

Who are ASM Journals? A Gender-based Analysis

Running title: A gender-based analysis of ASM journals

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1 Abstract

2 Despite 50% of biology Ph.D. graduates being women, the number of women that advance in
3 academia decreases at each level (e.g. from graduate to post-doctorate to tenure-track). Recently,
4 scientific societies and publishers have begun examining internal submissions data to evaluate
5 representation of, or bias against, women in their peer review processes; however, representation
6 and attitudes differ by scientific field and no studies to-date seem to have investigated academic
7 publishing in the field of microbiology. Using manuscripts submitted between January 2012 and
8 August 2018 to the 15 journals published by the American Society for Microbiology (ASM), we
9 describe the representation of women at ASM journals and the outcomes of their manuscripts.
10 Senior women authors at ASM journals were underrepresented compared to global and society
11 estimates of microbiology researchers. Additionally, manuscripts submitted by corresponding
12 authors that were women received more negative outcomes (e.g., editorial rejections, reviewer
13 recommendations, and decisions after review) than those submitted by men. These negative
14 outcomes were somewhat mediated by whether or not the corresponding author was based
15 in the US, and by the type of institution for US-based authors. Nonetheless, the pattern for
16 women corresponding authors to receive more negative outcomes on their submitted manuscripts
17 indicated a pattern of gender-influenced editorial decisions. We conclude with suggestions to
18 improve the representation of and decrease bias against women.

19 Importance

20 Barriers in science and academia have prevented women from becoming researchers and experts
21 that are viewed equivalent to their colleagues who are men. We evaluated the participation and
22 success of women researchers at ASM journals to better understand their success in the field of
23 microbiology. We found that women are underrepresented as expert scientists at ASM journals.
24 This is, in part, due to a combination of both low submissions from senior women authors and
25 increased rejection rates for women compared to men.

26 **Introduction**

27 Evidence has accumulated over the decades that academic research has a representation
28 problem. While at least 50% of biology Ph.D. graduates are women, the number of women
29 in postdoctoral positions and tenure-track positions are less than 40 and 30%, respectively
30 (1). There have been many proposed reasons for these disparities, which include biases in
31 training and hiring, the impact of children on career trajectories, a lack of support for primary
32 caregivers, a lack of recognition, lower perceived competency, and less productivity as measured
33 by research publications (1–7). These issues do not act independent of one another, instead they
34 accumulate for both individuals and the community, much as advantages do (8, 9). Accordingly,
35 addressing these issues necessitates multi-level approaches from all institutions and members of
36 the scientific community.

37 Scientific societies play an integral role in the formation and maintenance of scientific
38 communities. They host conferences that provide forums for knowledge exchange, networking,
39 and opportunities for increased visibility as a researcher. Scientific societies also frequently
40 publish the most reputable journals in their field, facilitating the peer review process to vet new
41 research submissions (10). Recently, scientific societies and publishers have begun examining
42 internal submissions data to evaluate representation of and bias against women in their peer
43 review processes. The American Geological Union found that while the acceptance rate of
44 women-authored publications was greater than publications authored by men, women submitted
45 fewer manuscripts than men and were used as reviewers only 20% of the time (11), a factor
46 influenced by the gender of the editor (12). Several studies have concluded that there is no
47 significant bias against papers authored by women (12–17). Recent reports of manuscript
48 outcomes at publishers for ecology and evolution, physics, and chemistry journals have found that
49 women-authored papers are less likely to have positive peer reviews and outcomes (18–21).

50 The representation of women scientists and gender attitudes differ by scientific field and no studies
51 to-date have investigated academic publishing in the field of microbiology. The American Society
52 for Microbiology (ASM) is one of the largest life science societies, with an average membership of
53 41,000 since 1990. In its mission statement, the ASM notes that it is “an inclusive organization,

54 engaging with and responding to the needs of its diverse constituencies” and pledges to “address
55 all members’ needs through development and assessment of programs and services.” One of
56 these services is the publication of microbiology research through a suite of research and review
57 journals. Between January 2012 and August 2018, ASM published 25,818 original research
58 papers across 15 different journals: *Antimicrobial Agents and Chemotherapy* (AAC), *Applied and*
59 *Environmental Microbiology* (AEM), *Clinical and Vaccine Immunology* (CVI), *Clinical Microbiology*
60 *Reviews* (CMR), *Eukaryotic Cell* (EC), *Infection and Immunity* (IAI), *Journal of Bacteriology*
61 (JB), *Journal of Clinical Microbiology* (JCM), *Journal of Virology* (JVI), *mBio*, *Microbiology and*
62 *Molecular Biology Reviews* (MMBR), *Genome Announcements* (GA, now *Microbiology Resource*
63 *Annoucements*), *Molecular and Cellular Biology* (MCB), *mSphere*, and *mSystems*. Two journals,
64 EC and CVI, were retired during the period under study and three journals, GA/MRA, MMBR, and
65 CMR, were excluded from the analysis due to their relatively low number of submissions. The goal
66 of our research study was to describe the population of ASM journals through the gender-based
67 representation of authors, reviewers, and editors and the associated peer review outcomes.

68 Results

69 Over 100,000 manuscript records were obtained for the period between January 2012 and August
70 2018 (Fig. 1). Each of these were evaluated by editors and/or reviewers, leading to multiple
71 possible outcomes. At ASM journals, manuscripts may be immediately rejected by editors instead
72 of being sent to peer review, often due to issues of scope or quality. These were defined as
73 editorial rejections and identified as manuscripts rejected without review. Alternately, editors
74 send a majority of manuscripts out for review by two or more experts in the field from a list
75 of potential reviewers suggested by the authors and/or editors. Reviewers give feedback to the
76 authors and editor, who decides whether the manuscript in question should be accepted, rejected,
77 or sent back for revision. Manuscripts with suggested revisions that are expected to take more
78 than 30 days to address are rejected, but generally encouraged to resubmit. If resubmitted,
79 the authors are asked to note the previous manuscript and the re-submission is assigned a
80 new manuscript number. Multiple related manuscripts were tracked together by generating a

81 unique grouped manuscript number based on the recorded related manuscript numbers. This
82 grouped manuscript number served dual purposes of tracking a single manuscript through multiple
83 rejections and avoiding duplicate counts of authors for a single manuscript. After eliminating
84 non-primary research manuscripts and linking records for resubmitted manuscripts, there were
85 79,189 unique manuscripts (Fig. 1).

86 We inferred genders of both peer review gatekeepers (e.g., editor-in-chief, editors, reviewers)
87 and authors on the manuscripts evaluated during this time period using a social media-informed
88 classification algorithm with stringent criteria and validation process (Supp Text). We recognize
89 that biological sex (male/female) is not always equivalent to the gender that an individual presents
90 as (man/woman), which is also distinct from the gender(s) that an individual may self-identify as.
91 For the purposes of this manuscript, we choose to focus on the presenting gender based on
92 first names (and appearance for editors), as this information is what reviewers and editors also
93 have available. Among the individuals inferred to be either men or women, the sensitivity and
94 specificity of our method were 0.97 when validated against a curated set of authors and editors
95 (Supp Text). In addition to identifying journal participants as men or women, this method of gender
96 inference resulted in a category of individuals whose gender could not be reliably inferred (i.e.,
97 unknown). We included those individuals whose names did not allow a high degree of confidence
98 for gender inference in the “unknown” category of our analysis, which is shown in many of the plots
99 depicting representation of the population. These individuals were not included in the comparison
100 of manuscript outcomes.

101 **Men dominated as gatekeepers and senior authors.** We first evaluated the representation
102 of men and women who were gatekeepers during the study period. Each journal is led by an
103 editor-in-chief (EIC) who manages journal scope and quality standards through a board of editors
104 with field expertise that, in turn, handle the peer review process. There were 17 EICs, 17.6% of
105 which were women. Four years before retirement, the EIC of CVI transferred from a man to a
106 woman, while JVI has had a woman as EIC since 2012. The total number of editors at all ASM
107 journals combined over the duration of our study (senior editors and editors pooled) was 1015,
108 28.8% of which were women.

109 Over 40% of both men and women editors were from US-based R1 institutions, defined as
110 doctoral-granting universities with very high research activity. Non-US institutions and U.S.
111 medical schools or research institutions supplied the next largest proportions of editors (Fig.
112 2A)(22). Since 2012, there was a slow trend toward equivalent gender representation among
113 editors (Fig. 2B). The trends for each journal varied considerably, though most had slow trends
114 toward parity (Fig. S1). CVI and *mSphere* were the only ASM journals to have accomplished
115 equivalent representation of both genders, with CVI having a greater proportion of women editors
116 than men before it was retired. EC was the only journal with an increasing parity gap.

117 Altogether, 30439 reviewers submitted reviews and 24.6% were inferred to be women. The
118 greatest proportion of reviewers (over 50% of all groups) came from non-US institutions, while
119 R1 institutions supplied the next largest cohort of reviewers (Fig. 2C). The proportions of each
120 gender were steady among reviewers at ASM journals (Fig. 2D) and representative of both the
121 suggested reviewers at all journals combined, and the actual reviewer proportions at most journals
122 (Fig. S2).

123 **Editorial workloads were not proportionate.** Across all journals combined, men handled
124 a slightly greater proportion of manuscripts than women, relative to their respective editorial
125 representations (Fig. 3A). This trend was present at most individual journals with varying degrees
126 of difference between workload and representation (Fig. S1). For instance, at *mSphere*, both
127 workload and proportions were identical; however, CVI, *mBio*, and JVI each had periods at which
128 the workload for women editors was much higher than their representation, with corresponding
129 decreases in the workload of men. In the years preceding its retirement, the representation of
130 women at CVI increased, decreasing the gap in editorial workload. However, representation
131 and relative workloads for men and women editors at JVI held steady over time, while the
132 proportionate workload for women at *mBio* has increased.

133 The median number of manuscripts reviewed by men, women, and unknown individuals was 2,
134 for each group. Half of those in the men, women, or unknown gender groups reviewed between
135 one and 5, 4, or 3 manuscripts each, respectively (Fig. 3B). Conversely, 44.6% of men, 40.1%
136 of women, and 48.6% of unknown gendered reviewers reviewed only one manuscript, suggesting

137 that women were more likely than other groups to review multiple manuscripts. Reviewers of all
138 genders accepted fewer requests to review from women editors (average of 47.8%) than from men
139 (average of 53.3%; Fig. 3C). Reviewers were also less likely to respond to women editors than men
140 (no response rate averages of 25.1 and 19.9%, respectively). Editors of both genders contacted
141 reviewers from all three gender groups in similar proportions, with women editors contacting 76.4%
142 of suggested reviewers and men contacting 74.1% (median of the percent contacted from each
143 gender group).

144 **Women were underrepresented as authors.** Globally, microbiology researchers are 60% men
145 and 40% women (23). In September 2018, 38.4% of ASM members who reported their gender
146 were women. We wanted to determine if these proportions were similar for authors at ASM
147 journals and to understand the distribution of each gender among submitted manuscripts and
148 published papers. We began by describing author institutions by gender. Over 60% of submitting
149 senior authors (last or corresponding) were from non-US institutions, followed by about 20% from
150 R1 institutions. The proportion of manuscripts submitted from US institutions by women was 31%
151 versus 36% from women at non-US institutions. Women were more highly represented at low
152 research universities and federal research institutions than at any other US-based institution (Fig.
153 4A). The proportions of all men and women authors at ASM decreased over time at equivalent
154 rates, as the proportion of unknown gendered authors increased; the ratio of men to women
155 authors was 4 to 3 (i.e., 57% men; Fig. 4B).

156 In the field of microbiology, order of authorship on manuscripts signals the type and magnitude
157 of contributions to the finished product. First and last authorships are the most prestigious.
158 First authors are generally trainees (e.g., students or post-docs) or early career researchers
159 responsible for performing the bulk of the project, while last authors are lead investigators that
160 supply conceptual guidance and resources to complete the project. Middle authors are generally
161 responsible for technical analyses and methods. Any author can also be a corresponding author,
162 which we identified as the individual responsible for communicating with publishing staff during
163 peer review (as opposed to an author to whom readers direct questions).

164 The proportion of manuscripts submitted with men and women as first authors remained constant

165 at 29.1 and 30.7%, respectively (Fig. 4C, dashed). The proportions of their published papers were
166 nearly identical at 33.1% for men and 33.8% for women. The proportion of submitted manuscripts
167 with men corresponding authors remained steady at an average of 41.6% and the proportion
168 with women corresponding authors was at 23.4% (Fig. 4D, dashed); the proportion for unknown
169 gendered authors declined. Both men and women corresponding authors had a greater proportion
170 of papers published than manuscripts submitted. Accordingly, manuscripts with corresponding
171 authors of unknown gender were rejected at a higher rate than their submission. The difference
172 between submitted manuscripts and published papers was 8.2% when men were corresponding
173 authors, but only 0.9% when women were corresponding authors. This trend was similar for middle
174 and last authors (Fig. S3).

175 Of 38594 multi-author manuscripts submitted by men corresponding authors, 23.5% had zero
176 women authors. In contrast, 7253 (36.3%) of manuscripts submitted by women corresponding
177 authors had a majority of the authors as women, exceeding those submitted by men corresponding
178 authors in both the number (3247) and percent (8.4) of submissions. Additionally, the proportion
179 of women authors decreased as the number of authors increased (Fig. S4). Men submitted 225
180 single-authored manuscripts while women submitted 69 single-authored manuscripts.

