* (mean male proportion = 0.074 ± 0.012, mean female proportion = 0.013 ± 0.003; $t = 1.73$, df = 18, $P < 0.001$); *Env. Entomol.* (mean male proportion= 0.041 ± 0.006, mean female proportion= 0.01 ± 0.002; $t = 1.73$, df = 19, $P < 0.001$), *JEE* (mean male proportion= 0.036 ± 0.005, mean female proportion= 0.007 ± 0.002; $t = 1.73$, df = 19, $P < 0.001$), *JME* (mean male proportion = 0.024 ± 0.003, mean female proportion = 0.005 ± 0.001; $t = 1.73$, df = 20, $P < 0.001$), *JIS* (mean male proportion= 0.073 ± 0.015, mean female proportion= 0.015 ± 0.004; $t = 1.73$, df = 18, $P < 0.001$), and the *Annual Review* (mean male proportion= 0.194 ± 0.019, mean female proportion= 0.024 ± 0.009; $t = 1.71$, df = 23, $P < 0.001$). Overall incidence of single-author papers for males significantly declined over time in all journals except *JME*: *Annual Review* ($F = 10.52$, df = 16, $P = 0.005$), *Annals* ($F = 27.1$, df = 16, $P < 0.001$), *Env. Entomol.* ($F = 16.55$, df = 16, $P = 0.001$), *JEE* ($F = 75.58$, df = 16, $P < 0.001$), *JME* ($F = 0.109$, df = 16, $P = 0.745$), and *JIS* ($F = 37.518$, df = 16, $P < 0.001$).

Proportion of single-authored papers by females did not change significantly with time: *Annual Review* ($F = 3.22$, df = 16, $P = 0.09$), *Annals* ($F = 0.199$, df = 16, $P = 0.661$), *Env. Entomol.* ($F = 0.582$, df = 16, $P = 0.457$), *JEE* ($F = 0.002$, df = 16, $P = 0.96$), *JME* ($F = 0.34$, df = 16, $P = 0.857$), and *JIS* ($F = 1.332$, df = 16, $P = 0.266$).

Significantly More Males Reviewed Articles for ESA Journals, But Proportion of Female Reviewers Has Risen Significantly Over Time

Reviewer population was extremely and significantly male-biased during the entire 17-year period (Table 3). Proportion of female reviewers differed according to journal ($F = 6.23$, df = 47, $P = 0.001$). The proportion of female reviewers used by *Annals* (0.225 ± 0.011), *Env. Entomol.*

