

Earth and Space Science



RESEARCH ARTICLE

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Key Points:

- Submissions to journals published by the American Geophysical Union increased during the COVID-19 pandemic
- Submissions from women increased with no proportional changes during the pandemic compared to before the pandemic
- Women declined to review at a higher rate than men and than their rates before the COVID-19 pandemic

Supporting Information:

Supporting Information may be found in the online version of this article.

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Effects of the COVID-19 Pandemic on Authors and Reviewers of *American Geophysical Union* Journals

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Abstract The COVID-19 pandemic affected the scientific workforce in many ways. Many worried that stay-at-home orders would disproportionately harm the productivity and well-being of women and early-career scientists, who were expected to shoulder more childcare, homeschooling, and other domestic duties while also interrupting field and lab research, essential for career advancement. AGU journal submission and author and reviewer demographic data allowed us to investigate the effect the pandemic may have had on many Earth and space scientists, especially on women and early career scientists. However, we found that submissions to AGU journals increased during the pandemic as did total submissions from women (with no difference in the proportion). Although the rate at which women agreed to review decreased slightly (down 0.5%), women still made up a larger proportion of agreed reviewers during the pandemic compared to 2 years earlier. Little difference was seen overall in median times to complete reviews except with women in their 40s and 70s, suggesting that they were affected more during the pandemic than other age and gender groups. Although AGU's data do not show that the effects of the pandemic decreased women's participation in AGU journals, the lag between research and writing/submitting may still be seen in later months, which we will continue to report on as we analyze the data. The stay-at-home orders may also have allowed people to devote time to writing up research conducted prepandemic; writing too can be done during down-time hours, which may have supported the increase in submissions to and reviews for AGU journals.

Plain Language Summary We analyzed submissions and review invitations to journals published by the American Geophysical Union (AGU) before and during the COVID-19 pandemic to see how various demographic groups' submitting and reviewing activities were affected by working from home and inaccessibility to research facilities. We found that submissions to AGU journals increased during the pandemic as did total submissions from women (with no difference in the proportion). The proportion of women invited to review increased from 23% before the pandemic to 24% during. Although the rate at which women agreed to review decreased slightly (down 0.5%), women still made up a larger proportion of agreed reviewers during the pandemic compared to 2 years earlier. Little difference was seen overall in median times to complete reviews except with women in their 40s and 70s, suggesting that they were affected more during the pandemic than other age and gender groups.

1. Introduction

The COVID-19 pandemic had broad effects on the scientific workforce, disrupting education, field and lab research, data collection, and more. It required many university scientists to adjust to online teaching, mentoring, and collaboration. Many women and early career researchers especially had to manage child and family care. Several studies found that the disruptions from the pandemic decreased women's article submissions overall (Andersen et al., 2020; Cui et al., 2021; Vincent-Lamarre et al., 2020) and specifically affected women in more advanced career stages (Squazzoni et al., 2020). Other studies examining submissions to Public Health (Bell & Fong, 2020) and journals (King & Frederickson, 2021) found that submissions during the pandemic increased from both men and women, but the percent increases of submissions from men were larger than those from women. However, other studies found little to no difference in submission rates of women during the pandemic (Babicz et al., 2021 [neuropsychology]; Fox & Meyer, 2021 [ecology]; Jordan & Carlezon, 2021 [biological psychiatry]; Mogensen et al., 2021; Quak et al., 2021 [radiology]). Some analyses found that especially in medical and public health fields, submissions from women on COVID-19 related articles were much lower than their share of submissions in 2020 before the pandemic, indicating that women did not have the amount of time or resources men had to pivot research and write manuscripts on the most important topic of the time (Amano-Patiño et al., 2020; Andersen et al., 2020; Cushman, 2020).

However, survey-based studies found negative impacts on productivity especially among women with young children. Krukowski et al., 2021 surveyed U.S. science, technology, engineering, math, and medical science faculty and found that men reported no difference in productivity, while women reported a significant decrease in submissions. Staniscuaski et al., 2021 produced similar results among Brazilian academics but also found that the productivity of Black women was the most impacted of all the demographic groups. Other surveys found that women reported being less productive and less satisfied with their job and work-life balance (Aubry et al., 2021; Feng & Savani, 2020). Myers et al., 2020 surveyed more than 4,500 faculty and principal investigators and found that those in fields with physical labs and time-sensitive projects saw the largest decreases in research time (30%–40% decrease). Fields such as math, economics, and health sciences found similar or more time spent on research. Aside from their scientific field, the factor most associated with a decrease in research time was having a child 0–5 years old—both for fathers and mothers. Being a woman, independent of having children, had a small, but negative effect on time devoted to research during the pandemic. Kim & Patterson, 2020 suggested that this increase in time parenting was reflected in social media posts; they analyzed tweets of male and female academics and found women tweeted more about family related issues and less about work compared to before the pandemic and compared to their male counterparts during the pandemic.

