Who are ASM Journals? A Gender-based Analysis

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Running title: A gender analysis of ASM journals

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Abstract

Importance

Introduction

Scientific societies play an integral role in the formation and maintanence of scientific communities. They host conferences that provide a forum for knowledge exchange, networking, and opportunities for increased visibility as a researcher. Scientific societies also frequently publish the most reputable journals in their field, facilitating the peer review process to vet new research submissions. As such, societies have great power to set both professional and scientfic norms in their community by choosing what behaviors are rewarded and what types of research are accepted for publication. Authorship is a coveted measure of success in academic research as it is a key criterium for hiring and promotion processes. Accordingly, editors and reviewers of research journals have a substantial influence over the futures of hopeful authors. While the membership of scientific societies is likely to reflect all those who participate in the field, regardless of career track, the gatekeepers for peer review (reviewers and editors) are more reflective of the academy than the society as a whole. **Citations**

Evidence has accumulated over the decades that academic research has a representation problem. While at least 50% of biology Ph.D. graduates are women, the number of women in postdoctoral positions and tenure-track positions are less than 40 and 30%, respectively @article{sheltzer_elite_2014}. Studies examining other metrics such as race and ethnicity find that less than 10% of all science and engineering doctorates were awarded to underrepresented minorities, while less than 25% of science and engineering doctorates in early career academia identify as non-white (NSF ADVANCE, 2014). Predictabily, the disparities increase alongside academic rank @article{potvin_diversity_2018}. There have been many proposed reasons for these disparities (particularly against women) that include biases in training and hiring, the impact of children on career trajectories, a lack of support for primary caregivers, a lack of recognition, and less productivity as measured by research publications. **Add citations** These issues do not act independant of each other, instead they are cumulative over time for both individuals and the community. Accordingly, addressing these issues necessitates multi-level approaches from all insititutions and members of the scientific community.

Recently, scientific societies and publishers have begun examining their own data to evaluate representation of, and bias against, women in their peer review processes. The American Geological Union found that while the acceptance rate of women-authored publications was greater than that for publications authored by men, women submitted fewer manuscripts than men and were used as reviewers only 20% of the time (Lerback, 2017), a factor influenced by the gender of the editor (Fox, 2016). Despite the disproportional representation of lead women authors, several studies have concluded that there is no significant bias aginst papers authored by women (C&W, 2011; Fox, 2016; Handly, 2015; Edwards, 2018). Conversely, two recent studies—one of the peer review process at eLife, a broad scope biology journal, and the other of outcomes at six ecology and evolution journals—found that women-authored papers are less likely to have positive reviews and outcomes (Murray, 2018; Fox and Paine, 2019).

However, representation and attitudes differ by scientific field and no studies to-date seem to have investigated academic publishing in the field of microbiology. The American Society for Microbiology (ASM) is one of the largest life science societies, with an average membership of 41,000 since 1990. In its mission statement, the ASM notes that it is “an inclusive organization, engaging with and responding to the needs of its diverse constituencies” and pledges to “address all members’ needs through development and assessment of programs and services.” One of these services is the publication of microbiology research through a suite of 13 journals. Led by the ASM Journals Department, these journals boast of “quality peer review and editorial leadership.” As bastions of the microbiology field, these journals are historically responsible for the progress of the field and success of microbiologists. The goal of this research study is two-fold: first, to understand the gendered representation of authors, reviewers, and editors at ASM journals; second, to examine the possibility of gender bias in peer review.

Results

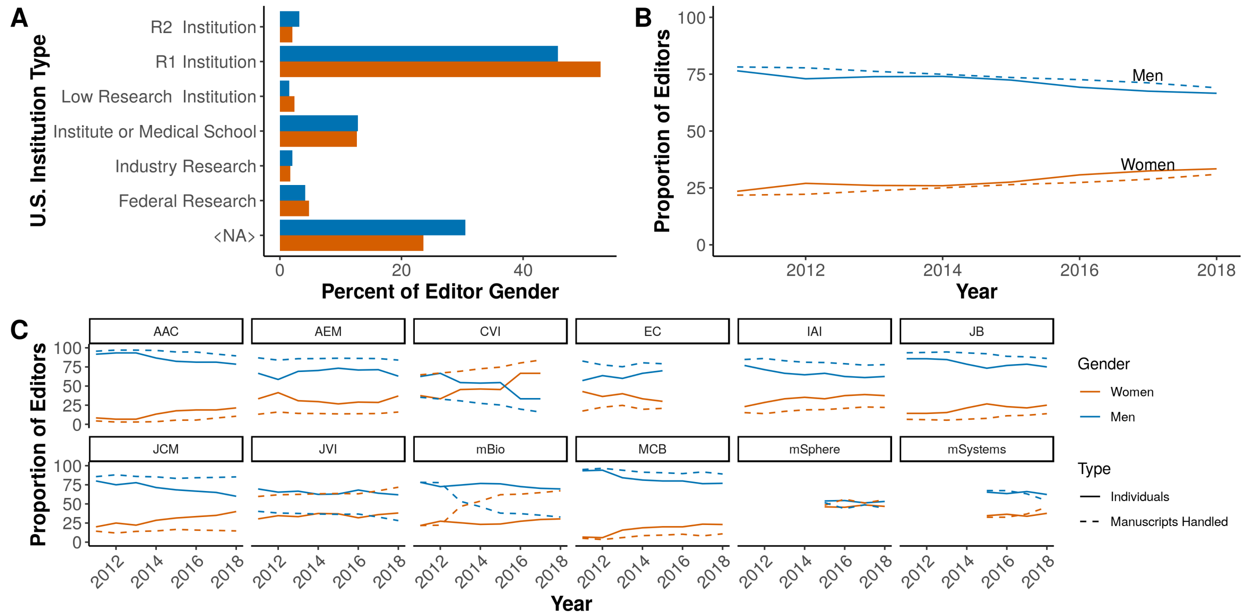

Figure 1. Gendered representation among editors. (A) Proportion of editors from insitution types by gender. NA represents non-categorized and non-US institutions. (B, C) Proportion of editors (solid line) and their workload (dashed lines) from 2012 to 2018. Editors and senior editors are pooled together, editorial rejections are excluded. Each individual was counted once per calendar year. Data for men are blue, and women orange. R1 and R2 assigned using Carnegie classifications.

Men dominate as gatekeepers and senior authors. The term gatekeepers collectively refers to those that facilitate the peer review process, such as editors-in-chief (EIC), editors, and reviewers. Between January 2012 and August 2018, ASM published 15 different journals: *Antimicrobial Agenst and Chemotherapy* (AAC), *Applied and Environmental Microbiology* (AEM), *Clinical and Vaccine Immunology* (CVI), *Clinical Microbiology Reviews* (CMR), *Eukaryotic Cell* (EC), *Infection and Immunity* (IAI), *Journal of Bacteriology* (JB), *Journal of Clinical Microbiology* (JCM), *Journal of Virology* (JV), *mBio*, *Microbiology and Molecular Biology Reviews* (MMBR), *Genome Announcements* (GA, now *Microbiology Resource Annoucements*), *Molecular and Cellular Biology* (MCB), *mSphere* and *mSystems*. This study only examines original research manuscripts, which eliminates three journals from the remaining analyses (CMR, GA, and MMBR).

Each journal is led by an editor-in-chief who manages journal scope and quality standards. Two journals, EC and CVI were retired during the period under study. In total, there were 17 EICs, 17.65% of which were women. In 2013, the leadership of CVI transferred from a man EIC, to a woman. The *Journal of Virology* (JVI) has had the same woman as EIC since 2012.

