Functional Ecology

British Ecological Society

Gender differences in patterns of authorship do not affect peer review outcomes at an ecology journal

Charles W. Fox, C. Sean Burns, Anna D. Muncy and Jennifer A. Meyer

There is a widespread perception in the academic community that peer review of scientific papers is subject to many biases. In particular, peer review might be influenced by the identity, gender, nationality or prestige of authors. In a previous study we found that the gender of editors and reviewers does affect the peer review process but does not affect peer review outcomes at *Functional Ecology*. Editor gender influenced the gender ratio of scientists invited to review (an effect mediated by editor seniority), and responses to review invitations differed between male and female invitees to review. However, gender did not influence peer review scores given by reviewers or decisions made by editors. In the current study we examine how patterns of authorship differ between men and women, and whether author gender influences the peer review process and/or editorial and peer review outcomes for papers submitted to *Functional Ecology* between 2010 and 2014.

Women represented approximately a third of all authors on papers submitted to *Functional Ecology*. Relative to overall frequency of authorship, women were underrepresented as solo authors (26% of authors on single-authored papers were women). On multi-authored papers, women were also underrepresented as last/senior authors (25% of last authors were women) but overrepresented as first authors (43% of first authors were women). The high proportion of female first authors for papers submitted to *Functional Ecology* shows that women are well-represented at the less senior levels in ecology. Women first authors were less likely than men first authors to serve as corresponding and submitting author of their papers. Notably, this difference was not influenced by the gender of the last author. Women were more likely to be authors on papers, and the gender ratio of all authors on a paper was on average less male-biased, if the last author was female.

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Papers with female and male authors were equally likely to be sent for peer review, across all authorship positions. Interestingly, papers authored by women were more likely to be reviewed by women. This is primarily because women were more likely to be invited to review if the authors on a paper were female than if the authors were male, and not because women were more likely to agree to review if the authors were female. Papers with female and male authors obtained equivalent peer review scores, and were equally likely to be accepted for publication. There was also no evidence that male editors or male reviewers treated papers authored by women differently than did female editors and reviewers, and no evidence that more senior editors reached different decisions than younger editors after review, or cumulative through the entire process, for papers authored by men versus women.

Our evidence here, and in Fox et al. (in press), is consistent in indicating that gender influences some aspects of the peer review process but that peer review outcomes at *Functional Ecology* are gender-neutral. We thus conclude from our pair of studies that gender of the participants influences the process of manuscript review – it influences who is chosen to review papers, the response of invitees to review invitations, and the time span of the review process. But, at the end of the process, gender of the participants does not affect editorial and peer review outcomes at this particular ecology journal.

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Gender differences in patterns of authorship do not affect peer review outcomes at an ecology journal

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Summary

1. There is a widespread perception in the academic community that peer review is subject to many biases and can be influenced by the identity and biographic features (such as gender) of manuscript authors.

2. We examined how patterns of authorship differ between men and women, and whether author gender influences editorial and peer review outcomes and/or the peer review process for papers submitted to the journal *Functional Ecology* between 2010 and 2014.

3. Women represented approximately a third of all authors on papers submitted to *Functional Ecology*. Relative to overall frequency of authorship, women were underrepresented as solo authors (26% were women). On multi-authored papers, women were also underrepresented as last/senior authors (25% were women) but overrepresented as first authors (43% were women). Women first authors were less likely than men first authors to serve as corresponding and submitting author of their papers; this difference was not influenced by the gender of the last author. Women were more likely to be authors on papers if the last author was female.

4. Papers with female authors (i) were equally likely to be sent for peer review, (ii) obtained equivalent peer review scores and (iii) were equally likely to be accepted for publication, compared to papers with male authors. There was no evidence that male editors or male reviewers treated papers authored by women differently than did female editors and reviewers, and no evidence that more senior editors reached different decisions than younger editors after review, or cumulative through the entire process, for papers authored by men vs. women.

5. Papers authored by women were more likely to be reviewed by women. This is primarily because women were more likely to be invited to review if the authors on a paper were female than if the authors were male.

6. Patterns of authorship, and the role undertaken as author (e.g., submitting and serving as corresponding author), differ notably between men and women for papers submitted to *Functional Ecology*. However, consistent with a growing body of literature indicating that peer review underlying the scholarly publishing process is largely gender-neutral, outcomes of editorial and peer review at *Functional Ecology* were not influenced by author gender.

Key-words: authorship, gender bias, gender discrimination, peer review, women in science

Introduction

Scholarly publication is the primary means by which scientific research is communicated among researchers. An individual's research contributions are therefore measured by their authorship on peer-reviewed scholarly articles, and authorship is a major determinant of success when scientists compete for research grants (Kaltman *et al.* 2014), apply for promotion or tenure (Wren *et al.* 2007), or receive recognition by their peers (Merton 1973). Though the specifics of what authorship order signifies vary by discipline (Zuckerman 1968; Frandsen & Nicolaisen 2010; Waltman 2012), author order (Shapiro, Wenger & Shapiro 1994; Zbar & Frank 2011; Cleary *et al.* 2012) and role (e.g., serving as corresponding author; Bhandari *et al.*

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2014) commonly signify either the magnitude or type of contribution made and so can affect the success of scientists (Sonnenwald 2007).

Patterns of authorship commonly differ between male and female scholars. Globally, women comprise <30% of authorships on scientific publications (Larivière *et al*. 2013; Burns 2015) and publish less frequently than do men (Symonds *et al*. 2006; Ledin *et al*. 2007; Long *et al*. 2015). The proportion of authors that are women has been increasing (Jagsi *et al*. 2006; Baethge 2008; Dotson 2011), but the degree of change varies substantially among journals and disciplines (Sidhu *et al*. 2009; Kongkiatkamon *et al*. 2010; Oertelt-Prigione 2012; Mauleón *et al*. 2013; West *et al*. 2013). In particular, men have historically been over-represented as first and last authors while women have been over-represented as middle authors (Martin 2012), though the under-representation of women at the first and last positions, especially first authors, has improved over the past couple of decades (West *et al*. 2013). Findings such as these suggest either differences between genders in preference for roles in the scientific research process or societal biases that affect the choices men and women make in their careers (Xie & Shauman 1998), either of which may result in different opportunities and rewards afforded to women vs. men in the scientific publishing process (Fox, Burns & Meyer 2015).

Peer review, in some form, has been a key feature of the scholarly communication system for nearly three centuries (Spier 2002; Hunter 2010). Despite this, there is a widespread perception among researchers that systemic biases influence peer review outcomes (Lee *et al*. 2013). In particular, the gender of authors may influence manuscript or grant peer review due to subconscious, or sometimes conscious, biases (Tregenza 2002). Bibliometric analyses consistently demonstrate differences in publication rates between men and women (Abramo, D'Angelo & Caprasecca 2009; Larivière *et al*. 2011; Barrios, Villarroya & Borrego 2013), and analyses of grant funding rates commonly demonstrate that men get more grants and/or more money (Bornmann, Mutz & Daniel 2007; Ley & Hamilton 2008; but see Marsh *et al*. 2009). However, the evidence on whether and to what extent these differences are generated by systemic gender discrimination is limited and inconsistent; differences in funding and/or publication rate can be due to gender disparity in rank and institutional prestige (Nakhaie 2002), research specialization (Leahey 2006), or manuscript/grant submission rates (van Arensbergen, van der Weijden & van den Besselaar 2012) between men and women, rather than discrimination per se.

A few early studies of peer review demonstrated that papers and grants authored by women were less well reviewed or less likely to be funded or published (Wenneras & Wold 1997), and suggested that women reviewers tend to be more favourable towards papers written by female authors (Lloyd 1990). However, few subsequent studies have found gender bias in peer review. Controlled experiments in the life sciences (Borsuk *et al*. 2009) or other fields (Knobloch-Westerwick, Glynn & Huge 2013), and correlational studies of editorial (or granting) decisions or reviewer ratings in the life sciences (Tregenza 2002; Primack *et al*. 2009) but primarily in the health sciences and other fields (Lane & Linden 2009; Heckenberg & Druml 2010; Walker *et al*. 2015 for manuscript review; Dickson 1997; Grant, Burden & Breen 1997; Friesen 1998; Ley & Hamilton 2008; Leemann & Stutz 2008; Sandström & Hällsten 2008; Marsh, Jayasinghe & Bond 2008, 2011; Mutz, Bornmann & Daniel 2015 for grant reviews), generally find that peer review is gender neutral, though there are some exceptions (e.g., Knobloch-Westerwick, Glynn & Huge 2013; Krawczyk & Smyk 2014). However, most manipulative studies use student populations as their raters, and the majority of analyses of peer review done by professional researchers look at grant applications; few have looked at manuscript submissions to academic journals. This is likely because the journal peer review process is typically quite secretive, whereas granting agency data on application and success rates is commonly made public.

