Who are ASM Journals? A Gender-based Analysis

Running title: A gender-based analysis of ASM journals

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Abstract

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. Recently, scientific societies and publishers have begun examining internal submissions data to evaluate representation of, and bias against, women in their peer review processes. However, representation and attitudes differ by scientific field and no studies to-date seem to have investigated academic publishing in the field of microbiology. Using manuscripts submitted between January 2012 and August 2018 to 13 journals published by the American Society for Microbiology (ASM), we describe the representation of women at ASM journals and the outcomes of their manuscripts. We find that senior women authors at ASM journals are underrepresented compared to global and society estimates of microbiology researchers. Additionally, manuscripts submitted by corresponding authors that were women, recieved more negative outcomes (e.g., editorial rejections, reviewer recommendations, and decisions after review), than those submitted by men. These negative outcomes were somewhat mediated by whether or not the corresponding author was based in the US or not and by the institution for US-based authors. However, the trend for women corresponding authors to receive more negative outcomes held, indicating a pattern of gender-influenced editorial decisions.

Importance

Women are underrepresented as senior scientists at ASM journals. This is due to a combination of both low submissions from senior women authors and increased rejection rates for women compared to men.

Introduction

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_elife_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, and less than 25% of science and engineering doctorates in early career academia identify as non-white (NSF ADVANCE, 2014). Predictably, the disparities increase alongside academic rank @article{potvin_diversity_2018}. There have been many proposed reasons for these disparities, particularly with regards to 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, lower perceived comptency, and less productivity as measured by research publications. **Add citations** These issues do not act independent 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 institutions and members of the scientific community.

Scientific societies play an integral role in the formation and maintenance 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. Recently, scientific societies and publishers have begun examining internal submissions 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 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). Several other studies have concluded that there is no significant bias against papers authored by women (C&W, 2011; Fox, 2016; Handly, 2015; Edwards, 2018). 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 research and review journals. Between January 2012 and August 2018, ASM published 15 different journals: *Antimicrobial Agents 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*. We attempted to assign genders to both peer review gatekeepers (e.g., editor-in-chief, editors, reviewers) and authors on the original research manuscripts (eliminating CMR, GA, and MMBR) evaluated during this time period. The goal of this research study is to describe the representation of authors, reviewers, and editors at ASM journals by gender and the associated peer review outcomes of their manuscripts.

Results

Men dominate as gatekeepers and senior authors. We first evaluated the representation of men and women who were gatekeepers at ASM during the study period. Each journal is led by an EIC who manages journal scope and quality standards. In total, there were 17 editor-in-chiefs (EIC), 17.65% of which were women. Two journals, EC and CVI were retired during the period under study. In 2013, the leadership of CVI transferred from a man EIC, to a woman. JVI has had the same woman as EIC since 2012. The EICs manage a board of editors with field expertise to handle the peer review process. The total number of editors over the duration of our study (senior editors and editors pooled) was 1016 and 28.74% were women.

Over 40% of both men and women editors were from US-based R1 institutions, with non-US and medical schools and institutions supplying the next largest proportions of editors (Fig. 1A). Since the start of our study, there has been a slow trend toward equivalent gender representation among editors (Fig. 1B). The trends for each journal studied vary considerably, though most have slow trends toward parity (Fig. S1). CVI and *mSphere* were 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.

Our data set contained # of manuscripts each of which contained a list of potential reviewers. A total of 30704 reviewers, 24.61% of which were women, agreed to act as reviewers when contacted. The greatest proportion of reviewers (over 50% of both men and women) come from non-US institutions, while R1 institutions supply the next largest cohort of reviewers (Fig. 1C). Over the time period studied, the proportions of each gender have held steady among reviewers at ASM journals (Fig. 1D) and is representative of both reviewer proportions at each journal, and the potential reviewers at all journals combined (Fig. S2).

Editorial workloads were not proportionate Across all journals, men handle a slightly greater proportion of manuscripts (blue) and women a slightly smaller proportion (orange), relative to their respective editorial representations (Fig. 1A). This trend continues across most journals with varying degrees of difference between workload and representation (Fig. S1). There were exceptions. At *mSphere*, workload and proportions were identical. However, CVI, *mBio*, and JVI, each have points at which the workload for women editors is much higher than their representation, with corresponding decreases in the workload of men. 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, while the proportionate workload for women at *mBio* has increased.

Between 2012 and 2018, the median number of manuscripts reviewed by individuals in each gender group is equivalent at 2. Half of men, women, and unknown genders reviewed between one and 5, 4, or 3 manuscripts each, respectively (Fig. 2B). 43.35, 38.97, and 47.45% of men, women, and unknown reviewers have reviewed only one manuscript (Fig. 2C). Reviewers of all genders, accepted fewer requests to review from women editors (average of 47.9066667%) than men (average of 53.4%) and were less likely to respond to women than men (average of 25.04 and 19.91%, respectively) (Fig. 2C). Editors of both genders contacted reviewers from all three gender groups at equivalent proportions, though women editors contact 76.29% of potential reviewers, compared to men who contact 73.92% (Fig. 2D).

Women were underrepresented as 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. We wanted to determine if these proportions were similar for authors at ASM journals and to understand the distribution of each gender among submitted and published manuscripts. We began by describing author institutions by gender. Over 60% of authors were from 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 gendered authors.

The proportion of papers submitted with men and women first authors have remained constant with an average of 29.64 and 31.08 percent, respectively (Fig. 3C). Their respective proportions of average published manuscripts were nearly identical at 33.16% for men and 33.85% for women. The proportion of submitted papers with men corresponding authors (defined in the methods) 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, were dissimilar (Fig. 3D). The difference between published and submitted proportions of manuscripts where men were corresponding authors is 7.4, and 0.79 for women corresponding authors. This trend is similar for middle and last authors (Fig. S3).

Of 39168 manuscripts submitted by men corresponding authors (single author papers excluded), 23.52% had zero women authors. 7403 (36.45%) of papers submitted by women corresponding authors have at least 51% of the authors as women, exceeding those submitted by men corresponding authors, 3305 (8.44%). We also found that the proportion of women authors decreases as the number of authors increases (Fig. S4). To verify that the trend is non-random, we ran a logistic regression model predicting the gender of the corresponding 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, the proportion of authors that were women, 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. Single author manuscripts and those with either all men or all women authors were excluded. The value of the area under the curve (AUC), for this model was 0.7. The AUC value ranges between one and zero, where the reliability of the prediction model increases with the AUC. The primary predictive driver of this model was the proportion of women authors on a paper, with a median weight of -3.64. All other variables had weights less than 1, indicating little to no influence on the model.

To better visualize the 7.52 decrease in the proportion of women who were first authors to those who were corresponding authors (Fig. 3CD), we asked the proportions at which women have been retained through the peer review system at ASM journals. During the period of time under study, there were 76215 women who participated as junior authors (first, middle) at ASM journals. Of those junior authors, 8.25% also participated as senior authors (last, corresponding), and 8.91% were listed as potential reviewers. 5.39% of the women junior authors participated as reviewers and, 0.25% held a role as editor. For men, there were a total of 84482 junior authors, where 13.59 were also senior authors, 16.72 considered as reviewers, and 11.11 actually reviewed. 0.66 of men junior authors were also editors at ASM journals.

Papers submitted by women have more negative outcomes than those submitted by men. To better understand the differences between published and submitted proportions for men and women authors (Fig. 3CD, Fig. S3), we next compared the rejection rates of men and women at each author stage (e.g., first, middle, corresponding, and last). Middle authors were rejected at similar rates for men and women, a 0.11 percentage point difference across all journals combined. However, manuscripts with senior women authors were rejected more frequently than those authored by men with -2.26 and -1.2 percentage point differences for corresponding and last authors, respectively (Fig. 4A). Breaking it down by individual journals, there were 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 after two bottlenecks, initial review by the editor and the first peer review. Papers authored by women were editorially rejected as much as 12 percentage points more often than those authored by men (Fig. 4B). 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 were equally likely to be accepted after the first round of review (Fig. 4C, 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. S5).

To understand how gatekeeper (editor/reviewer) genders influence decisions (e.g., Fig. 4C), we grouped editor decisions and reviewer suggestions according to the gatekeeper gender. 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. 5A). Reviewers were more likely to suggest rejections for women as compared to men, though no difference in revise suggestions were observed (Fig. 5B). Both men and women reviewers recommended rejection more often for women-authored manuscripts though only men recommended acceptance more often for men-authored manuscripts (Fig. 5C). Women reviewers suggested revision on women-authored papers more often than men-authored manuscripts.

To evaluate whether or not manuscript decisions were random when gender is taken into account, we used a logistic regression model to predict whether or not a manuscript was reviewed (i.e., editorially rejected or not). When accounting for 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 0.62. Because the AUC value was above 0.6, the editorial rejection decisions were not completely random, though the model reliability is low. This suggests that other factors influence gender-based decisions.

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 obscure, 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 over-represented in more prestigious (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 changes from -3.87 to -1.51, though trends across journals were consistent (Fig. 6A). Similarly, trends in the difference in percentage points of decisions after review for US-based authors mirror those seen for all corresponding authors at the journal level in Figure 4B. Though there were changes in the values for all journals combined. The over-performance of women in rejection decisions decreases from -5.5 to -3.39, and the over-performance of men in revise only decisions from 5.46 to 3.43 (Fig. 6B). The rate of accept decisions changed from -3.87

to -0.05 after restricting the analysis to US-based authors. These results suggest that the country of origin (e.g, US versus not) accounts for some gender bias, particularly 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-evaluated the difference in percentage points for men and women. Editorial rejections occurred most often for women from medical schools or institutes, followed by those from R2 institutions (Fig. 6C). Manuscripts submitted by men from medical schools or institutes were accepted proportionally more often than those submitted by women. The difference in percentage points for corresponding authors from medical schools or institutes seems to be spread across most ASM journals, while the editorial rejection of papers from R2 institutions seems to be driven primarily by JCM (Fig. S6AB). The occurrence of rejections after review occurred more often for manuscripts submitted by women than those submitted by men, regardless of editor gender (Fig. 6D). There were a couple of exceptions where women authors from low research and industry research institutions received more positive decisions by men editors.