181 We hypothesized that we would be able to predict the inferred gender of the corresponding author.
182 We trained a logistic regression model to predict the inferred gender of the corresponding author
183 using the following variables: whether the corresponding author's institution was in the U.S., the
184 total number of authors, the proportion of authors that were women, whether the paper was
185 published, the gender of senior editors and editors, the number of revisions, and whether the
186 manuscript was editorially rejected at any point. We measured the model's performance using the
187 area under the receiver operating characteristic curve (AUROC). The AUROC value is a predictive
188 performance metric that ranges from 0.0, where the model's predictions are completely wrong,
189 to 1.0, where the model perfectly distinguishes between outcomes. A value of 0.5 indicates the
190 model did not perform better than random. The median AUROC value of our model to predict the
191 corresponding author's inferred gender was 0.7. The variable with the largest weight (i.e., the most
192 predictive value), in our model was the proportion of women authors. These results indicate that
193 manuscript submission data was capable of predicting the inferred gender of the corresponding

194 author, but that prediction was primarily driven by the percentage of authors that were inferred to
195 be women.

196 As described above, first authors were slightly more likely to be women (30.7%W vs 29.1%M), but
197 corresponding authors were significantly more likely to be men (23.44%W vs 41.59%M). A concern
198 is that if authors are not retained to transition from junior to senior status, they are also left out of
199 the gatekeeping roles. Since authorship conventions indicate that last and corresponding authors
200 are typically senior authors, we combined both first and middle authors into the “junior” author role
201 and tracked individuals through the possible roles at ASM journals. There were 75451 women
202 who participated as junior authors (first/middle) at ASM journals. Of those junior authors who
203 were women, 8.2% also participated as senior authors (last/corresponding), 8.9% were potential
204 reviewers and 5.4% participated as reviewers. 0.2% of women junior authors were also editors at
205 ASM journals. For men, there were a total of 83727 junior authors, where 13.6% also participated
206 as senior authors, 16.7% were potential reviewers, and 11.1% actually reviewed. 0.7% of men
207 junior authors were also editors at ASM journals. Overall, women were half as likely to move to
208 senior author or reviewer roles, and 30% as likely to be an editor than men.

209 **Manuscripts submitted by women have more negative outcomes than those submitted**
210 **by men.** To better understand the differences between published and submitted proportions
211 for men and women authors (Fig. 4CD, Fig. S3), we compared the rejection rates of men and
212 women at each author stage (first, middle, corresponding, and last). Middle authors were rejected
213 at equivalent rates for men and women (a 0 percentage point difference across all journals).
214 However, manuscripts with senior women authors were rejected more frequently than those
215 authored by men with -1.6 and -0.9 percentage point differences for corresponding and last
216 authors, respectively (Fig. 5A, vertical line). The overall trend of overperformance by men was
217 most pronounced at JB, *mSystems*, *mBio*, and *mSphere*. The greatest differences were observed
218 when comparing the outcome of corresponding authors by gender, so we used this sub-population
219 to further examine the difference in manuscript acceptance and rejection rates between men and
220 women.

221 We next compared the rejection rates for men and women corresponding authors after two review

points, initial review by the editor and the first round of peer review. Manuscripts authored by women were editorially rejected by as much as 12 percentage points more often than those authored by men (Fig. 5B). The difference at all ASM journals combined was -3.8 percentage points (vertical line). *MCB* and *mBio* had the most extreme percentage point differences. Manuscripts authored by men and women were equally likely to be accepted after the first round of review (Fig. 5C, right panel). However, women-authored papers were rejected (left panel) more often while men-authored papers were more often given revision (center panel) decisions. The differences for rejection and revision decisions after review were -5.6 and 5.6 percentage points, respectively (Fig. 5C, vertical lines). *JB*, *AAC*, and *MCB* had the most extreme differences for rejection and revision decisions. Percentage point differences were not correlated with journal prestige as measured by 2018 impact factors ($R^2 = -0.022$, $P = 0.787$).

In addition to manuscript decisions, other disparate outcomes may occur during the peer review process (24). To determine whether accepted women-authored manuscripts spent more time between being submitted and being 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. Manuscripts authored by women took slightly longer (from submission to ready for publication) than those by men at some journals (*mSphere*, *mBio*, *mSystems*, *CVI*, *JB*, *JCM*, *AEM*) despite spending similar amounts of time in the ASM journal peer review system (Fig. S5), and having the same median number of revisions prior to acceptance (Median = 2, IQR = 0).

To understand how a gatekeeper's (editor/reviewer) gender influenced decisions (e.g., Fig. 5C), we grouped editor decisions and reviewer suggestions according to the gatekeeper's gender. Both men and women editors rejected proportionally more women-authored papers, however the difference in decisions were slightly larger for men-edited manuscripts (Fig. 6A). Reviewers were more likely to suggest rejection for women-authored manuscripts as compared to men, although a minimal difference in revise recommendations was observed (Fig. 6B). Both men and women reviewers recommended rejection more often for women-authored manuscripts although men recommended acceptance and revision more often for men-authored manuscripts than women did (Fig. 6C).

251 To evaluate if gender played a role in manuscript editorial decisions, we trained a logistic
252 regression model to predict whether a manuscript was reviewed (i.e. editorially rejected or not).
253 We used the inferred genders of the senior editor, editor, and corresponding author, as well as
254 the proportion of authors that were women as variables to train the model. The median AUROC
255 value was 0.61, which indicated that editorial decisions were not random, however, the AUROC
256 value was relatively low indicating that there are factors other than those included in our model
257 that influence editorial decisions.

258 **Multiple factors contribute to the overperformance of men.** The association between gender
259 and manuscript decision could be attributed to gender bias by journal gatekeepers, however, there
260 are other types of bias that may contribute to, or obscure, overt gender bias; for instance, a recent
261 evaluation of peer-review outcomes at *eLife* found evidence of preference for research submitted
262 by authors from a gatekeeper's own country or region (18). Other studies have documented
263 prestige bias, where men are over-represented in more prestigious (i.e., more respected and
264 selective) programs (25). It is therefore possible, that what seems to be gender bias could be
265 geographic or prestige bias interacting with the increased proportion of women submitting from
266 outside the US or at lower prestige institutions (e.g., the highest rate of submissions from women
267 were at low research institutions, 37%; Fig. 4A).

268 To quantify how these factors affected manuscript decisions, we next looked at the outcome of
269 manuscripts submitted only by corresponding authors at US institutions, because these institutions
270 represented the majority of manuscripts and could be classified by the Carnegie Foundation (22).
271 When only considering US-based authors, the difference for editorial rejections increased from
272 -3.8 to -1.4 percentage points (Fig. 7A). The difference in decisions after review for US-based
273 authors mirrored those seen for all corresponding authors at the journal level (Fig. 7B). The
274 over-representation of women in rejection decisions increased from -5.6 to -4.4 percentage points,
275 and the over-representation of men in revise only decisions decreased from 5.6 to 4.2 (Fig. 7B).
276 The difference in the rate of accept decisions changed from -1.4 to 0.2 percentage points after
277 restricting the analysis to US-based authors. These results suggest that the country of origin
278 (i.e., US versus not) accounted for some of the observed gender bias, particularly for editorial
279 rejections.

280 To address institution-based prestige bias, we split the US-based corresponding authors
281 according to the type of institution they were affiliated with (based on Carnegie classification)
282 and re-evaluated the differences for men and women (22). Editorial rejections occurred most
283 often for women from medical schools or institutes, followed by those from R2 institutions: 32%
284 and 28% of manuscripts from each institution were submitted by women, respectively (Fig. 7C,
285 Fig. S6A). This difference in the editorial rejections of corresponding authors from medical
286 schools or institutes was spread across most ASM journals, while the editorial rejection of papers
287 submitted from women at R2 institutions was driven primarily by submissions to JCM. Evaluating
288 the difference in acceptance rates by institution and gender mirrored that of editorial rejections
289 for some journals, where submissions from men outperformed submissions from women. For
290 instance, manuscripts submitted by men from medical schools or institutes were accepted up to
291 20 percentage points more often than those submitted by women (Fig. S6B).

292 To evaluate if these factors affect manuscript decisions, we trained a logistic regression model
293 to predict whether a manuscript was editorially rejected, using the variables: origin (US vs non),
294 institution (US institution type), number of authors, proportion of authors that were women, and
295 the inferred genders of both gatekeepers and corresponding authors. The model had a median
296 AUROC value of 0.67, which indicated a non-random interaction between these factors and
297 editorial decisions. Manuscripts from authors at U.S. “other” institutions, men EICs, men that
298 were corresponding authors from “other” U.S. institutions, and women from medical schools and
299 institutes were more associated with editorial rejections (Fig. S6C). Conversely, manuscripts from
300 R1 institutions, authors from the U.S., EICs that were women, and the number of authors were
301 more likely to be associated with review (Fig. S6C). These results confirm that the country of
302 origin and class of institutions impact decisions in a non-random manner, though not as much as
303 gender.

304 A final factor we considered was whether the type of research pursued by men as opposed
305 to women may impact manuscript outcomes. Black women philosophers and physicists have
306 described the devaluation of non-traditional sub-disciplines in their fields (26–28). While
307 originally focused on bias against Black women—the intersection of two historically marginalized
308 identities—the concept that researchers in an established core field might be skeptical of less

309 established, or non-traditional, sub-field research likely applies elsewhere. A bias against
310 sub-fields in a gendered context has recently been observed in the biomedical sciences, where
311 NIH proposals focusing on women's reproductive health were the least likely to be funded (29).
312 To explore the phenomenon in ASM journals, we looked at the editorial rejection rates of all
313 manuscripts (regardless of origin or institution) for each research category at the five largest
314 ASM journals: AAC, AEM, IAI, JVI, and JCM. Together, these journals account for 47% of the
315 manuscripts analyzed in this study across 55 categories.

316 The number of submissions in each category ranged from 1 ("FDA Approval" at AAC) to 2952
317 ("Bacteriology" at JCM) while the acceptance rates varied from 29.4% ("Chemistry:Biosynthesis"
318 at AAC) to 71.3% ("Structure and Assembly" at JVI) (Table 1). We argued that the number of
319 submissions to each category could help indicate core versus periphery subfields, (i.e., core
320 subfields would have more submissions than periphery subfields) and based on the literature
321 to-date, we expected that periphery subfields might have a higher participation of women. Women
322 submitted on average 35.3% of the manuscripts to each category, ranging from 20% to 86%
323 (Table 1). There was not a correlation between the proportion of women authors and the number
324 of submissions ($R^2 = -0.0177$, $P = 0.779$) to each category. Nor was there a correlation between
325 the proportion of women authors and the category acceptance rate ($R^2 = 0.041$, $P = 0.078$). These
326 data suggest that there was not a relationship between the participation of women and either the
327 number of submissions or the acceptance rate of categories in our dataset.

328 We next looked at the differences of performance for men and women in each category at two
329 decision points: editorial rejection and rejection after the first review. Each journal focuses on
330 a different facet of microbiology or immunology, making the results difficult to compare directly.
331 However, the pattern of increased rejection rates for women over men was maintained across
332 most categories with some categories displaying major differences in gendered performance (Fig.
333 S7). For instance, the "Biologic Response Modifier" (e.g., immunotherapy) sub-category at AAC,
334 had extreme differences for both editorial rejections and rejections after review, about -30 and -40
335 percentage points, respectively. While that category had a relatively low number of submissions
336 ($N = 44$), 43% were from women (Fig. S7A). One category, "Mycology", was represented at two
337 journals, AEM and JCM. At both journals, men overperformed relative to women in this category.

338 At AEM, there were 73 “Mycology” submissions, 44% from women authors that had a difference
339 of almost -20 for editorial rejection outcomes and -10 for rejections after review (Fig. S7B). JCM
340 had 587 “Mycology” submissions with a submission rate of 39% from women authors (Fig. S7D).
341 Differences between outcomes were almost -10 for editorial rejections and -12 for rejections after
342 review at JCM.

343 Because of these extreme percentage point differences in categories with high women
344 authorship, we next asked if the number of women participating in a particular category was
345 related to manuscript outcomes. There was no correlation between the difference in editorial
346 rejection by category and the percent of women that were either authors ($R^2 = -0.003$, $P = 0.363$)
347 or editors ($R^2 = -0.018$, $P = 0.765$). The percent of women authors and percent of women editors
348 in journal categories did not correlate either ($R^2 = -0.007$, $P = 0.682$), which is likely related
349 to the underrepresentation of women editors in categories dominated by women authors (e.g.,
350 “Epidemiology”). These data suggest the possibility of persistent (e.g., by editors and reviewers)
351 bias against women in particular fields (e.g., “Mycology”), though it does not seem to relate to
352 either the number of submissions or participation of women in those subfields.

353 Discussion

354 We described the representation of men and women at ASM journals between January 2012 and
355 August 2018 and compared editorial outcomes according to the authors’ gender. Women were
356 consistently under-represented (30% or less in all levels of the peer review process) excluding first
357 authors, where women represented about 50% of authors where we could infer a gender (Figs. 2
358 and 4). Women and men editors had proportionate workloads across all ASM journals combined,
359 but those workloads were disproportionate at the journal level and the overburdened gender varied
360 according to the journal (Figs. 3 and S1). Additionally, manuscripts submitted by corresponding
361 authors that were women received more negative outcomes (e.g., editorial rejections) than those
362 submitted by men (Figs. 5 and 6). These negative outcomes were somewhat mediated by whether
363 the corresponding author was based in the US, the type of institution for US-based authors, and
364 the research category (Figs. 7 and S7). However, the trend for women corresponding authors to

365 receive more negative outcomes held, indicating a pattern of gender-influenced editorial decisions
366 regardless of journal prestige (as determined by impact factor). Together, these data indicate a
367 persistent bias against senior women microbiologists who participate in ASM journals.