The purpose of this study is to test (i) whether patterns of authorship differ between men and women for papers submitted to the ecology journal *Functional Ecology* and (ii) whether author gender influences the peer review process at this journal. A previous study (Fox, Burns & Meyer 2015) found that editor gender influenced the gender ratio of scientists invited to review (an effect mediated by editor seniority), and that responses to review invitations differed between male and female invitees to review, but that gender did not influence peer review scores given by reviewers or decisions made by editors. Here, we extend our analyses to the influence of author gender on the peer review process, and test for possible interactions between author and either editor or reviewer gender.

Materials and methods

DATA SET

Functional Ecology uses *ScholarOne Manuscripts* (previously *Manuscript Central*) to manage manuscript submissions and peer review. We extracted data on the editorial and peer review process from *ScholarOne* on 19 December 2014 for all 'standard' papers submitted to *Functional Ecology* between 1 January 2010 and 30 June 2014 (inclusive). 'Standard' papers include all typical research studies (empirical or theoretical), but exclude review papers, commentaries, perspectives, editorials and other types of papers not considered typical research manuscripts. We chose 30 June 2014 as our cut-off to ensure that all papers examined had completed the editorial process at the time the data were extracted from *ScholarOne*. Over this time period (January 2010–June 2014) the journal received 3528 submissions of standard papers. Of these standard papers, 2298 were assigned to a handling editor, 1770 papers were sent out for peer review, and 551 were invited to revise and/or were accepted for publication.

AUTHORSHIP ON PAPERS

Data in *ScholarOne* is author-entered and so author lists in the database are sometimes incomplete and usually ordered incorrectly. We thus determined authorship on papers from the cover

page of the submitted manuscript and not from the data extracted from *ScholarOne*. PDFs of manuscripts submitted to *Functional Ecology* were available in *ScholarOne* only from 2010 onwards, which limited the time frame of our study. PDFs were only available for one version of the paper. For papers that were rejected, the PDF available was always the original version of the paper. For papers that had been revised, the PDF available was usually the last version viewed by the handling and/or senior editors. This difference in which version of a paper is available will only introduce error in our analyses if authorship on the paper changed during the manuscript revision process; though minor authors are sometimes added to papers in revision, it is exceedingly rare for the first, corresponding or last authors to change between versions.

Authors were categorized as *First Author* (the first name listed in the author list), *Last Author* (the last name listed in the database), *Corresponding Author* (the author identified on the cover page of the manuscript as author to whom correspondence should be sent) and/or *Submitting Author* (the author who actually submitted the manuscript in *ScholarOne*). Corresponding and submitting authors were usually but not always the same. A small percentage of papers (2·6%) had no corresponding author listed on the paper, or had two corresponding authors listed; these were excluded from analyses of corresponding authorship. The last author is included in our analyses because it is common in ecology for the last author to be the senior author, i.e., the person overseeing the laboratory and advising students, post-docs or other scientists on the project. That this is commonly the case is suggested from the observation that the last author (on papers with two or more authors) was the submitting author 18% of the time. However, we cannot know for any specific paper whether the last author is the senior author.

AUTHOR AND REVIEWER GENDER

Author gender was determined using the online database genderize.io. This database includes >200 000 unique names and assigns a probability that each name is male or female given the distribution of genders for these names in the database. If the name of the first, corresponding or senior author was not listed in genderize.io, we used an internet search to determine gender (we searched for individual web pages or entries in online databases that included a photograph of the individual or other language indicating their gender). We had the most difficulty genderizing names of authors from Asian countries. This is because genderize.io includes few names from Asian cultures, transliteration into Roman alphabet may obscure differences in names, and because we could not find websites for many of these authors.

Our data set includes 14280 author entries (a mean of 5·2 authors per paper). 128 authors listed no first name on their submission and so cannot be genderized; these individuals are not included in our analyses. Of the remaining authors, 13284 author names (93%) were present in genderize.io; 94% of these names were $\geq 0{\cdot}70$ probability of being one gender or the other, and 85% of names were categorized as $\geq 0{\cdot}90$ probability of being one gender or the other. Considering only authors in non-Asian countries, 97% of author names were listed in genderize.io (with half of the remaining authors successfully found in an internet search), with 97% of these identified to gender with $\geq 0{\cdot}70$ probability and 94% identified to gender with $\geq 0{\cdot}90$ probability.

We also know the gender of almost all reviewers in our database. Reviewer gender was determined similarly to author gender, first using genderize.io, followed by an internet search for all reviewers whose probability of being a specific gender in the genderize.io database was $< 0{\cdot}99$. Additional details are provided in Fox, Burns & Meyer 2015.

AUTHOR AND REVIEWER GEOGRAPHIC LOCATION

Our data set contains the geographic location (country) of most authors who submitted a paper to *Functional Ecology*. To categorize localities, we used the M.49 area codes and their continental regions as defined by the United Nations' Statistical Commission (unstats.un.org). There were two exceptions: (i) we divided the Americas into Latin America (which includes North America south of the United States–Mexico border) and North America (the United States and Canada), and (ii) we divided Europe into the United Kingdom and 'other Europe'. This second change reflects that a British learned society (the *British Ecological Society*) owns *Functional Ecology* and thus the journal receives a large number of papers from British authors (greater representation of authors from the United Kingdom than expected from the distribution of ecologists in the world).

We also know the geographic location of most reviewers in our database. As for authors, reviewer geographic locations are reviewer-entered and reflect the most recent location of the reviewer according to their last database entry. Some scientists move between countries/continents during their careers, and such changes may not be reflected in our database. Nonetheless, we expect most reviewer location data to be correct, with the errors creating random noise in the data.

EDITOR GENDER, GEOGRAPHY AND SENIORITY

The journal editors are all known by the journal staff, so their gender and geographic location are also known. *Editor Seniority* was calculated as the number of years between when an editor got their PhD and the year they handled each specific paper. Because PhD degrees are awarded at various times of year and we only know the year (not month) of graduation, our estimates of academic seniority should be considered plus-or-minus ~2 years of the actual time between the date of interest and the actual PhD graduation of the editor.

EDITORIAL AND PEER REVIEW OUTCOMES

We limit our examination of the editorial and peer review process to the initial submission of a paper to the journal. Editorial and peer review of revised manuscripts is not considered.

Throughout our analysis, we distinguish three stages of the editorial and peer review process. Firstly, papers are screened by senior editors before being assigned to a handling editor (*Paper Assigned to Editor* [yes/no]); a large proportion of papers are declined at this stage (Fox & Burns 2015). Associate editors then perform their own screening and decide whether to send the paper out for review (*Paper Reviewed*[yes/no]. Once reviews are obtained, a final decision is made on the paper (*Decision*[reject/revision request]).

For each review invitation, the journal also tracks whether the reviewer responds to the invitation email (yes/no), how long each invitee takes to respond to the invitation (in days), whether they agree to review [yes/no], how long each reviewer takes to submit their review (in days) and the review score (range 1–4; details in Table 1 of Fox, Burns & Meyer 2015 and Table S1, Supporting information).

ANALYSES

For statistical analyses, each manuscript represents a single data point that includes one first author, one corresponding author, one author gender ratio, a single handling editor, and so on. The exception is the analysis of the interaction of author and reviewer

gender, for which each manuscript has two data points, one for each gender of reviewer (see below).

Most of the variables we examine in this study have binary responses: the gender of the author (f/m), whether a paper is sent for peer review (yes/no), the decision on a paper (reject/not reject). For analyses in which our dependent variables are binary we used logistic regression with models of the form: *DependentVariable = Year + IndependentVariables + Interactions*. *Year* was included in all models (except those sorted by year) as a categorical variable that represents when the paper was submitted. Logistic regression analyses were performed using SAS PROC LOGISTIC or PROC SAS GLIMMIX, both of which provide the same results but allow different modelling options. We used general linear models to analyse time data (time to respond to invitation, time from acceptance to submission of review) and reviewer scores (using SAS PROC GLM). Time to respond to the review invitation and time from acceptance to submission of review were log-transformed before analysis to meet the assumptions of analysis of variance. All categorical variables were treated as fixed effects except that *Handling Editor Identity* was included as a random effect (nested within *Handling Editor Gender*) for analyses that include the effect of *Handling Editor Gender*, and *Senior Editor Identity* was included as a random effect in analyses of senior editor pre-review rejection rates.