Corresponding authors who were men from non-US institutions consistently over-perform compared to women from non-US institutions. About 15 percentage points more manuscripts submitted by men from non-US institutions were accepted after review, than those submitted by women (Fig. 6C). Editors that were men rejected 20 percentage points more manuscript submitted by women than those submitted by men, whereas the difference for women editors is much smaller at -5 (Fig. 6D). These trends amplify those seen from difference in percentage points of review recommendations (Fig. S6CD).

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), number of authors, proportion of authors that were women, and the genders of both gatekeepers and authors. This model predicted whether or not a manuscript was editorially rejected and had a median AUC of 0.68 indicating non-random interaction between these factors. Those factors with the greatest positive impacts (i.e., increased likelihood of editorial rejection) were US Inst Type Other, Sen Editor Men, Other US Inst Men, Med School & Institutes Women.

The factors with the greatest negative impacts (i.e., increased liklihood of going to review) were R1 Univ, US, Sen Editor Women, Num Authors. These results confirm that the country of origin and prestige bias impact decisions in a non-random manner, but gender-based factors were still at play.

Discussion

In this paper we described the representation of men and women at ASM journals between January 2012 and August 2018, and compared editorial outcomes according to the author gender. We found that women were consistently represented at 30% or less in all levels of the peer review process, excluding junior authors where women were X percent. Women and men editors had proportionate workloads accross all ASM journals combined, but those workloads were disproportionate at the journal level and the overburdened group varied according to the journal. Additionally, manuscripts submitted by corresponding authors that were women, recieved more negative outcomes (e.g., editorial rejections, reviewer recommendations, and decisions after review), than those submitted by men. These negative outcomes were somewhat mediated by whether or not the corresponding author was based in the US or not and by the institution for US-based authors. However, the trend for women corresponding authors to receive more negative outcomes held, indicating a pattern of gender-influenced editorial decisions.

While the proportion of women as first authors is equivalent to data obtained globally from self-reported at ASM, it was higher than the proportion of senior women authors at ASM journals. Additionally, half as many women than men who were junior authors at ASM journals were also senior authors and the representation of women decreased as the status (e.g., reviewer, editor) increased. These observations are consistent with for representation of senior women in academic biological sciences and the observation that women are more likely to leave academia during the transition from postdoc to investigator (Martinez, 2007). These data indicate that microbiology (as represented by ASM journals) is not exempt from the so-called “leaky pipeline”.

How to define representation and determine what the leadership should look like are recurring questions in STEM. We argue that if all things were considered equal than representation for men and women corresponding authors, reviewers, and editors would be at about 50% each. However, that is not (yet) the case, so we argue that the goal should depend 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 (i.e., 50% should be women if the goal were an aspirational leadership.). This allows expansion of the potential reviewer network and thus recruitment into those positions. Conversely, 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 (i.e., since 23.5% of corresponding authors to ASM journals are women, then 23-24% of reviewers should be women). Balancing the workload is particularly important given the literature indicating that women faculty have higher institutional service loads than their counterparts who are men.

In contrast to institutional service, the editing workload at ASM jounals seems to be predominantly borne by men, according to the proportion of representation. Possible explainations for the difference in gatekeeper representation and editor workloads could be that women are more likely to conduct research on the fringes of research fields. Their separation from the historical center of a field decreases their percieved competency, which could result in research typecasting and lower manuscript handling responsibilities. Other posibilities are that the increased service load decreases their ability to handle larger editorial loads or that since status as an editor is “prestigous”, the workload is prefferentially diverted to editors that are men. Any of these situations can be compounded by the increased proportion of potential reviewers that either do not accept, or do not respond to, requests to review from women editors. This increases the proportion of reviewers that women editors must contact, adding additional time and work to their editorial burdens. Three journals, *mBio*, CVI, and JVI are exceptions with regards to editorial workloads. At these journals, the editorial workloads of women exceeds their representation. A possible explaination for CVI and JVI is that both of these journals have been led by women EICs, who perhaps have increased confidence in their women editors. Alternately, the tendency for reviewers to reject requests to review from editors that are women extends to editors that are men rejecting requests to handle manuscripts from EiCs that are women. Our data differ from those of Fox, 2016(?) who found that the gender of the contacted reviewer depended on the gender of the editor, but supports findings X are less likely to respond to requests from editors that are women.

Our data also supports previous studies finding that women are more likely to collaborate with other women and that women are less likely to be on highly collaborative papers. In our linear regression models, the number of authors on a manuscript was the largest contributor to avoiding editorial rejections, suggesting that highly collaborative research is preferred by editors. It is, therefore, disturbing that when the number of authors exceed 30 on a manuscript, the proportion of women is always below 51%, despite equivalent numbers of trainees in the biological sciences (Fig. S4). Additionally, while women corresponding authors submit fewer papers, more of them, both numerically and proportionally, have more than 50% women authors, compared to those submitted by men corresponding authors. Previous research suggests that women who collaborate with other women recieve less credit for these publications than when they collaborate with men (Wiedman, 2019), and that women are more likely to yield corresponding authorship to collegues that are men (Fox). The gender-based segregation of collaborations at ASM journals has consequences in pay and promotion and could be a factor in the decreased retention of senior women at ASM journals.

The under representation of women as corresponding authors in publication at ASM journals has negative consequences for their careers and microbiology since it is their role as a senior author that impacts their status in the field. 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 under representation of women as senior authors and reviewers hampers their career progression and even their desire to progress since status in the peer review process also signals adoption of the researcher into the scientific community (Buckley et al, 2014). 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).

The support of academic research journals for women has been the topic of many papers, which note the lack of women authors relative to men. However, submissions data is required to determine if the lack of representatiion is due to low submissions or bias during peer review. We have shown that there is a disparity in submissions from senior women in microbiology compared to men, but this does not fully account for the difference in publications by men and women corresponding authors at ASM journals. There is also a consistent trend favoring positive outcomes for manuscripts submitted by corresponding authors that are men over women. Manuscripts submitted by corresponding authors who are women are editorially rejected at greater rates than those submitted by men, and gatekeepers of both genders favor revisions for manuscripts authored by men than by women. Neither geographic (e.g., US or not) nor prestige bias can fully account for the gender-based bias observed.

We do not have sufficient data to determine the specific nature of the implicit biases observed, but there are several possibilites. Curiously, while the median of manuscript versions before publication is identical for both men and women, manuscripts authored by women have increased rejection rates and time between submission and publication. This suggests that manuscripts submitted by women are given more revisions (i.e., work) from reviewers and/or their competency to complete revisions within the prescribed 30 days is doubted, compared to men. This observation fits with previous studies documenting that a greater burden of proof is required for women to achieve similar competency as men (Blair-Loy, 2017). Even if a gatekeeper doesn't personally know the corresponding author, women and men have adopted different writing styles that can act as cues to the author's gender. In particular, the increased requirements of competency for women leads to manuscripts with increased explanations and detail than those authored by men (Kolev, 2019; Erin). Finally, 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 due to the cumulative affects of bias (cites). 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 further decreasing percieved competency to those at the established center of the field in turn increasing the difficulty to obtain funding and publish in more traditional journals.

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 this many journals or on the field of microbiology. Critics might argue that the effect size is too small to really matter. However, the consistency of the trends to benefit men corresponding authors over women, across all journals included in this study and literature to-date confirms that this descriptive study is highly relevant for the ASM as a society. Our findings offer opportunities to address 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 (i.e., previously submitted) manuscripts, number of 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 personal 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.

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

Defining manuscript outcomes Many papers are immediately rejected by editors/EICs instead of being sent to peer review, often due to issues of scope or perceived quality. These were defined as editorial rejections and identified as manuscripts rejected without record of review.

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. If resubmitted, the authors are asked to note the previous (related) manuscript and the re-submission 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.

Institution classification To identify the communities represented, we used Carnegie classifications to group US-based institutions into R1, R2, low (not R1 or R2), and medical research. Research institutes, industry, and federal research groups were identified using the internet. Medical schools and institutions (e.g., Mayo clinic) were grouped together. Industry and federal research were grouped separately. The “Other” category represents uncategorized US institutions. Non-US institutions are a category on their own.

Manuscript outcome analysis and presentation In the field of microbiology, order of authorship on manuscripts signal the type and magnitude of contributions to the finished product with first and last authorship being the most prestigious. First authors are assumed to be trainees (e.g., students or post-docs) responsible for the bulk of the project, while last authors are lead investigators, supplying conceptual guidance and resources to complete the project. Middle authors are generally responsible for technical analyses and methods. Any author can also be a corresponding author, which can be defined as either the individual to whom questions are directed by readers or the individual responsible for communicating with publishing staff during peer review. We use the latter definition for our analysis.

To better visualize and understand the differences in outcomes according to author gender, we calculated the difference in percentage points between the proportion of that outcome for men and women. To correct for the disparity in the participation of women relative to men at ASM journals, all percentage point comparisons are made relative to the gender and population in question. For instance, 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.

Logistic regression models For the L2-regularized logistic regression models, we established modeling pipelines for a binary prediction task. First, we randomly split the data into training and test sets so that the training set consisted of 80% of the full data set while the test set was composed of the remaining 20% of the data. To maintain the distribution of the 2 model outcomes that was found with the full data set, we performed stratified splits. The training data was used to build the models and the test set was used for evaluating predictive performance. To build the models, we performed an internal five-fold cross-validation where we tuned the cost hyper-parameter, which determines the regularization strength where smaller values specify stronger regularization. This internal cross-validation was repeated 100 times. Then, we trained the full training data set with the selected hyper-parameter values and applied the model to the held-out data to evaluate the testing predictive performance of each model. The data-split, hyper-parameter selection, training and testing steps were repeated 100 times to get a reliable and robust reading of model performance. Models were trained using the machine learning wrapper caret package (v.6.0.81) in R (v.3.5.0).