The EICs manage a board of editors with field expertise to help manage the peer review process as needed. The total number of editors over the duration of our study (senior editors and editors pooled) was 1016 and 28.74% were women. We wanted to know what communities these editors represented so we used Carnegie classifications to group US-based insititutions into R1, R2, low (not R1 or R2), and medical research. Medical and institutions (e.g., Mayo clinic) were grouped together and two other categories added to represent industry and federal research. The NA category represents uncategorized US institutions and non-US institutions. Over 40% of both men and women editors are from US-based R1 institutions, with uncategorized US and non-US institutions supplying the next largest proportion of editors (Fig. 1A).

To understand if men and women editors had proportionate workloads, we calculated the percent of manuscripts handled by men and women editors, not including editorial rejections. This was plotted overtime along with the proportion of each gender. Since the start of our study, there has been a slow trend toward gender parity of editors (Fig. 1B, solid lines), which is representative of senior editor trends. The trends for each journal studied vary considerably, though most have slow trends toward parity (Fig. 1C, solid lines). CVI and *mSphere* are the only ASM journals to have accomplished equivalent representation of both genders, with CVI having a greater proportion of women editors than men before it was retired. EC is the only journal with an increasing parity gap.

Across all journals, men handle a slightly greater proportion of manuscripts (blue dashed) and women a slightly smaller proportion (orange dashed), relative to their respective editorial representations (Fig. 1B). This trend continues accross most journals with varying degrees of difference between workload and representation (Fig. 1C). There are exceptions. At *mBio* and *mSphere*, workload and proportions are identical. However, at CVI and JVI, the workload for women editors is much higher than their representation, while the workload of men is considerably less than their representation would suggest. In the years preceding its retirement, the representation of women at CVI increased, which acted to decrease the gap with their workload. However, representations and relative workloads for men and women editors at JVI have held steady over time.

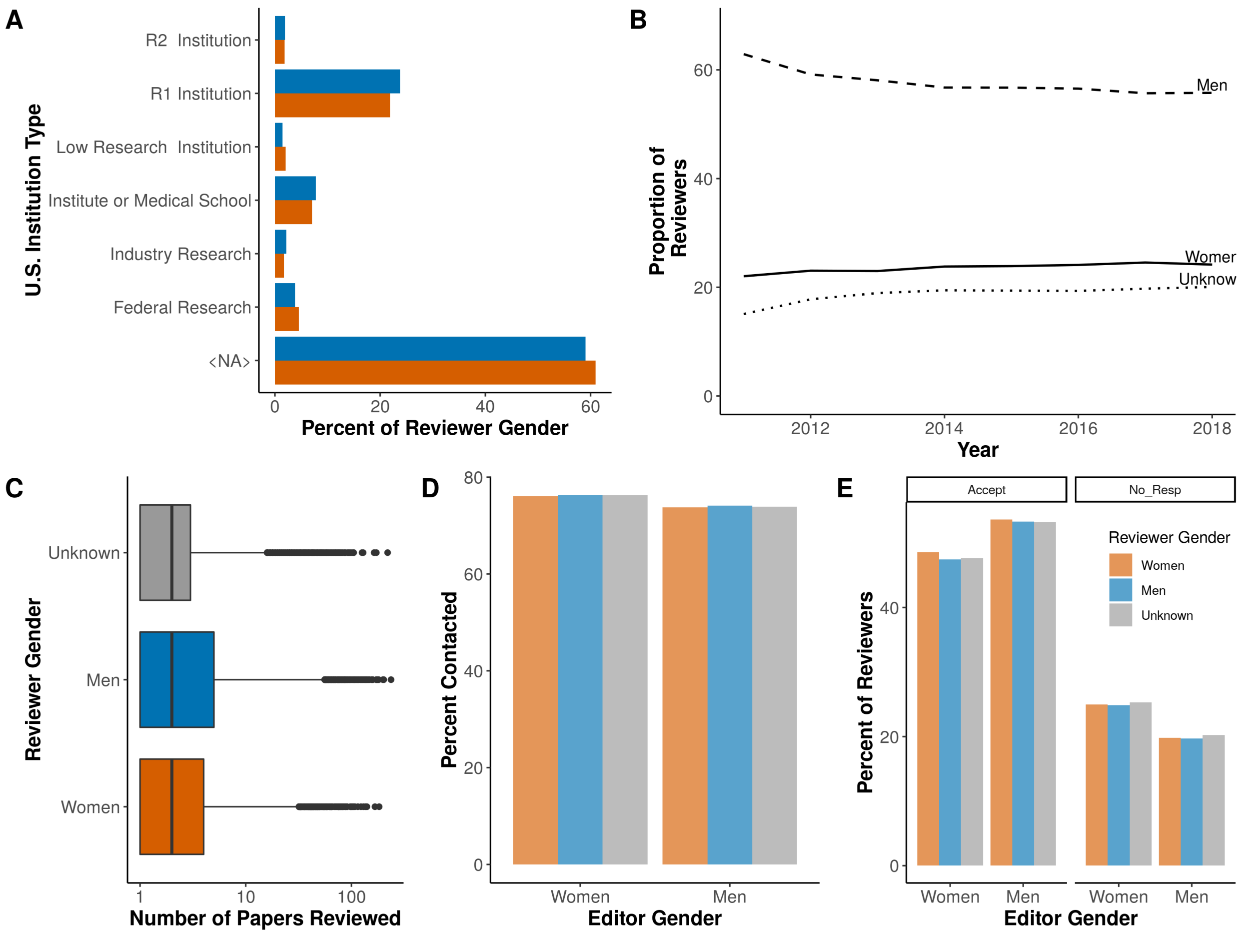

Figure 2. Reviewer representation, workload, and response to requests to review. (A) Proportion of men and women reviewers from insitution types. NA represents non-categorized and non-US institutions. (B) Proportion of each gender listed as a possible reviewer from 2012 to 2018. (C) Boxplot comparison of total papers reviewed by each individual according to gender. (D) Percent of each reviewer gender contacted to review, according to the editor's gender. (E) The percent of reviewers by gender that either accepted the opportunity to review or did not respond to a request to review, split according to the editor's gender. Reviewers were assigned one of three genders: men (blue/dashed), women (orange/solid), or unknown (gray/dotted).

Given the relatively small number of editors at ASM journals, their presenting genders where identified by hand while the genders of reviewers and authors were predicted from their first names. Assigning gender by first name resulted in 3 possible outcomes: men, women, and unknown (when gender could not be assigned with confidence, see Methods for validation). Our dataset contained 30704 reviewers, 24.61% of which were women. As with editors, the greatest proportion of reviewers (about 60% of both men and women) come from non-categorized US institutions and non-US institutions, while R1 institutions supply the next largest cohort of reviewers (Fig 2A). Over the time period studied, the proportions of each gender have held steady among reviewers at ASM journals (Fig. 2B) and is representative of both reviewer proportions at each journal, and the potential reviewers at all journals combined (Fig. S1 AB). The median number of papers reviewed by individuals in each gender group is equivalent, with a trend to more men reviewing a greater quantity of manuscripts (Fig. 2B). 3275, 6413, and 3176% of men, women, and unknown reviewers have reviewed only one manuscript. Editors of both genders contact reviewers from all three gender groups at equivalent proportions, though women editors contact more reviewers than men (Fig. 2D). This is likely because reviewers of all genders, accept fewer, and ignore more, requests to review from women editors than men (Fig. 2E).