368 The proportion of women as first authors is higher than data obtained globally and from
369 self-reported ASM membership data, which was higher than the proportion of senior women
370 authors at ASM journals. Only half as many women who were junior authors at ASM journals
371 were also senior authors when compared to men, and the representation of women decreased as
372 the prestige (e.g., reviewer, editor) increased. These trends are consistent with representation of
373 senior women in academic biological sciences and the observation that women are more likely
374 to leave academia during the transition from postdoc (junior) to investigator (senior) (30). These
375 data indicate that microbiology (as represented by ASM journals) is not exempt from the issues
376 that limit the retention of women through academic ranks.

377 How to define representation and determine what the leadership should look like are recurring
378 questions in STEM. Ideally, the representation for men and women corresponding authors,
379 reviewers, and editors would reflect the number of Ph.D.s awarded (about 50% each, when
380 considered on a binary spectrum). We argue that the goal should depend on the workload and
381 visibility of the position. Since high visibility positions (e.g., editor, EIC) are filled by a smaller
382 number of individuals that are responsible for recruiting more individuals into leadership, filling
383 these positions should be done aspirationally (i.e., 50% should be women if the goal were an
384 aspirational leadership). This allows greater visibility for women as experts, expansion of the
385 potential reviewer network, and recruitment into those positions (31–33). Conversely, lower
386 visibility positions (e.g., reviewers) require effort from a greater number of individuals and should
387 thus be representational of the field to avoid overburdening the minority population (i.e., since
388 23.5% of corresponding authors to ASM journals are women, then 20–25% of reviewers should
389 be women). Balancing the workload is particularly important given the literature indicating that
390 women faculty have higher institutional service loads than their counterparts who are men (34).

391 In contrast to institutional service, the editing workload at ASM journals seems to be predominantly
392 borne by men. A possible explanation for the difference in gatekeeper representation and editor

393 workloads is that women are more likely to study non-traditional sub-disciplines (26–28). Their
394 separation from the traditional center of a field decreases their perceived competency, which
395 could result in research typecasting and lower manuscript handling responsibilities. However,
396 our data could not confirm this phenomenon at ASM journals. Another possibility is the increased
397 proportion of potential reviewers that either did not accept, or did not respond to, requests to review
398 from women editors. This increases the proportion of reviewers that women editors must contact,
399 adding additional time and work to their editorial burdens, thus making them seem less efficient
400 (i.e., less capable) than men editors. Three journals, *mBio*, CVI, and JVI were exceptions with
401 regards to editorial workloads. At these journals, the editorial workloads of women exceeds their
402 representation. A possible explanation for CVI and JVI is that both of these journals have been
403 led by women EICs. The tendency for reviewers to reject requests to review from editors that are
404 women, may also extend to editors that are men; this could result in men editors being more likely
405 to reject requests to handle manuscripts from EICs that are women. Our data differ from those
406 of Fox, Burns, and Meyer who found that the gender of the editor influenced the gender of the
407 contacted reviewers (12), but supports findings that women editors contact more reviewers than
408 men (35).

409 Our data also revealed some disturbing patterns in gendered authorship that have implications for
410 the retention of women microbiologists. Previous research suggests that women who collaborate
411 with other women receive less credit for these publications than when they collaborate with men
412 (36), and that women are more likely to yield corresponding authorship to colleagues that are
413 men (19). In our linear regression models, the number of authors on a manuscript was the
414 largest contributor to avoiding editorial rejections, suggesting that highly collaborative research
415 is preferred by editors (37). This observation was supported by the positive correlation between
416 citations and author count (Fig. S6). It was concerning that when the number of authors exceeded
417 30 on a manuscript (N=59), the proportion of individuals inferred to be women was always below
418 51%, despite equivalent numbers of trainees in the biological sciences (Fig. S4). Additionally,
419 while women corresponding authors submitted fewer manuscripts, more of them (both numerically
420 and proportionally), had a majority of women co-authors, compared to those submitted by men
421 corresponding authors, which supports previous findings that women are more likely to collaborate

422 with other women (21, 38–40). This gender-based segregation of collaborations at ASM journals
423 likely has had consequences in pay and promotion for women and could be a factor in the
424 decreased retention of senior women. It would likely be aggravated by the under representation of
425 women as corresponding authors, which may also have negative consequences for their careers
426 and microbiology, since senior authorships impact status in the field. Buckley et al., suggested
427 that being selected as a reviewer increases the visibility of a researcher, which has a direct
428 and significant impact on salary (16). Therefore, the under representation of women as senior
429 authors and reviewers likely hampers their career progression and even their desire to progress,
430 since status in the peer review process also signals adoption of the researcher into the scientific
431 community (16, 41). The retention of women is important to the progress of microbiology since less
432 diversity in science limits the diversity of perspectives and approaches, thus stunting the search
433 for knowledge.

434 Whether academic research journals support women has been the topic of many papers, which
435 note the lack of women authors publishing relative to men in high impact journals (42–48).
436 However, submissions data is required to determine if the lack of representation is due to low
437 submissions or bias during peer review. Using such data, we have shown that there is a disparity
438 in submissions from senior women in microbiology compared to men, but this does not fully
439 account for the difference in publications by men and women corresponding authors at ASM
440 journals (Fig. 4). When examining manuscript outcomes, we found a consistent trend favoring
441 positive outcomes for manuscripts submitted by corresponding authors that were men (Fig. 5).
442 Manuscripts submitted by corresponding authors who were women were editorially rejected at
443 greater rates and gatekeepers of both genders favored rejection for manuscripts authored by
444 women. Neither geographic (i.e., US or not), institution type, nor sub-discipline could fully account
445 for the observed gender-based bias (Fig. 6, Fig. 7, Fig. S6, Fig. S7). Instead, the presence
446 of bias favoring men over women from U.S. R1 institutions and medical schools and institutes
447 suggests that the bias persists, even in environments with generally excellent resources and
448 infrastructure for research. Science and the peer review system select for decisions that are often
449 based on the assumption that scientists are objective, impartial experts. As a result, scientists
450 who believe themselves immune to bias are making decisions that inherently rely on biases

451 to speed the process. The types of biases at play and their potential roles in peer review are
452 well documented (49, 50). For instance, previous studies show that a greater burden of proof
453 is required for women to achieve similar competency as men and that women are less likely to
454 self-promote (and are penalized if they do) (6, 51, 52). These and similar biases might train
455 women to be more conservative in their manuscript submissions, making our observed bias even
456 more concerning.

457 Even if a gatekeeper does not know the corresponding author or their gender, there remain ample
458 avenues for implicit bias during peer review. The stricter standard of competency has led women
459 to adopt different writing styles from men, resulting in manuscripts with increased explanations,
460 detail, and readability than those authored by men (24, 53). These differences in writing can act
461 as subtle cues to the author's gender. Additionally, significant time, funds, and staff are required to
462 be competitive in highly active fields, but women are often at a disadvantage for these resources
463 due to the cumulative affects of bias (8, 9). As a result, corresponding authors that are women may
464 be spending their resources in research fields where competition impacts are mitigated and/or on
465 topics that are historically understudied. This has the disadvantage of further decreasing perceived
466 competency of these women scientists compared to those studying core research field(s) (26–28).
467 Alternatively, non-traditional research may be seen as less impactful, leading to poorer peer review
468 outcomes (29). These possibilities are reflected in our data, since while the number of revisions
469 before publication is identical for both men and women, manuscripts authored by women have
470 increased rejection rates and time spent on revision. This suggests that manuscripts submitted
471 by women receive more involved critiques (i.e., work) from reviewers and/or their competency to
472 complete revisions within the prescribed 30 days is doubted, compared to men. Women may
473 also feel that they need to do more to meet reviewer expectations, thus leading to longer periods
474 between a decision and resubmission. Finally, our data show a penalty for women researching
475 mycology (Fig. S7). Despite being among the most deadly communicable diseases in 2016 (along
476 with tuberculosis and diarrheal diseases), mycology is an underserved, and underfunded, field
477 in microbiology that has historically been considered unimportant (54–56). Microbiology would
478 benefit from a more nuanced evaluation of sub-fields to better understand how they interact with
479 gender and peer review outcomes.

480 A limitation to our methodology is the use of an algorithm to infer gender from first names. This
481 method left us with a category of unknown gendered individuals and the gender of an individual
482 may be interpreted differently according to the reader (e.g., Kim is predominately a woman's name
483 in the U.S., but likely a man's name in other cultures). The increase in unknown gendered authors
484 corresponds to an increase in submissions to ASM journals from Asian countries, particularly
485 China. Anecdotally, most editorial rejections are poor quality papers from Asia. Our method had
486 low performance on non-gendered languages from this region (Supp Text) resulting in exclusion
487 of many Asia-submitted manuscripts from the decision outcome analyses, which increased our
488 confidence that the trends observed were gender-based. Another concern might be the small
489 effect size observed in many analyses. The consistency of decisions to benefit men corresponding
490 authors over women across all journals included in this study, in addition to accumulated literature
491 to-date, confirms that this descriptive study is highly relevant for the ASM as a society. Our findings
492 offer opportunities to address gendered representation in microbiology and systemic barriers in
493 peer review at our journals.

494 All parties have an opportunity and obligation to advance underrepresented groups in science
495 (57). We suggest that journals develop a visible mission, vision, or other statement that commits
496 to equity and inclusion and includes a non-discrimination clause regarding decisions made by
497 editors and editors-in-chief. This non-discrimination clause would be backed by a specific protocol
498 for the reporting of, and response to, instances of discrimination and harassment. Second, society
499 journals should begin collecting additional data from authors and gatekeepers such as race,
500 ethnicity, gender identity, and disabilities. This data should not be readily available to journal
501 gatekeepers, but instead kept in a dis-aggregated manner that allows for public presentation and
502 tracking the success of inclusive measures to maintain accountability. Third, society journals
503 can implement mechanisms to explicitly provide support for women and other minority groups,
504 reward inclusive behavior by gatekeepers, nominate more women to leadership positions, and
505 recruit manuscripts from sub-fields that are more likely to attract women and other minorities (29).
506 Gatekeepers and authors can help advance women (and other marginalized groups) within the
507 peer review system by changing how they select experts in their field. For instance, authors can
508 suggest more women as reviewers using "Diversify" resources (58), while reviewers can agree to

509 review for women editors more often. Editors can rely more on manuscript reference lists and data
510 base searches than personal knowledge to recruit reviewers (59), and journals can improve the
511 interactivity and functionality of the reviewer selection software. Given the propensity for journals
512 to recruit editors and EiCs from within their already biased reviewer pools, opening searches
513 to include more scientists in their reviewer pool and/or editors from outside the journal while
514 enacting more transparent processes could be a major component of improving representation.
515 Growing evidence suggests that representation problems in STEM are due to retention rather than
516 recruitment. We need to align journal practices to foster the retention of women and other minority
517 groups.

518 Most approaches to overcoming bias focus on choices made by individuals, such as
519 double-blinded reviews and implicit bias training. These cannot fully remedy the effects of
520 bias and may even worsen outcomes (60, 61). Since bias (gender, geographic, prestige, or
521 otherwise) is partially the result of accumulated disadvantages and actions resulting from implicit
522 biases, a structural, system-wide approach is required. Broadly, peer review is a nebulous process
523 with expectations and outcomes that vary considerably, even within a single journal. Academic
524 writing courses suffer similar issues and have sought to remedy them with rubrics. When
525 implemented correctly, rubrics can reduce bias during evaluation and enhance the evaluation
526 process for both the evaluator and the evaluatee (62–65). We argue that rubrics could be
527 implemented in the peer review process to focus reviewer comments, clarify editorial decisions,
528 and improve the author experience. Such rubrics should increase the emphasis on solid research,
529 as opposed to novel or “impactful” research, the latter of which is a highly subjective measure
530 (66, 67). This might also change the overall negative attitude toward replicative research and
531 negative results, thus bolstering the field through reproducibility. We also argue that reconsidering
532 journal scope and the membership of their honorary editorial boards might help address structural
533 barriers of bias against women (and other minorities) in peer review. Expanding journal scope and
534 adding more handling editors would improve the breadth of research published, thus providing
535 a home for more non-traditional and underserved research fields (the case at *mSphere* with an
536 increased pool of editors). Implementing these steps to decrease bias—review rubrics, increased
537 focus on solid research, expansion of journal scopes and editorial boards—will also standardize

538 competency principles for researchers at ASM journals and improve microbiology as a whole.

539 Although the level of bias at many ASM journals is small, it is present. Peer review at ASM
540 journals is not immune to the accumulated disadvantages against women in microbiology.
541 However, the adaptation of women (and other marginalized groups) to bias (e.g., area of research
542 and communication styles), make it impossible to address at the individual level. Instead, we
543 must commit to changing the fundamental structure and goals of peer review to minimize bias.
544 We encourage ASM journals, as well as other societies, to institute more fair and transparent
545 procedures and approaches of peer review. The self-correcting nature of science is a badge that
546 scientists wear proudly, but no single report or action can correct the inertia of a millenniums-old
547 institution. Instead, it requires the long-standing and steady actions of many. Our findings reflect
548 many similar reports, and suggest concrete actions to correct the inertia of peer review at all
549 levels. The next step is commitment and implementation.

550 **Data and Methods**

551 **Data.** All manuscripts handled by ASM journals (e.g., *mBio*, *Journal of Virology*) that received
552 an editorial decision between January 1, 2012 and August 31, 2018 were supplied as XML files
553 by ASM's publishing platform, eJP. Data were extracted from the XML documents provided,
554 manipulated, and visualized using R statistical software (version 3.4.4) and relevant packages.
555 Variables of interest included: the manuscript number assigned to each submission, manuscript
556 type (e.g., full length research, erratum, editorial), category (e.g., microbial ecology), related
557 (i.e., previously submitted) manuscripts, number of versions submitted, dates (e.g., submission,
558 decision), author data (e.g., first, last, and corresponding authorship, total number of authors),
559 reviewer data (e.g., recommendation, editor decision), and personal data (names, institutions,
560 country) of the editors, authors, and reviewers. For this analysis, only original, research-based
561 manuscripts were included, e.g., long- and short-form research articles, New-Data Letters,
562 Observations, Opinion/Hypothesis articles, and Fast-Track Communications. To help protect the
563 confidentiality of peer review, names were removed from all records, and identifying data (e.g.,
564 manuscript numbers, days of date), were replaced with randomized values.