In the geosciences, the American Geosciences Institute (AGI) surveyed U.S. geoscientists throughout 2020 and 2021. Both academic and nonacademic geoscientists reported that during June through December 2020, their primary professional tasks were completing literature reviews, writing, and conducting online and computational research. Fieldwork was curtailed overall, although it increased in summer and fall but decreased in late fall through winter 2020 into 2021, and they reported that the decrease in access to facilities and decrease in personnel was affecting their work (Gonzales & Keane, 2021a). Data collected in April 2021 showed that of academic faculty, during the academic year 2020–2021 women in all tenure-related career stages reported spending more time teaching than their male peers (Gonzales & Keane, 2021b) and more female academics reported reduced work hours due to childcare and other domestic responsibilities than male academics and male and female nonacademic geoscientists (Gonzales & Keane, 2021c).

To explore these impacts for Earth and space scientists, we examined the participation of authors and reviewers by age and gender in American Geophysical Union (AGU) journals during the pandemic compared to the 2 years before it. AGU's data provides a rich view of the effects of the pandemic on scientific publishing across the world. We are able to merge publications and membership data, which include year of birth and gender information for many authors, to assess levels of participation. In the three years analyzed, almost 26,000 distinct people submitted manuscripts to AGU journals, and more than 58,000 distinct people were asked to review. As the pandemic continues with additional waves of COVID variants, and the effects of curtailed research materialize, we will continue to analyze author and reviewer data and will publish follow-up reports as appropriate.

2. Methodology

Using this approach of merging data sets, AGU has assessed authorship and reviewing participation and dynamics by author gender, country of residence, age, and race/ethnicity (Hanson et al., 2020; Lerback & Hanson, 2017; Lerback et al., 2020). In this analysis, we compare data on submissions and peer reviews in 22 AGU journals from March 2018 through February 2020 (baseline) to those from March 2020 through February 2021, the latter of which covers the period when most universities and agencies worldwide required remote work. Throughout this analysis, we analyzed gender, age, country, and race/ethnicity of the corresponding author. This is the person doing the immediate work of finalizing and submitting the manuscript, coordinating with co-authors, and overseeing revisions. For AGU journals, the corresponding author is also the first author on 72% of submitted manuscripts in the time period analyzed. Although author contribution data would provide richer information, AGU only recently implemented the CREDiT (author contribution) taxonomy, so author contribution information especially prior to the pandemic, is incomplete for comparison. We reviewed the same demographic data for first authors, and similar annual trends emerged. Throughout this paper, every subsequent instance of “author” indicates “corresponding author.”

Submission and peer review data, including the country of address of all authors, comes from AGU's article submission and peer review system whereas gender, race/ethnicity, and year of birth are from AGU member profiles (all of three of which are optional fields). We matched the peer review system profile with the member

profile using primary email address. For the 3 years analyzed, we matched 51% of authors with self-provided gender from the AGU member database and 30% with gender determined by Gender API, a gender determiner database, for a total of 81% of authors with self-provided or assumed gender (Table S1 in Supporting Information S1). Gender API returns a binary gender based on first name and country and a confidence score of each guess; in this analysis, we only included Gender API results greater than 89% confidence.

We also tested the accuracy of Gender API output by inputting author data with self-provided gender from AGU member profiles. The API assigned 67% of the authors with a binary gender at a confidence of greater than 89%. Of these, the API correctly identified 94% of women and 96% of men as such for a total of 95% correctly assessed.

51% of the distinct invited reviewers had gender from their member profile and 34% inferred from Gender API for a total of 85% with a binary gender (Table S1 in Supporting Information S1). Race/ethnicity is also matched to author and reviewer data using self-provided data from AGU member profiles, but many of the categories are U.S.-centric, so match rates were low: 13% of authors and 14% of invited reviewers had race/ethnicity matched, whereas U.S. authors and invited reviewers had higher match rates of 36% and 33%, respectively (Table S1 in Supporting Information S1).

2020 was the first year the AGU member profile included the gender choice “nonbinary,” and several individuals selected this option, but only two who appeared as authors or reviewers in our data set. In all cases, less than 0.01% of authors or reviewers identified as non-binary so these were excluded from our analysis. Proportional calculations by gender and age exclude those with gender that was neither self-provided nor able to be confidently guessed. We have tested and clarified where the results based on self-reported gender are consistent with the larger data set that includes guessed gender.

Collectively, gender, and age data allow us to disaggregate data and more precisely identify effects among specific demographic groups while decreasing the risk of incorrect gender assignment such as in studies where gender algorithms are applied to all authors. All data supporting figures and conclusions in this analysis is published on Zenodo at Wooden and Hanson, 2021.

AGU journals use a single-anonymized review process where the editor, associate editor (if used), and reviewers know the names and institutions of the authors. The reviewer may choose to sign their name to their review, which is passed on to the author within the reviewer comments, but reviewer names are not automatically sent to the author.