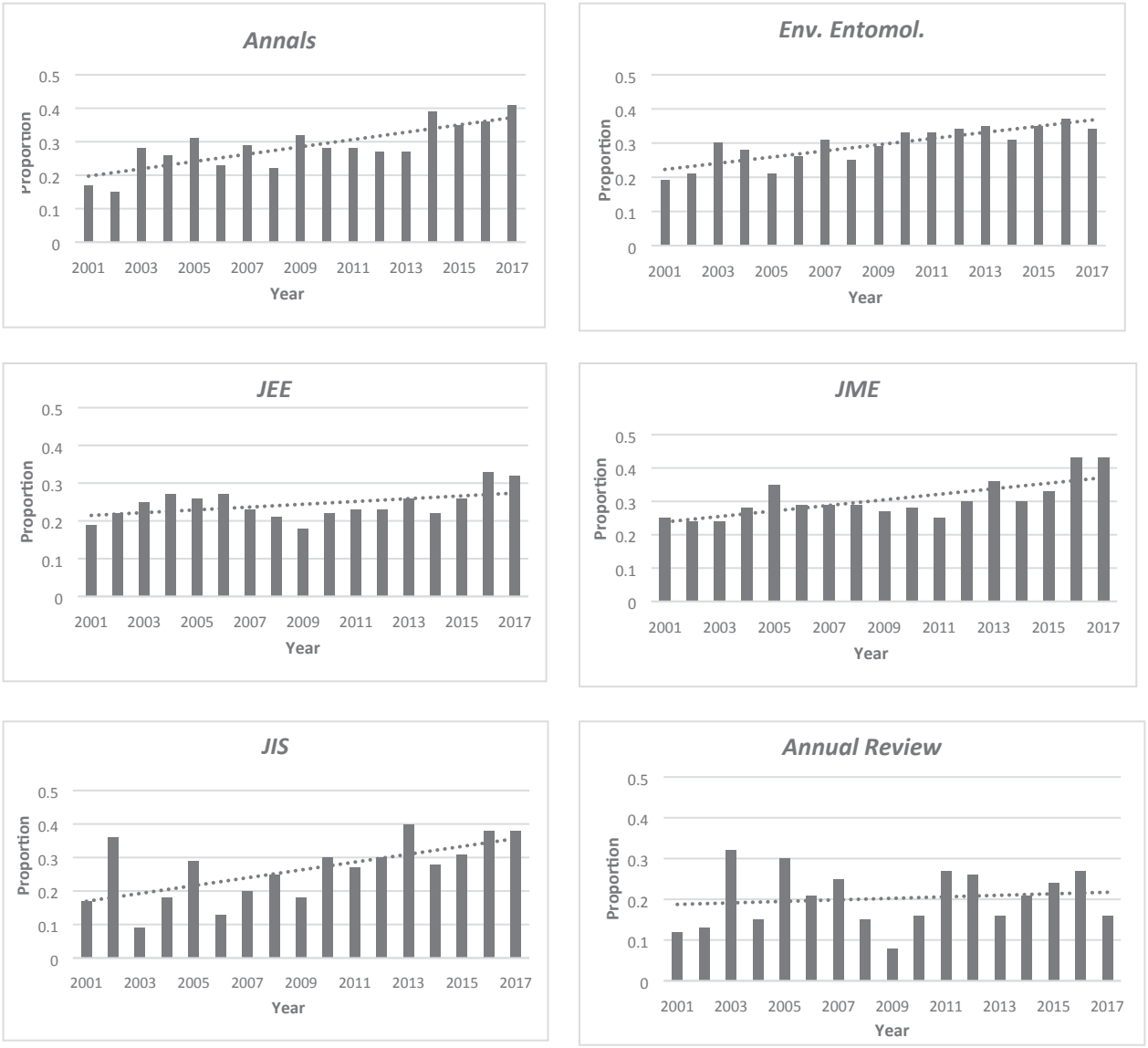

Fig. 1. Female first author proportions in five ESA journals and the *Annual Review of Entomology* for the years 2001–2017. Proportion of female first authors in the *Annals*. The equation for the line is $y = 0.0109x + 0.1863$, $R^2 = 0.6233$. Proportion of female first authors in *Env. Entomol*. The equation for the line is $y = 0.009x + 0.2139$, $R^2 = 0.7008$. Proportion of female first authors in *JEE*. The equation of the line is $y = 0.0037x + 0.2109$, $R^2 = 0.2165$. Proportion of female first authors in *JME*. The equation for the line is $y = 0.0083x + 0.2299$, $R^2 = 0.5157$. Proportion of female first authors in *JIS*. The equation for the line is $y = 0.0117x + 0.1575$, $R^2 = 0.4125$. Proportion of female first authors in the *Annual Review*. The equation for the line is $y = 0.0019x + 0.1856$, $R^2 = 0.0183$.

(0.211 ± 0.01), and *JME* (0.245 ± 0.014) did not differ significantly. Mean share of female reviewers for *JEE* (0.181 ± 0.009) differed significantly with that for *Annals* and *JME*, but not with *Env. Entomol.*

As with the incidence of female first authors, proportion of female reviewers rose significantly over time: for *Annals*, 0.81% per year ($F = 7.388$, df=10, $P = 0.024$); for *Env. Entomol.*, 0.92% per year ($F = 85.8$, df=10, $P < 0.001$); for *JEE*, 0.76% per year ($F = 62.787$, df=12, $P = 0.011$); and for *JME*, 1.0% per year ($F = 28.039$, df = 12, $P < 0.001$) (Fig. 2).

Since there were only 2-yr data on reviewers for *JIS*, these data were not analyzed.

Proportion of First Female Authors and Proportion of Female Reviewers Are Significantly Related in Three of the Five ESA Journals

In all ESA journals except *JEE*, regression of proportion of first and sole female authors on proportion of female reviewers was significant, demonstrating a positive relationship between peer review by females and female authorship (Fig. 2).