For analyses of authorship patterns on papers we used the full data set (all papers) with each paper treated as a single data point. However, for analyses testing for differential treatment of papers written by male and female authors (i.e., all sections of the results except 'The distribution of male and female authorships on papers') we excluded papers for which the first and/or corresponding author is from Asia (511 submission, 14·5% of total submissions). For bias to occur, consciously or subconsciously, it is necessary that editors and reviewers be able to identify author gender from their names. Asian names are less familiar to most editors and reviewers working with *Functional Ecology*, most of whom are in non-Asian countries. 52% of the names of Asian authors in our data set are either not listed in genderize.io or return a probability of ≤70% one gender suggesting that these names are either not commonly encountered outside of Asia or are commonly androgynous. By contrast, only 6% of non-Asian names are either not listed in genderize.io or return a score of ≤70% of one specific gender.

To examine whether there was an interaction between author and reviewer gender, we limited our analysis to papers that had at least one reviewer of each gender (n = 351).

Results

THE DISTRIBUTION OF MALE AND FEMALE AUTHORSHIPS ON PAPERS

Women occupied 34·5% of all authorship positions on manuscripts submitted to *Functional Ecology* (averaged across years; Fig. 1). On papers with just one author (n = 122 paper), that author was female just 26·0% of the time. On papers with two or more authors, women occupied a substantially larger proportion of first author positions (43·1% of first authors were women) than expected from their overall frequency of authorship, but a much lower proportion of last authorships (24·6% of last authors were women). Women were also listed as the corresponding author on the cover page for 37·6% of manuscripts and served as submitting author for 37·8% of manuscripts, both less often than they were first authors (Fig. 1). Some of these distributions of authorship varied

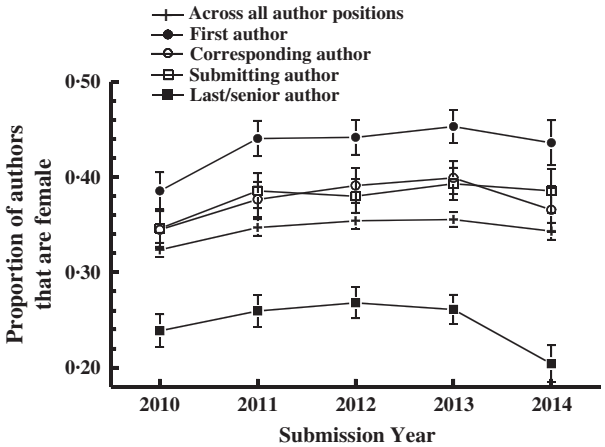

Fig. 1. The distribution of authorships on papers submitted to *Functional Ecology* from 1 January 2010 to 30 June 2014. The gender ratio across all author positions is calculated first across all authors on a paper, and then averaged across papers. The gender ratio at different authorship positions is only for multi-authored papers (excluding single-authored papers).

statistically, but none varied substantially, across the authors' geographic regions (Table 1).

Women occupy a larger proportion of first author positions on papers if the last author is female (Fig. 2a; $X^2_1 = 4{\cdot}54$, $P = 0{\cdot}03$; considering only papers with two or more authors). This appears to be because a higher proportion of all authors on a paper are women (the gender ratio of non-last authors) when the last author is female (Fig. 2b; $X^2_1 = 16{\cdot}5$, $P < 0{\cdot}001$). In a logistic regression including both the senior author gender and author gender ratio (*FirstAuthorGender = Year + SeniorAuthorGender + AuthorgenderRatio*[excluding senior author] + *Interactions*), the gender of the first author of the paper is predicted by the gender ratio of all non-last authors ($X^2_1 = 627{\cdot}3$, $P < 0{\cdot}001$) but not by the gender of the last author ($X^2_1 = 0{\cdot}0$, $P = 0{\cdot}98$). This analysis suggests that women are more often first authors on papers with female last authors because there are more female authors (across all positions) on papers that have female last authors.

If the first author was female, she was less likely to be listed as the corresponding author on the cover page (Fig. 3a; $X^2_1 = 18{\cdot}0$, $P < 0{\cdot}001$) and less likely to be the submitting author (the author who actually submitted the manuscript in *ScholarOne*; $X^2_1 = 33{\cdot}1$, $P < 0{\cdot}001$) than if the first author was male. Neither of these differences were influenced by the gender of the last author (last author gender and last author-x-first author gender interactions were all non-significant at $P > 0{\cdot}25$ for each). The probability that the first author was also the corresponding and/or submitting author also varied across geographic regions (Fig. 3b; corresponding author: $X^2_6 = 264{\cdot}7$, $P < 0{\cdot}001$, submitting author: $X^2_6 = 132{\cdot}6$, $P < 0{\cdot}001$); most notably, first authors from Asia were least likely to serve as corresponding authors of papers. Importantly, there was no evidence of an author gender-x-geographic region interaction (corresponding author: $X^2_6 = 4{\cdot}42$, $P = 0{\cdot}62$, submitting

Table 1. Variation in authorship on papers submitted to *Functional Ecology* according to the geographic location of the first author on the paper. Means are calculated by first averaging across papers (one data point per paper) within years, and then averaging across years. Proportions for first, corresponding and last authors are for multi-authored papers only

	Number of authors (mean ± std err)*	Proportion female authors (all positions)†	Proportion of authors on single-authored papers that are female¶	Proportion of first authors that are female‡	Proportion of corresponding authors that are female‡	Proportion of last authors that are female‡
Asia	3·67 ± 0·23	0·33	0	0·37	0·40	0·30
Africa	4·31 ± 0·23	0·37	0·26	0·41	0·30	0·29
Europe	4·39 ± 0·11	0·35	0·28	0·45	0·39	0·24
Latin America	4·18 ± 0·11	0·35	0	0·45	0·37	0·19
North America	3·52 ± 0·13	0·35	0·20	0·42	0·39	0·28
Oceania	3·72 ± 0·20	0·32	0·20	0·46	0·39	0·19
United Kingdom	4·23 ± 0·15	0·33	0·33	0·42	0·39	0·22
Variation among years§	$F_{4,3387}$ = 3·53**	X^2_4 = 3·72*ns*	–	X^2_4 = 4·87*ns*	X^2_4 = 5·88*ns*	X^2_4 = 4·25*ns*
Variation among regions§	$F_{6,3387}$ = 13·28***	X^2_6 = 21·2**	–	X^2_6 = 4·24*ns*	X^2_6 = 12·4*ns*	X^2_6 = 15·8*
Year-x-region interaction§	$F_{24,3387}$ = 1·11*ns*	X^2_{24} = 16·9*ns*	–	X^2_{24} = 26·1*ns*	X^2_{24} = 25·7*ns*	X^2_{24} = 18·2*ns*

*Analysis of variance, model: *NumberOfAuthors* = *Year* + *Region* + *Interaction*, with *Year* and *Region* as fixed effects and each paper treated as a single data point (SAS Proc Mixed).
†Logistic regression, model: *NumberOfFemaleAuthors*/*TotalNumberOfAuthors* = *Year* + *Region* + *Interaction*, with *Year* and *Region* as fixed effects and each paper treated as a single data point (SAS Proc Logistic).
‡Logistic regression, model: *GenderOfAuthor*(f/m) = *Year* + *Region* + *Interaction*, with *Year* and *Region* as fixed effects and each paper treated as a single data point (SAS Proc Logistic).
§*ns* = $P > 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
¶Sample sizes for single-authored papers are too small for meaningful statistical analysis (*Year-x-Geography* cells); Africa (n = 3 papers across all years), Asia (n = 21); Europe (n = 30); Latin America (n = 3); North America (n = 44); Oceania (n = 11); United Kingdom (n = 9).

author: X^2_6 = 8·34, P = 0·21); i.e., female authors are similarly less likely to serve as corresponding or submitting authors than are men across all geographic regions (the apparent switch in this pattern for authors from Africa is accompanied by large errors due to small sample sizes; Fig. 3b).