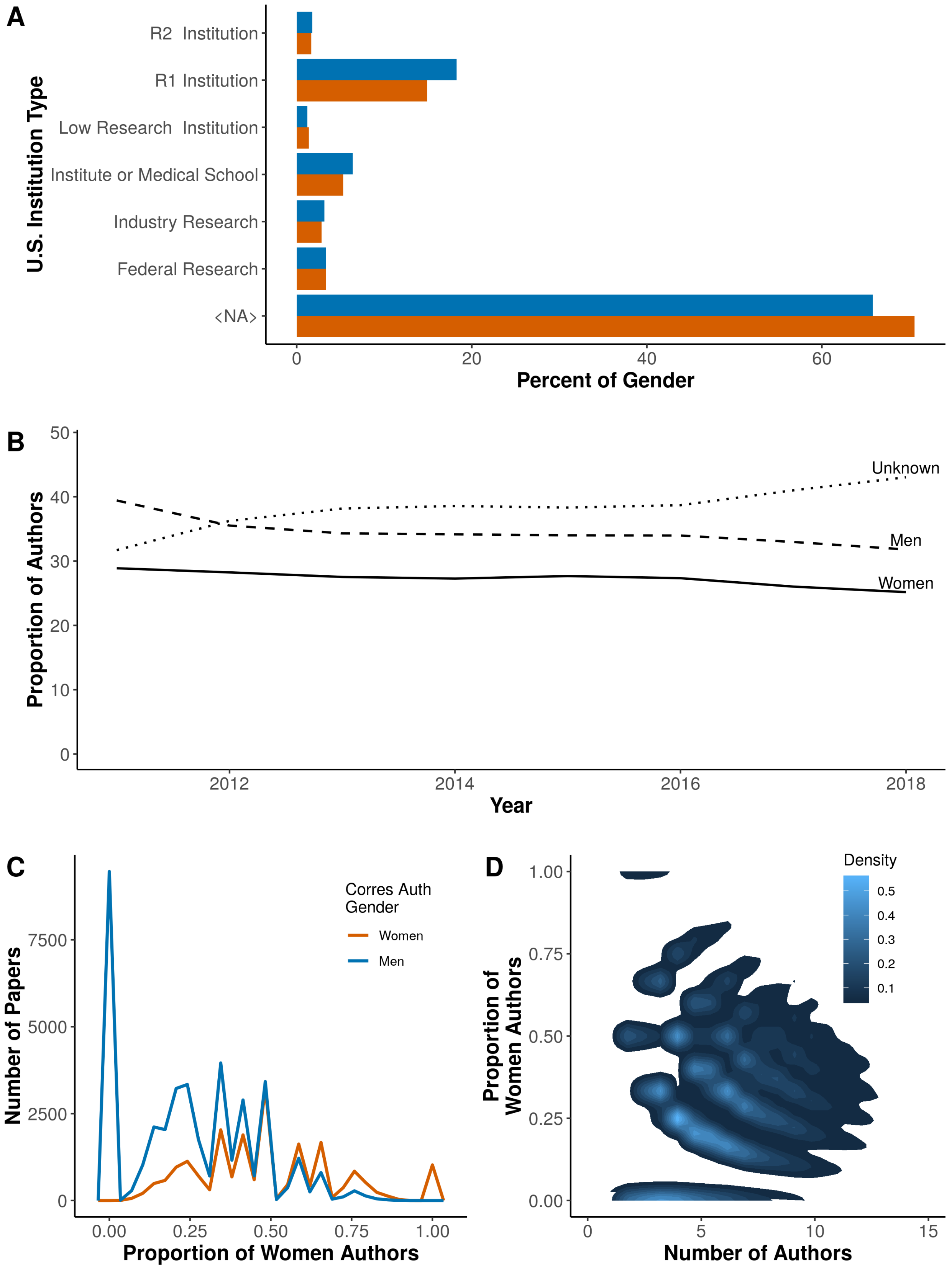

Figure 3. Author representation by gender. The proportion of (A) men and women authors

from US institutions (NA indicates US non-categorized and non-US institutions), (B) men, women and unknown authors from 2012 - 2018. The proportion of women authors on submitted papers according to (D) the gender of the corresponding author or (E) the number of authors. Unique manuscripts submitted from 2012 to 2018.

The institution orgin of submitting men and women authors is similar to that of editors and reviewers, where over 60% are at US non-categorized and non-US institutions, followed by 20% from R1 institutions (Fig. 3A). The proportions of men and women authors at ASM have decreased over time at equivalent rates, with a ratio of men to women authors of 4:3 since 2012 (or, 57% men) (Fig. 3B). This decrease corresponds with an increase in the proportion of unknown authors. Globally, microbiology researchers are 60% men and 40% women (Elsevier report). At ASM in September 2018, 38.37% of members who reported their gender, were women.

Of 39168 manuscripts submitted by men corresponding authors (single author papers excluded), 9212 lack any women authors. The number of papers submitted by women corresponding authors where women comprise more than 50.99% of the authors is 7403 and exceeds those submitted by men corresponding authors 3305 (Fig. 3C). Additionally, the proportion of women authors decreases as the number of authors increases (Fig. 3D). To verify that the trend is non-random, we ran a logisitic regression model predicting the gender of the corresonding author. Variables of the model included whether or not the corresponding author's institution was in the U.S. or not, the total number of authors, whether or not the article was published, the gender of senior editors and editors, the number of revisions, and whether or not the manuscript was editorially rejected. The value of the area under the curve (AUC), for this model was 0.72, meaning that the model could correctly predict gender 72 percent of the time. With a median weight of 4.09, the primary predictive driver of this model was the proportion of women authors on a paper (even excluding single author and all men author papers). All other variables had weights less than 1, indicating that the proportion of women authors was the primary driver of this model.