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 data set. Predicted genders were assigned to individuals in the following order: first names and country, first names, middle names and country, middle names (Fig. S7). The presenting gender (man/woman) of editors and senior editors in our data set 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 (Broderick & Casadevall 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 data sets (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 data set 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 data set where country data were included (Table S1). 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 (Table S1, in bold).

To understand the extent of geographic bias in our gender assignment against regions and languages with gender-less 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 data set, the top five countries associated with names were United States, Germany, United Kingdom, France, China and the countries with the highest proportion of un-predicted genders when country data were supplied are Cambodia, Iceland, Indonesia, Ireland, 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 un-predicted 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 un-predicted names (Fig. S8). The top five countries with the greatest impact on un-predicted names, and thus the countries receiving the most negative bias from genderize were Canada, China, Ireland, Belgium, Sweden (Fig. S9). 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 data set and tested its validity on a small portion. All first names collected from our data set 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 data set, the presenting gender (man/woman) of editors and senior editors in our data set 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 data set, the five countries with the most individuals were United States, China, Japan, France, Germany and the countries with the highest proportion of un-predicted genders were Burundi, Chad, Kingman Reef, Korea (North), Democratic People's Republic of, Maldives, where the maximum number of names supplied ranged from 1 to 4. Proportionally, fewer names in our full data set were assigned gender than in our validation data set (40.01% un-predicted versus 27.14% un-predicted, 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 (Fig. S10). These data indicate what we previously predicted, that the genderize algorithm has bias against countries with gender-neutral naming conventions.

Code and data availability Anonymized data and code for all analysis steps, logistic regression pipeline, and an Rmarkdown version of this manuscript, is available at https://github.com/SchlossLab/Hagan_Gender_mBio_2019/

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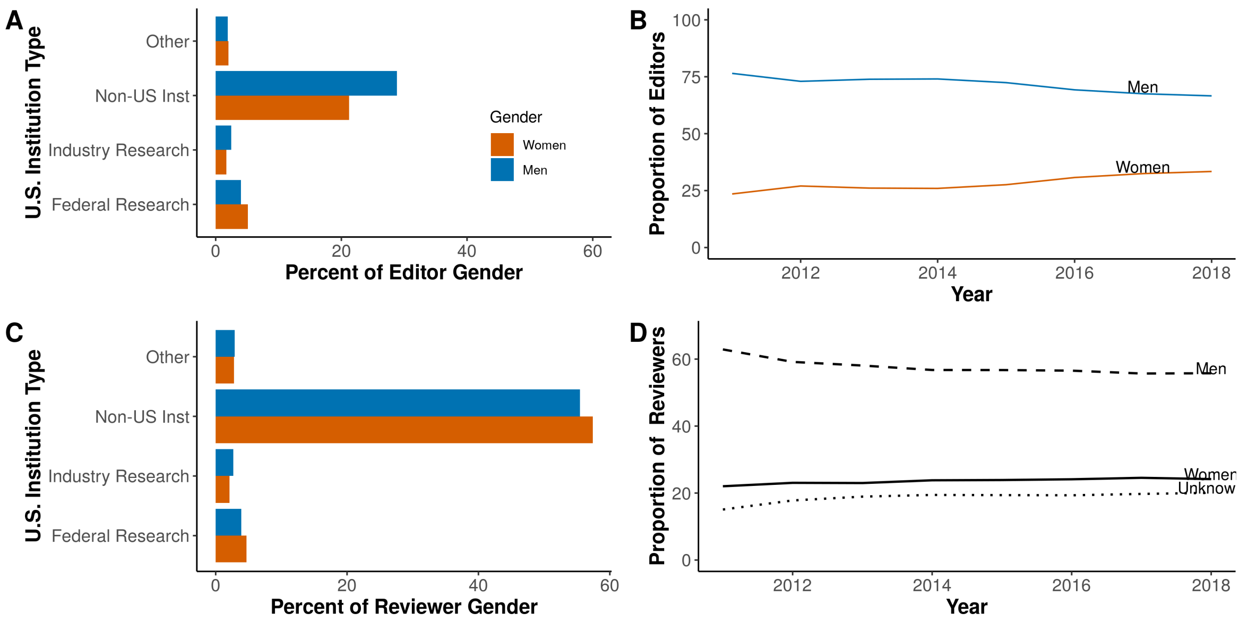


Figure 1. Gendered representation among gatekeepers. Proportion of editors from (A) institution types and (B) over time from 2012 to 2018. Editors and senior editors are pooled together. Proportion of reviewers from (C) institution types and (D) over time from 2012 to 2018. (A,C) Institutions within each gender add to 100%.(B,D) Each individual was counted once per calendar year, proportions of each gender add to 100% per year.

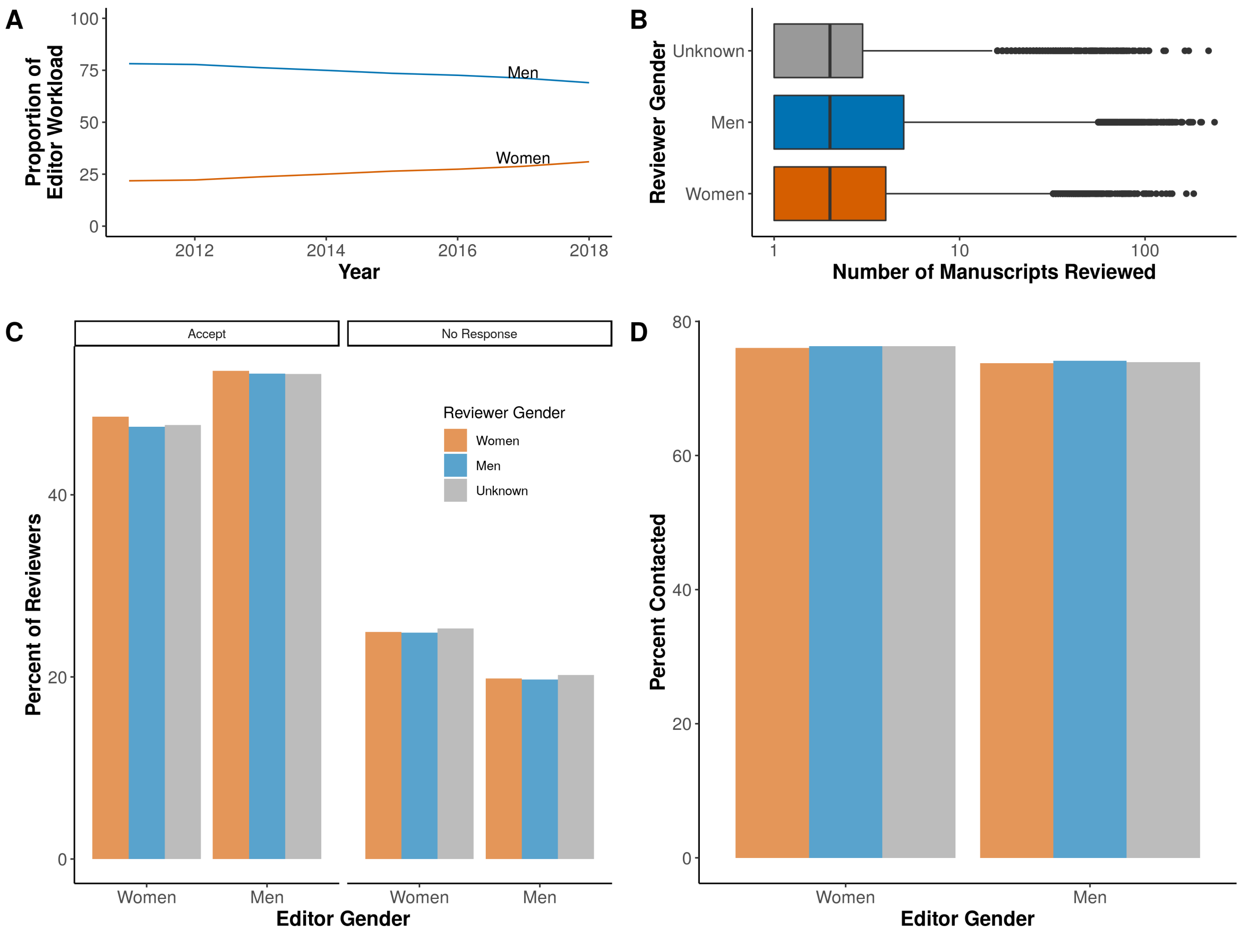


Figure 2. Gatekeeper workload and response to requests to review. (A) Proportion of manuscript workloads by men and women editors, editorial rejections excluded. (B) Box plot comparison of total manuscripts reviewed by each individual according to gender. (C) The percent of reviewers by gender that either accepted the opportunity to review or did not respond to a request to review, split according to the editor's gender. (D) Percent of each potential reviewer gender contacted to review, according to the editor's gender.