There was no evidence that the number of authors varied with the gender of the first, corresponding or last author ($P > 0.27$ for each), or with the gender ratio of all authors on the paper ($F_{4,3514}$ = 0·31, P = 0·58). The number of authors on papers increased over the five years, from an average of 3·7 ± 0·07 in 2010 to 4·4 ± 0·09 in 2014 (2011: 4·0 ± 0·07, 2012: 4·0 ± 0·07, 2013: 4·2 ± 0·12)(*Year* effect in univariate model: $F_{4,3519}$ = 5·84, $P < 0.001$). The average number of authors varied across geographic regions - it was highest in Europe, the United Kingdom and Africa (mostly South Africa) and lowest in North America and Asia (Table 1).

THE RELATIONSHIP BETWEEN AUTHOR GENDER AND OUTCOMES OF THE EDITORIAL AND PEER REVIEW PROCESS

All papers submitted to the journal are first evaluated by one of our Senior Editors and only a subset of these are assigned to a handling editor. We found no evidence that gender of the first, corresponding or last author influenced the probability that a paper was sent to a handling editor (model: *SentToHandlingEditor* (yes/no) = *Year* + *AuthorGender* + *Interaction*, with *SeniorEditor* as a random effect; $P > 0.14$ for all author gender and interaction effects; note that all senior editors are male so *SeniorEditorGender* is not included in the analysis) (Fig. 4). There was a suggestion in the data that papers with a higher proportion of female authors were slightly less likely to be sent to a handling editor (*AuthorGenderRatio*: X^2_1 = 5·9, P = 0·02; *Year-x-AuthorGenderRatio Interaction*, X^2_4 = 4·39, P = 0·36). However, the effect size was quite small (one percentage point for every 20% increase in the proportion of women on a paper) and becomes non-significant when correcting for multiple comparisons or if the non-significant interaction is removed from the model. Also, the best fit model (that with the lowest AIC) includes only *Year* and not *AuthorGenderRatio*.

After a manuscript has been assigned to a handling editor, that editor can decide whether to send the paper out for review or decline it without review. The probability that the handling editor sent a paper out for review varied significantly among individual editors, but there was no evidence that the gender of the first, corresponding or senior author, or the gender ratio of all authors on the manuscript, affected this probability (Fig. 4) (model: *SentForReviewByHandlingEditor* (yes/no) = *Year* + *AuthorGender* + *Interaction*, with *SeniorEditor* as a random effect; $P > 0.14$ for all author gender and interaction effects).

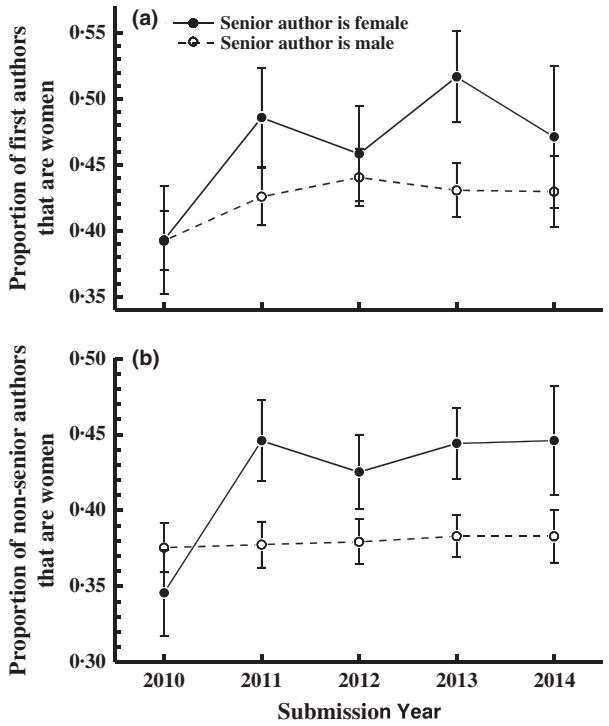

Fig. 2. (a) The proportion of first authors that are women when the last author is a woman, and (b) the gender ratio (proportion women) of authors on the papers (excluding the last author) when the last author is a woman.

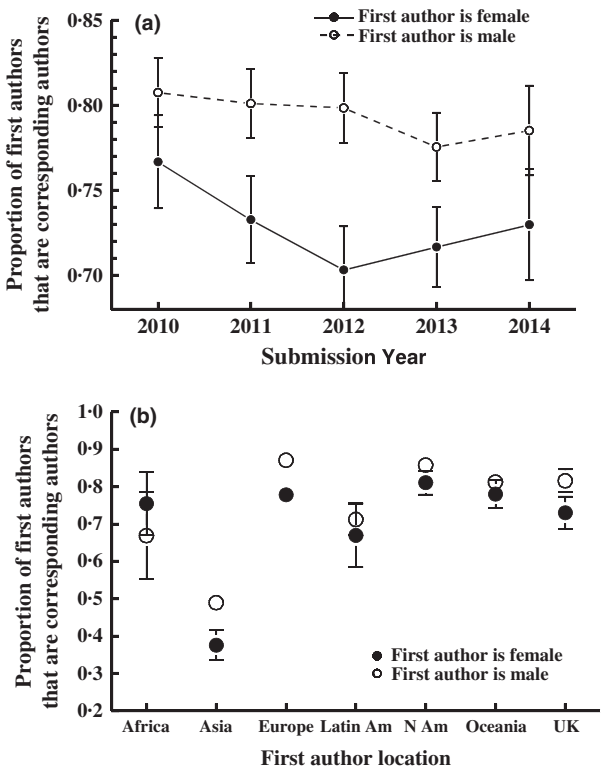

Fig. 3. The proportion of first authors that serve as corresponding author of their manuscript. (a) Variation across years for all papers submitted to the journal. (b) Variation across geographic regions (first author location). Means are ± standard errors. For panel b, proportions are calculated first across all papers within a submission year and then averaged across years. Statistical models for panel b: *CorrAuthor* = *Year* + *FirstAuthorGender* + *AuthorLocality* + *Gender-x-LocalityInteraction*; *Year:* $X^2_4 = 3{\cdot}06$, $P = 0{\cdot}55$; *FirstAuthorGender*: $X^2_1 = 7{\cdot}04$, $P = 0{\cdot}008$; *AuthorLocality:* $X^2_6 = 264{\cdot}7$, $P < 0{\cdot}001$: *Interaction*: $X^2_6 = 4{\cdot}42$, $P = 0{\cdot}62$.

Manuscripts sent for review were not, on average across all papers, scored differently depending on the gender of the first, corresponding or last author or the gender ratio of all authors (analysis of variance, model: *ReviewScore* = *Year* + *AuthorGender* + *Interaction*; statistics in legend of Fig. 5). Following review, the review score was a highly significant predictor of whether a paper was rejected vs. invited for revision ($P < 0{\cdot}001$ in all analyses) but there was no evidence that any of the author gender variables affected the handling editor's decision (Fig. 4) (including review score as a covariate in the model; *RevisionInvitedIfReviewed* (yes/no) = *Year* + *AuthorGender* + *Interaction*, with *HandlingEditor* as a random effect; $P > 0{\cdot}27$ for all author gender and interaction effects when *ReviewScore*; excluding review score from the analysis, $P > 0{\cdot}16$ for all author gender and interaction effects). Cumulative across all stages of the editorial process, we found no evidence that gender of the authors (first, last or corresponding) or author gender ratio on a paper (across all author positions) affected the probability that the paper is declined from the journal (Fig. 4) (Model: *RevisionInvited*(yes/no) = *Year* + *AuthorGender* + *Interaction*, with *HandlingEditor* as a random effect; *AuthorGender*: $P > 0{\cdot}11$ for each; *AuthorGender*-x-*Year* interaction: $P > 0{\cdot}27$ for each).

Interestingly, papers with more authors were less likely to be rejected at the senior editor review stage, and thus more likely to be sent to handling editors; each additional author increased the probability of success at the senior editor stage by $1{\cdot}96 \pm 0{\cdot}87$ percentage points (averaged across years) ($X^2_1 = 16{\cdot}9$, $P < 0{\cdot}001$; this analysis deletes one manuscript with 87 authors; the next highest was 20 authors). However, there was no evidence that the number of authors was predictive of the success of a paper at any subsequent stage of the editorial process [paper sent for review by the handling editor ($X^2_1 = 0{\cdot}85$, $P = 0{\cdot}36$), the peer review score ($F_{1,1505} = 0{\cdot}32$, $P = 0{\cdot}57$) or the probability a paper is rejected after peer review ($X^2_1 = 1{\cdot}06$, $P = 0{\cdot}30$)] and no evidence that number of authors affected the outcome cumulative across all parts of the editorial process ($X^2_1 = 1{\cdot}19$, $P = 0{\cdot}28$).