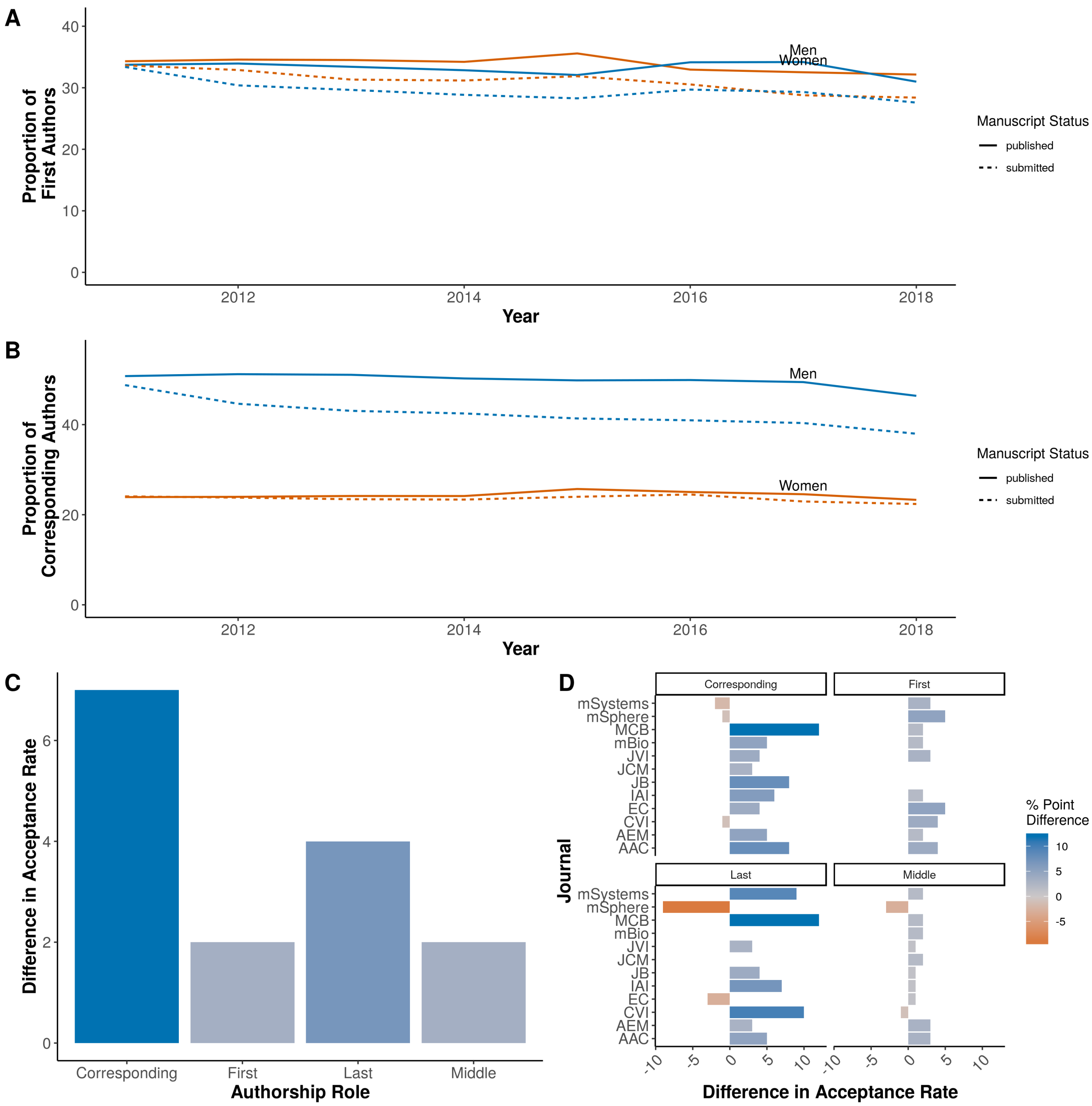

Figure 4. The difference in percentage points of papers accepted The proportion of (A) first authors and (B) corresponding authors from 2012 - 2018. Solid lines indicate individuals, dashed indicate proportion of manuscripts submitted. Men indicated by blue and women by orange. The difference in percentage points of papers accepted at (C) all journals or (D) for each journal. Unique manuscripts were split according to the gender of the corresponding, first, last, and middle author(s), and the acceptance rate for each group calculated. The difference in acceptance rate was determined by subtracting the acceptance rate of women-authored papers from men-authored papers. The shade (ranging from orange to blue) indicates the outperforming

gender. No bar indicates no difference in percentage points.

The proportion of papers submitted with men (blue dashed) and women (orange dashed) first authors have remained constant with an average of 29.64 and 31.08 percent, respectively (Fig. 4A). Their respective proportions of published manuscripts are nearly identical at 33.16% for men and 33.85% for women. The proportion of submitted papers with men corresponding authors has remained steady at an average of 42.45% and the proportion with women corresponding authors at 23.56%. However, their respective proportions of published manuscripts, 49.85% for men and 24.35% for women, are dissimilar (Fig. 4B). The published manuscript proportion where men are corresponding authors has a 7.4 gap in percentage points, while the gap for women corresponding authors is only 0.79. These trends are similar across individual journals (Fig. SX).

We wanted to know whether the increase in published proportions are proportionally equivalent for men and women corresponding authors or if this was evidence for disproportionate success by men relative to women. To answer this question, we calculated the difference in percentage points between a given outcome for men and women, e.g., the percentage point difference in acceptance rates is the acceptance rate for men minus the acceptance rate for women. A positive value indicates that men receive the outcome more often than women, whereas a negative value indicates that women outperform men in the given metric. To correct for the disparity in the participation of women relative to men at ASM journals, all percentage point comparisions are made relative to the gender and population in question. First, we calculated the difference in acceptance rate percentage points for men and women at each author type (e.g., corresponding, first, last, and middle). Men outperformed women in all authorship roles across ASM journals combined, with the greatest difference seen for corresponding authors at 7 percentage points (Fig. 4C). When broken down by journals, there is a clear trend to overperformance by men in both corresponding and last authorship categories, with some exceptions (Fig. 4D). The primary exception is *mSphere*, where papers with a woman last or corresponding author are accepted 9 percentage points more than those authored by a man.

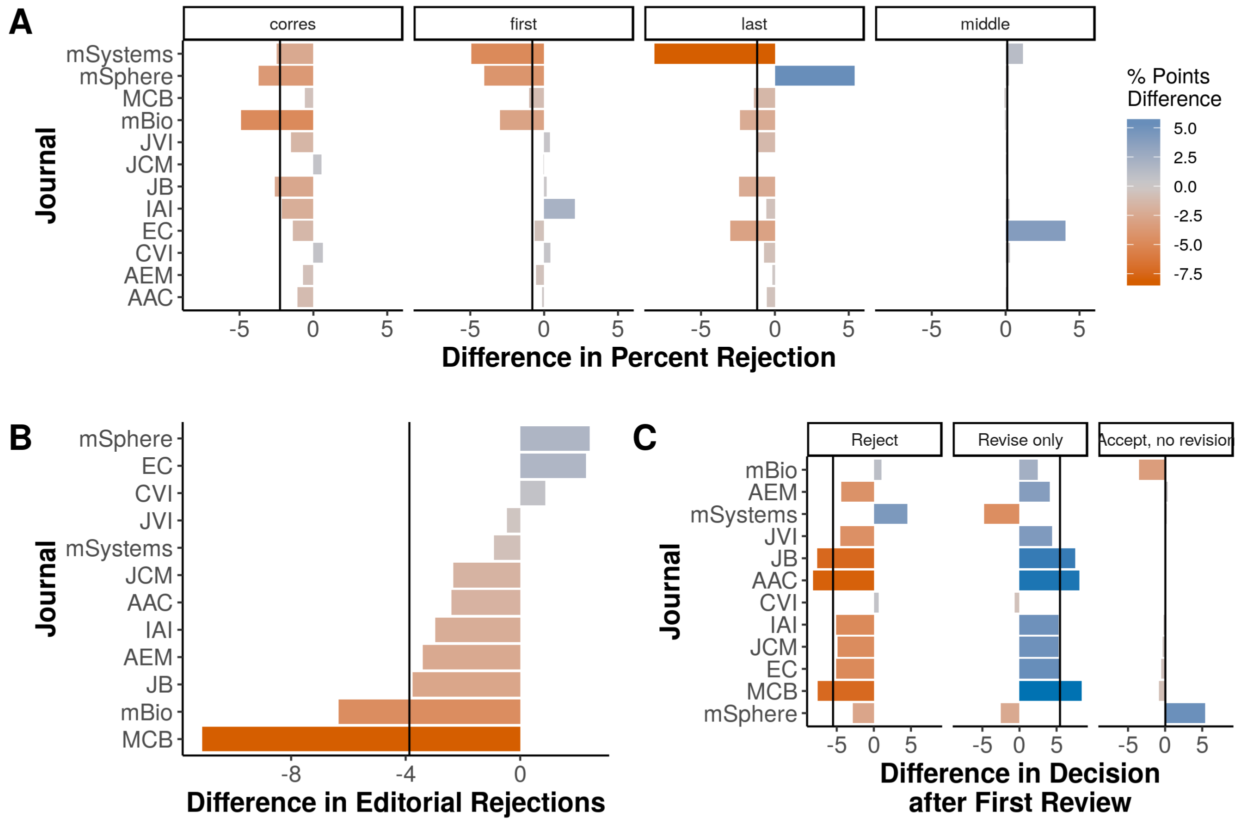

Figure 5. Difference in rejection rates by author gender. The percent of manuscripts rejected by author gender and type (e.g., corresponding, first, last, middle) at (A) all journals combined or at (B) each journal, which shows the difference in percent rejection rates. (C) The difference in percent editorial rejection rates at each journal, vertical line indicates the difference for all journals combined. (D) The difference in percentage points between each decision type following the first peer review, vertical lines indicate the difference value for all journals combined. The difference in rejection rates was determined by subtracting the rejection rate of women-authored papers from men-authored papers within each category. The shade (ranging from orange to blue) indicates the outperforming gender. No bar indicates no difference in percentange points.