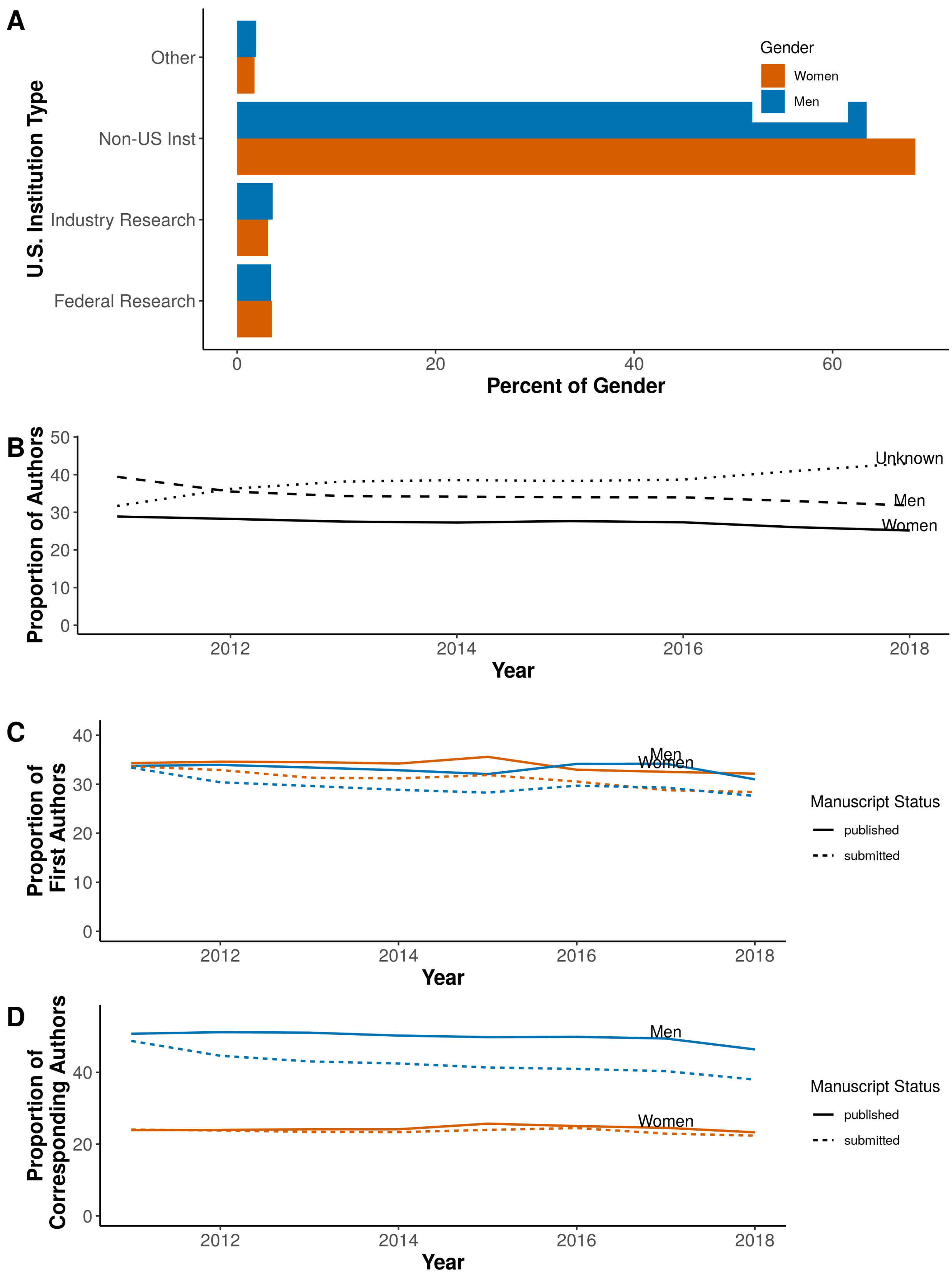


Figure 3. Author representation by gender. The proportion of (A) men and women authors from

each institution type, (B) men, women, and unknown authors from 2012 - 2018. Each individual counted once per calendar year. The proportion of (C) first authors and (D) corresponding authors from 2012 - 2018 on submitted (dashed) and published (solid) manuscripts.

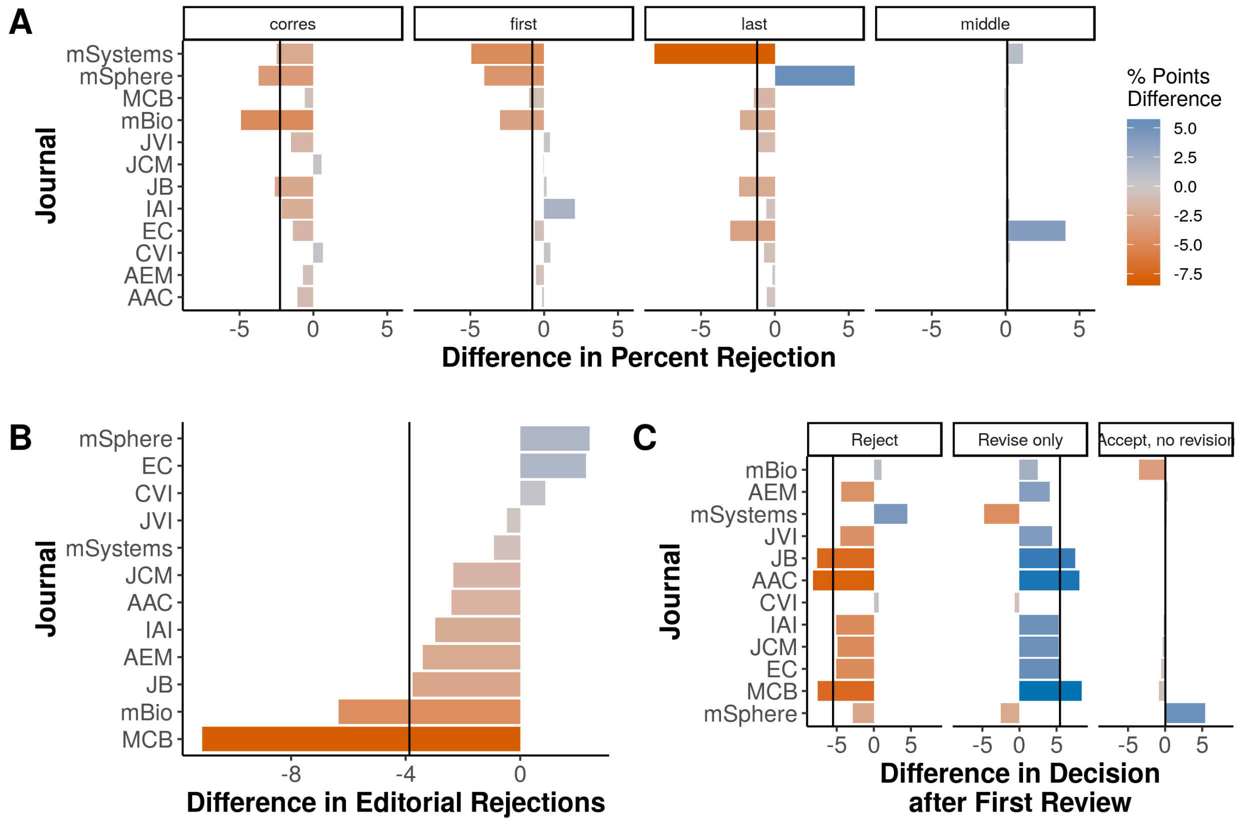


Figure 4. Difference in rejection rates by corresponding author gender. The percent of manuscripts rejected by author gender and type (e.g., corresponding, first, last, middle) at (A) all journals combined. (B) The difference in percent editorial rejection rates for corresponding authors at each journal, vertical line indicates the difference for all journals combined. (D) The difference in percentage points between each decision type for corresponding authors following the first peer review, vertical lines indicate the difference value for all journals combined. Absence of a bar indicates no difference in percentage points.

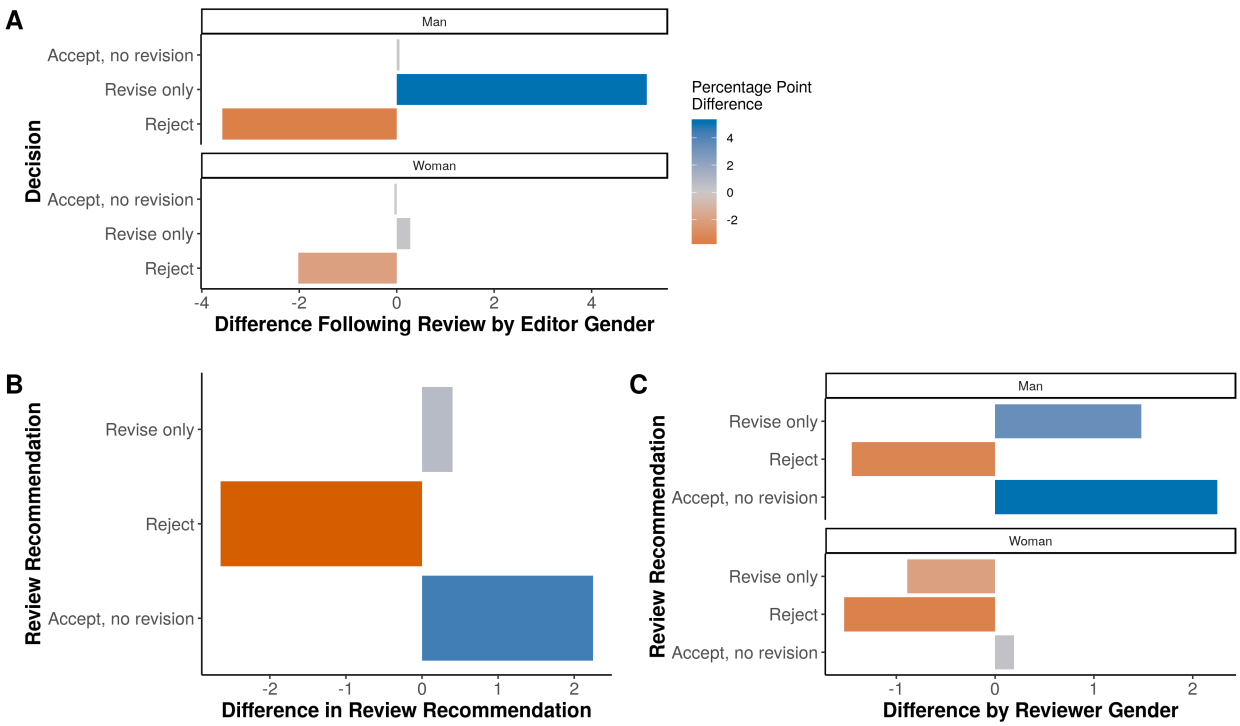


Figure 5. Difference in decisions or recomendations according to the gatekeeper gender. (A) Effect of editor gender on the difference in percentage points for decisions following review at all journals combined. (B) Difference in percentage points for review recommendations and (C) how that is affected by reviewer gender.