The proportion of female reviewers was also significantly smaller than proportion of first female authors per year: *Annals* ($t = 5.54$, df = 9, $P < 0.001$); *Env. Entomol.* ($t = 14.544$, df = 10, $P < 0.001$); *JEE* ($t = 5.767$, df = 11, $P < 0.001$); and *JME* ($t = 3.983$, df = 10, $P = 0.003$) (Fig. 2).

Discussion

This research demonstrates that females are significantly underrepresented as first authors and reviewers on entomology publications, at least those published by ESA. Although it is possible that other American or international entomology journals show different publication patterns, it appears to be unlikely since men dominate the entomology profession in the United States (Walker 2018), and authorship in international STEM journals such as *Nature* are also

Table 1. Comparison of male and female first authors (pooled) in ESA journals (*Annals of the Entomological Society of America, Environmental Entomology, Journal of Economic Entomology, Journal of Medical Entomology, and Journal of Insect Science*)

	Males	Females	χ^2	df	*P*	Null hypothesis sex ratio (male: female)
2001	499	123	30.967	1	<0.001	70:30
2002	461	125	20.971	1	<0.001	70:30
2003	500	171	26.707	1	<0.001	65:35
2004	593	233	16.748	1	<0.001	65:35
2005	561	214	49.548	1	<0.001	60:40
2006	612	212	69.932	1	<0.001	60:40
2007	533	192	55.195	1	<0.001	60:40
2008	580	181	83.375	1	<0.001	60:40
2009	666	212	91.954	1	<0.001	60:40
2010	684	266	110.929	1	<0.001	55:45
2011	740	261	144.87	1	<0.001	55:45
2012	603	240	93.07	1	<0.001	55:45
2013	583	273	112.266	1	<0.001	50:50
2014	696	278	179.388	1	<0.001	50:50
2015	610	272	129.528	1	<0.001	50:50
2016	529	307	58.952	1	<0.001	50:50
2017	474	276	52.272	1	<0.001	50:50

Table 2. Comparison of male and female first authors in the *Annual Review of Entomology*

Year	Males	Females	χ2	df	*P*	Null hypothesis sex ratio (males: females)
2001	22	3	3.857	1	0.049	70:30
2002	26	4	3.968	1	0.046	70:30
2003	17	8	0.99	1	0.753	65:35
2004	17	3	3.516	1	0.061	65:35
2005	16	7	0.877	1	0.349	60:40
2006	22	6	4.024	1	0.045	60:40
2007	18	6	2.25	1	0.134	60:40
2008	23	4	7.136	1	0.008	60:40
2009	23	2	10.667	1	0.001	60:40
2010	27	5	11.157	1	0.001	55:45
2011	19	7	3.433	1	0.064	55:45
2012	17	8	3.324	1	0.068	55:45
2013	26	5	14.226	1	<0.001	50:50
2014	23	6	9.966	1	0.002	50:50
2015	25	8	8.758	1	0.003	50:50
2016	19	7	5.538	1	0.019	50:50
2017	21	4	11.56	1	<0.001	50:50

skewed toward males (Bendels et al. 2018). Further research might focus on other American and international journals.

Women were first authors of papers in *JEE* significantly less often than in *Annals*, *Env. Entomol.*, and *JME,* which may suggest that women may submit more manuscripts to *Annals*, *Env. Entomol.*, and *JME* than to *JEE*. Female entomologists may be more attracted to areas less typically covered by *JEE*, such as medical entomology, social behavior, and ecology, and thus, there may be fewer females working in areas traditionally addressed in this journal. It is also notable that *JEE* has significantly fewer female reviewers than *Annals* and *JME*, which may account in part for the lower share of female first authors, especially since proportions of female authors and reviewers are significantly related to each other.

It is not surprising that female first author proportion was lowest in the *Annual Review* since it has been amply demonstrated that journals publishing review-type articles have a lower percentage of female authors (Brooks et al. 2014, Milhakjevic-Brandt et al. 2016, Filardo et al. 2016, Holman et al. 2018, Shen et al. 2018b, Silver et al. 2018). In fact, it has been shown that impact factor and female publication rate are inversely related for some journals (Bendels et al. 2018, Shen et al. 2018a), possibly because women submit even fewer manuscripts to high-impact journals (Filardo et al. 2016, Lerchenmueller et al. 2018), or because women are less likely to be invited to write reviews than are men (Conley and Stadmark 2012). Holman et al. (2018) estimated that review journals ask men to submit papers at about twice the rate that women are asked. With a 2019 impact-factor of 13.86 (Clarivate Analytics), the *Annual Review* is the highest ranked journal in entomology. Increase in female authorship over time is also slower in higher-impact journals (Caplar et al. 2017).