Papers submitted by women have more negative outcomes than those submitted by men. To better understand the percentage point difference in gendered performance (Fig. 4), we next compared the rejection rates at each author stage. Middle authors were rejected at similar rates for men and women, a 0.11 percentage point difference across all journals combined. However, senior woman-authored manuscripts are rejected more frequently than those authored by men with percentage point differences of -2.26 and -1.2 for corresponding and last authors, respectively (Fig. 5A). Breaking it down by individual journals, there are several instances where the overall trend is repeated or even amplified (e.g., AAC, IAI, JB, *mBio*, MCB). The greatest effect was observed when comparing the gender of corresponding authors, so we used this sub-population to further examine the difference in acceptance/rejection rates.

We next compared the rejection rates for men and women corresponding authors at two different bottlenecks, before and after the first peer review. Many papers are immediately rejected by editors/EICs instead of being sent to peer review, often due to issues of scope or percieved quality. We refer to these as editorial rejections. Alternately, editors could send papers out for review by two or three experts in the field. The reviewers make suggestions to the editor who decides whether the manuscript in question should be accepted, rejected, or sent back for revision. At ASM journals, manuscripts with suggested revisions that are expected to take more than 30 days are rejected, but generally encouraged to resubmit. Papers authored by women are editorially rejected as much as 12 percentage points more often than those authored by men (Fig. 5B). The percentage point difference at all ASM journals combined is -3.87 (vertical line), and two journals, MCB and *mBio*, have more extreme percentage point differences. Papers authored by men and women are equally likely to be accepted after the first round of review (Fig. 5C, right panel). However, women-authored papers were rejected more often (left panel) while men-authored papers were more often given revision decisions (center panel). Three journals, JB, AAC, and MCB, have percentage point differences more extreme than for all ASM journals combined in both rejection (-5.5) and revision (5.46) decisions (vertical lines).

In addition to manuscript decisions, other disparate outcomes may occur during the peer review process. To determine whether women-authored papers spent more time between being submitted and ready for publication, we compared the number of revisions, days spent in the ASM peer review system, and the number of days from submission to being ready for publication to those authored by men. Papers authored by women take slightly longer (from submission to ready for publication) than men at some journals (*mSphere*, *mBio*, *mSystems*, CVI, JB, JCM, AEM) despite spending similar amounts of time in the ASM journal peer review system, and having equivalent median number of revisions prior to acceptance (Fig. S3).

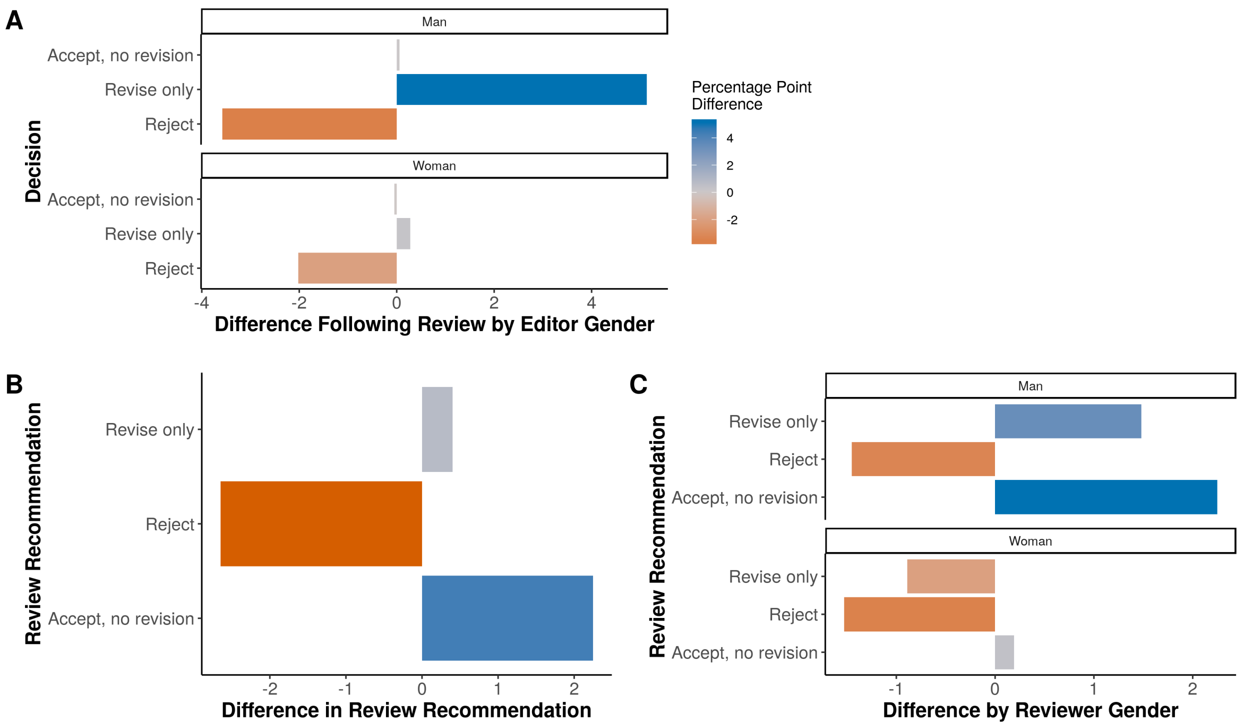

Figure 6. Difference in decisions or recomendations according to the gatekeeper gender. (A) Effect of editor gender on the difference in percentage points for decisions following review at all journals combined. (B) Difference in percentage points for review recommendations and (C) how that is affected by reviewer gender.

We next wanted to understand how gatekeeper (editor/reviewer) genders influenced the outcomes observed in Fig. 5C. To answer this question, editor decisions and reviewer suggestions were grouped according to the gatekeeper gender then the percentage point difference between manuscripts submitted by men and women corresponding authors was calculate. Both men and women editors rejected proportionally more women-authored papers, with men editors making revise decisions on papers authored by men more often than those authored by women (Fig. 6A). Reviewers are more likely to suggest rejections for women as compared to men, though no difference in revise suggestions were observed (Fig. 6B). Both men and women reviewers recommended rejection more often for women-authored manuscripts though only men reccomended acceptance more often for men-authored manuscripts (Fig. 6C). Women reviewers suggested revision on women-authored papers more often than men-authored manuscripts.

To evaluate whether or not manuscript decisions are random when gender is taken into account, we used a logistic regression model to predict whether or not a manuscript was reviewed (e.g., editorially rejected or not). Our variables included the genders of the senior editor, editor, and corresponding author, as well the proportion of authors that were women. The median AUC of this model was 0.59, indicating that the decisions are not completely random. However, because the value was below 0.6 the included variables are not sufficent to create a reliable model. This suggests that other factors influence gender-based decisions.