2.1. Submissions Before the COVID-19 Pandemic

Submissions to AGU journals have increased annually since 2015, and this trend continued into the pandemic. Between the two years before the pandemic (March 2018–February 2020) submissions increased 7% from just over 15,000 to almost 16,500 (Figure 1a). In both 2018 and 2019, overall submissions decreased slightly each season throughout each year (Figure 1b). In the 2 years before the pandemic, women submitted 23.4% and 22.7% manuscripts with authors with self-provided or API gender (Figure 1c). Submissions from women were greatest in 2018 during the Northern Hemisphere (NH) summer and in 2019 during fall (Figure 1d). In the 2 years before the pandemic, more manuscripts were submitted by men and women in their 30s than any other age cohort (among authors with self-provided age and self-provided or API gender) (Figure 2).

Submissions from China-based authors continued to outpace the growth in submissions from the US and in the 2 years before the pandemic, submissions from the US and China accounted for 30% each of all submissions. Submissions from authors in Europe remained steady between these 2 years and accounted for around 20% of submissions (Figure 3).

In the 2 years before the pandemic, of U.S. submitting authors with self-provided race/ethnicity (~40% of all authors), 62% identified as white, 17% as “other”, and 15% as Asian American. Other categories represented fewer than 10% of submitting authors (Figure S1 in Supporting Information S1).

2.2. Submissions During the COVID-19 Pandemic

From March 2020–February 2021, submissions to AGU journals increased by almost 900, a 5% increase compared to the year before (Figure 1a). This growth was smaller than the growth seen between 2018 and 2019