It is welcome news that publication rates for female first authors have significantly risen over the study period in four of the six entomology journals examined, similar to that seen in other STEM journals (Franco-Cardenas et al. 2015, Yun et al. 2015, Piper et al. 2016, Helmer et al. 2017, Khan et al. 2018). This rise, however, is only about 1% per year, which is also consistent with yearly rate of

Table 3. Comparison of pooled numbers of male and female reviewers of ESA journals (*Annals of the Entomological Society of America, Environmental Entomology, Journal of Economic Entomology, Journal of Medical Entomology, and Journal of Insect Science*)

	Males	Females	χ^2	df	*P*	Null hypothesis gender ratio (male: female)
2003	877	181	148.879	1	<0.001	65:35
2004	591	101	126.643	1	<0.001	65:35
2006	739	146	203.691	1	<0.001	60:40
2007	631	154	135.881	1	<0.001	60:40
2008	1,287	298	296.782	1	<0.001	60:40
2009	1,390	343	294.864	1	<0.001	60:40
2010	1,392	354	431.265	1	<0.001	55:45
2011	1,295	317	418.053	1	<0.001	55:45
2012	1,239	373	311.266	1	<0.001	55:45
2013	1,293	382	495.475	1	<0.001	50:50
2014	992	270	413.062	1	<0.001	50:50
2015	1,579	407	691.633	1	<0.001	50:50
2016	1,472	501	477.872	1	<0.001	50:50
2017	1,028	552	143.403	1	<0.001	50:50