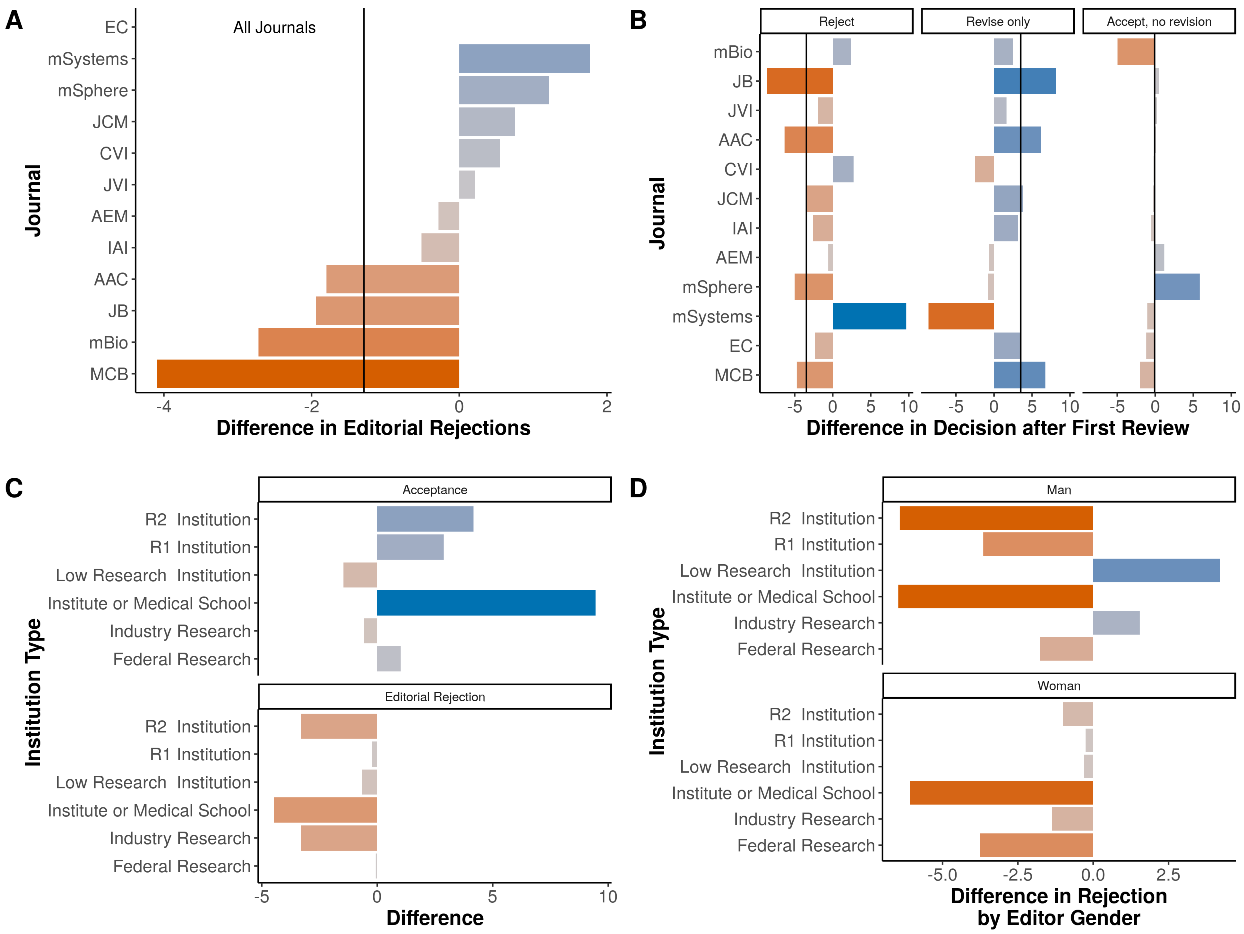

Figure 7. Impact of origin and U.S. institution type on manuscript decisions by gender. Difference in percentage points for corresponding authors in the U.S. (A) editorial rejections, (B) following first review, and by U.S. institution types (C) acceptance and editorial rejections (D) acceptance decisions according to editor gender. Vertical line indicates value for all ASM journals combined. NA indicates non-categorized US institutions or non-US institutions.

Country and institute of origin contribute to overperformance by men. The issue of non-random, gender-based manuscript decisions could be attributed to gender bias by journal gatekeepers, however, there are other types of bias that may contribute to, or obsure, overt gender bias. For instance, a recent evaluation of peer-review outcomes at *eLife* found evidence of geographic homophiliy, that is, reviewers exhibited preference for research submitted by authors from their own country or region (Murray, 2019). Other studies have documented prestige bias, where men are overrepresented in more prestigous (i.e., more respected and competent) programs (Weeden, 2017). It is therefore possible, that what seems to be gender bias could be geographic or prestige bias interacting with the increased proportion of women submitting from outside the US or at lower prestige institutions (e.g., low research institutions) (Fig. 3A).

To try to separate how these factors affect manuscript decisions among corresponding authors, we next looked at the outcome of papers submitted only by corresponding authors at US institutions. When only considering US-based authors, the difference in percentage points for editorial rejections drops from -3.87 to -1.29, though trends across journals are consistent (Fig. 7A). The difference in percentage points for decisions after review mirror those of Figure 5, at the journal level (Fig. 7B). There are also changes in the values for all journals combined. The overperformance of women in rejection decisions decreases from -5.5 to -3.47, and from 5.46 to 3.51, for the overperformance of men in revise only decisions. The rate of accept decisions changed from -3.87 to -0.08 after restricting the analyisis to US-based authors. These results suggest that the country of origin (e.g, US versus not) accounts for some gender bias, particulary for editorial rejections, but not all of it.

To address prestige bias, we next split the US-based corresponding authors according to their institution and re-evaluted the difference in percentage points for men and women. Editorial rejections occured most often for women from industry, R2, and medical schools or institutes while manuscripts submitted by men from medical schools or institutes, R1, and R2 instutitions were accepted more often than those submitted by women (Fig. 7C). The occurence of rejections after review occured more often for manuscripts submitted by women than those submitted by men, regardless of editor gender (Fig. 7D). There are a couple of exceptions where women authors from low research and industry research institutions recieved more positive decisions by men editors. The institution types from which manuscripts submitted by women had the greatest difference in percentage points from those submitted by men are medical schools or institutes and R2 institutions, with values of `top_two[[1,6]]` and `top_two[[2,6]]`, respectively. To understand if these factors affect manuscript decisions in a non-random manner, we used logistic regression model that took into account both origin (US vs non), institution (US institution type) and the genders of both gatekeepers and authors. This model predicted whether or not a manuscript was published and had a median auc of 0.61 indicating non-random interaction between these factors. Those factors with the greatest postive impacts on liklihood of publication were X.inst.gender.Industry.Research.female., X.inst.gender.Industry.Research.male., X.inst.gender.Institute.or.Medical.School.male., US.inst.yes. The factors with the greatest negative impacts on publication were US.inst.no, X.inst.gender.R2..Institution.female., X.inst.gender.R2..Institution.male., inst.gender.NA.female. These results confirm that the country of origin and prestige bias impact decisions in a non-random manner, but gender-based factors are still at play.