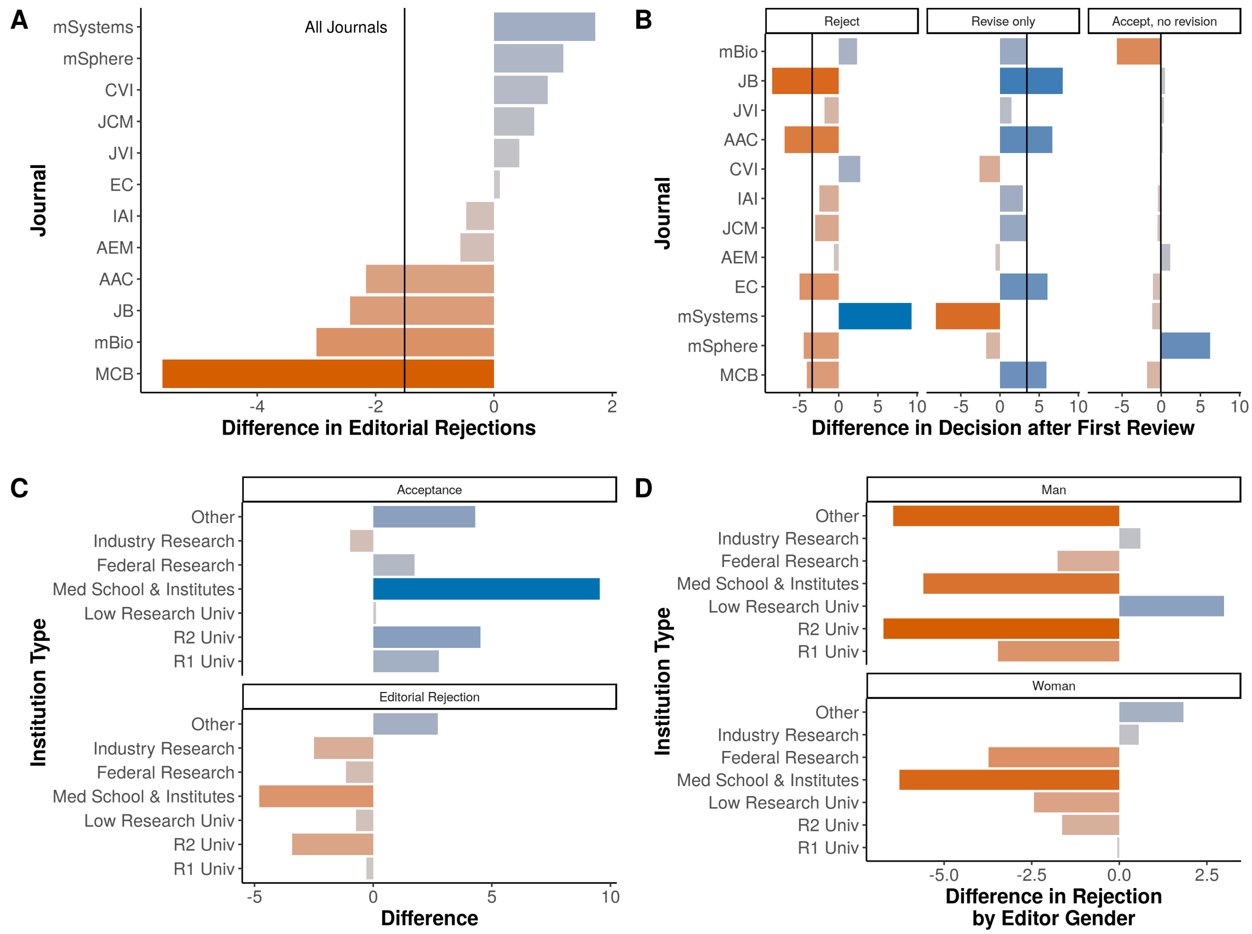


Figure 6. Impact of origin and U.S. institution type on manuscript decisions by gender. Difference in percentage points for (A) editorial rejections and (B) following first review of manuscripts submitted by US-based corresponding authors. Vertical line indicates value for all ASM journals combined. (C) Difference in percentage points for acceptance and editorial rejections according to institution types and (D) acceptance decisions by to editor gender and institution types.

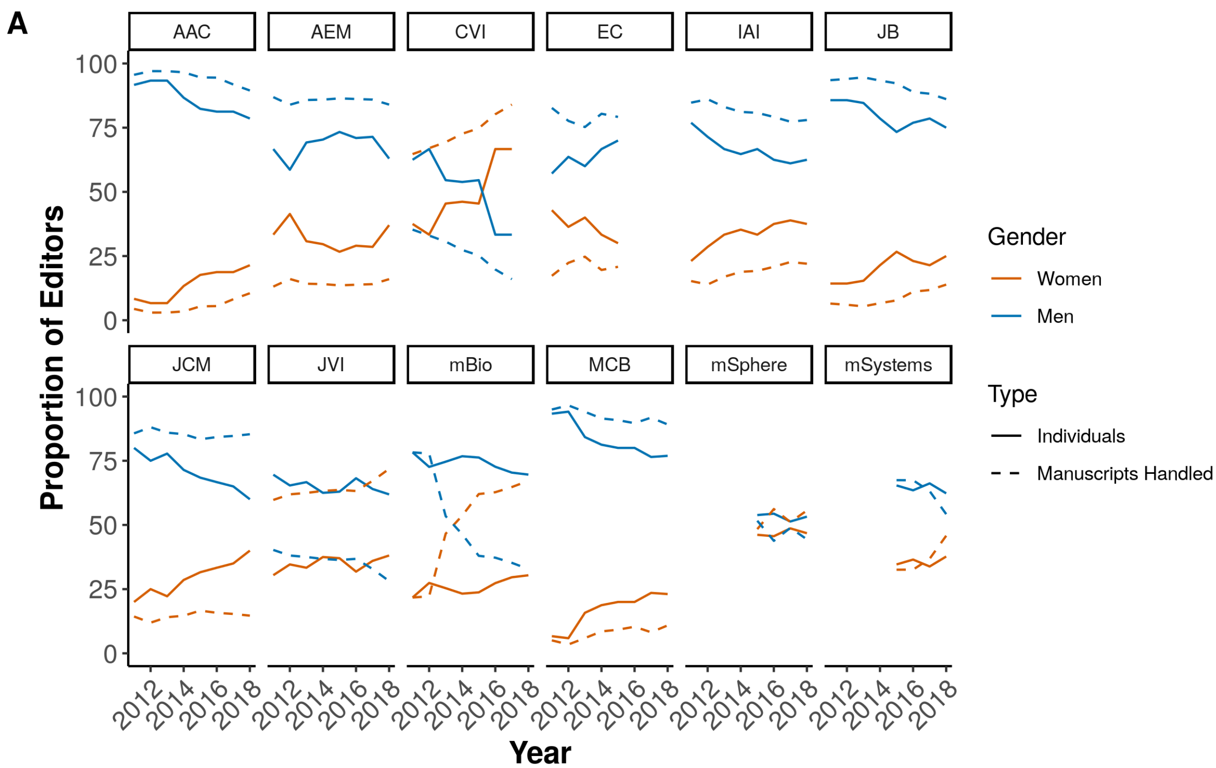


Figure S1. The proportion of editors (solid line) and their workloads (dashed line) at each ASM journal from 2012 to 2018.