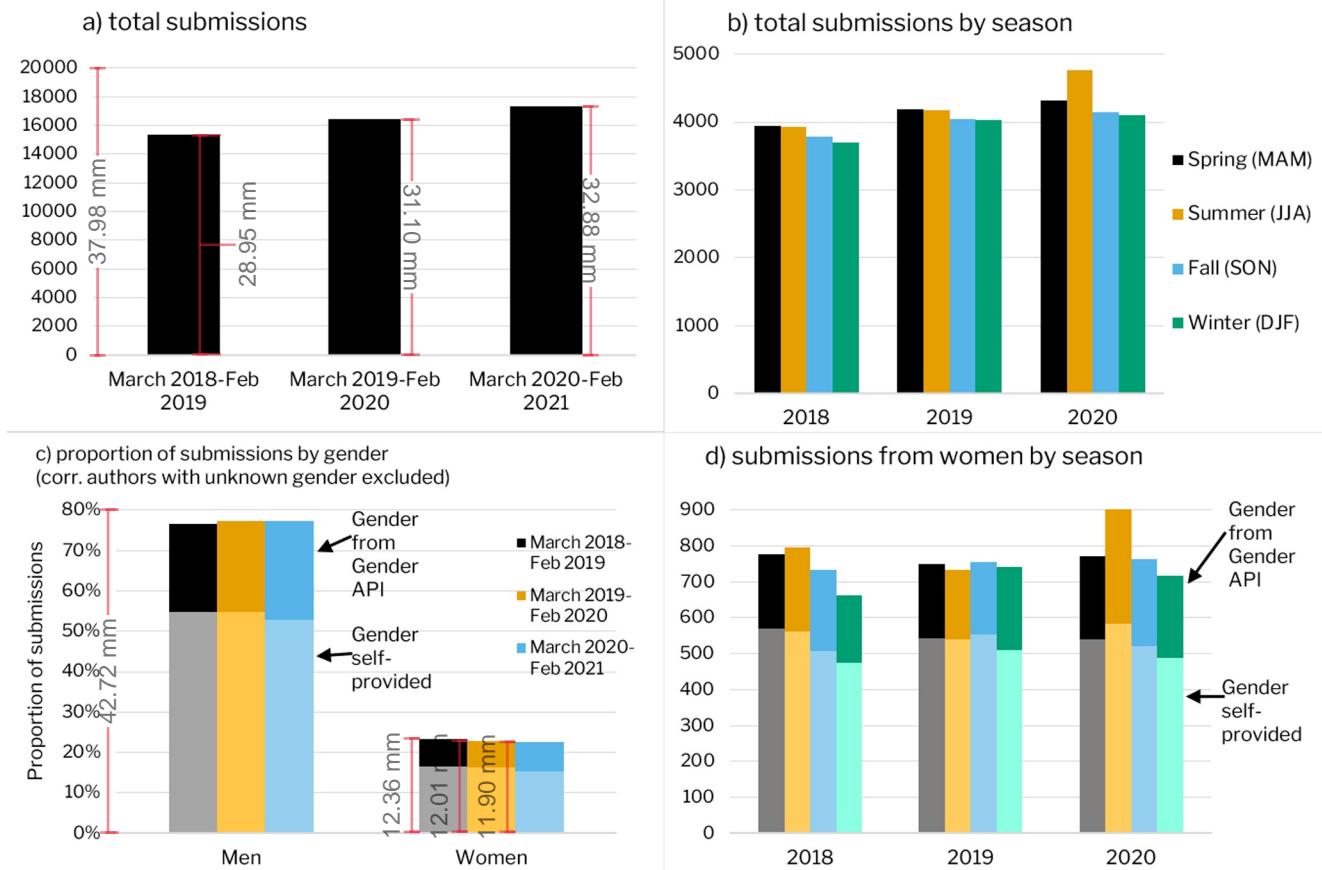


Figure 1. Count of manuscript submissions to American Geophysical Union journals before and during the pandemic with (a) counts of submissions each year, (b) counts of submissions in each Northern Hemisphere season March 2018–February 2021, (c) proportion of submissions from women and men, distinguishing submissions from authors with self-provided (lighter hue) and assumed gender from Gender API (darker hue) and submissions from unknown gender authors excluded from proportional calculations, and (d) counts of submissions from women by season March 2018–February 2021, distinguishing counts of submissions from women with self-provided gender (lighter hue) from those with gender from Gender API (darker hue). Spring season includes March, April, and May; summer includes June, July, and August; fall includes September, October, and November; and winter includes the December of that year and January and February of the following year.

(+7%) but was in the range of typical year-to-year increases in years prior to the period of this analysis. Submissions increased noticeably during the NH summer of 2020 compared to other seasons and compared to summers 2018 and 2019 (Figure 1b). This increase was likely a result of restrictions on travel and on field and lab work, which allowed time for writing manuscripts, as supported by the AGU survey results (Gonzales & Keane, 2021a).

The pandemic did not curtail submissions to AGU journals from women overall (self-provided and API gender), which was a concern at the start of the pandemic. Women submitted 176 more manuscripts to AGU journals during the pandemic compared to the two years before and at essentially the same proportion. Submissions from women also contributed to the spike in submissions during summer 2020: submissions from women in summer 2020 represented a 16% increase from spring 2020 and a 23% increase from summer 2019 (Figure 1).

The age distribution of submitting authors 2 years before the pandemic was similar to the age distribution of submitting authors during, although both men and women in their 20s submitted proportionally fewer manuscripts during the pandemic compared to the 2 years before (Figure 2). Submissions from women in their 20s decreased slightly, and submissions from men in their 40s increased slightly during the pandemic compared to two preceding years (Figure 2).

It was feared that countries where the impacts of the COVID-19 pandemic have been most severe (e.g., a high number of cases, fewer medical care facilities and resources, weaker remote work infrastructure, etc.) would show the largest decrease in scientific outputs. However, at least on a large scale as shown in Figure 3, submissions

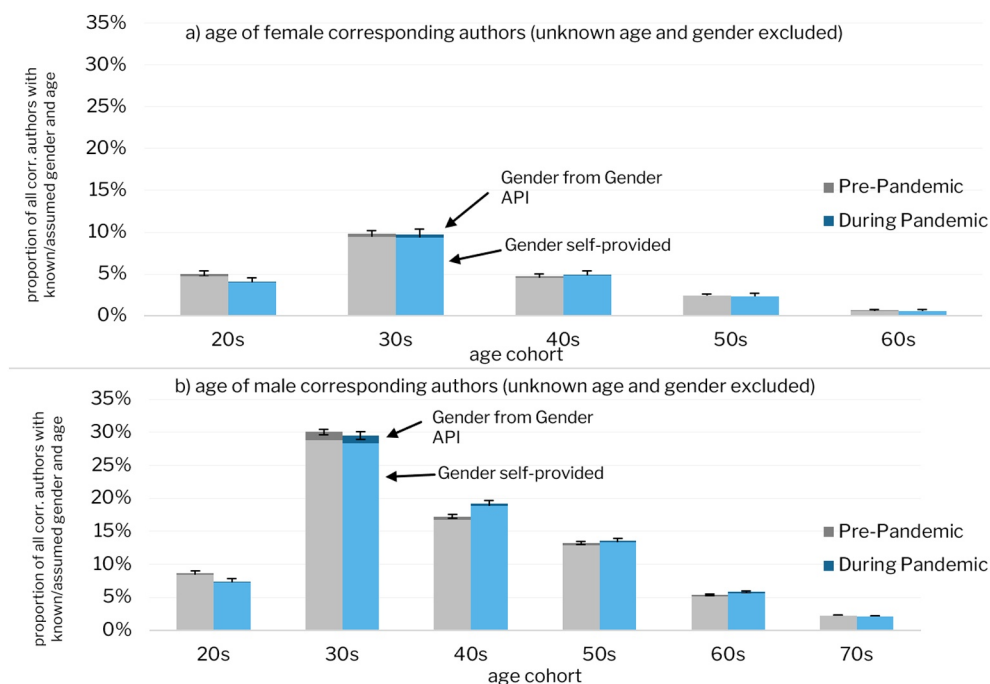


Figure 2. Proportion of submissions before and during the pandemic by age and gender of corresponding author, calculated as a proportion of total submissions with corresponding authors with self-provided or assumed gender and self-provided age (i.e., authors with unknown age or gender are excluded from proportional calculations). Graphs distinguish authors with self-provided gender from authors with assumed gender from Gender API. (a) Female authors with known age as a percentage of total authors with known age and gender and (b) male authors with known age as a percentage of total authors with known age and gender. Women older than 70 and men older than 80 not shown due to illegibility of graphs. Error bars indicate a 95% confidence interval in this and all subsequent figures with error bars.