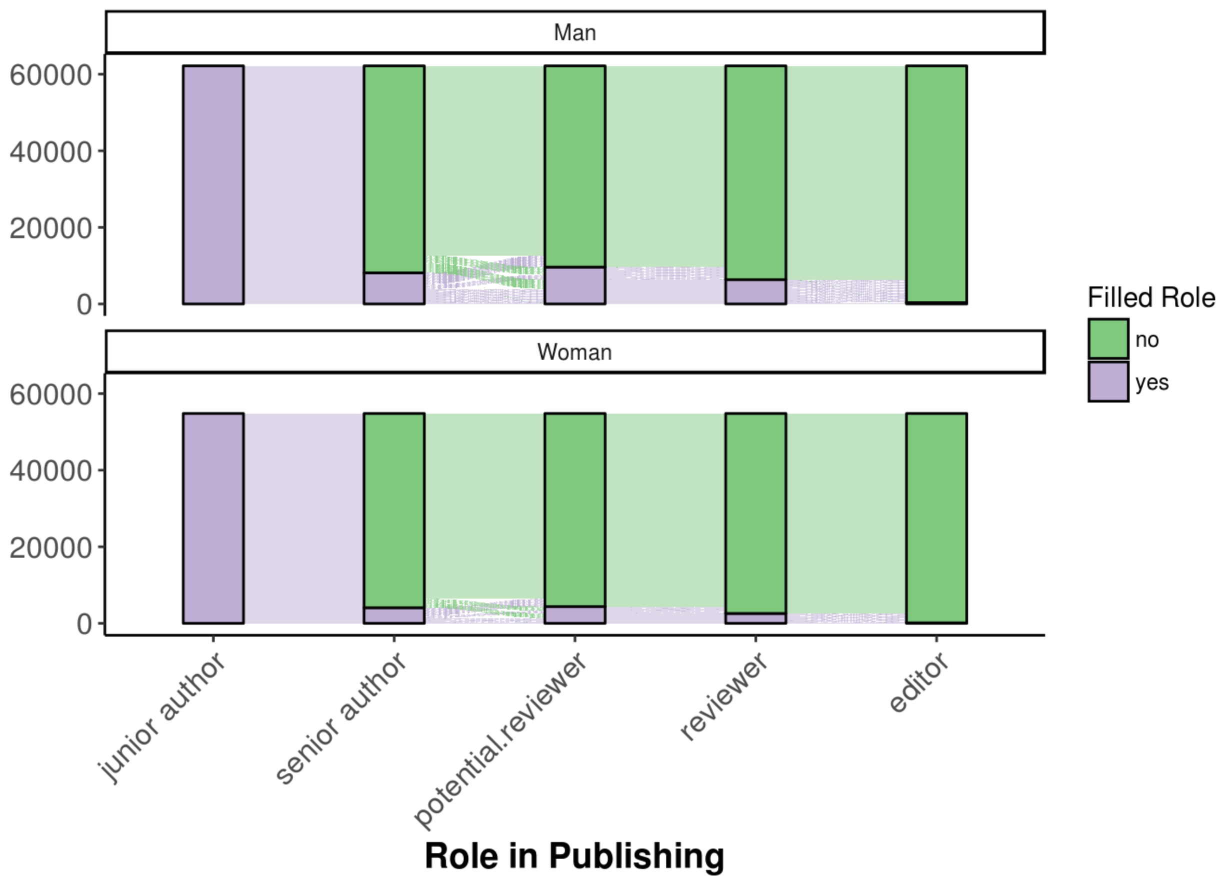

Figure 8. The retention of each gender through the publishing roles. All junior (first or middle) authors were split by gender and tracked through their roles in academic publishing from senior

author (last or corresponding), potential reviewer (considered), reviewer (accepted), or editor. Color indicates whether (purple) or not (green) the individual participiated in that role at any point from 2012 to 2018.

While the differences in percentage points described may seem small, they accumulate to reinforce the decreased representation of women as senior authors seen in Fig. 4A. To better visualize this and the 7.52 decrease in the proportion of women who are first authors to those who are corresponding authors, we asked the proportions at which women have been retained through the peer review system at ASM journals.

There were 84482 men and 76215 women who were junior authors at ASM journals during the period of time under study. Of those junior authors, 13.59 of the men were also senior authors, 16.72 considered as reviewers, 11.11 actually reviewed, and 0.66 were editors at ASM journals. At 8.25, 8.91, and 5.39, 0.25, just half as many women progressed through each role at ASM journals.

Discussion

The under representation of women as corresponding authors in publication at ASM journals has negative consequences for their careers and microbiology. Buckley et al, suggest that being selected as a reviewer increases visibility of a researcher, which has a direct & significant impact on salary. Therefore, the underrepresentation of women as reviewers hampers their career progression and even their desire to progress since reviewing also signals adoption of the researcher into the scientific community (Buckley et al, 2014). This is supported by Lerback and Hanson who noted that "It [reviewing] provides positive feedback that a scholar is respected and participating in their field and fosters self-confidence, all of which lead to increased retention of women." (Lerback & Hanson, 2017) Retention of women in science is important to the progress of microbiology as a field since less diversity in researchers limits the diversity of perspectives, approaches, and thus stunts the search for knowledge. In addition to boosting productivity and knowledge, more diverse and equitable organizations are more inclusive and supportive for all members (Potvin, 2018). It is thus a moral and scientific imperity for scientific societies and journals, such as ASM, to improve its own diversity, equity and inclusion efforts. The remainder of this manuscript will focus on actions that can be taken at multiple levels of the peer review system to support these efforts.

Certain attributes of biological scientific societies correlate with increased gender representation at leadership levels (Potvin, 2018). Using the scientific society "health checklist" developed from these observations, we propose the following suggestions to improve representation at society journals. First, the development of a visible mission, vision, or other commitment to equity and inclusion that includes a non-discrimination clause regarding decisions made by editors and editors-in-chief. This non-discrimination clause would be backed by a specific protocol for the reporting of, and responding to, instances of discrimination and harassment. In the long term, society journals should begin collecting additional data about authors and gatekeepers (e.g., race, ethnicity, sexual orientation, gender identity, and disabilities). Such author data should not be readily available to journal gatekeepers, but instead kept in a disagreggated manner that allows the public presentation to track success of inclusive measures and maintain accountability. Society journals can also impliment mechanisms to explicity provide support for women and other minority groups, e.g, by providing APC waivers, reduced copyediting services, reward inclusive behavior by gatekeepers, encourage women to take up leadership positions and provide gender-neutral, non-exclusive social activities.

A common debate when filling leadership positions is whether they should be representational of the field or aspirational. For instance, since 23.56% of corresponding authors to ASM journals are women, then 23.56% of gatekeepers of a representational leadership would be women. Conversely, 50% of gatekeepers would be women if the goal were an aspirational leadership. We argue that whether a goal should be representational or aspirational depends on the workload and visibility of the position(s). Since high visibility positions (e.g., editor, EIC) are filled by a smaller number of individuals that are responsible for recruiting more individuals into leadership, filling these positions should be done aspirationally. This allows expansion of the potential reviewer network and thus recruitment into those positions. These lower visibility positions (e.g., reviewers) require a greater number of individuals and should thus be representational of the field to avoid overburdening the minority population. Outside of leadership appointment, all parties, journals, gatekeepers, and authors, can help advance women (and other minority groups) within the peer review system. For instance, authors can suggest more women as reviewers using "Diversify" resources (e.g., DiversifyMicrobiology), while reviewers can agree to review for women editors more often. Editors can rely more on manuscript reference lists and data base searches than personal knowledge (Fox et al, 2016), and journals can improve the interactivty and functionality of the peer review selection software.

Addressing bias (gender, geographic, prestige or otherwise) during peer review process is a more difficult challenge, since it is partially the result of accumulated disadvangates and microaggressions (the actions resulting from implict biases). Implict bias training for gatekeepers is a start, as might be double-blinded peer review, a common practice in social sciences. To support efforts of making peer review more transparent, the review process could be unblinded following the editor's final decision on a manuscript. However, these solutions are only bandaids on a deeply infected wound, since both focus on the superficial issue of individuals instead of the underlying structure of the system that has selected for the bias at hand.

Reconsidering journal scope and the overall attitude toward replicatitive and negative results might help address structural barriers to representation of women in peer review. Significant time, funds, and staff are required to be competitive in highly active fields (e.g., *Clostridium difficile*, HIV), but women are often at a disadvantage for these resources (cites for service work). As a result, corresponding authors that are women may be spending their resources at the lesser competitive fringes of research fields (**citation**). This has the disadvange of making them seem "less competent" to those at the established center of the field. The decrease in percieved researcher competency and research validity increase the difficulty to obtain funding and publish in more traditional journals. Expanding journal scope could provide a home for these innovative research fields, bolster the field through reproduciblity, and improve the competentcy demonstration of these researchers.

Few papers have found disparities between rejection rates of men and women and to our knowledge, this is the first paper to collectively examine this issue with either submissions data from 10+ journals or on the field of microbiology. Critics might argue that the effect size is too small to really matter or that there are too many unaccounted factors to draw conclusions. We acknowledge that these are limitations of our study along with a limited journal dataset, an absence of reviewer comments for sentiment analysis, and that many ASM journals have a narrow focus while the broad scope journals are relatively new. All of these factors prevent us from generalizing our results across microbiology as a field. However, the consistency of the trends to benefit men corresponding authors over women, across all journals included and literature to-date confirms that this study is highly relevant for the ASM as a society and offers opportunities to address both gendered representation in microbiology and systemic barriers to peer review at our journals.