INTERACTIONS BETWEEN HANDLING EDITOR GENDER AND AUTHOR GENDER

In the previous section, we included handling editor in our analyses (as a random effect) to control for among-editor variation in decisions. The handling editor effect was always statistically significant. We thus explored whether the gender of the handling editor influenced whether papers authored by male vs. female authors have different fates.

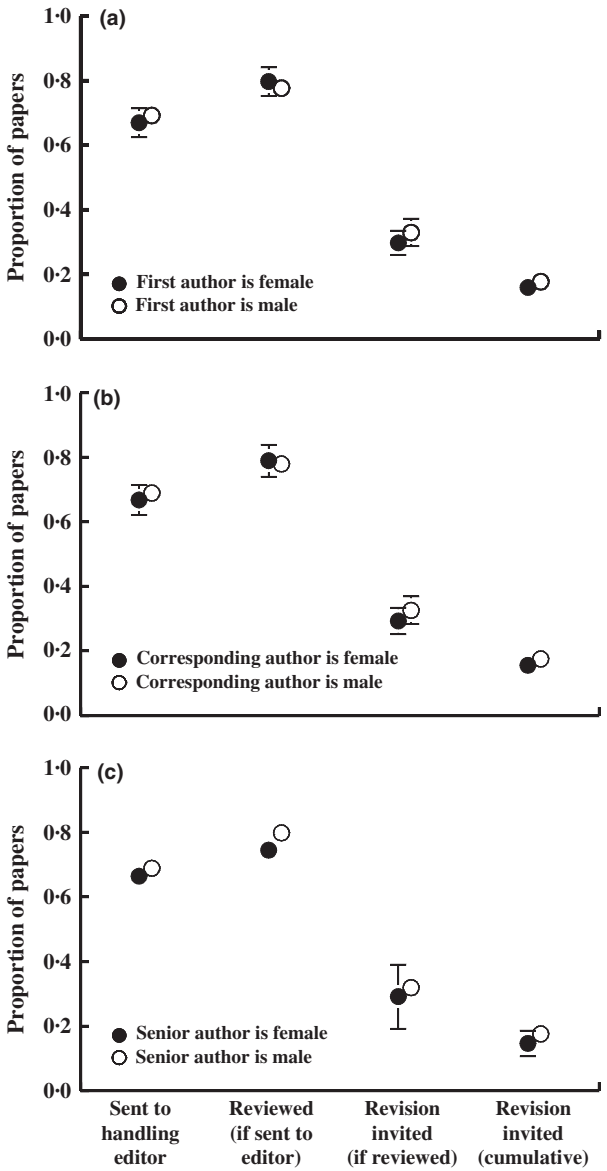

Fig. 4. The probability that papers successfully pass through each stage of the peer review process according to (a) first, (b) corresponding or (c) senior author gender. Papers 'Sent to handling editor' are those not rejected by the senior editors at their initial screening. 'Revision invited (cumulative)' is the cumulative probability across all editorial and review stages. Note that the suggestion in Fig. 4c that papers with male last authors are more likely to be sent for review is not statistically significant when among-editor variance is included in the statistical model (as a random effect) but becomes significant when the among-editor variation is removed from the statistical model ($X^2_4 = 5{\cdot}57$, $P = 0{\cdot}02$). An expanded version of this figure, with results broken out by year, is included in the Fig. S1 (Supporting information).

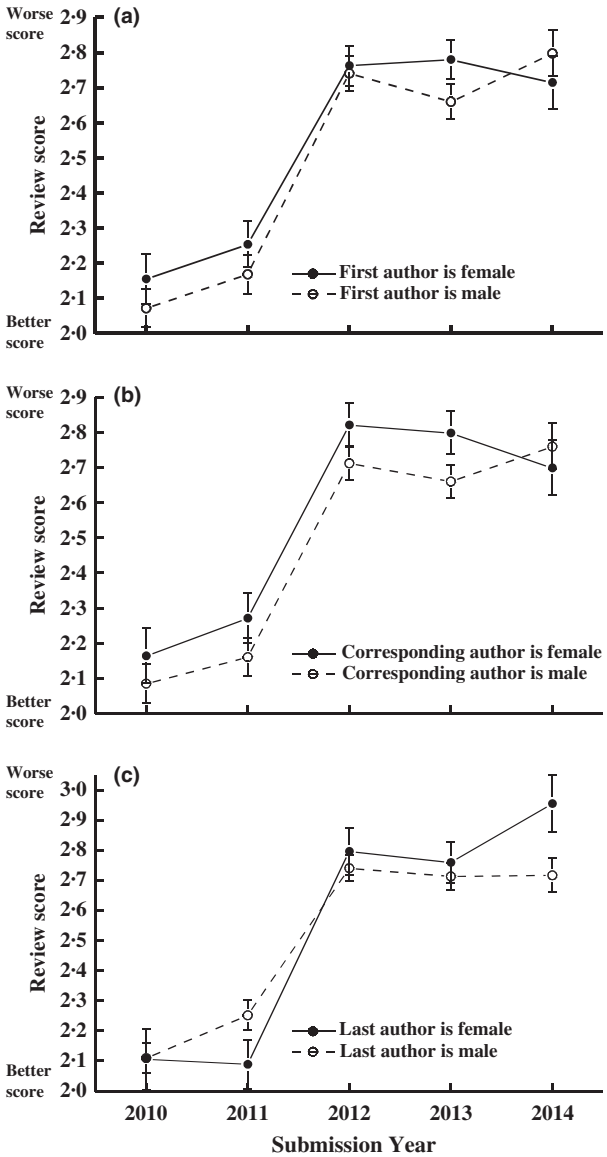

Fig. 5. Scores given to papers by reviewers according to (a) first, (b) corresponding or (c) senior author gender. Note that a lower rating is better (1 is the best possible, 4 is the worst possible). The significant change in mean scores between 2011 and 2012 is because the journal changed the scoring instructions provided to reviewers starting January 2012. Note that there are no statistically significant differences between male and female authors and no significant gender-x-year interactions (analysis of variance, model: *ReviewScore* = *Year* + *AuthorGender* + *Interaction*; *FirstAuthorGender*: $F_{1,1591} = 1{\cdot}43$, $P = 0{\cdot}23$; *CorrAuthorGender*: $F_{1,1527} = 3{\cdot}53$, $P = 0{\cdot}06$; *LastAuthorGender*: $F_{1,1572} = 0{\cdot}58$, $P = 0{\cdot}45$; *AuthorGenderRatio* (not shown on figure): $F_{1,1598} = 0{\cdot}33$, $P = 0{\cdot}57$; $P > 0{\cdot}14$ for all interactions). The suggestion in Fig. 5b that papers with female corresponding authors are scored differently than those with male corresponding authors is not statistically significant.

We found no evidence that female vs. male editors were assigned a greater proportion of papers with more female authors ($P > 0{\cdot}18$ for all author gender variables). We also found no evidence of an interaction between editor and author gender on how likely editors were to send papers out for review (model: *SentForReviewByHandlingEditor* [yes/no] = *Year* + *HandlingEditorGender* + *AuthorGender* + *AuthorGender-x-EditorGender Interactions*, with *HandlingEditor*[nested within *HandlingEditorGender*] included as a random effect; $P > 0{\cdot}15$ for all *AuthorGender* effects; $P > 0{\cdot}27$ for all interactions). Lastly, there was no evidence of an interaction between editor and author gender on

how likely editors were to request revisions of a manuscript after peer review (*RevisionInvitedIfReviewed* [yes/no] = *Year* + *HandlingEditorGender* + *AuthorGender* + *AuthorGender-x-EditorGender Interactions*, with *HandlingEditor*[nested within *HandlingEditorGender and ReviewScore* included as a covariate; $P > 0{\cdot}23$ for all *AuthorGender* effects; $P > 0{\cdot}19$ for all interactions).