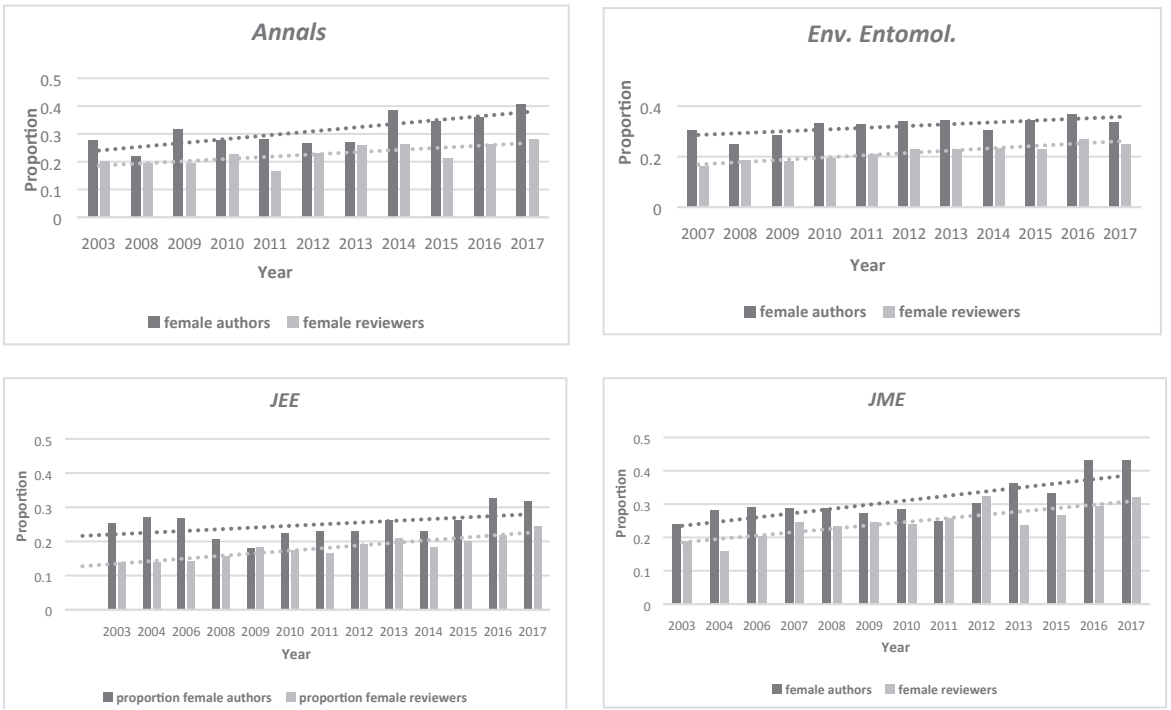

Fig. 2. Relationship of female authors and female reviewers in ESA journals. Proportion of female first authors and female reviewers for the *Annals*, 2003–2017. Regression of proportion of female authors on proportion of female reviewers, $F = 5.71$, df = 10, $P = 0.041$. Female author line equation: $y = 0.0139x + 0.2261$, $R^2 = 0.6248$. Female reviewer line equation: $y = 0.0081x + 0.1774$, $R^2 = 0.5407$. Proportion of female first authors and female reviewers for *Env. Entomol.*, 2007–2017. Regression of proportion of female authors on proportion of female reviewers, $F = 9.08$, df = 10, $P = 0.014$. Female author line equation: $y = 0.0071x + 0.2787$, $R^2 = 0.4871$. Female reviewer line equation: $y = 0.0092x + 0.1597$, $R^2 = 0.9051$. Proportion of female first authors and female reviewers for *JEE*, 2003–2017. Regression of proportion of female authors on proportion of female reviewers, $F = 2.811$, df = 12, $P = 0.128$. Female author line equation: $y = 0.0049x + 0.2113$, $R^2 = 0.2154$. Female reviewer line equation $y = 0.0076x + 0.1197$, $R^2 = 0.8599$. Proportion of female first authors and female reviewers for *JME*, 2003–2017. Regression of proportion of female authors on proportion of female reviewers, $F = 6.3$, df = 12, $P = 0.029$. Female author line equation: $y = 0.0127x + 0.222$, $R^2 = 0.6337$. Female reviewer line equation: $y = 0.0103x + 0.1748$, $R^2 = 0.7115$.

change in female authors in other journals (Shen et al. 2018b), and has not kept pace with the percentage of women graduating with doctorates in entomology that year (Walker 2018) again, similar to that seen in other journals (Helmer et al. 2017). This indicates that changes in publications need to be made to bring female authorship up to levels at least on par with female doctoral graduation rates.

A finding of fewer female single-authored articles than male single-authored papers is consistent with results in a wide range of academic disciplines (West et al. 2013) and may simply be a reflection of the historical predominance of men in STEM, or suggest that males have more resources to perform research. Certainly, there are fewer women in entomology, and the proportion of women declines with each step up the rung in academic entomology (Walker 2018), as well as in academia in general (Bakker and Jacobs 2016). To the extent that last authors may be the principal investigators on the project which produced the research, the fact that females are significantly underrepresented in professional entomology may be an explanatory factor.

Multiple authorship is an increasingly popular publication strategy: there is an increasing trend in the number of authors per paper (Dehdarirad et al. 2015), possibly due to the need to have collaborative teams work on complex research projects (Abt 2007), or because of an increased chance of acceptance when papers have multiple authors (Tregenza 2002). Working with a higher number of collaborators yields more publications, and papers with multiple coauthors appear to be more visible and tend to receive more citations (Beaudry and Lariviere 2016, Wagner 2016). However, women in STEM have significantly fewer coauthors than do men (Wagner 2016), which is probably related in part to women's smaller networks, and may play a role in the lower citation rates of female authors if citation rate is indeed influenced by number of coauthors.

Broadly, there are several possible factors responsible for underrepresentation of female authors:

Women receive less funding for research than men. A pervasive cause of lower STEM female authorship rates is the historically lower funding amounts received by women (Filardo et al. 2016, Wagner 2016, Zeng et al. 2016, Van den Besselaar and Sandstrom 2017, Badawy et al. 2018, Tamblyn et al. 2018). Recently, female first-time applicants for National Institute of Health funding received significantly less money than did male first-time applicants (Oliveira et al. 2019), which is in line with past NIH funding patterns (Hechtman et al. 2018). The female funding deficit appears to be a self-perpetuating issue since it has been shown that those applicants who have already won grants for research have a significant advantage over other applicants to win future grants (Bol et al. 2018). Those who publish fewer papers receive lower amounts of funding in future (Duch et al. 2012).