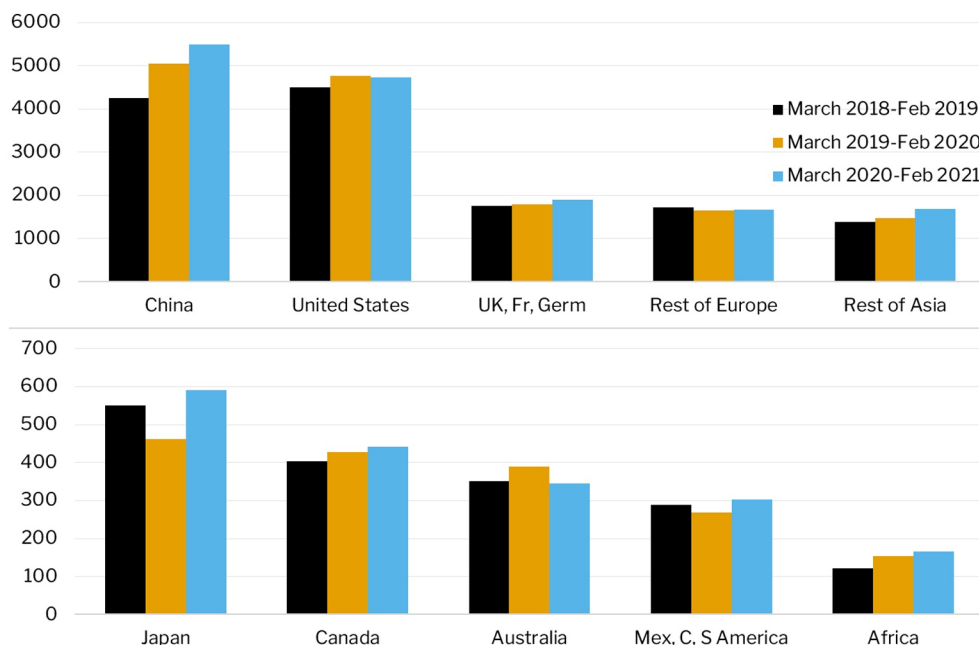


Figure 3. Submissions by country-region of author in 2 years before the pandemic and year of the pandemic; divided into (top) regions submitting the most manuscripts and (bottom) regions submitting the fewest for scale legibility.

increased from most regions during the pandemic. Although AGU journals received more submissions from China during the pandemic compared to the 2 years before, submissions from China were increasing over the past 5 years (data not shown), and this difference cannot be tied solely to the pandemic. Submissions increased significantly from authors in Germany during the pandemic compared to the two previous years (Figure S2 in Supporting Information S1) and from Japan compared to the year before, but not compared to 2 years before (Figure S2 in Supporting Information S1).

The increase in submissions from China and India were also predominantly by men, and this contributed to the smaller proportional growth in submissions from women during the pandemic and in earlier years. See for example, Figure S3 in Supporting Information S1 which shows that from March 2020–February 2021, of the authors based in China 47% were men, 8% women, and 45% of unknown gender. Of those based in India, 11% were women. In comparison, 25% of the authors from other top-submitting countries like the U.S. and U.K were women and only 5%–10% were of unknown gender.

Submissions from U.S.-based authors of racial/ethnic groups varied little before and after the pandemic, with a notable increase in the submissions from authors identifying as “Other” likely due to an increase in global participation, as some of the categories were based on American groups (e.g., “African American”) and a very slight increase in the submissions from those identifying as Hispanic/Latinx (Figure S1 in Supporting Information S1) although none of the differences are statistically significant.

2.3. Quality of Submissions

One concern was whether the increase in submissions during the pandemic was because researchers worked on lower quality manuscripts that they had not prioritized before the pandemic. We tested this hypothesis by considering the desk rejections by editors, which occur before peer review, and did not see any differences: During the pandemic 25.6% of submissions were rejected without peer review compared to 26.1% in the year before (Figure S4a in Supporting Information S1). Of the manuscripts that went through external review, the rejection rate decreased 0.6% from 38.9% in the year before to 38.2% during the pandemic (Figure S4b in Supporting Information S1).

Since AGU has been analyzing author gender data, submissions from women authors have been accepted at a higher rate than those for men and unknown gender (see especially Lerback et al., 2020). A more recent study examining 145 journals across many fields also found women-authored manuscripts were accepted at a higher rate than submissions from men (Squazzoni et al., 2020). In the 2 years before the pandemic and the year of the pandemic, 6%–7% more manuscripts with female corresponding authors were accepted than those with male corresponding authors, as seen in Figure 4.