565 **Institution classification.** To identify the communities represented, we used Carnegie
566 classifications to group US-based academic institutions into R1 research (very high research
567 activity), R2 research (high research activity), four-year medical schools, or low research (i.e.,
568 not R1, R2, or medical school) (22). Research institutes (e.g., Mayo Clinic, Cold Springs
569 Harbor), industry (e.g., pharmaceutical), and federal (e.g., NIH, CDC) research groups were
570 identified using the internet. Four-year medical schools and research institutions were grouped
571 together since these typically share research prestige and have considerable resources to
572 support research. Industry and federal research were grouped separately. The “Other” category
573 represents uncategorized US institutions. Non-US institutions were a category on their own.

574 **Gender inference.** The genderize.io API was used to infer an individual’s gender based on their
575 given name and country where possible. The genderize.io platform uses data gathered from social
576 media to infer gender based on given names with the option to include an associated language or
577 country to enhance the probability of successful inference. Since all manuscripts were submitted
578 in English, which precludes language association for names with special characters, names were
579 standardized to ASCII coding (e.g., “José” to “Jose”). We next matched each individuals’ country
580 against the list of 242 country names accepted by genderize.io. Using the GenderGuesser
581 package for R, all unique given names associated with an accepted country were submitted to
582 the genderize.io API and any names returned without an inferred value of either male or female
583 were resubmitted without an associated country. The data returned include the name, inferred
584 gender (as “male”, “female”, “unknown”), the probability of correct gender inference (ranging
585 from 0.5 to 1.0), and the number of instances the name and gender were associated together
586 (1 or greater). The inferred genders of all given names (with and without an associated country)
587 whose probabilities were greater or equal to a modified probability (pmod) of 0.85 were used to
588 infer genders (man/woman) of the individuals in our data set (Supp Text). The presenting gender
589 (man/woman) of editors and senior editors in our data set was inferred by hand using Google
590 where possible, and the algorithm was validated using both editor and published data (Supp
591 Text)(5).

592 **Manuscript outcome analysis.** To better visualize and understand the differences in outcomes
593 according to author gender, we calculated the difference in percentage points between the

594 proportion of that outcome for men and women. To correct for the disparity in the participation
595 of women relative to men at ASM journals, all percentage point comparisons were made relative
596 to the gender and population in question. For instance, the percentage point difference in
597 acceptance rates was the acceptance rate for men minus the acceptance rate for women. A
598 positive value indicated that men received the outcome more often than women, whereas a
599 negative value indicated that women outperformed men in the given metric.

600 **Logistic regression models.** For the L2-regularized logistic regression models, we established
601 modeling pipelines for a binary prediction task (68). First, we randomly split the data into training
602 and test sets so that the training set consisted of 80% of the full data set while the test set
603 was composed of the remaining 20% of the data. To maintain the distribution of the two model
604 outcomes found with the full data set, we performed stratified splits. The training data was
605 used to build the models and the test set was used for evaluating predictive performance. To
606 build the models, we performed an internal five-fold cross-validation where we tuned the cost
607 hyper-parameter, which determines the regularization strength where smaller values specify
608 stronger regularization. This internal cross-validation was repeated 100 times. Then, we trained
609 the full training data set with the selected hyper-parameter values and applied the model to
610 the held-out data to evaluate the testing predictive performance of each model. The data-split,
611 hyper-parameter selection, training and testing steps were repeated 25 times to get a reliable and
612 robust reading of model performance. Models were trained using the machine learning wrapper
613 caret package (v.6.0.81) in R (v.3.5.0).

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

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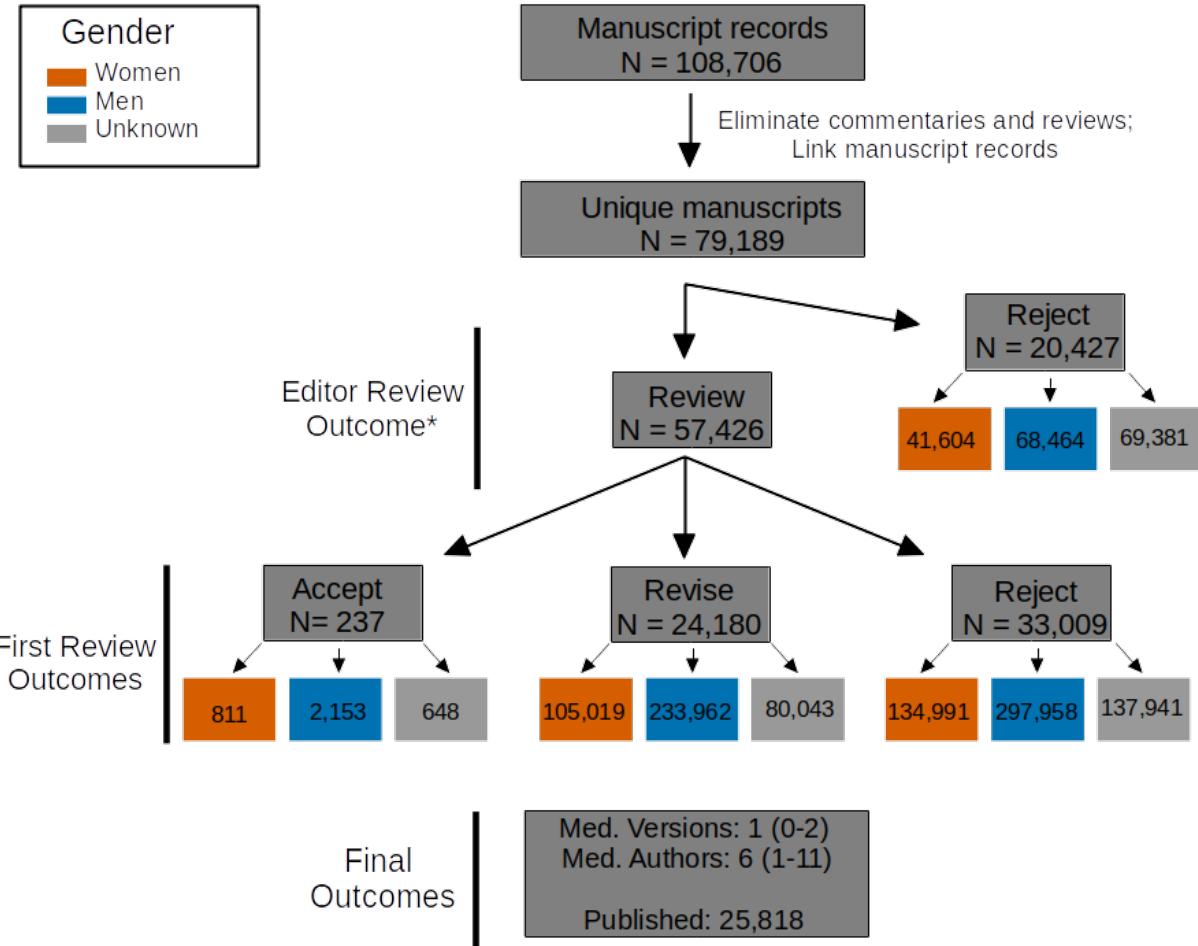
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790 Table 1. Analysis of sub-discipline participation by women corresponding authors at five ASM
 791 journals.

Journal Category		N	% Accepted	% Editors	% Women Authors
AAC	Analytical Procedures	135	43.0	14	29
AAC	Antiviral Agents	836	56.5	6	33
AAC	Biologic Response Modifiers	44	40.9	12	43
AAC	Chemistry; Biosynthesis	109	29.4	10	32
AAC	Clinical Therapeutics	1060	48.9	13	31
AAC	Epidemiology and Surveillance	765	52.3	14	40
AAC	Experimental Therapeutics	1329	57.4	13	28
AAC	FDA Approvals	1	NA	NA	NA
AAC	Mechanisms of Action: Physiological Effects	597	51.8	14	30
AAC	Mechanisms of Resistance	1783	60.0	14	36
AAC	Pharmacology	878	66.6	13	29
AAC	Susceptibility	1051	46.8	12	39
AEM	Biodegradation	302	38.4	35	26
AEM	Biotechnology	802	37.9	30	27
AEM	Environmental Microbiology	2395	30.3	35	42
AEM	Enzymology and Protein Engineering	340	46.5	28	24
AEM	Evolutionary and Genomic Microbiology	279	48.4	32	30
AEM	Food Microbiology	1216	38.2	33	39
AEM	Genetics and Molecular Biology	587	51.8	32	36
AEM	Geomicrobiology	151	44.4	34	37
AEM	Invertebrate Microbiology	317	45.7	29	37
AEM	Methods	529	39.7	30	29
AEM	Microbial Ecology	1121	35.8	29	37
AEM	Mycology	73	47.9	33	44

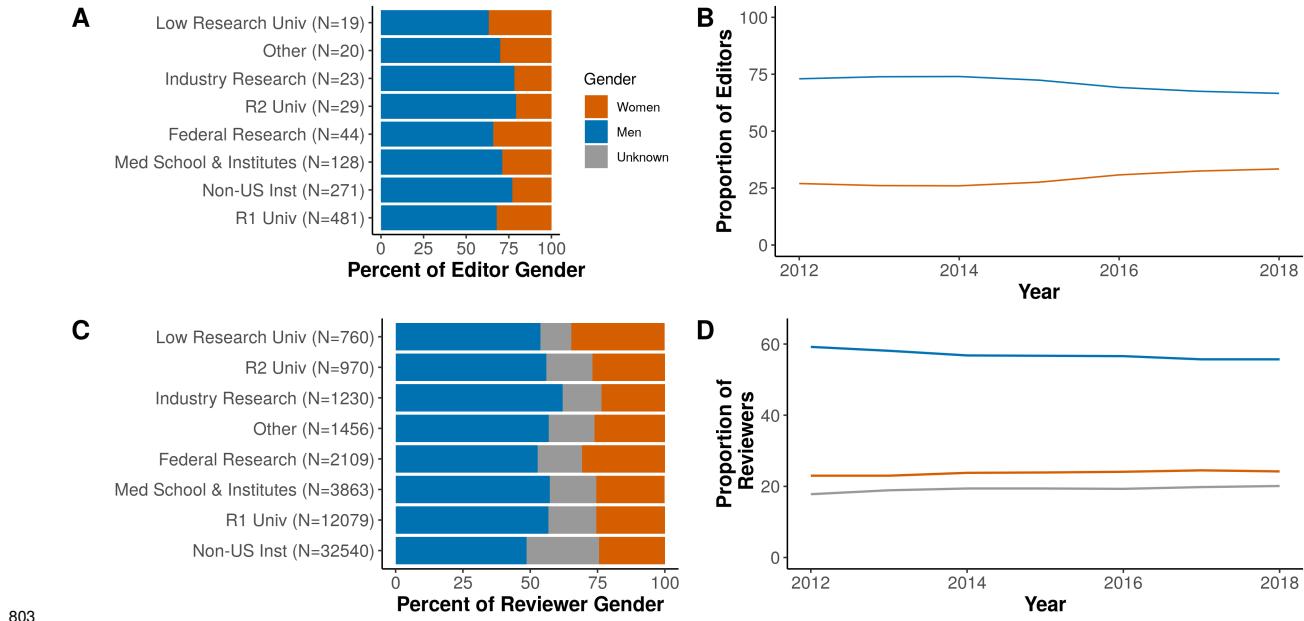
			%	% Women	% Women
Journal Category		N	Accepted	Editors	Authors
AEM	Physiology	356	50.3	32	31
AEM	Plant Microbiology	346	36.4	29	39
AEM	Public and Environmental Health	893	34.0	32	45
	Microbiology				
IAI	Bacterial Infections	716	58.4	35	36
IAI	Cellular Microbiology: Pathogen-Host	685	55.2	35	37
	Cell Molecular Interactions				
IAI	Fungal and Parasitic Infections	353	59.5	33	33
IAI	Host Response and Inflammation	763	50.2	35	40
IAI	Host-Associated Microbial Communities	7	57.1	43	86
IAI	Microbial Immunity and Vaccines	342	56.4	35	32
IAI	Molecular Genomics	33	60.6	37	33
IAI	Molecular Pathogenesis	617	68.4	35	31
JCM	Bacteriology	2952	33.2	27	41
JCM	Chlamydiology and Rickettsiology	80	32.5	25	41
JCM	Clinical Veterinary Microbiology	364	32.7	29	40
JCM	Epidemiology	854	29.7	30	45
JCM	Fast-Track Communications	5	40.0	33	40
JCM	Immunoassays	139	36.0	31	41
JCM	Mycobacteriology and Aerobic	510	42.9	32	41
	Actinomycetes				
JCM	Mycology	587	37.3	19	39
JCM	Parasitology	337	33.2	27	34
JCM	Virology	1140	37.5	29	41
JVI	Cellular Response to Infection	604	51.2	36	32
JVI	Gene Delivery	98	41.8	32	20
JVI	Genetic Diversity and Evolution	883	51.1	39	27

Journal Category		N	Accepted %	% Women	
				Editors	Authors
JVI	Genome Replication and Regulation of Viral Gene Expression	813	64.6	39	23
JVI	Pathogenesis and Immunity	1622	60.4	35	33
JVI	Prions	92	69.6	56	22
JVI	Structure and Assembly	725	71.3	39	29
JVI	Transformation and Oncogenesis	154	59.1	39	36
JVI	Vaccines and Antiviral Agents	1149	59.2	36	28
JVI	Virus-Cell Interactions	2414	63.6	40	30