Women have less time for research than men. Time inequities between male and female scientists may begin in graduate school and continue into the professional career (Feldon et al. 2017). Female graduate students may be more often supported by teaching assistantships, with male graduate students more often supported by research assistantships, leaving women less time to do research and write manuscripts (Lubienski et al. 2018). In the few short years between graduate school and embarking on a professional career, when scientists are competing for jobs, women are usually already behind men in publication output, contributing to lower employment levels in STEM in for women (Knobloch-Westerwick et al. 2015, Cameron et al. 2016, Broderick and Casadevall 2017, Lerchenmueller et al. 2018). Symonds et al. (2006) estimated that it takes women up to 5 yr to achieve the same publication output as it takes men to accomplish in 2 yr. At the faculty level, women typically have heavier teaching loads than men, giving them less time to devote to research, which leads to fewer publications; this may be especially true since, on average, women occupy lower academic ranks than do men (Jagsi et al. 2006, Van den Besselaar and Sandstrom 2017, Epstein and Lachmann 2018). In addition, family obligations are still borne disproportionately by women, which diminishes the amount of time available for women scientists to spend on research and writing manuscripts (Hunter and Leahey 2008, West et al. 2013, Lubieski et al. 2018). In fact, a recent study (Cech and Blair-Loy 2019) estimates that up to 43% of women with STEM jobs stop working in science altogether after having a child.

Women are typically less confident of their scientific abilities than men. As a group, women are less confident of their abilities to publish their research than are men, and may therefore submit fewer manuscripts as a result (West et al. 2013, Lerback and Hanson 2017, Mendoza-Denton et al. 2017, Cooper et al. 2018, Freeman et al. 2018, Lubienski et al. 2018). Women may also be less experienced, comfortable, or assertive about negotiating the first authorship position in collaborations with male research team members, perhaps due to a reluctance to compete with others (Balafoutas et al. 2018, Murray et al. 2018)—especially men, resulting in a lower proportion of first-authored papers by women (West et al. 2013, Bendels et al. 2018, Holman et al. 2018, Lubienski et al. 2018). Publishing opportunities frequently arise from networking with other scientists. Because men have more experience in networking (Lariviere 2013, West 2013) or because women feel unwelcome in men's professional networks (Greguletz et al. 2019), women are less likely to form such advantageous bonds than men, which reduces the number of possible publications that women can attain (Van Arensbergen et al. 2012). Some research suggests that even when men and women collaborate on research projects, women may perform more of the execution of the project, while men more often design studies, and thus men end up more likely to be listed as authors on those publications (Macaluso et al. 2016, Feldon et al. 2017). This pattern appears early: publication as a graduate student has been positively correlated with encouragement from advisors and mentors, with male students reporting higher levels of backing than female students (Lubienski et al. 2018). Women in male-dominated academic majors also experience greater gender harassment than those in gender-neutral majors, which may lead women to believe that they need to overperform to be good enough (Dresden et al. 2018). This may result in women spending more time polishing manuscripts than men (Smith et al. 2013, Feldon et al, 2017), while men pursue a comparatively high-risk strategy of sending out as many manuscripts as possible to journals with as high an impact factor as possible (Beaudry and Lariviere 2016), in the hopes of paper acceptance and establishing a professional reputation as quickly as possible. It has been demonstrated that scientists who publish articles early in their careers tend to have a more productive lifetime publication record (Laurance et al. 2013). Gender differences in publication rates may also reinforce the low self-confidence of many female scientists and indeed, lead to even lower self-esteem (Cameron et al. 2013).