2.4. Peer Review Before the Pandemic

In the two years before the pandemic, 76% and 73% of all submissions were sent to peer review, which required more than 54,000 and more than 58,000 reviewer invitations, respectively (Figure 5a). Reviewer agree rates were similar in both years at 46.5% and 45.8% (Figure 6a). In both years, 22%–23% of the review invitations were to women (proportional calculation excludes invitations sent to those with unknown gender)—with more than 12,000 requests sent to women each year. U.S.-based reviewers received 45% of total review invitations, while Europe-based reviewers received 33% each year; although proportionally still low, the review invitations sent to scientists in China increased over the past 3 years (Figure 5c).

Before the pandemic, women accepted 45% and 43% of the invitations each year, only slightly lower than men, who agreed to review at a rate of 46% in both years (Figure 6a). Younger reviewers accepted more often than more senior reviewers, and women in their 50s and 60s accepted least often. Men agreed to review at a higher rate overall compared to women and within each age cohort (Figures 6b and 6d).

Female reviewers were younger than male reviewers, in part reflecting the overall demographics of the AGU membership and as also reflected in the median age of physical sciences doctorates in the US (median age for

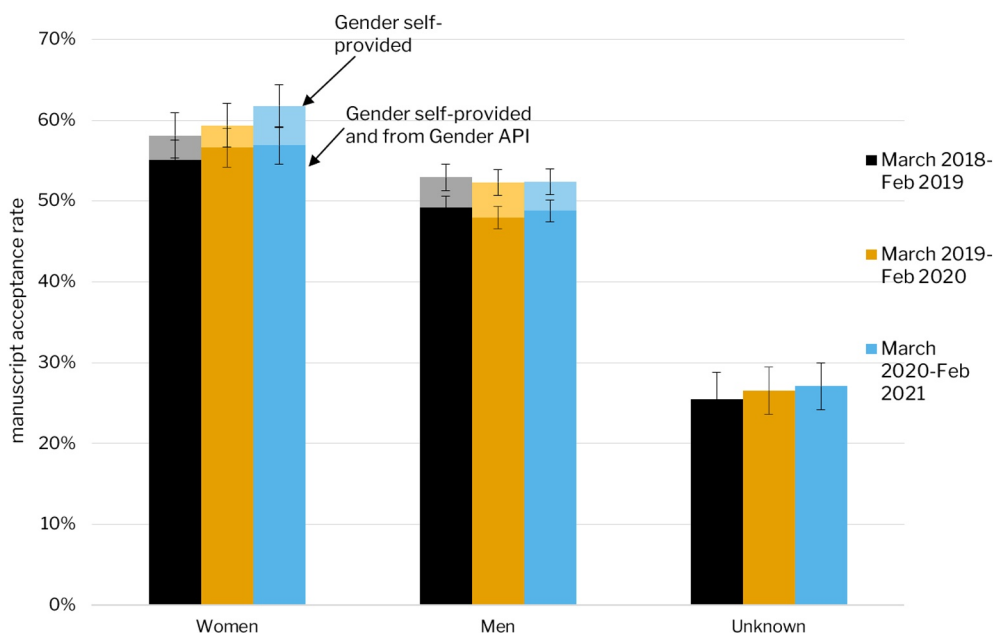


Figure 4. Acceptance rates by corresponding author gender distinguishing acceptance rates of those with self-provided gender from self-provided and guessed gender. Acceptance rates of manuscripts from authors with self-provided gender are calculated by dividing their accepted submissions by their total submissions with final decision. Acceptance rates of total men and women (both self-provided and assumed gender) are similarly calculated.

women is 40; men 50) (National Science Foundation, 2021). Women in their 30s made up 45% of the female reviewers (Figure 7a) whereas men in their 30s only accounted for 31% of male reviewers (Figure 7b). Men in their 50s and 60s made up a larger proportion of male reviewers (Figure 7b) than women in their 50s and 60s did of female reviewers (Figure 7a).

2.5. Peer Review During the Pandemic

During the pandemic, 620 more submissions were sent to review than the year before, but in both years, this represented 73% of submissions. Total review invitations increased by about 1,400 during the pandemic, a 2% increase in the number of invitations sent (Figure 7a).

Invitations to women increased by ~1,000, a 1% increase in the proportion of invitations to women (Figure 5). Also increased were invitations to reviewers in most country-regions and especially to researchers in China, continuing a trend seen before the pandemic: in the year before the pandemic, invitations to China-based reviewers accounted for 6.1% but increased to almost 7% during the pandemic.

Women accepted 0.5% fewer invitations during the pandemic compared to the earlier period, following a larger decrease between 2018 and 2019; thus, the cause of the change may be unrelated to the pandemic. And, as we heard from anecdotes, some people had more time to review while others had less.