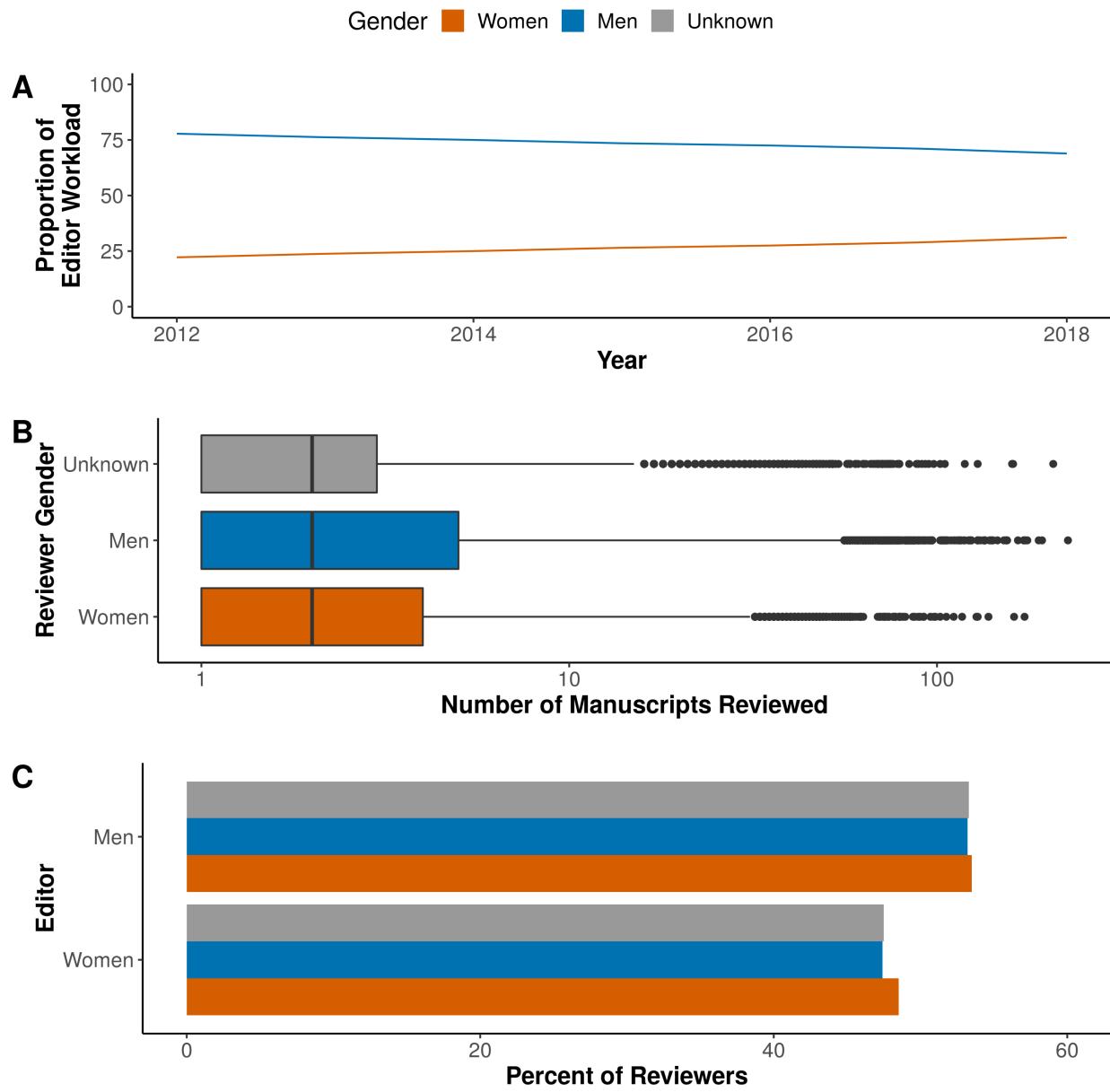
792

793 **Figure 1. Overview of manuscript outcomes.** 108,706 manuscript records were obtained
 794 for the period between January 2012 and August 2018. After eliminating non-primary research
 795 manuscripts and linking records for resubmitted manuscripts, we processed 79,189 unique
 796 manuscripts. The median number of versions was 1 (IQR=0-2) with a median of 6 (IQR=1-11)
 797 authors per manuscript. As of August 2018, 34,196 of these were published at ASM journals.
 798 Revisions were requested for 24,016 manuscripts and 53,436 manuscripts were rejected at
 799 their first submission. The number of individuals (e.g., author, editor, reviewer) involved in each
 800 category of manuscript decision are indicated in the colored boxes: women (orange), men (blue),
 801 and unknown (gray). *A small number were given revise (242) or acceptance (1094) decisions
 802 without review.

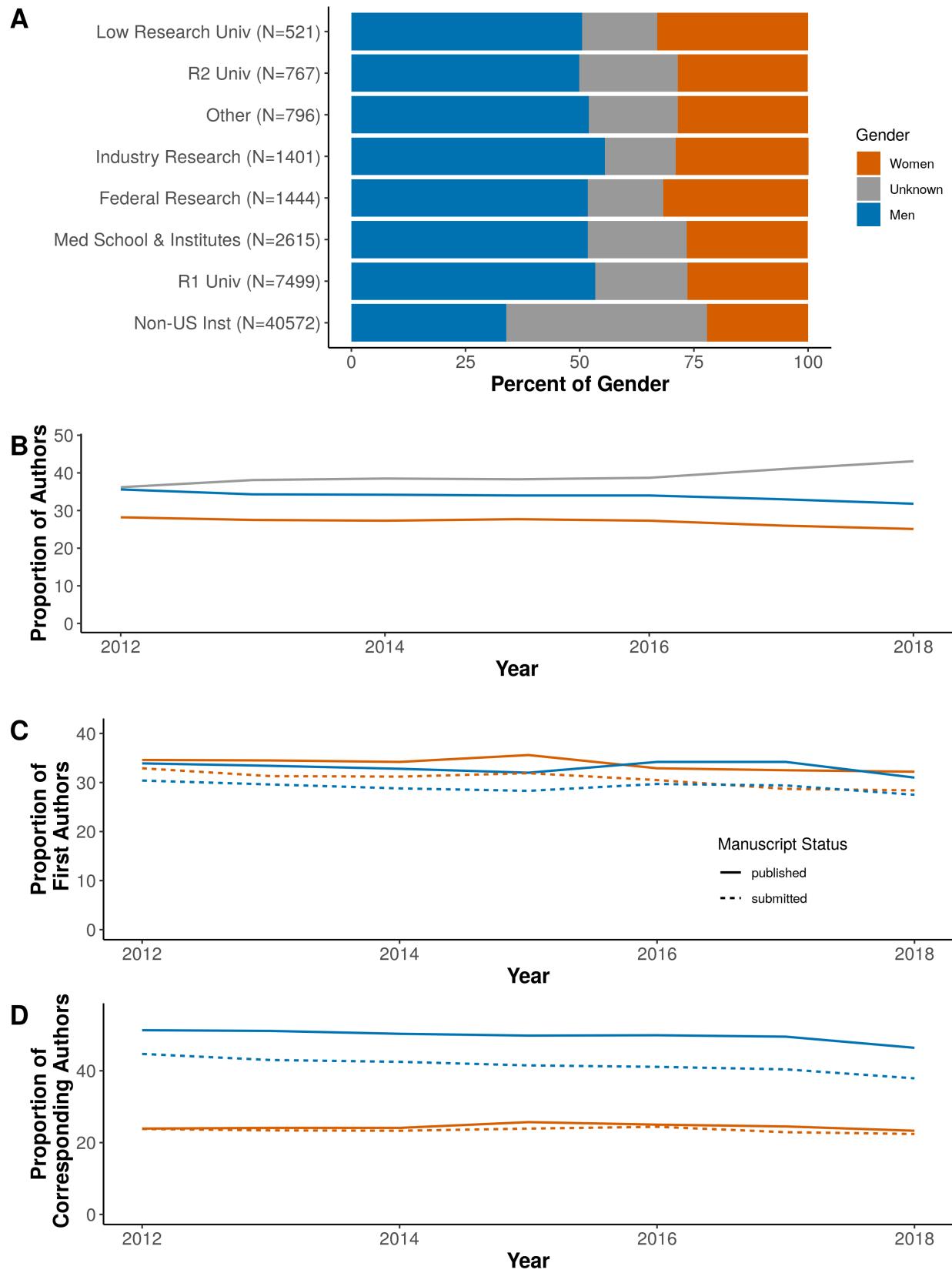


803

804 **Figure 2. Gendered representation among gatekeepers.** Proportion of editors from (A)
 805 institution types and (B) over time. Editors and senior editors are pooled together. Proportion of
 806 reviewers from (C) institution types and (D) over time. (A,C) Each gender equals 100% when all
 807 institutions are summed.(B,D) Each individual was counted once per calendar year, proportions
 808 of each gender add to 100% per year.



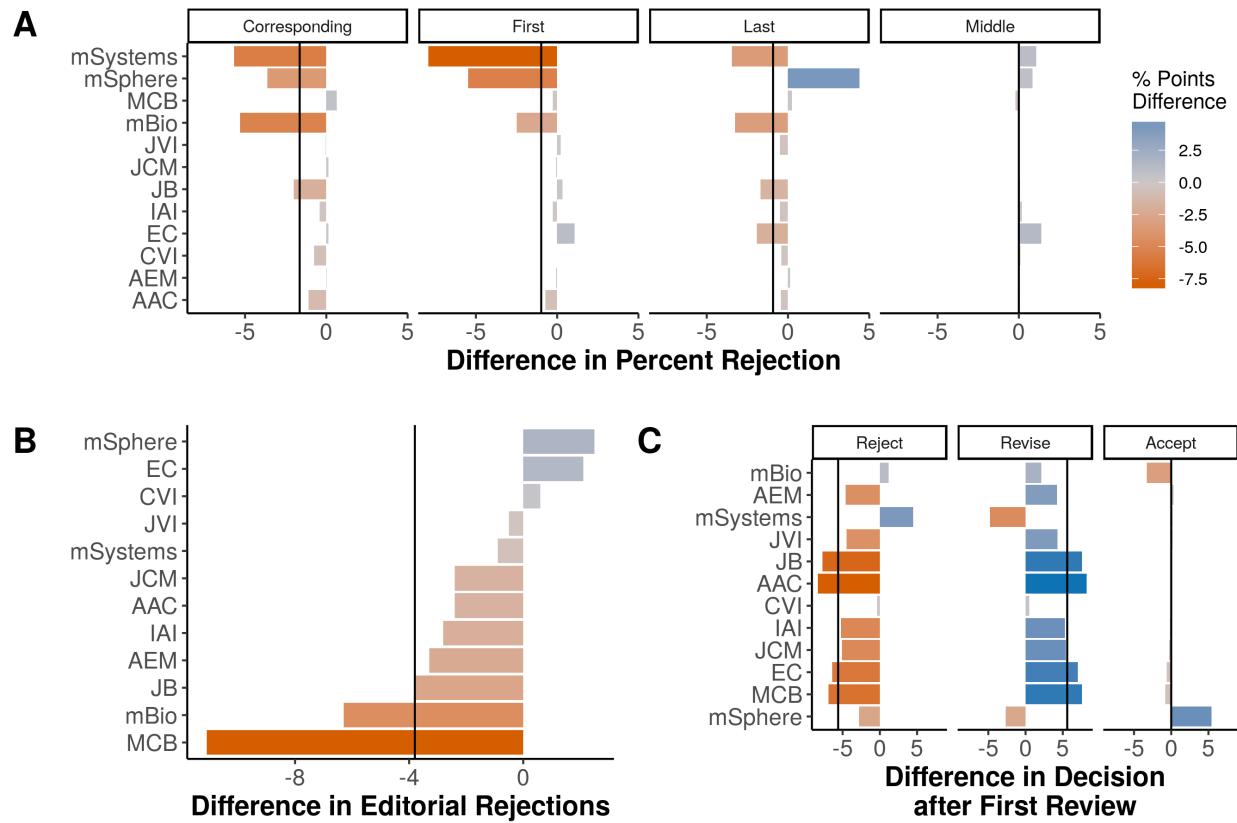
809
810 **Figure 3. Gatekeeper workload and response to requests to review.** (A) Proportion of
811 manuscript workloads by men and women editors, editorial rejections excluded. (B) Box plot
812 comparison of all manuscripts, by reviewer gender. (C) The percent of reviewers by gender that
813 accepted the opportunity to review, split according to the editor's gender.