Peer review may favor male authors: Peer review may contribute to women's lower publication rates. Ideally, the purpose of peer review is to evaluate a paper's scientific merit and importance to the discipline (Lee et al. 2013), and has generally been regarded as fair (Rees 2011). However, in recent years, the effect of bias on peer review has been investigated as a factor which may lead to publication differences in some groups of authors. Paper acceptance may be affected by reviewers' judgments explicitly or implicitly influenced by external factors such as author affiliation, prestige, and nationality (Tregenza 2002, Lee et al. 2013, Fox et al. 2017, Reingewertz and Lutmar 2018, Murray et al. 2018), or gender (Paludi and Bauer 1983, Borsuk et al. 2009, West et al. 2013, Fox et al. 2017, Bradshaw and Courchamp 2018, King et al. 2018, Manlove and Belou 2018, Murray et al. 2018, Fox and Paine 2019). This bias may be exacerbated by the fact that in many STEM journals, males predominate as reviewers of manuscripts (Grod et al. 2008, Borsuk et al. 2009, Amrein et al. 2011, Cho et al. 2014, Fox et al. 2015, Helmer et al. 2017, Lerback and Hanson 2017, Buell et al. 2018). Male reviewers may be predisposed to favor articles by male authors over those by females (Borsuk et al. 2009, Rees 2011, Murray et al. 2018). Those male authors may benefit from the 'Matthew effect', in which males are implicitly assumed to produce better quality scientific work than females (Rossiter 1993, Knobloch-Westerwick et al. 2015).

In the ESA journals examined here, reviewer populations were highly and significantly male-dominated over the entire period, which is consistent with other journals in STEM (Borsuk et al. 2009, Fox et al. 2015, Helmer et al. 2017, Lerback and Hanson 2017, Nature 2018). The predominance of male reviewers in ESA journals

likely is responsible for at least part of the lower number of female authors.

Female reviewer proportion rose significantly over time for *Annals*, *Env. Entomol.*, *JEE*, and *JME*, similar to changes observed at other journals (Helmer et al. 2017, Nature 2018). But, the rate of change is still very low. As more and more female journal editors are appointed, they select more female reviewers (Buckley et al. 2014, Fox et al. 2015, Lerback and Hanson 2017). The operational homophily in male reviewers appears to apply to female reviewers as well, where women appear to rank articles by female authors higher than those by males (Helmer et al. 2017, Bradshaw and Courchamp 2018). As with female first authors, *JEE* showed the slowest rate of increase in proportion of female reviewers. This may reflect the proportionately higher number of men publishing in *JEE*, and a possibility that *JEE* is seen as a more "traditional" entomology journal, so fewer females submit papers to it.

Proportion of female reviewers in the ESA journals investigated was significantly smaller than that of female first authors, which is also consistent with patterns seen in some STEM journals (Helmer 2017, Lerback and Hanson 2017). When editors ask scientists to review manuscripts, it is generally a recognition of experience with the subject, and since men have historically been in leadership positions in science longer than women, this may help explain this pattern (Helmer et al. 2017). Female reviewer rates may also be depressed if women decline invitations to review manuscripts because of heavier teaching and service responsibilities (Lerback and Hanson 2017) or family obligations, thereby leaving a male-skewed reviewer population by default. Authors may also have asked for male rather than female reviewers to evaluate their manuscripts (Lerback and Hanson 2017).

My results showed that for three of the five ESA journals, female first author and female reviewer proportions were significantly related. This may result from a slowly changing pattern of more and more women going into professional entomology, and consequently submitting manuscripts to journals. As share of female authors rises, women entomologists gain incrementally higher leadership positions such as reviewers, editors, and editorial board members. As more female reviewers are assigned manuscripts, the likelihood of acceptance of female-authored papers rises, in a mutually reinforcing cycle. Women should be encouraged not to feel hesitant about promoting themselves and their careers (Brooks et al. 2014), and in writing up and submitting their research results for publication.

Journals play an integral role in assuring that the best scientific papers are published, implementing a peer review process which ensures that nonrelevant characteristics such as gender, race, sexual identity, national origin, age, and other factors are not allowed to influence the process. The best approach may be through a double-blind review system. Currently, ESA journals utilize a single-blinded review process in which reviewers' identities are masked to authors. However, some studies have suggested that the use of double-blind reviews, in which both reviewer and author identities are concealed, may help achieve gender parity (Budden et al. 2008, Tomkins et al. 2017, Okike et al. 2016). ESA can also help improve diversity in their journals and in entomology in general by recruiting editors and reviewers, which reflect underrepresented populations of entomologists (such as the active canvasing for open journal editorial positions at last year's national annual meeting). Since publication record is so important for the continued success of scientists, it is critical for the career development of female entomologists and other underrepresented groups in entomology that we address and resolve this issue.

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