INTERACTIONS BETWEEN REVIEWER AND AUTHOR GENDER

Over the 4·5 years for which we have data, 351 papers were reviewed by both one male and one female reviewer. The mean scores given to papers, averaged across all papers, did not differ between male and female reviewers in any year (Wilcoxon signed-rank test, $P > 0{\cdot}54$ for each year). The score given by women reviewers on papers was positively correlated (across manuscripts) with the score given by male reviewers (analysis of covariance, $ReviewScore_{Female} = Year + ReviewScore_{Male}$, + Interaction; covariate: $F_{1,341} = 9{\cdot}92$, $P = 0{\cdot}002$; Interaction: $F_{4,341} = 0{\cdot}13$, $P = 0{\cdot}97$). Notably, this relationship did not differ depending on the gender of the authors (i.e., there were no significant author gender or author gender-x-male reviewer score interactions in the model *FemaleReviewerScore* = *Year* + *MaleReviewerScore* + *AuthorGender* + *Interactions*; *AuthorGender*: $F_{1,342} < 1{\cdot}77$, $P > 0{\cdot}18$, *Interaction*: $F_{1,342} < 1{\cdot}11$, $P > 0{\cdot}28$ for all author positions).

As an alternative analysis, we tested whether the difference between scores given by male reviewers and female reviewers (male reviewer score - female reviewer score) differed depending on whether the authors of a paper were male or female. If men gave generally more negative or women generally more positive review scores, or vice versa, to papers authored by women, we expect that the difference in review scores between male and female reviewers to differ for male vs. female authors. We found no such difference; the average difference in reviewer score given by male and female reviewers did not depend on the gender of the first author ($F_{1,344} = 1{\cdot}11$, $P = 0{\cdot}29$), the corresponding author ($F_{1,344} = 0{\cdot}19$, $P = 0{\cdot}66$), the senior author ($F_{1,344} = 0{\cdot}29$, $P = 0{\cdot}59$), or the author gender ratio ($F_{1,344} = 1{\cdot}05$, $P = 0{\cdot}41$).

EDITOR SENIORITY

In a previous analysis (Fox, Burns & Meyer 2015), we found that senior editors differed from younger editors in the proportion of women they selected to review (*EditorSeniority* = years since PhD at the time of handling a manuscript). We thus examined whether editor seniority differentially affected the decisions editors made on papers authored by males vs. females. We found no evidence that more senior editors were more or less likely to send papers for review if the first or last/senior author was female (model: *PaperReviewed* = *Year* + *CorrAuthorGender* + *EditorSeniority* + *AuthorGender-x-HandlingEditorSeniority* interaction with *HandlingEditor* as a random effect; non-significant interaction, $P > 0{\cdot}64$, for first and last author gender, and for author gender ratio). The only suggestion of an editor seniority effect was a significant interaction between the gender of the corresponding author and the seniority of the handling editor (*CorAuthorGender-x-HandlingEditorSeniority*) influencing the likelihood that a paper is sent for peer review ($X^2_1 = 6{\cdot}2$, $P = 0{\cdot}01$). However, though this interaction was significant when included in the model, removing it from the model reduces model AIC. More importantly, this interaction between corresponding author gender and editor seniority (if real) did not carry through to the final decisions on papers; we found no evidence that more senior editors reached different decisions after review, or cumulative through the entire process, for papers authored by men vs. women (*AuthorGender-x-HandlingEditorSeniority* interaction: $P > 0{\cdot}47$ for all author gender variables).

THE RELATIONSHIP BETWEEN AUTHOR GENDER AND OTHER ASPECTS OF THE PEER REVIEW PROCESS

In previous analyses (Fox, Burns & Meyer 2015) we found that *editor* gender affected responses to review invitations (the Associate Editor handling a manuscript is identified in peer review invitations); invitees to review for *Functional Ecology* were less likely to respond to review invitations, and less likely to agree to review, if the handling editor for a paper was female. This suggests that reviewers were influenced, albeit only slightly, by the gender of participants in the editorial process. Here, we examine whether *author* gender likewise influences reviewer responses to review invitations.

We found no evidence that the gender of the first or corresponding author influenced how likely invitees responded to review invitations, how quickly they responded to review invitations, whether they agreed to review (if they responded), whether they returned their review (if they agreed to review) or how quickly they returned their review (if they agreed) (model: *ReviewVariable* = *Year* + *AuthorGender* + *Interaction*; $P > 0{\cdot}29$ for *AuthorGender* and the *Interaction* for all response variables). There was a significant effect of senior author gender on the probability that invitees agreed to review; invitees were *more* likely to agree to review (if they responded to the review invitation) if the last author was female rather than male ($X^2_1 = 5{\cdot}27$, $P = 0{\cdot}02$). However, the effect size was very small ($73{\cdot}5 \pm 0{\cdot}7\%$ of reviewers that replied to review invitations agreed to review if the last author was female, averaged across years, compared to 70·0% if the last author was male) and there was no evidence that last author gender influenced any other aspect of the peer review process ($P > 0{\cdot}16$ for how likely invitees responded to review invitations, how quickly they responded to review invitations, whether they returned their review, and how quickly they returned their review).

Interestingly, the gender ratio of the reviewers that agreed to review differed for papers authored by female vs. male authors ($P < 0{\cdot}03$ for corresponding author gender, last author gender, and author gender ratio, but $P = 0{\cdot}15$ for first author gender). Specifically, reviews were more likely to be written by women if the paper had a female corresponding or senior author (proportion of reviewers that are women when corresponding author is female: $29{\cdot}5 \pm 1{\cdot}4\%$, male: $24{\cdot}9 \pm 1{\cdot}4\%$; proportion when the last author is female: $30{\cdot}0 \pm 1{\cdot}3\%$, male: $25{\cdot}7 \pm 1{\cdot}1\%$). This suggests that either (i) editors are inviting more women as prospective reviewers if the authors on a paper are female, or (ii) male and female reviewers are responding differently to invitations to review if the authors are male vs. female. We thus tested these two hypotheses.

Hypothesis A: We found that editors do invite more women to review if the first, corresponding or last author is female and if the gender ratio of authors on the manuscript is more female (Fig. 6; statistics in figure legends). Though we also found that female editors invited more female reviewers than did male editors (averaged across all papers; as previously reported by Fox, Burns & Meyer 2015; $P < 0{\cdot}001$ for all models), this editor gender effect did not explain the result that more women were invited to review papers with female authors; including handling editor gender in our model did not account for the *AuthorGender* effect described above (*AuthorGender* remained significant in all analyses), and there was no significant *AuthorGender-x-EditorGender interaction* ($P > 0{\cdot}27$ for all author gender metrics).

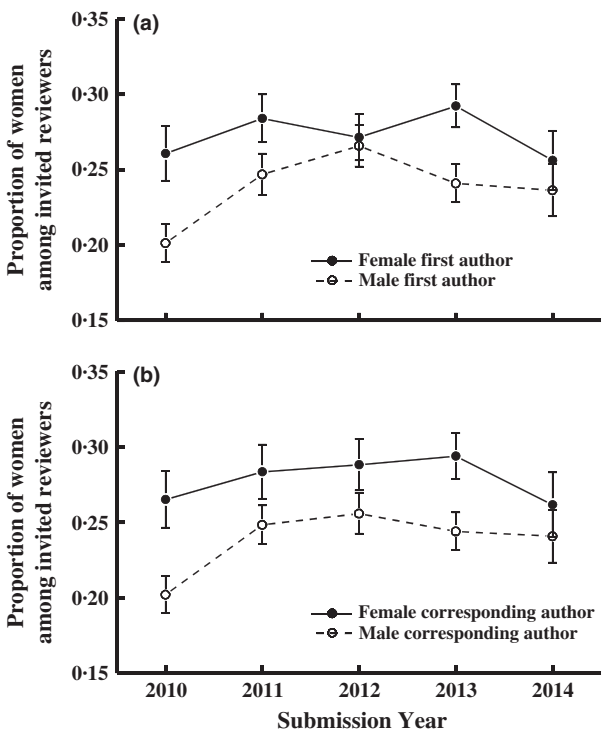

Fig. 6. The proportion of invited reviewers that were women for papers with female or male (b) first or (b) corresponding authors. Editors invite more female reviewers when the paper authors are women. Statistical models; (a) *Year:* $X^2_4 = 14{\cdot}4$, $P = 0{\cdot}006$; *FirstAuthorGender*: $X^2_1 = 14{\cdot}7$, $P < 0{\cdot}001$; *Interaction*: $X^2_4 = 1{\cdot}4$, $P = 0{\cdot}85$; (b) *Year:* $X^2_4 = 14{\cdot}2$, $P = 0{\cdot}007$; *CorrAuthorGender*: $X^2_1 = 18{\cdot}0$, $P < 0{\cdot}001$; *Interaction*: $X^2_4 = 1{\cdot}3$, $P = 0{\cdot}87$; Results for senior author gender (not shown): *Year:* $X^2_4 = 5{\cdot}63$, $P = 0{\cdot}23$; *SeniorAuthorGender*: $X^2_1 = 15{\cdot}2$, $P < 0{\cdot}001$; *Interaction*: $X^2_4 = 2{\cdot}2$, $P = 0{\cdot}70$; Results for author gender ratio: *Year:* $X^2_4 = 12{\cdot}2$, $P = 0{\cdot}02$; *AuthorGenderRatio*: $X^2_1 = 22{\cdot}2$, $P < 0{\cdot}001$; *Interaction*: $X^2_4 = 4{\cdot}8$, $P = 0{\cdot}31$.