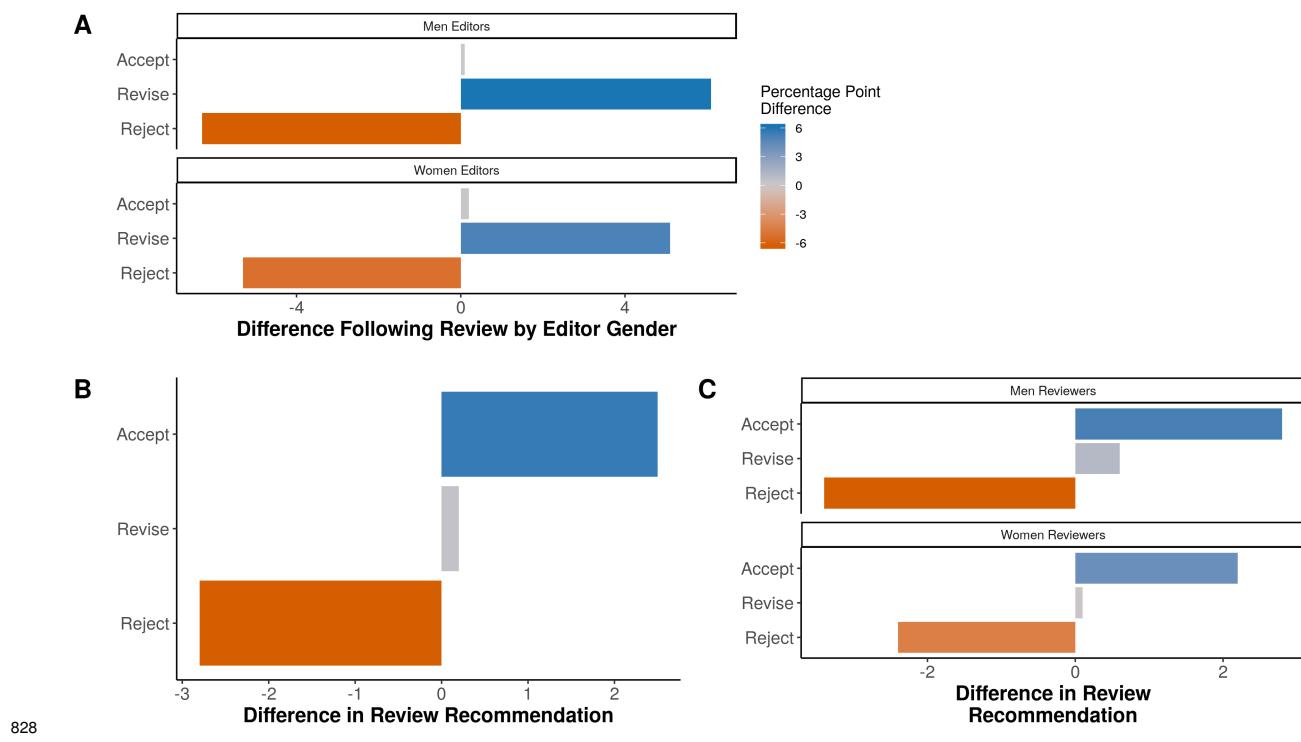
814

815 **Figure 4. Author representation by gender.** The proportion of (A) men and women senior

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

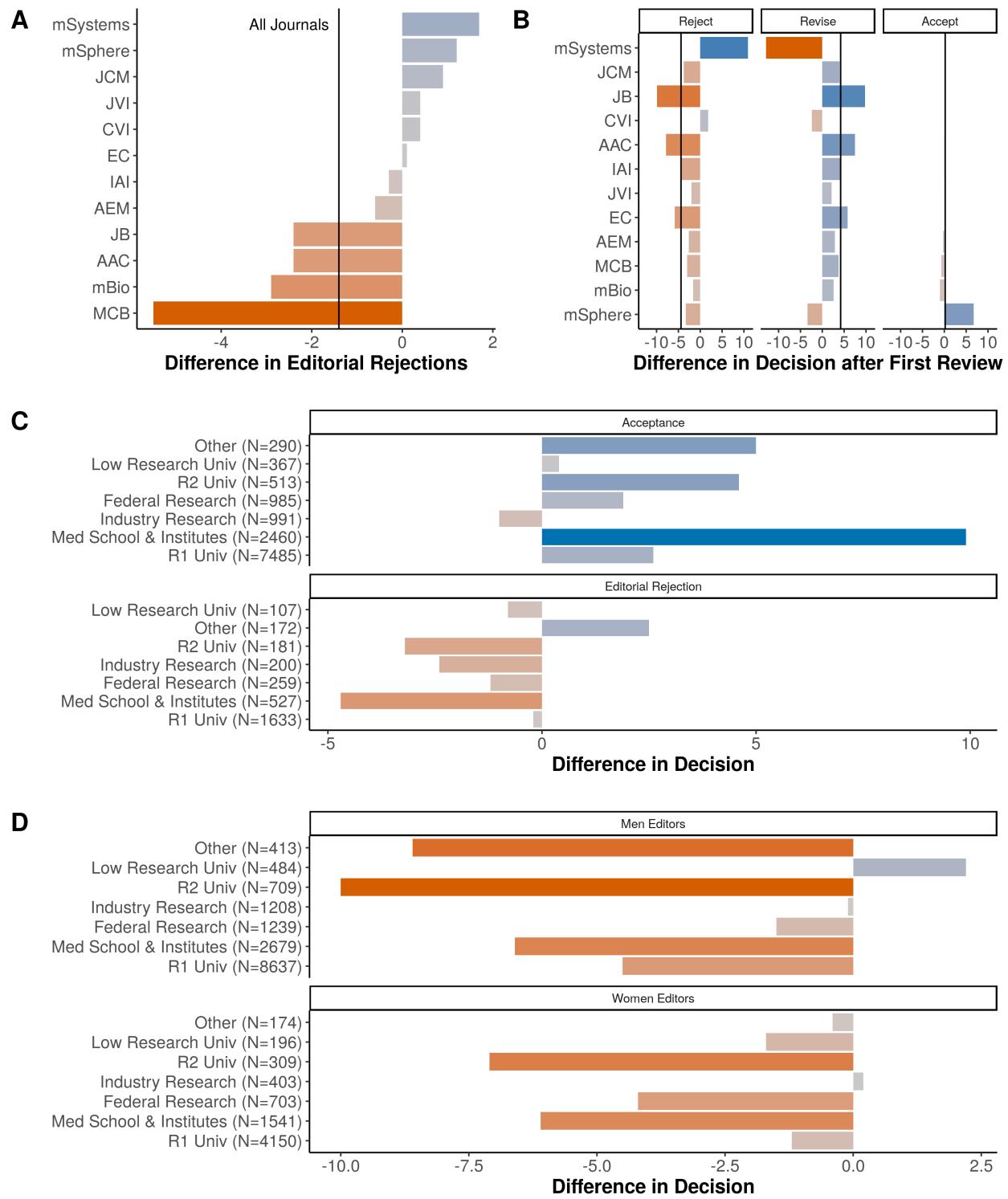


820
821 **Figure 5. Difference in manuscript outcomes by author gender.** (A) The percent of
822 manuscripts rejected by author gender and type (e.g., corresponding, first, last, middle) at
823 any stage across all journals where 0 indicates equal rates of rejection. (B) The difference in
824 percent editorial rejection rates for corresponding authors at each journal. (C) The difference in
825 percentage points between each decision type for corresponding authors following the first peer
826 review. Vertical lines indicate the difference value for all journals combined. Absence of a bar
827 indicates no difference, or parity.



828 **Figure 6. Difference in decisions or recommendations according to the gatekeeper gender.**

829 (A) Effect of editor gender on the difference in decisions following review. (B) Difference in
 830 percentage points for review recommendations and (C) how that is affected by reviewer gender.
 831 (A-C) All journals combined.

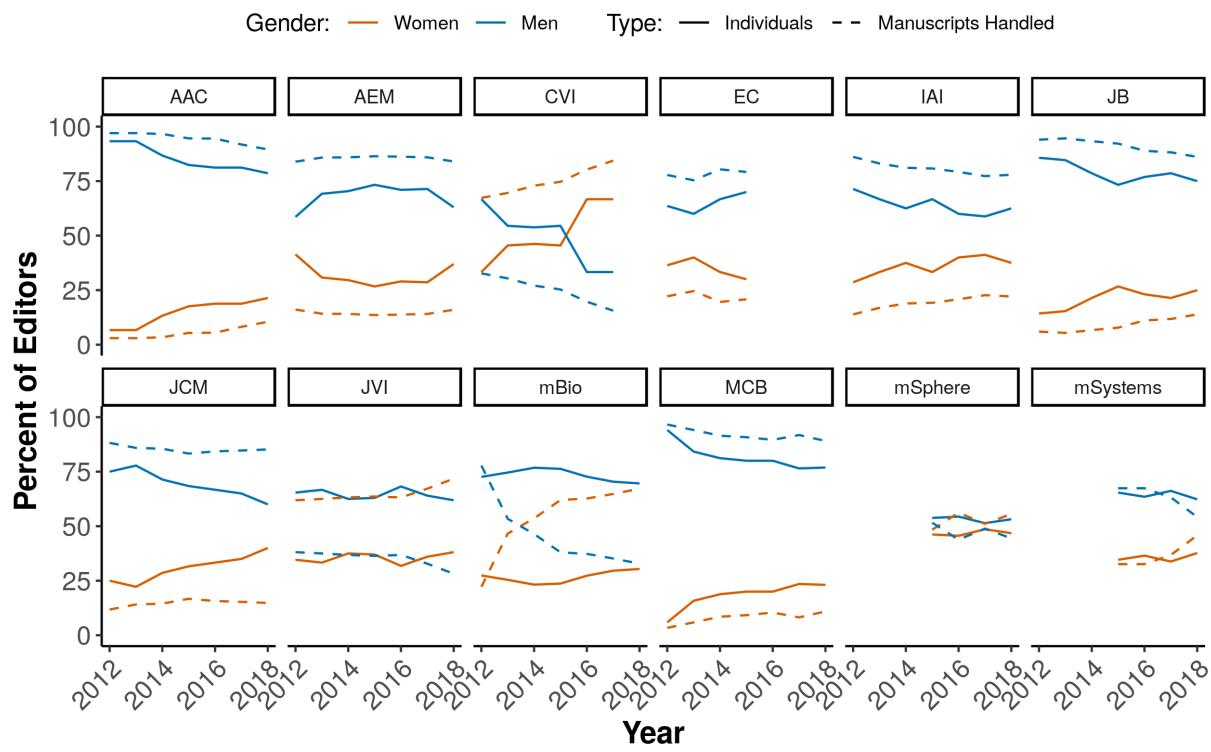


833

834 **Figure 7. Impact of origin and U.S. institution type on manuscript decisions by gender.**

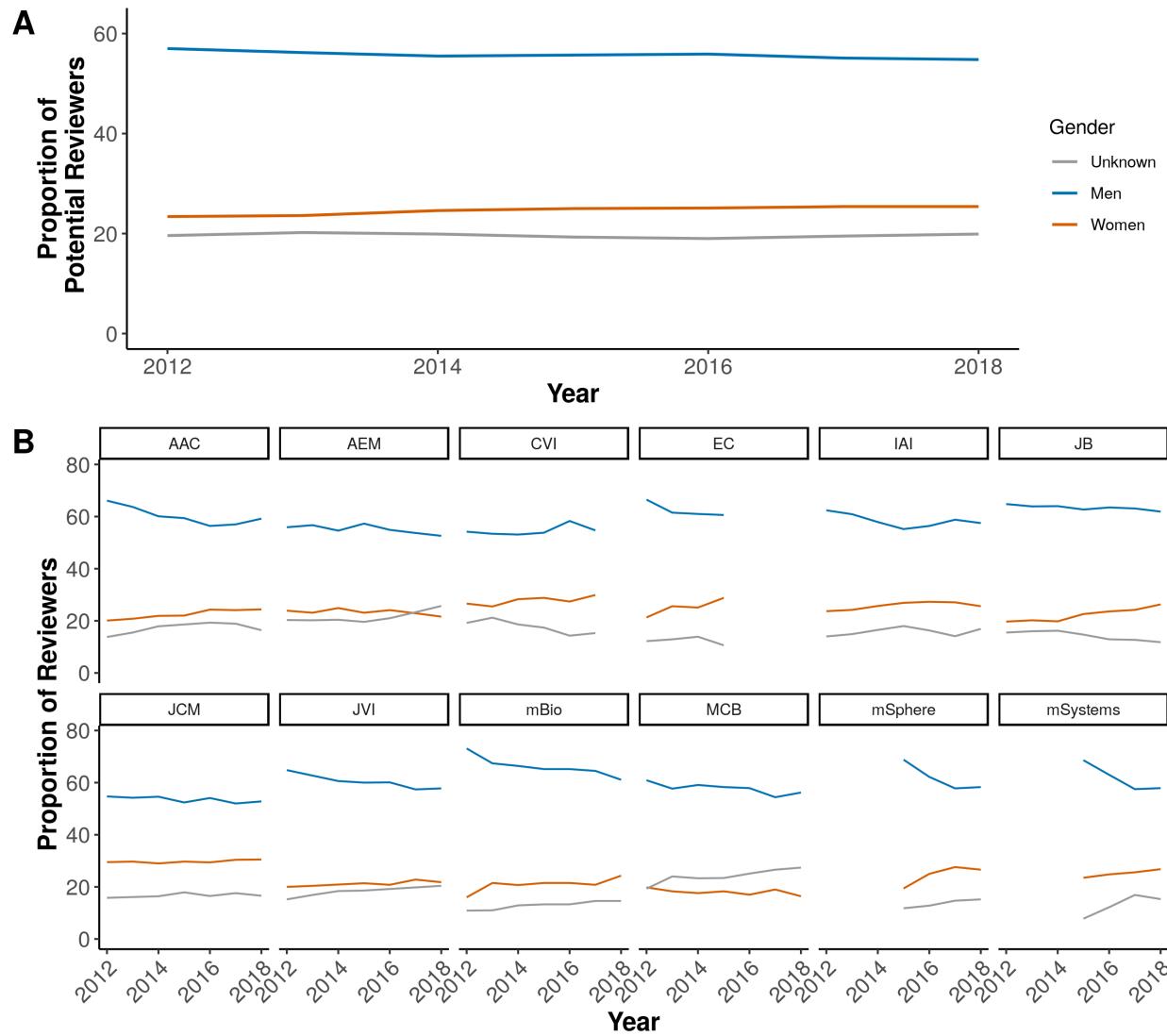
835 Difference in percentage points for (A) editorial rejections and (B) following first review of
 836 manuscripts submitted by US-based corresponding authors. Vertical line indicates value for

837 all ASM journals combined. (C) Difference in percentage points for acceptance and editorial
838 rejections according to institution types and (D) acceptance decisions by editor gender and
839 institution type.