During the pandemic, acceptance rates by reviewers in various countries showed little variation compared to prepandemic rates and none of the differences were statistically significant, so figures are not shown here.

Women in their 20s, 70s, and 40s declined at a higher rate during the pandemic compared to prepandemic periods. In turn, relatively fewer men in their 20s accepted than in the 2 years before; however, none of these differences were statistically significant (Figure 6b). We found that younger scientists were more eager to review, as men and women in their 20s and 30s had the highest agree rates. By the end of the first year of the pandemic,

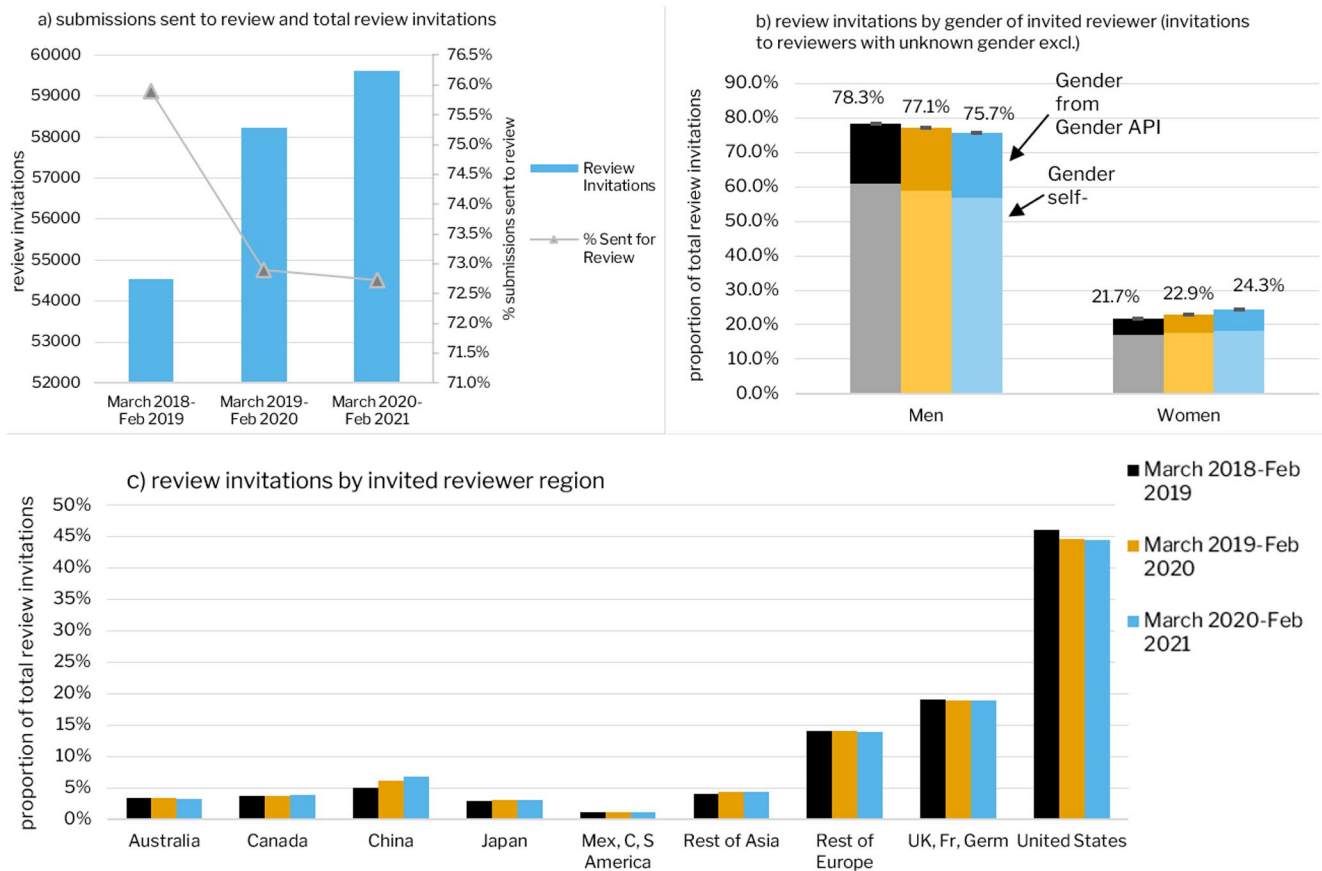


Figure 5. (a) Submissions sent to review and reviewer invitations sent in years before and during the pandemic. (b) Proportion of review invitations to women and men distinguishing those with self-provided and assumed gender (proportional calculations exclude invitations to those with unknown gender). (c) Proportion of review invitations by invited reviewer region.

women comprised 22% of the total reviewers with self-provided and assumed gender, a slight increase from the two previous years (Figure 6c).