Hypothesis B: In a previous study, Fox, Burns & Meyer (2015) found that men invited to review were less likely to respond to review invitations, and less likely to agree to review, if the handling editor for the manuscript was female. Women invited to review showed no such difference in response depending on the gender of the handling editor. We thus analysed our author data separately for male and female invitees. We found no evidence that women that were invited to review were more likely to respond to review invitations ($P > 0{\cdot}28$) or agree to review if they responded ($P > 0{\cdot}21$) if the author was male or female. In contrast, men who were invited to review were less likely to respond to review invitations if the authors on a paper were female ($X^2_1 = 16{\cdot}2$, $P < 0{\cdot}001$ for author gender ratio; $P < 0{\cdot}03$ for first and corresponding author gender; $P = 0{\cdot}56$ for senior author gender). However, the effect size is very small (e.g., averaging only two percentage points difference between papers corresponded by women vs. men).This effect also appears to be largely, but not entirely, due to the editor gender effect described above (men respond to review invitations less often if the handling editor is female); when we include editor gender in the statistical model (and editor identity nested within editor gender as a random effect), the only author gender effect that remains marginally significant is author gender ratio, and the proportion variance explained by author gender drops substantially ($X^2_1 = 4{\cdot}75$, $P = 0{\cdot}03$). Of men that responded to review invitations, invitees were not less likely to agree to review (if they responded) if the authors were female ($P > 0{\cdot}10$ for all author gender variables).

Discussion

In this study, we examined whether patterns of authorship on papers submitted to *Functional Ecology* differed between male and female authors, and tested whether the gender of authors influences the peer review process or peer review outcomes. We find that women were less likely to be sole or last author, but more likely to be first author, relative to their overall frequency of authorship. Women were also less likely to serve as corresponding author of their papers than were men when they were first author. Despite these clear differences in pattern of authorship, we found no compelling evidence of gender discrimination in the peer review process – papers with female authors were equally successful at all stages of the editorial and peer review process.

PATTERNS OF AUTHORSHIP

Women occupied about a third of all authorships, averaged across all positions, on papers submitted to *Functional Ecology*. Relative to this, they were over-represented as first authors (43%) but underrepresented as last authors (25%) and underrepresented on single-authored papers (26%). That women are overrepresented as first authors (relative to authorship across all positions) has been observed in some disciplines (e.g., van der Weijden & Medina 2014), whereas women are underrepresented as first authors in other disciplines (van Arensbergen, van der Weijden & van den Besselaar 2012); this variation is likely in part due to variation in conventions on authorship order across fields (van Arensbergen, van der Weijden & van den Besselaar 2012; West *et al*. 2013). Generally, though, the representation of women as first authors has been increasing (West *et al*. 2013).

Women are better represented as first authors on submissions to *Functional Ecology* than in the global scientific literature (Larivière *et al*. 2013) and better represented in submissions to *Functional Ecology* during the time period of our study than they were in the broader literature in ecology and evolution between 1990 and 2011 (women represent ~24% of first authors in ecology and evolution for papers archived in JSTOR; West *et al*. 2013; http://www.eigenfactor.org/gender/#). That women are more commonly first author than last author is a typical result for analyses of authorship in biology and medical journals (e.g., Jagsi *et al*. 2006; Feramisco *et al*. 2009; Kongkiatkamon *et al*. 2010; Dotson 2011; West *et al*. 2013; Erren *et al*. 2014). This is likely due to demographic differences between individuals who occupy the first vs. last author positions on papers. First authors on papers are commonly students and post-docs, populations for which female representation is quite high in the sciences (Jagsi *et al*. 2006). In contrast, last author is commonly (though not always) the senior scientist for the project; e.g., the lab supervising professor or grant primary investigator, populations for which women remain underrepresented (Jagsi *et al*. 2006).

Women are more likely to co-author papers with other women, and men with other men, compared to expectations if the genders associate randomly (Shah *et al*. 2013; Long *et al*. 2015). We observed this at *Functional Ecology*; in particular, we see that papers with female last authors include a higher proportion of women authors at other positions, including first author, than do papers with male last authors. This likely reflects two phenomena. First, women tend to (on average) have slightly different research interests than do men, both in ecology (Bonnet, Shine & Lourdais 2004; West *et al*. 2013; details at www.eigenfactor.org/gender/#) and in other fields (Lipetz 1999; Rigg, McCarragher & Krmenec 2011; Long *et al*. 2015). This leads to a non-random association of women across subdisciplines. Second, women students may be more likely to enter graduate school under female mentors (Tenenbaum, Crosby & Gliner 2001). This association of female students with female mentors may be driven by commonality of research interests (as noted above) but may also reflect a preference by women for female mentors (Blake-Beard *et al*. 2011). Either mechanism would generate a non-random association between gender of the senior author and gender of the other authors. Importantly, although we do find a non-random association between senior author gender and the gender of other authors, we find no evidence of bias specifically against female first-authorship when the senior author is male; instead, the proportion of female authors is lower across all positions when the senior author is male, with this reduced the proportion of women authors across all positions leading to a lower proportion of female first authors on papers with male senior authors.

Women first authors were less likely to serve as the corresponding author or submitting author of their paper than were men first authors for papers submitted to *Functional Ecology*. A similar difference between men and women in the frequency of corresponding authorship was observed for a European medical journal (Heckenberg & Druml 2010). Women tend to leave science at a higher rate than do men (Fox 2008), and we suspect that the 'missing' female corresponding authors are women who left science, or at least left academic research, following graduate school or their post-doctoral research, and that the corresponding authors on those papers are primarily their graduate or post-doctoral advisors. Alternatively, women may expect to face a gender-biased editorial process and so defer corresponding authorship to their collaborators more frequently than men. However, our data do not support this latter hypothesis; we saw no evidence that women were less likely to serve as corresponding author if the senior author was male. Instead, women may more frequently defer corresponding authorship to their coauthors for other reasons: they may more frequently (i) lack the confidence necessary to serve as corresponding author (or have advisors that lack confidence in them), (ii) be less assertive than men in taking charge of the manuscript submission process (e.g., in competition with strong-willed coauthors or advisors), or (iii) have less time available (such as due to non-work responsibilities, or additional non-research responsibilities at work) than do male first authors.

The number of authors on papers submitted to *Functional Ecology* increased noticeably in just the 5 years of this study. Similar increases have been observed for a variety of academic fields (Wren *et al*. 2007; Larivière *et al*. 2013). Research performed by larger research teams, producing papers with more authors, tends to be more impactful (or at least more highly cited) than research done by individuals or small groups (Wuchty, Jones & Uzzi 2007), even after controlling for self-citations (Larivière *et al*. 2014). The increasing number of authors on papers may reflect the increasingly interdisciplinary and collaborative nature of research (Larivière *et al*. 2014). Alternatively, it may reflect an increase in the inclusion of contributors with minor roles in the project as authors

(Danell 2014) possibly in response to incentives related to impact, productivity measures or career advancement. As the number of authors increases, ambiguity over author contributions, and how authorship order reflects these contributions, necessarily increases (Zuckerman 1968). It is commonly recognized in the biological sciences that first and last author are the key positions, but the roles of middle authors, and even the last author, can vary substantially among papers (Wren *et al.* 2007). Of note for our analysis is that the number of authors on papers was not correlated with gender of the authors. This contrasts with an observation by Shah *et al.* (2013) who found that papers with female first authors (but not female last authors) tended to have more authors, and that of Bozeman & Gaughan (2011) who found that, when controlling for other variables, women tend to have more collaborators than do men.