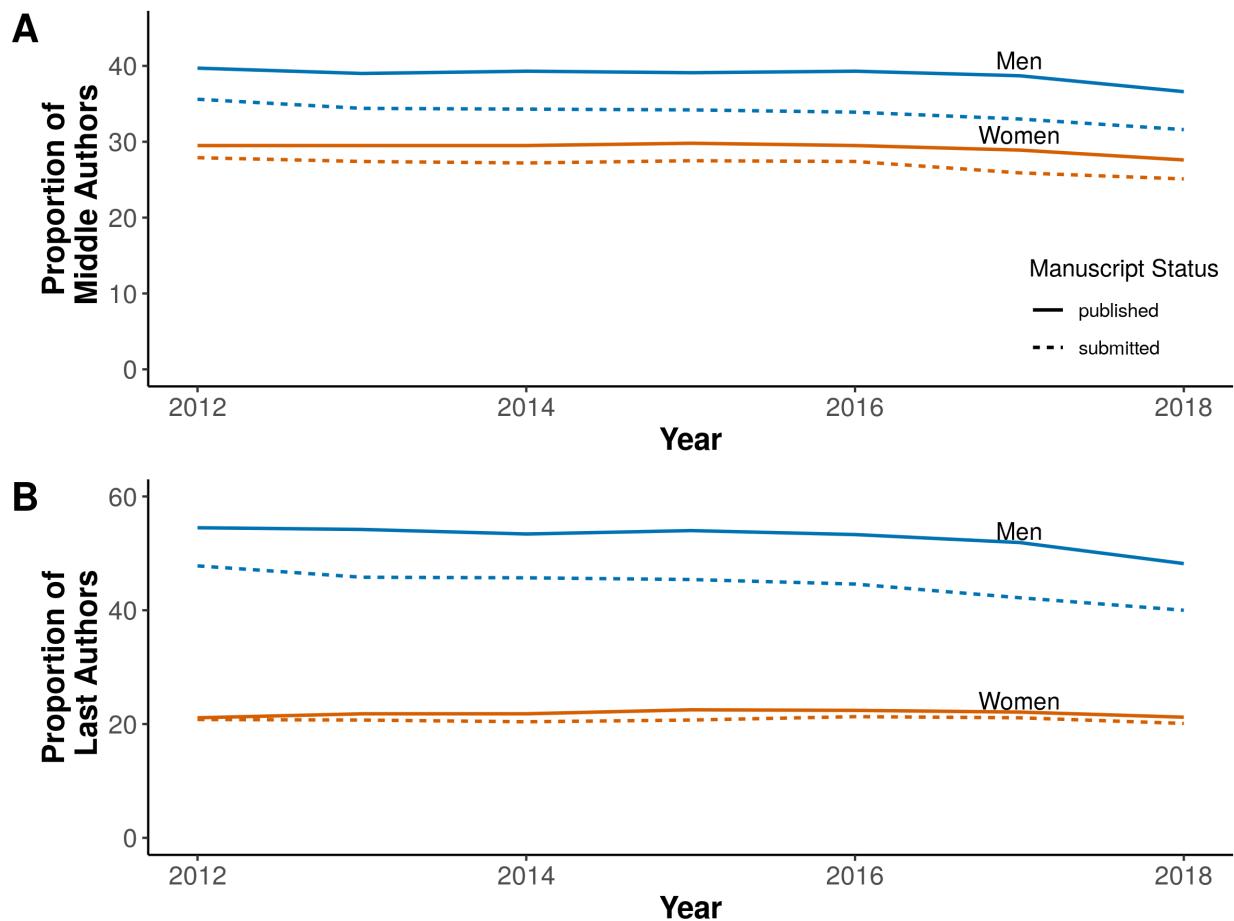
840

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



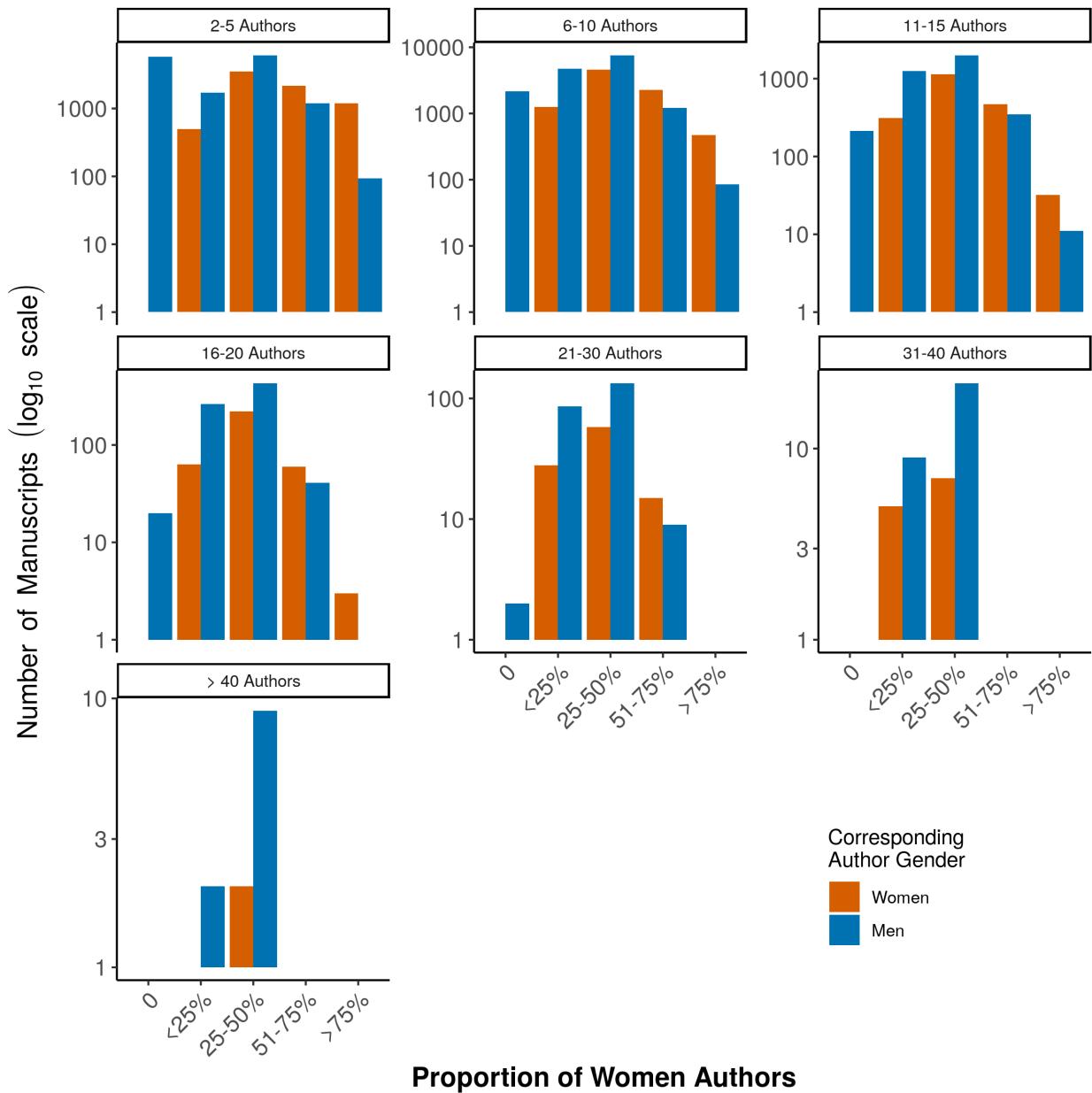
843

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



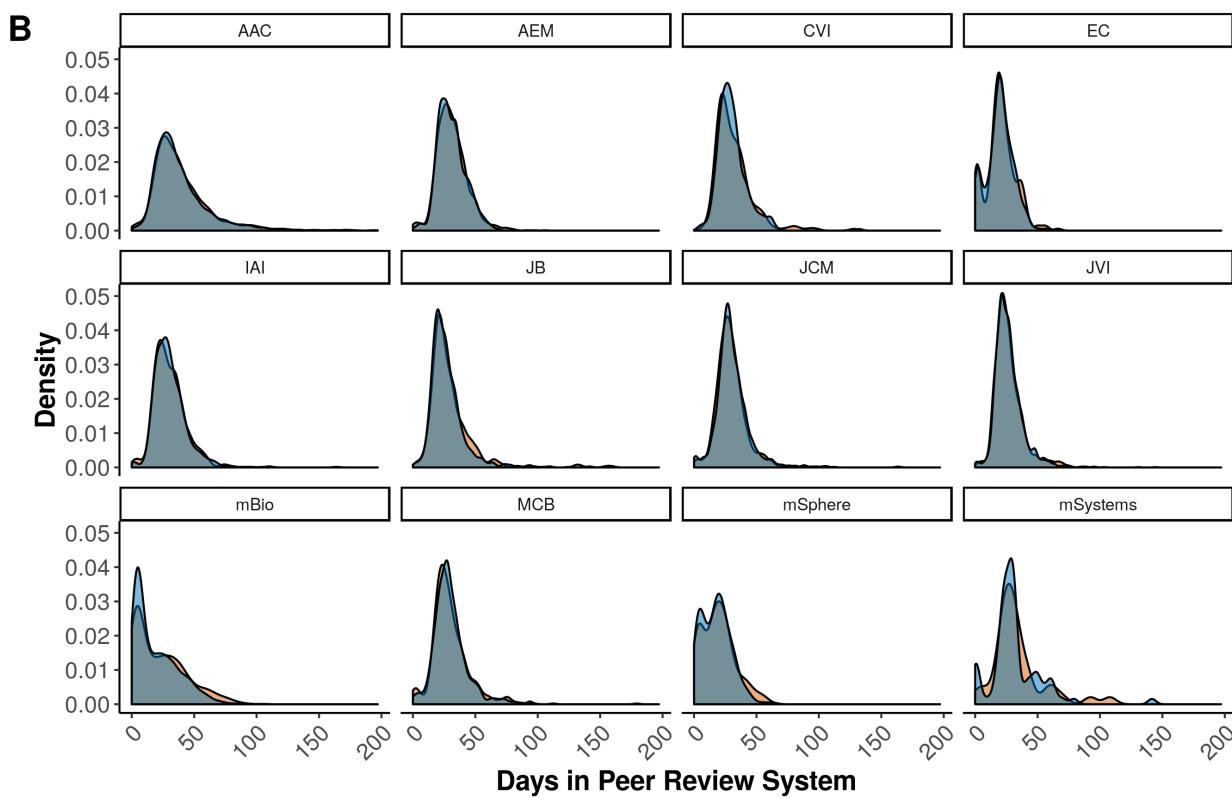
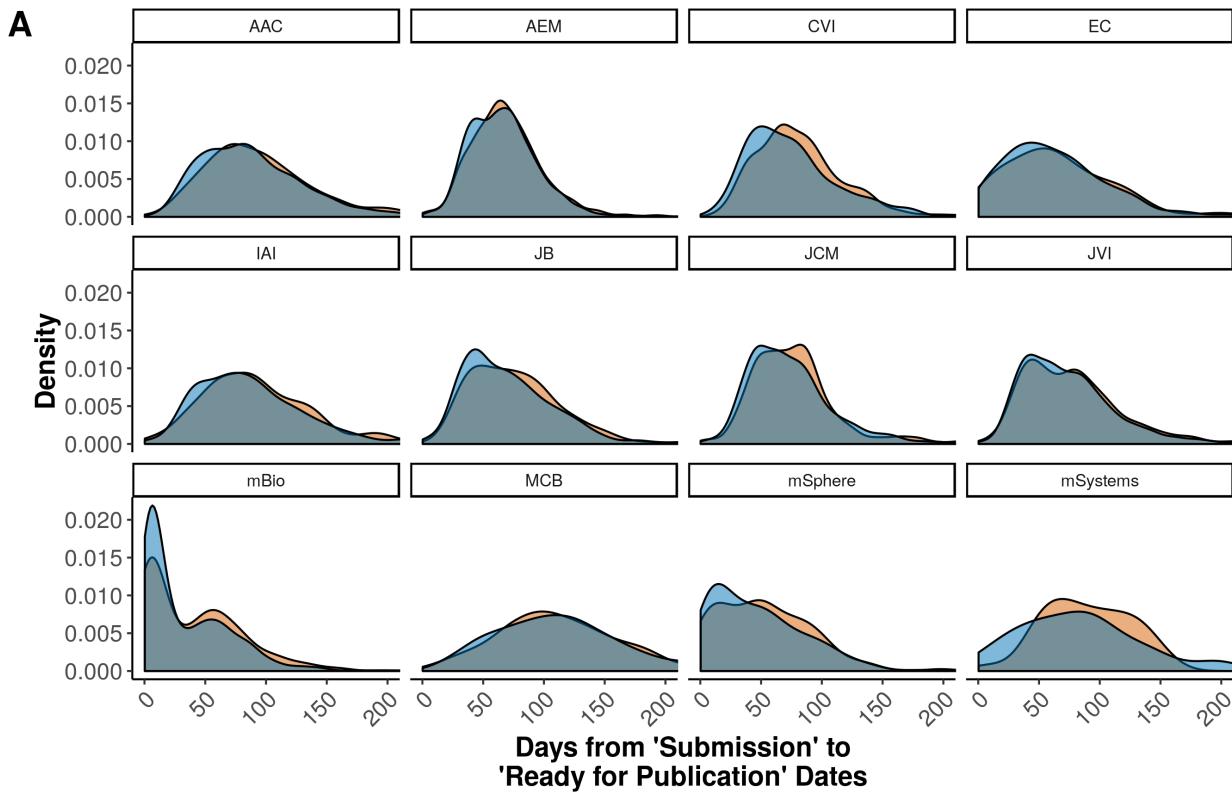
846

847 Figure S3. The proportion of all submitted (dashed line) and published (solid line) (A) middle and
 848 (B) last authors by gender at each ASM journal.