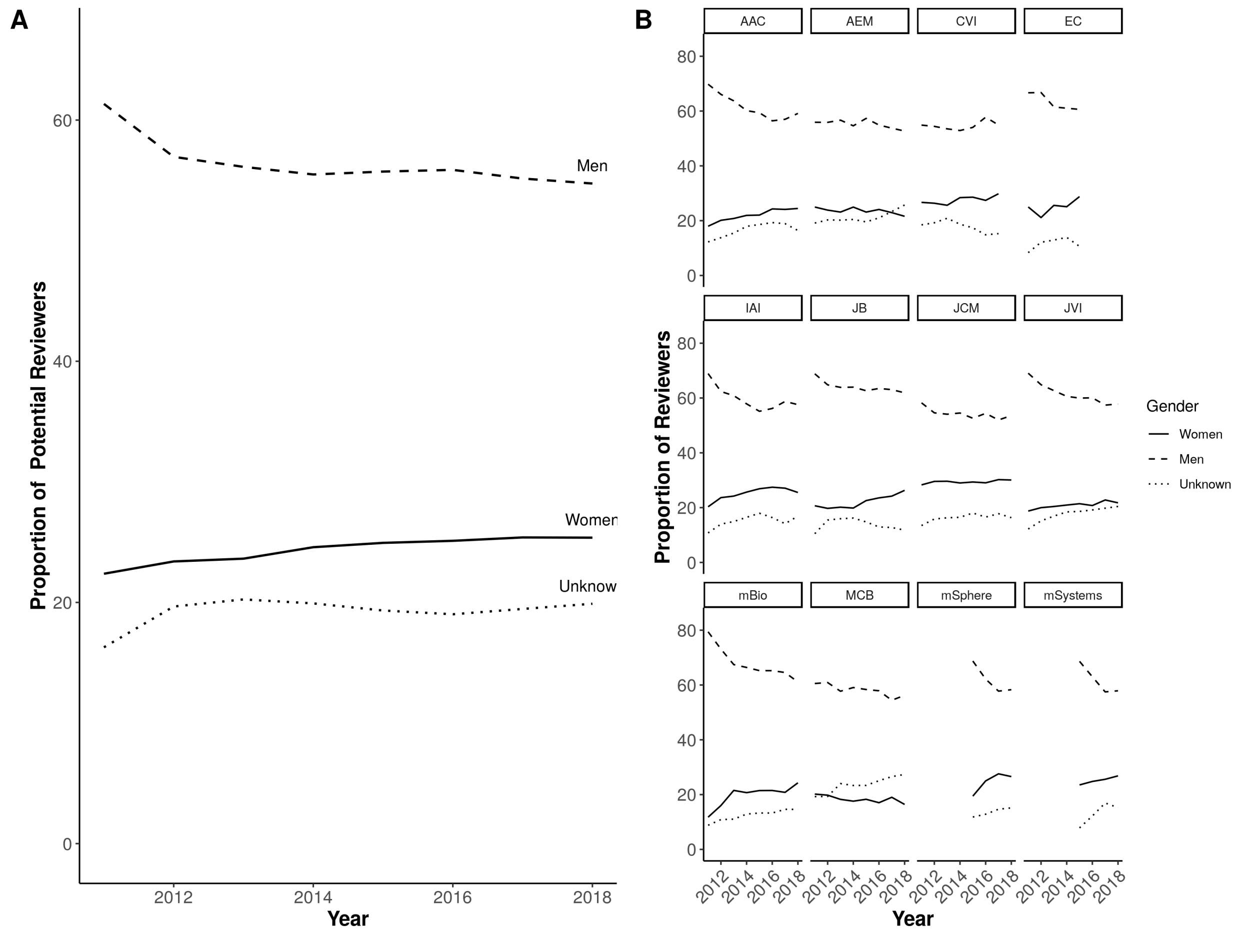


Figure S2. The proportion of (A) potential reviewers at all ASM journals combined, (B) reviewers at each ASM journal.

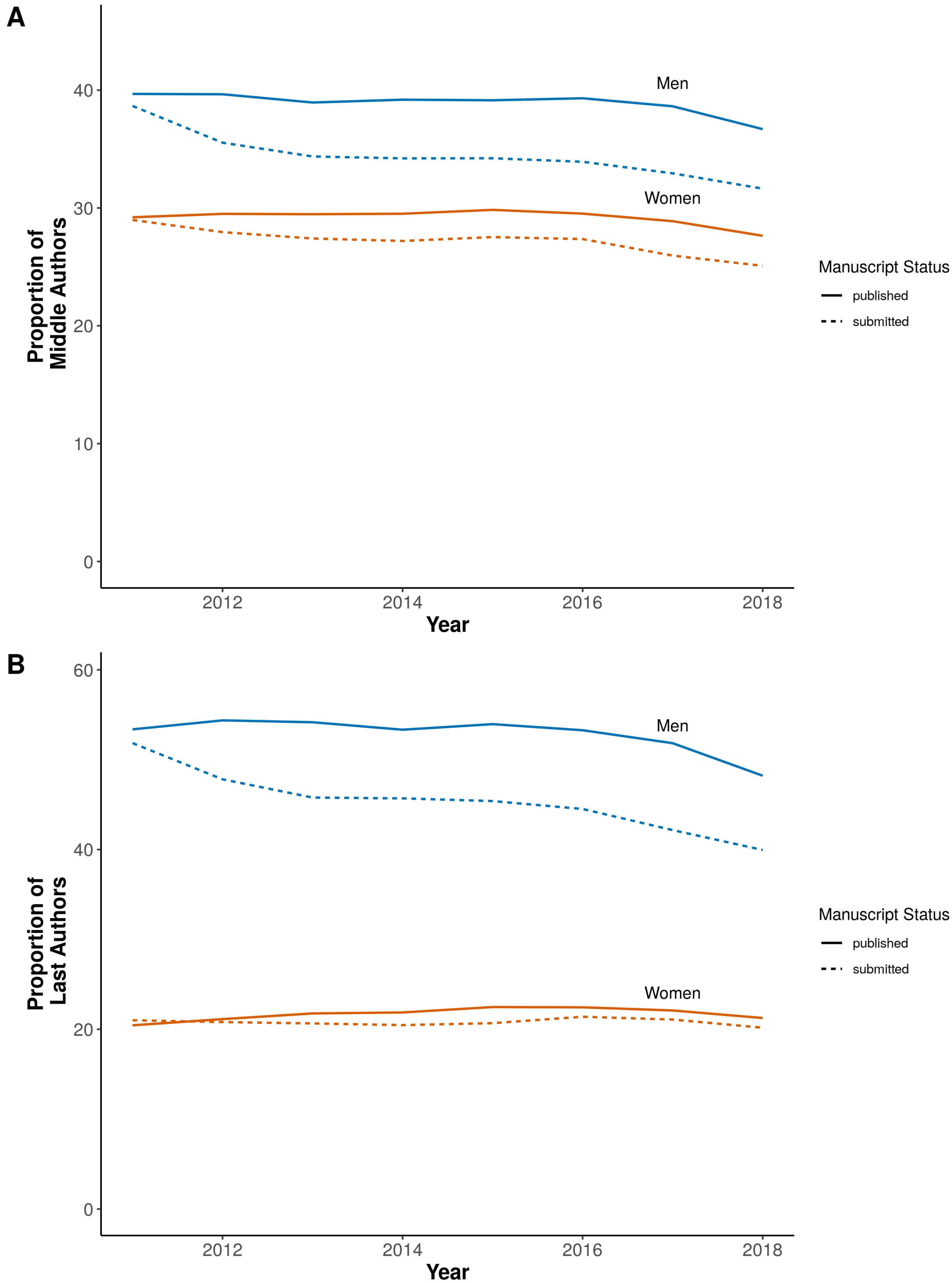


Figure S3. The proportion of all submitting (dashed line) and publishing (solid line) (A) middle and

(B) last authors by gender at each ASM journal.

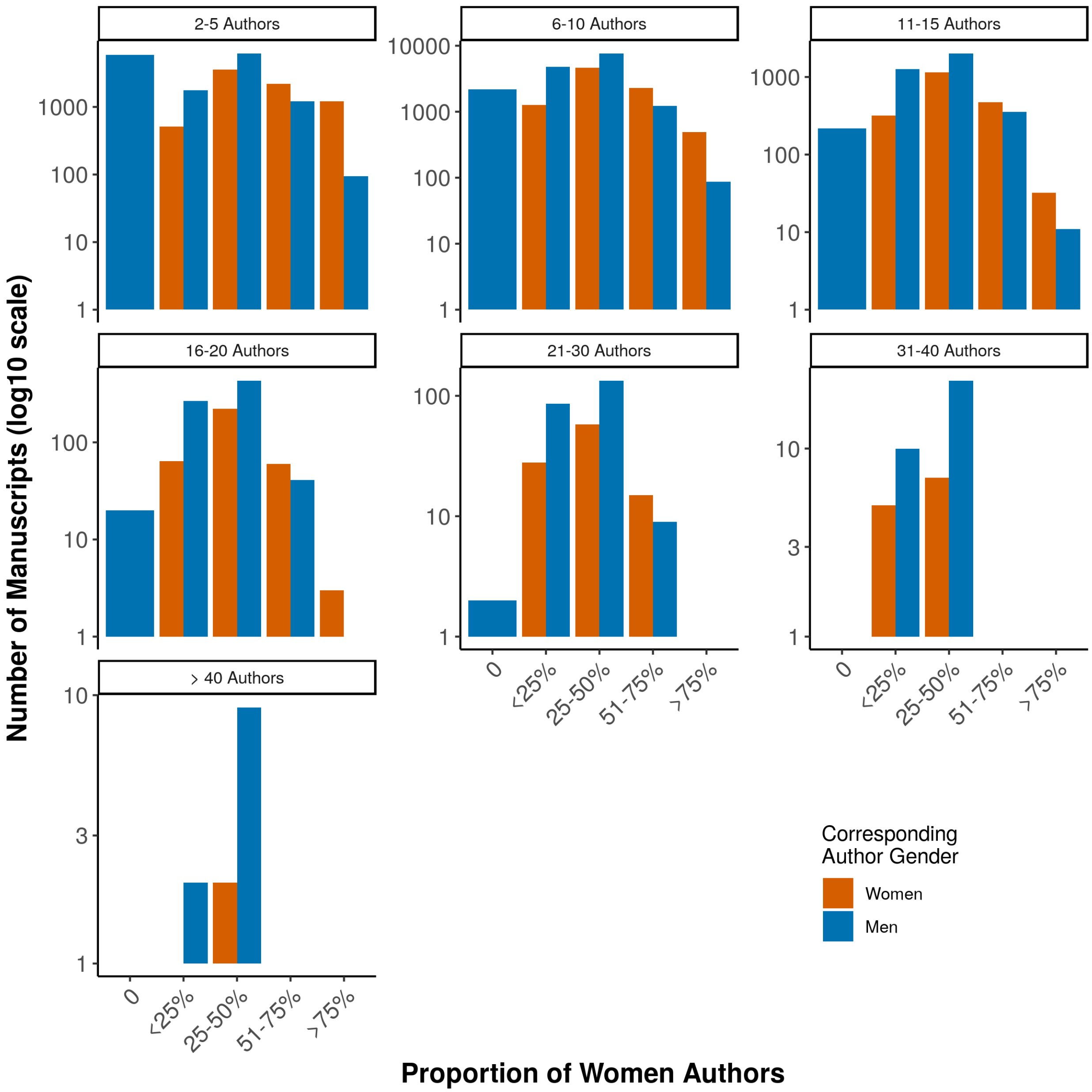
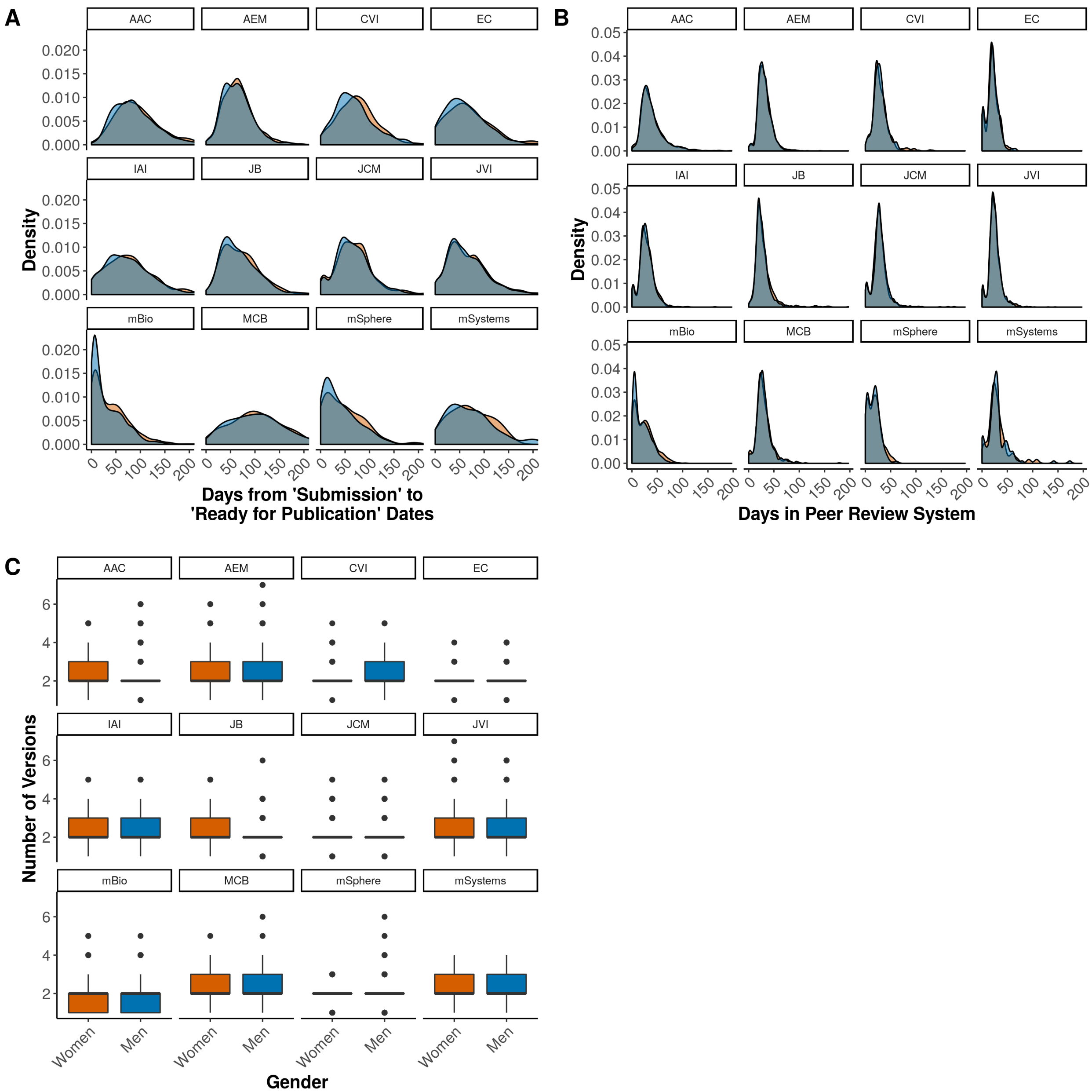