DOES AUTHOR GENDER INFLUENCE PEER REVIEW?

For *Functional Ecology* we found little evidence that author gender influenced outcomes at any stage of the editorial and peer review process, and no evidence that female reviewers responded to author gender differently than did male reviewers. Papers with female authors were equally likely to be sent for peer review, obtained equivalent peer review scores (regardless of reviewer gender), and were equally likely to be accepted for publication, compared to papers with male authors. These results are consistent with the majority of studies that tested for evidence of systemic biases in peer review based on author gender for journal manuscript submissions. A couple of early studies of journal peer review presented evidence that papers authored by women were more harshly reviewed or less likely to be accepted (controlling for review scores; Petty, Fleming & Fabrigar 1999), and that female reviewers responded differently to author gender than did male reviewers (e.g., Lloyd 1990). However, subsequent studies generally find no evidence of differences in peer review scores or editorial outcomes for papers authored by men vs. women (Tregenza 2002; Primack *et al.* 2009; Lane & Linden 2009; Heckenberg & Druml 2010; Buckley *et al.* 2014; but see Walker *et al.* 2015), and no author gender-x-editor gender interactions (Lane & Linden 2009; Walker *et al.* 2015). The difference in results between early studies and more recent studies may be reflect the increased number of women in science and better social attitudes about women in science (Walker *et al.* 2015). Controlled manipulative studies, in which author identity is manipulated on text provided to a study population, have more mixed results. Most find that text authored by men and women is rated the same (Blank 1991; Borsuk *et al.* 2009), and that there is no evidence of same-gender bias (Borsuk *et al.* 2009; Knobloch-Westerwick, Glynn & Huge 2013; Krawczyk & Smyk 2014), but a few find evidence that works authored by women are rated lower. For example, students rated conference abstracts with male authors to be of greater scientific quality (Knobloch-Westerwick, Glynn & Huge 2013), and rated economics papers authored by men as more publishable (Krawczyk & Smyk 2014; though economics as a field may be more male-biased than the biological sciences, van Arensbergen, van der Weijden & van den Besselaar 2012). Overall, though gender biases are clearly evident in many aspects of academic research and careers (e.g., recruitment of editors, symposium participation invitations, evaluation of academic job applicants; Moss-Racusin *et al.* 2012; Fox, Burns & Meyer 2015 and citations therein), and there are occasional instances where gender discrimination by specific editors or reviewers influences scientific publishing, on balance most evidence indicates that the peer review process underlying scientific publication is gender-neutral, or close enough to gender-neutral for biases to be difficult to detect.

Our analysis tests for gender differences in manuscript outcomes throughout the entire editorial and peer review process. It thus avoids the problem of bibliometric analyses (analysis of gender distributions on published papers) that confounds actual gender discrimination with author behaviour. For example, comparing author gender distributions before vs. after adoption of double-blind peer review (Budden *et al.* 2008) requires consideration of changing author behaviour over time, including the changing proportion of women publishing in the field (Webb, O'Hara & Freckleton 2008) and changes in behaviour specifically stimulated by changes in peer review models (e.g., women who perceive that there is gender discrimination may preferentially submit papers to journals with double-blind peer review). However, our study is entirely correlational with no manipulative elements. We thus do not (cannot) control for variation in manuscript quality or other variables that might differ between male- and female-authored papers and that could obscure biases that might be present. If, for example, papers authored by women are generally higher quality than papers authored by men (Symonds *et al.* 2006), the absence of a difference in peer review scores or editorial outcomes would demonstrate a discriminatory rather than gender-neutral process.

We found a non-random association between author gender and reviewer gender - reviews obtained by *Functional Ecology* were more likely to be written by women if the authors on the paper were women. This was primarily because editors invited more women to review if the authors were female, though there was also a small influence of author gender on whether male invitees respond to review invitations. The former effect makes sense given the known gender variation among research areas within ecology (Bonnet, Shine & Lourdais 2004; West *et al.* 2013); given that reviewers are chosen to have expertise overlapping with the topic of the manuscript, and that the proportion of women varies among subfields, we expect some gender association between authors and reviewers even if reviewers are chosen at random (regarding gender) from the pool of people with appropriate expertise for each

paper. Testing whether there is a non-random relationship between author and reviewer gender beyond that caused by gender structuring in the subfields of ecology requires that papers be categorized by subject area compared to actual author gender ratios for each subfield, a project well beyond the scope of this paper. The second effect - that men were less likely to respond to review invitations if the authors were female - is a concerning result, suggestive of real gender discrimination. This effect is similar to one observed previously for editor gender - men (but not women) invited to review for *Functional Ecology* were less likely to respond to review invitations, and less likely to agree to review, if the editor was female (Fox, Burns & Meyer 2015; see also Gilbert, Williams & Lundberg 1994). As in the current study, the effects in Fox, Burns & Meyer (2015) were small (just a couple percentage points), but present most years and in the direction predicted if there is gender discrimination (albeit very slight) against women authors (this study) or editors (Fox, Burns & Meyer 2015).

Conclusions

Women and men differ in their patterns of authorship on papers submitted to *Functional Ecology*. Women represent about a third of all authors (across all positions), but are overrepresented (relative to overall authorship) as first authors and underrepresented as last and solo authors. Notably, female first authors were less likely than male first authors to serve as the submitting or corresponding author of their papers, possibly reflecting well-documented gender differences in attrition from scientific careers. The overrepresentation of women as first authors is a positive sign that women are well-represented at the less senior levels in ecology; however, for this to translate into growth in the proportion of women at more senior positions, the scientific community needs to reduce the rate of attrition of women from science so that they play more dominant roles in the research process.

Though authorship patterns differ between men and women, we found little evidence that author gender influenced peer review scores or editorial decisions. The few analyses that suggest gender differences in editorial decisions are at most marginally statistically significant (and thus non-significant after controlling for multiple comparisons) and of very small effect size. Our evidence here, and in Fox, Burns & Meyer (2015), is consistent in indicating that peer review *outcomes* are gender-neutral, but that gender does influence some aspects of the peer review *process*. For example, Fox, Burns & Meyer (2015) found that editor and reviewer gender influence reviewer recruitment and the time span of the review process, although the influences were generally small. We thus conclude from our pair of studies that gender of the participants influences the process of manuscript review - it influences who is chosen to review papers, the response of invitees to review invitations, and the time span of the review process. But, at the end of the process, gender of the participants does not affect editorial and peer review outcomes at this particular ecology journal.

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Data accessibility

Data for this project are deposited in the Dryad Digital Repository (doi: 10.5061/dryad.0mv3q). However, because the data set contains information on human subjects, the data available at Dryad are anonymized and lacking variables that allow parts of the data set to be de-anonymized. Please see the metadata accompanying the Dryad submission for additional details.

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Supporting Information

Additional Supporting information may be found in the online version of this article:

Figure S1. The probability that papers successfully pass through each stage of the peer review process according to (a) first, (b) corresponding or (c) senior author gender.
Table S1. Reviewer score categories used by *Functional Ecology* during the time period covered by this study.

Supplemental material for **"Gender differences in patterns of authorship do not affect peer review outcomes at an ecology journal**"

Charles W. Fox, C. Sean Burns, Anna D. Muncy and Jennifer A. Meyer

Table S1. Reviewer score categories used by *Functional Ecology* during the time period covered by this study.

January 2010 through December 2011

1=Accept following minor revision

2=Requires major revision

3=Reject, topic not of enough importance or general interest for *Functional Ecology*

4=Reject, quality of dataset/manuscript not adequate for *Functional Ecology*

January 2012 through June 2014

1=An extremely novel paper that is in the top 10% of all papers you have read in the broader field of ecology

2=A strong contribution to the broader field of ecology

3=Solid work, but largely confirmatory

4=Weak or flawed, or not of enough importance and general interest for *Functional Ecology*

Figure S1. The probability that papers successfully pass through each stage of the peer review process according to (A) first, (B) corresponding or (C) senior author gender. See Figure 4 in the paper for additional details.