Data and Methods

Data All manuscripts handled by ASM journals (e.g., *mBio*, *Journal of Virology*) that received an editorial decision between January 1st, 2012 and August 31st, 2018 were supplied as XML files by ASM's publishing platform, eJP. Data were extracted from the XML documents provided using R statistical software (version 3.4.4) and the `XML` package (R citation). Data manipulation was handled using the `tidyverse`, `lubridate`, and `xml2` packages for R. Variables of interest included: the manuscript number assigned to each submission, manuscript type (e.g., full length research, erratum, editorial), category (e.g., microbial ecology), related (previously submitted) manuscripts, versions submitted, dates (e.g., submission, decision), author data (e.g., first, last, and corresponding authorship, total number of authors), reviewer data (e.g., reviewer score, recommendation, editor decision), and person data (names, institutions, country) of the editors, authors, and reviewers. For this analysis, only original, research-based manuscripts were included, e.g., long- and short-form research articles, New-Data Letters, Observations, Opinion/Hypothesis articles, and Fast-Track Communications.

It is common practice at ASM journals for manuscripts whose reviewers recommend extensive experimental revisions be given a decision of "reject with resubmission encouraged". If resubmitted, the authors are asked to note the previous (related) manuscript and the resubmission is assigned a new manuscript number. Multiple related manuscripts were tracked together by generating a unique grouped manuscript number based on the recorded related manuscript numbers. This grouped manuscript number served multiple purposes including: tracking a single manuscript through multiple rejections or transfers between ASM journals and to avoid duplicate counts of the same authors for the same manuscript.

Data were visualized using the `ggplot`, `scales`, `RColorBrewer`, and `ggalluvial` packages for R.

Institution classification

Bias analysis and presentation

Logistic regression models

Gender prediction and assignment The gender assignment API genderize.io was used to predict an individual's gender based on their given names, and country where possible. The genderize.io platform uses data gathered from social media to predict gender based on given names with the option to include an associated language or country to enhance the odds of successful prediction. Since all manuscripts are submitted in English, precluding language association for names with special characters, names were standardized to ASCII coding (e.g., "José" to "Jose"). We next matched each individuals country against the list of X country names accepted by genderize.io. Using the `GenderGuesser` package for R, all unique given names associated with an accepted country were submitted to the genderize.io API and any names returned without a predictive assignment of either male or female were resubmitted without an associated country. All predictive assignments of either male or female are returned with a probability match of 0.50 or greater. The predicted genders of all given names (with and without an associated country) whose probabilities were greater or equal to our arbitrary success cut off of 0.65 were used to assign predicted gender to the individuals in our dataset. Predicted genders were assigned to individuals in the following order: first names and country, first names, middle names and country, middle names (Supplemental Fig. 1). The presenting gender (man/woman) of editors and senior editors in our dataset was hand validated using Google where possible.

We recognize that biological sex (male/female) is not always equivalent to the gender that an individual presents as (man/woman), which is also distinct from the gender(s) that an individual may self-identify as. For the purposes of this manuscript, we choose to focus on the presenting gender (man/woman/unknown) based on their first names and/or appearance (for editors). In the interest of transparency, we include those individuals whose names don't allow a high degree of confidence for gender assignment in the "unknown" category of our analysis.

Validation of gender prediction We first validated the algorithm using a set of 3265 names whose gender had been hand-coded based on appearance and were generously provided to us by ___ (preprint cite). The names were supplied to the genderize algorithm both with and without the accompanying country data. The data returned include the name, predicted gender (male, female, na), the probability of correct gender assignment (ranging from 0.5 to 1.0), and the number of instances the name and gender were associated together (1 or greater). The genderize algorithm returned gender predictions for 2899 when first names were given and 2167 when country data was also supplied (732 names were associated with countries unsupported by genderize).

Sensitivity and specificity, are measurements of the algorithm's tendency to return correct answers instead of false positives (e.g., a man incorrectly gendered as a woman) or false negatives (e.g., a woman incorrectly gendered as a man). The closer these values are to 1, the smaller the chance that the algorithm will return the correlating false response. Accuracy is a composite measure of the algorithm's ability to differentiate the genders correctly. These measurements were calculated from the datasets (with and without country data supplied) at three different probability threshold cutoffs: the default genderize (0.5), a probability threshold of 0.85 (0.85), and a modified probability of 0.85, which factors in the number of instances returned (pmod0.85)(citations).

At the 0.5 threshold, the dataset returned a sensitivity of 0.8943 and specificity of 0.9339 for an accuracy of 0.911, compared to a marginally higher accuracy of 0.9146 for the dataset where country data were included (Supplemental Table 1). Generally speaking, the accuracy increases as the threshold increases along with slight trade offs between sensitivity and specificity. For the purposes of our analysis, we opted to use the pmod0.85 threshold moving forward (Supplemental Table 1, in bold).

To understand the extent of geographic bias in our gender assignment against regions and languages with genderless naming conventions, or that lack social media for incorporation into the genderize algorithm, we compared the number of names predicted without associated country data to when country data was also supplied. In our test dataset, the top five countries associated with names were United States, Germany, United Kingdom, France, and China and the countries with the highest proportion of un-predicted genders when country data were supplied are Cambodia, Iceland, Indonesia, Ireland, and Mexico, where the maximum number of names supplied ranged from 1 to 15. To determine the impact of each country towards the overall percentage of names whose genders were not predicted (27.14%), we found the difference between the percent of names unpredicted for each country and the overall percentage, multiplied by the proportion of observations from that country to the total observations and finally divided by the overall percentage of unpredicted names (Supplemental Fig. 2). The top five countries with the greatest impact on unpredicted names, and thus the countries receiving the most negative bias from genderize were Canada, China, Ireland, Belgium, and Sweden (Supplemental Fig. 3). These data suggest that there is likely some bias against countries with gender-neutral naming conventions (China), and indicates the stringency with which the algorithm applies gender to names that are accompanied by country data. For instance, strongly gendered names such as Peter and Pedro were not assigned gender when associated with Canada.

We next applied the genderize algorithm at the pmod0.85 threshold to our journals dataset and tested its validity on a small portion. All first names collected from our dataset were submitted to genderize both with and without country data. Only those predictions whose pmod were equivalent or greater than 0.85 were carried to the next step. The predicted genders were assigned to individuals in the following order: first names and country, first names, middle names and country, middle names. Given the relatively small number of editors and senior editors in our dataset, the presenting gender (man/woman) of editors and senior editors in our dataset was hand-validated using Google where possible. Of the 1072 editor names, 938 were predicted by genderize for an accuracy of 0.9989339, thus increasing our confidence in the gender predictions where made.

In our full dataset, the five countries with the most individuals were United States, China, Japan, France, and Germany and the countries with the highest proportion of un-predicted genders were

Burundi, Chad, Kingman Reef, Korea (North), Democratic People's Republic of, and Maldives, where the maximum number of names supplied ranged from 1 to 4. Proportionally, fewer names in our full dataset were assigned gender than in our validation dataset (40.01% unpredicted versus 27.14% unpredicted, respectively). Since adjusting the workflow to predict the gender of names both with and without country data, the countries receiving the most negative bias from genderize were China, Japan, Korea, Republic of, India, Taiwan, Province of China (Supplemental Fig. 4). These data indicate what we previously predicted, that the genderize algorithm has bias against countries with gender-neutral naming conventions.

Code availability The code for all analysis steps, including an Rmarkdown version of this manuscript, is available at https://github.com/SchlossLab/Hagan_Gender_mBio_2019/

Acknowledgements

References