Figure S4. The proportion of women authors on submitted manuscripts according to the number of authors and the gender of the corresponding author.



578 Figure S5. Comparison of time to final decision and impact by gender. The number days (A)
579 between when a manuscript is initially submitted then finally published and (B) that a manuscript
580 spends in the ASM peer review system. How the impact of papers published by men (blue) versus
581 women (orange) vary according to (C) cites and (D) total reads. Citation data includes articles
582 published between 36 and 48 months prior to August 2018. Total reads includes both HTML and
583 PDF online views for articles published between 12 and 24 months prior to August 2018. Impact
584 data are divided by the number of months published.

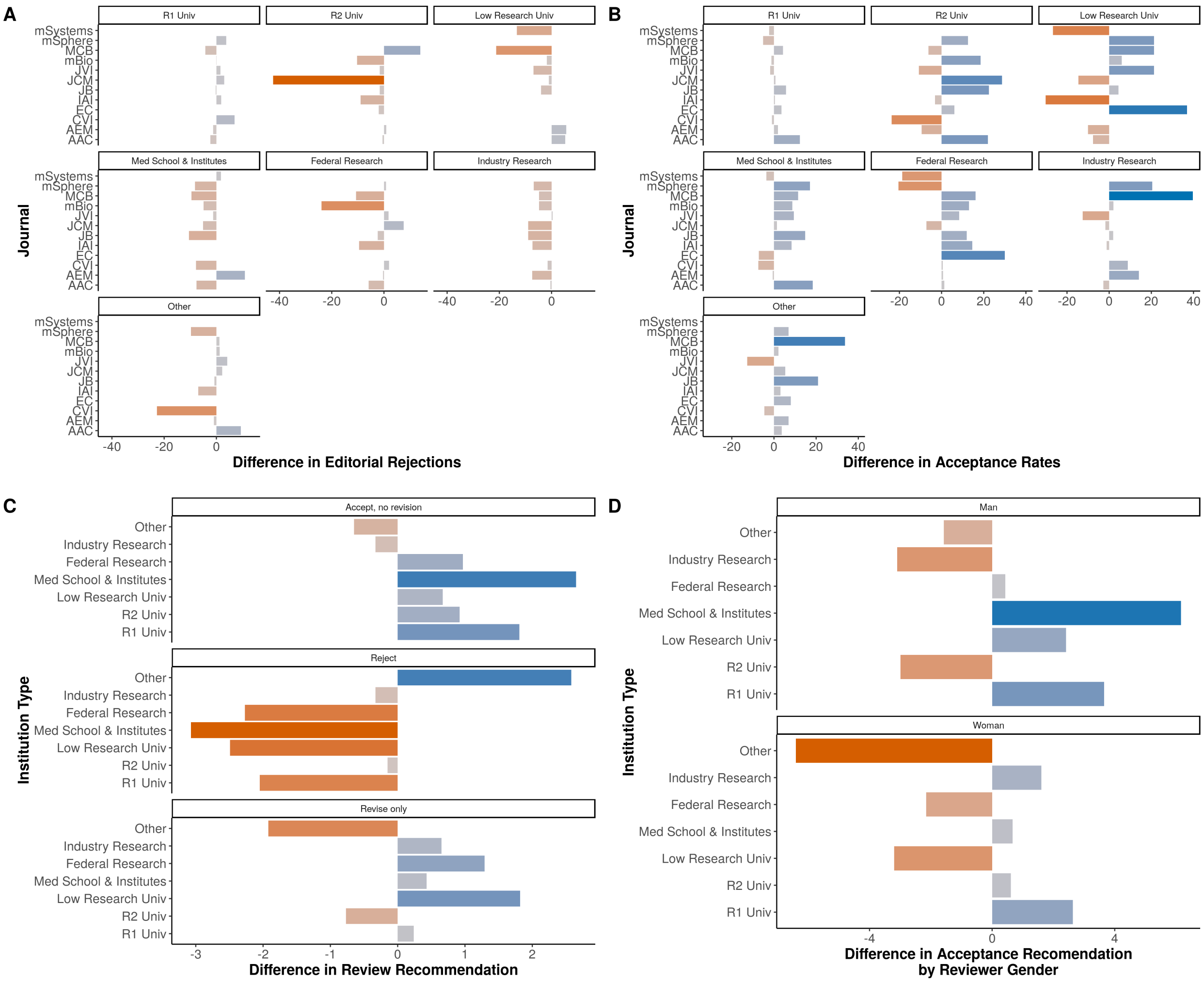


Figure S6. Difference in acceptance and rejections by institution type.

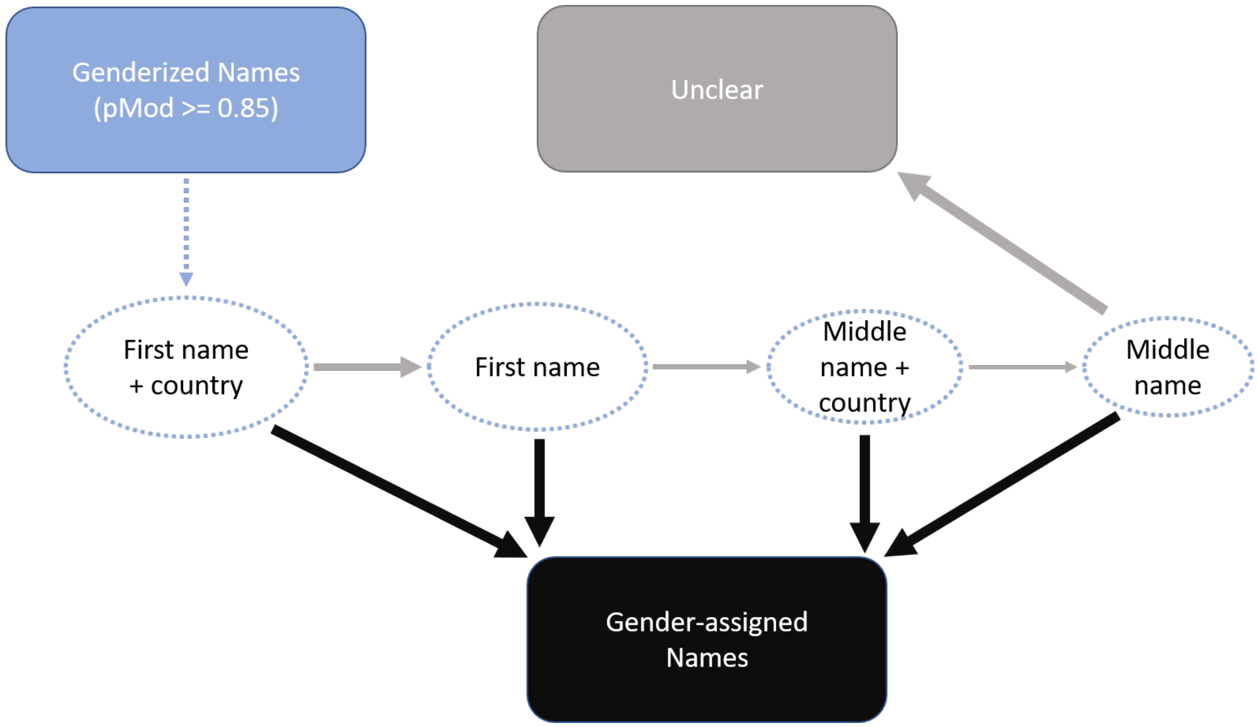


Figure S7. Schematic of gender prediction and assignment.