849

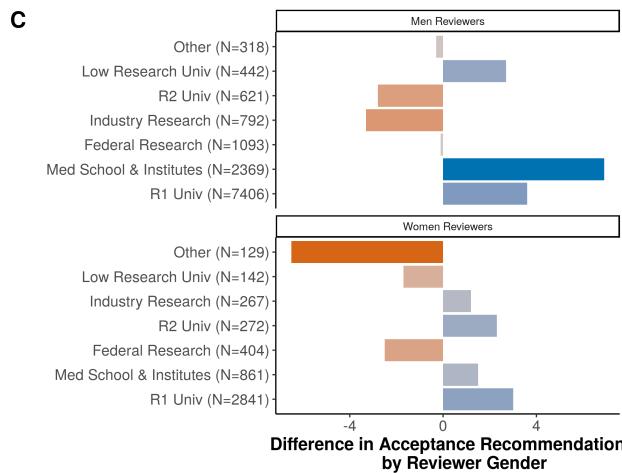
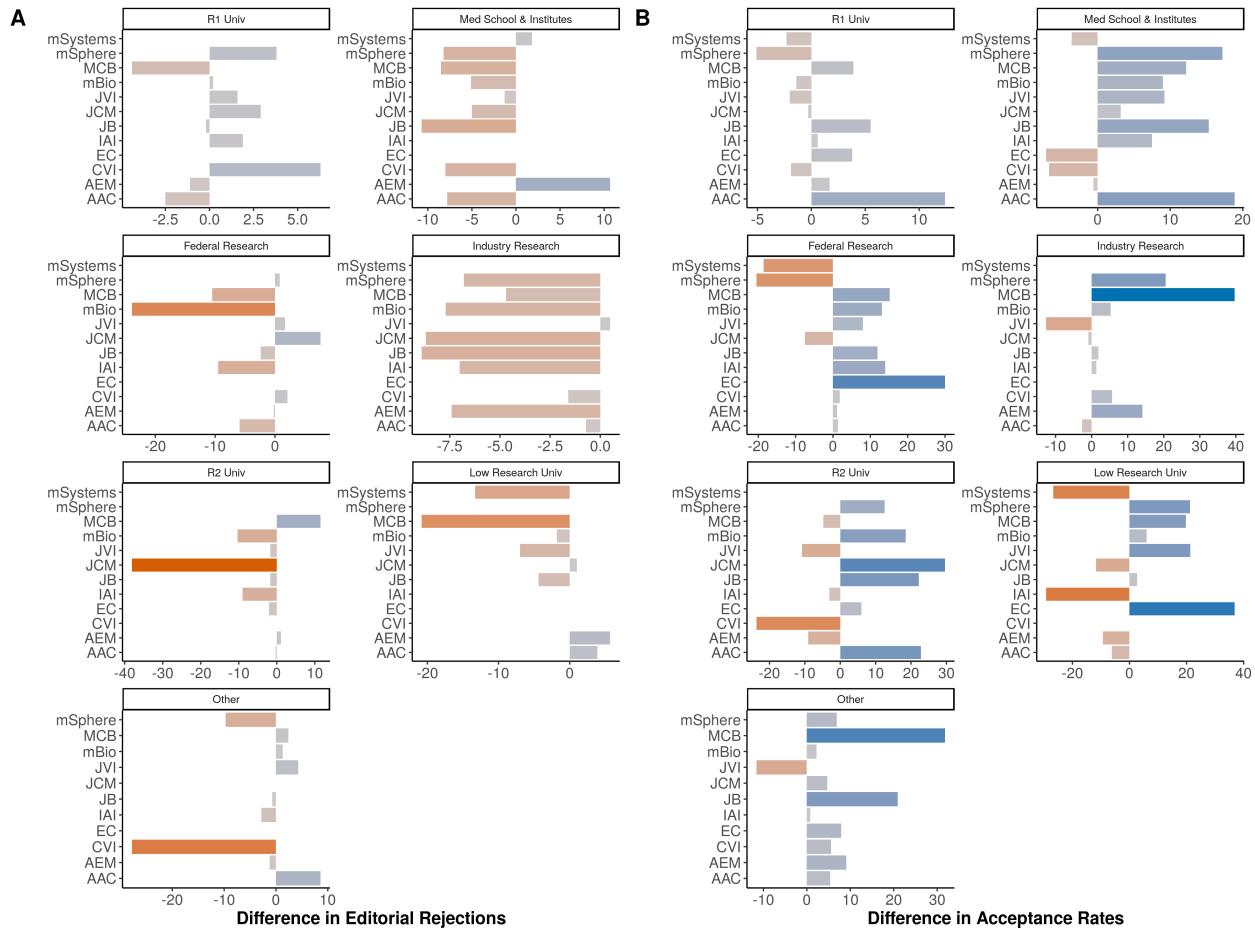
850 Figure S4. The proportion of women authors on submitted manuscripts according to the number
 851 of authors and the gender of the corresponding author. Y axis indicates the total number of
 852 manuscripts on a \log_{10} scale.



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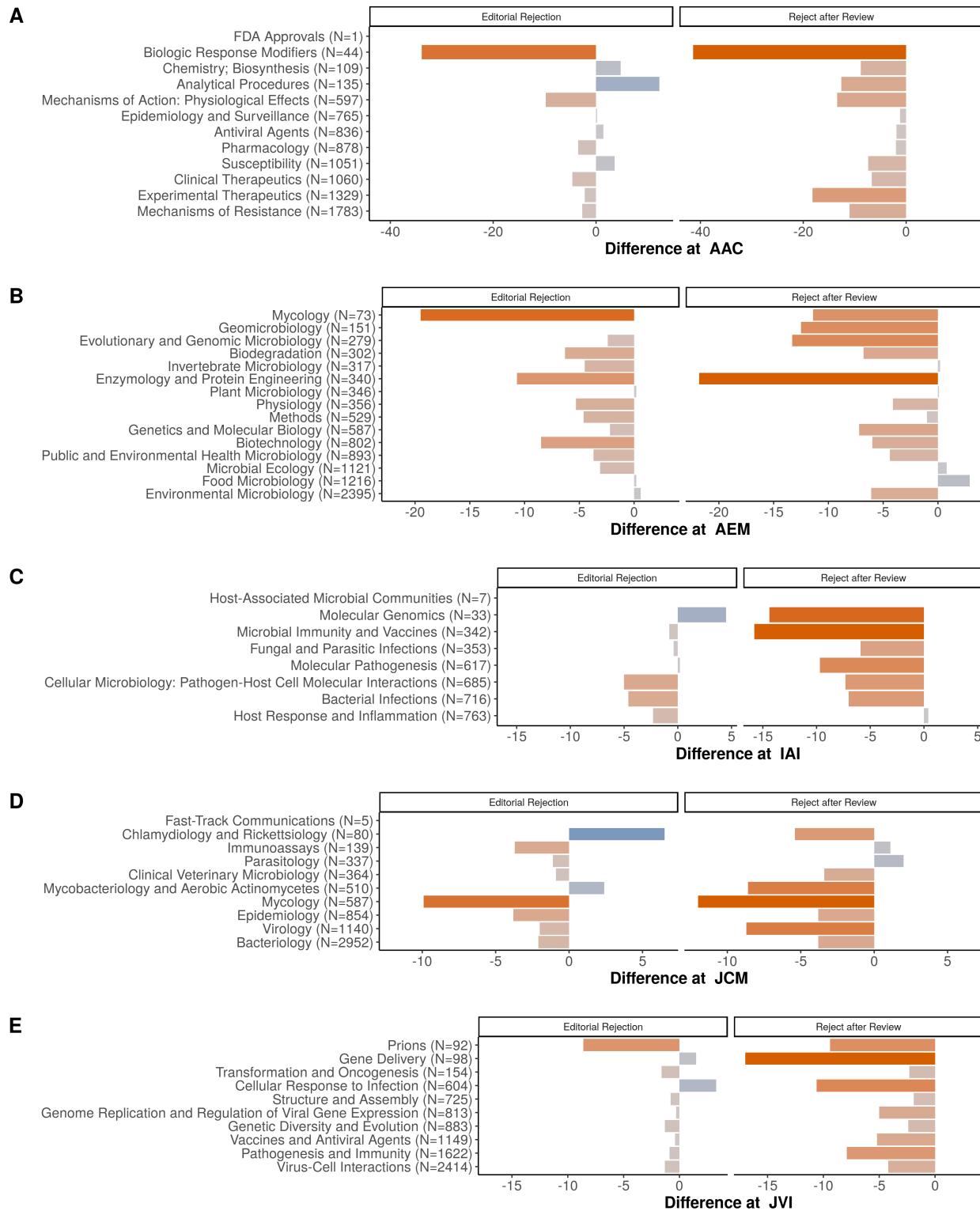
854 Figure S5. Comparison of time to final decision and impact by gender. The number of days (A)

855 between when a manuscript is initially submitted and finally published or (B) that a manuscript
856 spends in the ASM peer review system.



857

858 Figure S6. Difference in A) editorial rejection and B) acceptance rates by journal and institution
 859 type. C) Difference in review recommendations by reviewer gender and author institution type. D)
 860 Median importance (black dot) of features affecting editorial rejections, and their range. Color of
 861 smaller dots (N=25) indicate the direction of the impact.



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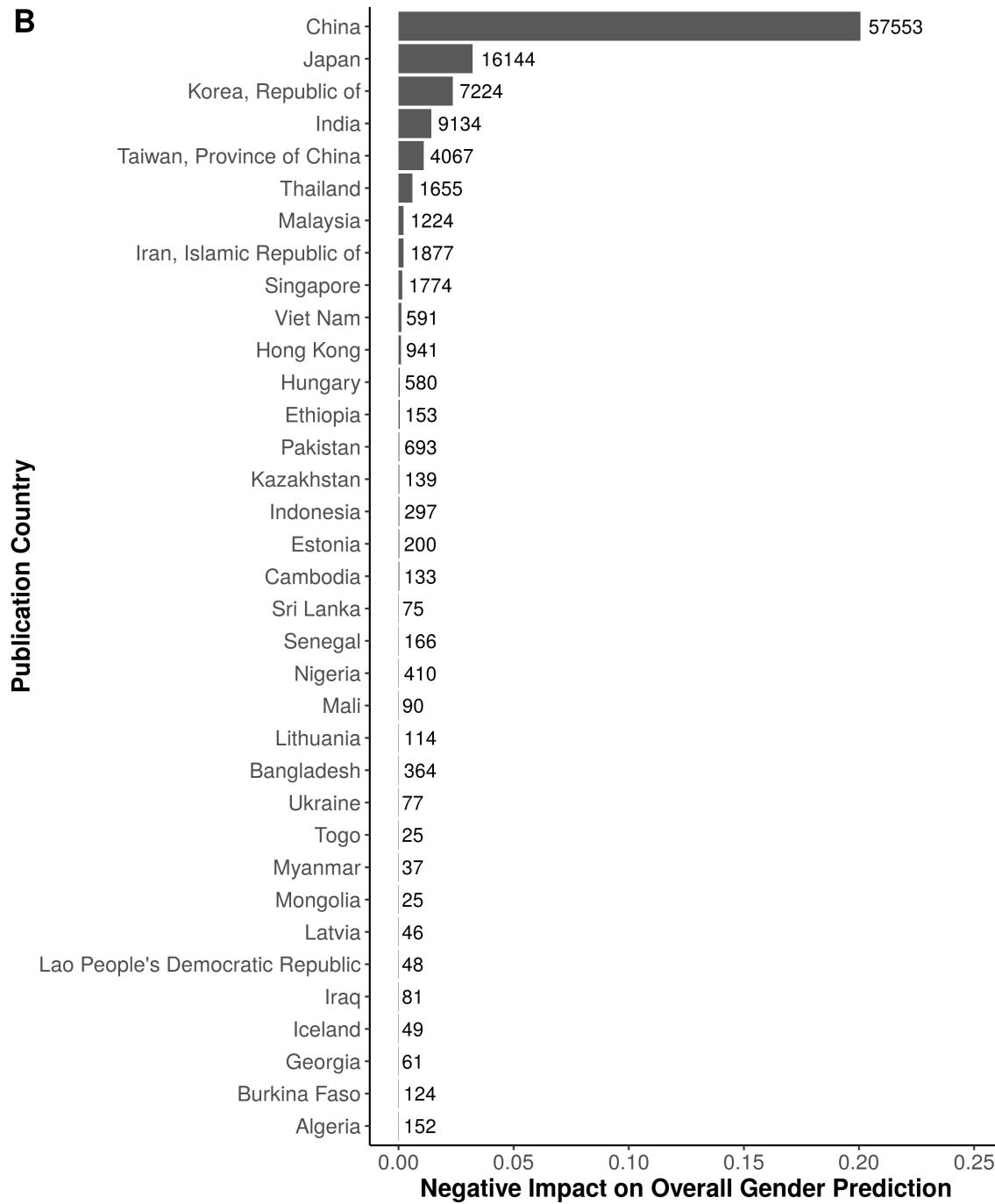
863 **Figure S7.** Difference in editorial rejections and rejections after review by corresponding author
864 gender and manuscript category at (A) AAC, (B) AEM, (C) IAI, (D) JCM, and (E) JVI. In

⁸⁶⁵ parentheses: N = the number of manuscripts submitted.

A

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

B



Figure

867 S8. (A) Equation for calculating negative bias by genderize algorithm. C indicates a country. (B)
868 The negative impact of each country on the overall gender inference of the full data-set. Number
869 to the right of each column is the total number of names associated with that country.