Table S1. sensitivity/specificity/accuracy of genderize thresholds. Bolded text denotes the accuracy of the threshold used in all further analyses.

	First Names			Plus Country Data		
Measure	p0.5	p0.85	pmod0.85	p0.5	p0.85	pmod0.85
Sensitivity	0.8943	0.9516	0.971	0.9055	0.9471	0.9669
Specificity	0.9339	0.9593	0.972	0.9265	0.9553	0.9727
Accuracy	0.9110	0.9549	**0.9714**	0.9146	0.9507	**0.9695**

$$\boldsymbol{Impact_C} = \left| \frac{(\%\ \boldsymbol{Unpredicted_C} - \%\ \boldsymbol{Unpredicted_{Total}})\ \boldsymbol{x}\ \left(\frac{\boldsymbol{Observations_C}}{\boldsymbol{Observations_{Total}}}\right)}{\%\ \boldsymbol{Unpredicted_{Total}}} \right|$$

Figure S8. Equation for calculating negative bias by genderize. C indicates an individual country.

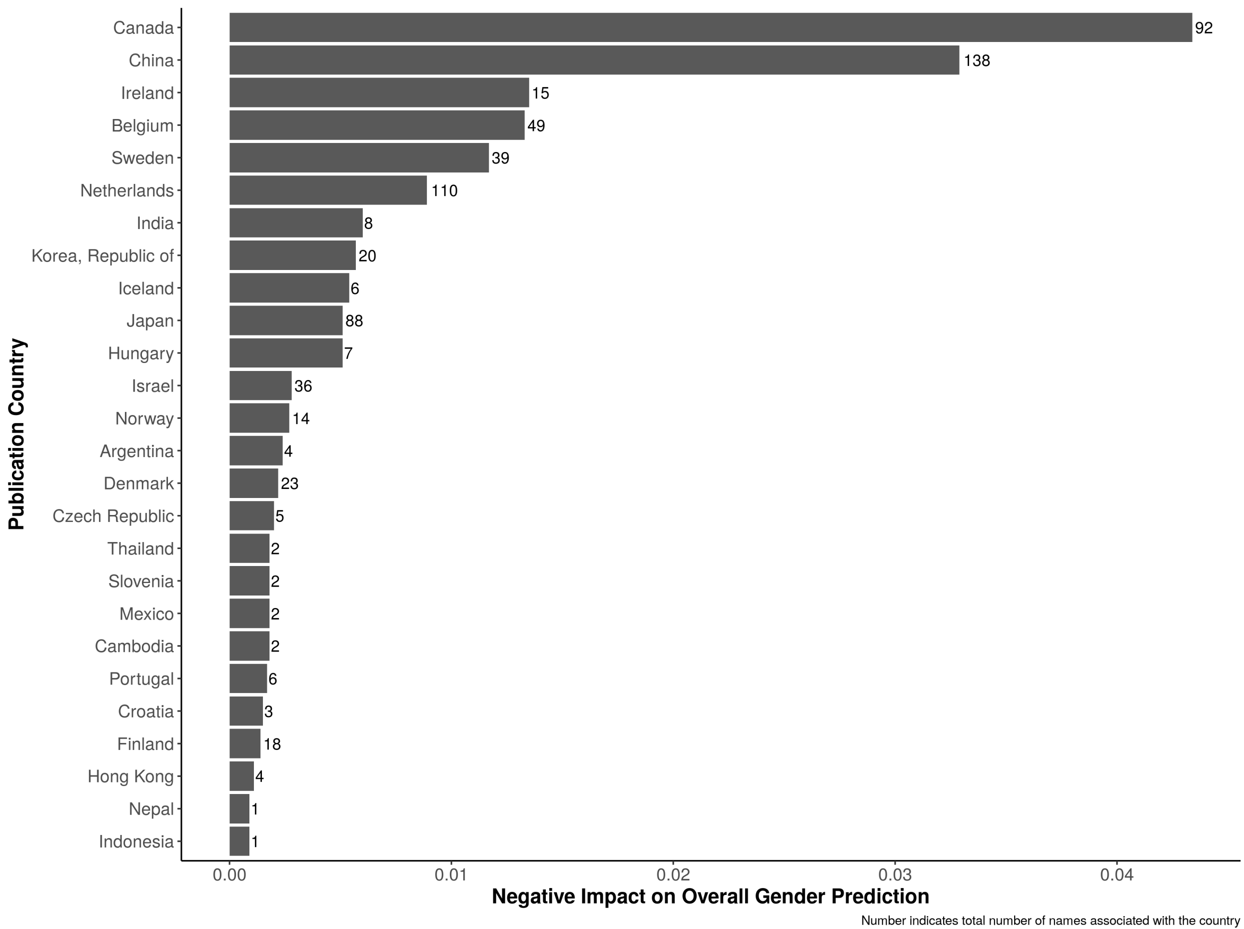


Figure S9. The negative impact of each country on the overall gender prediction of the validation dataset. Number indicates the total number of names associated with each country.

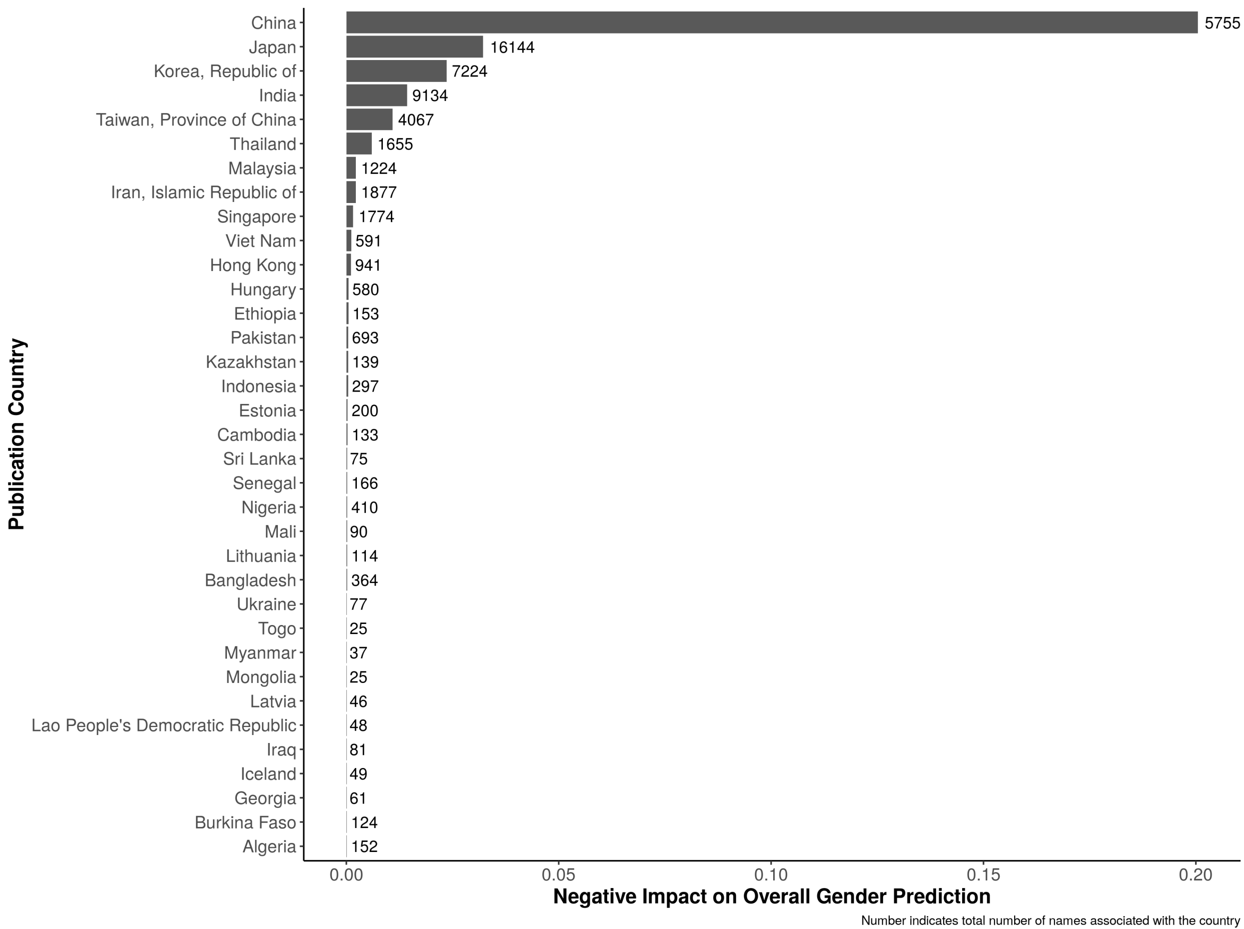


Figure S10. The negative impact of each country on the overall gender prediction of the full dataset. Number indicates the total number of names associated with each country.

References