We see in Figure 7a a slightly higher proportion of men and women in their 30s contributing reviews and a slightly lower portion of women in their 40s, 50s, and 60s contributing reviews. However, none of these differences are statistically significant from year's before the pandemic. We also see in Figure 7a that women in their 30s made up a larger proportion of total female reviewers than men in their 30s made up of total male reviewers. The age and gender distribution across the *entire* reviewer pool varied insignificantly (by 1% or less) prepandemic compared to during it (Figures 7c and 7d).

During editor board meetings, some editors expressed fear of inviting women to review too often because of a potential increase in women's childcare and teaching responsibilities. Indeed, Figure 8 shows fewer review invitations per woman than per man (determined by email address). However, editors expanded the number of distinct individuals invited to review ("reviewer pool") from more than 31,000 in the year before the pandemic to more than 34,000 during the pandemic and invited the same people less often than before the pandemic and across all gender groups. In all 3 years, before and during the pandemic, editors invited the same women less often than the same men as shown in Figure 8.

2.6. Review Process

The average days to complete reviews during the pandemic changed negligibly compared to years before (the median days to review remained at 21 days in all three periods) as seen in Figure 9.

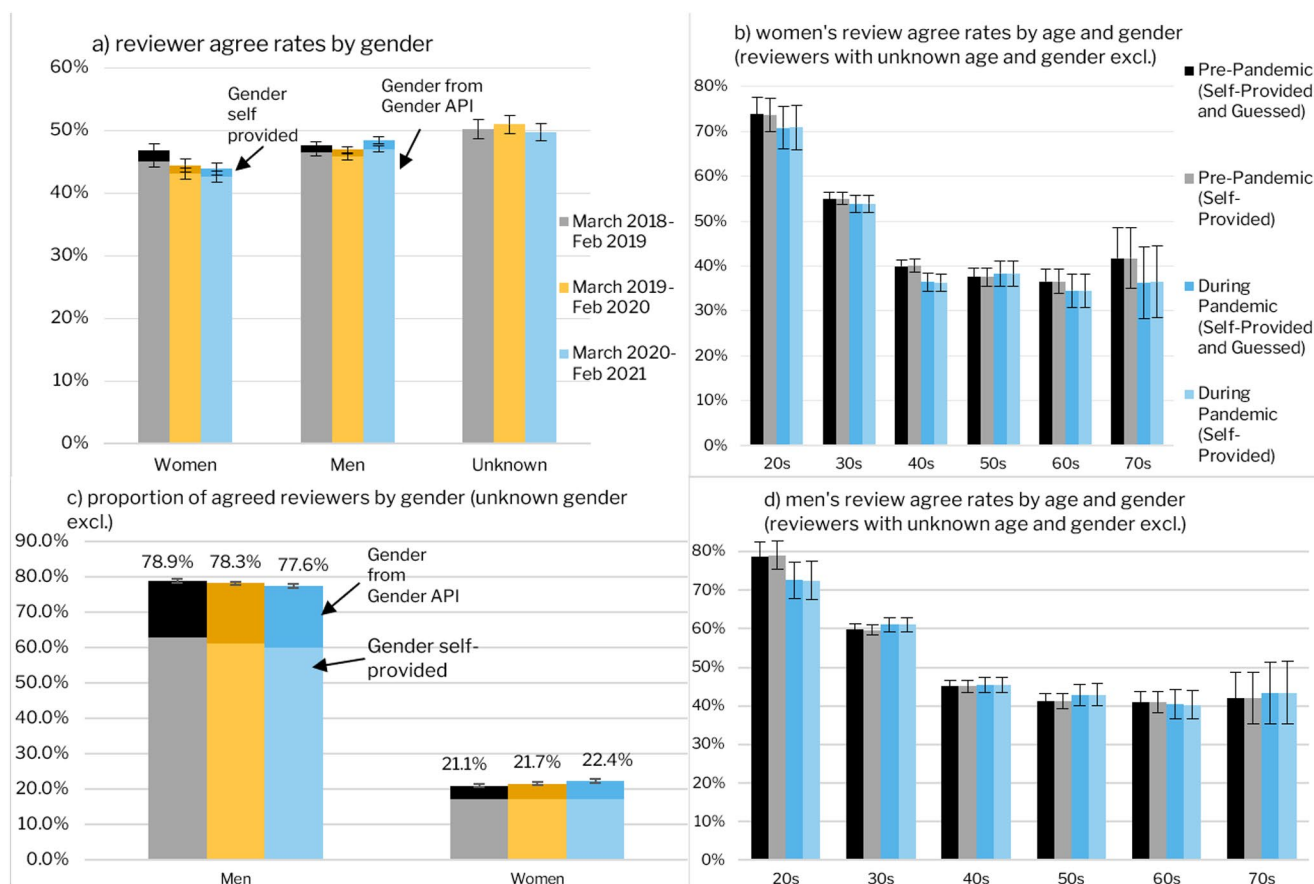


Figure 6. Reviewer agree rates by (a) gender, (b) women's age cohort and (d) men's age cohort. (c) Proportion of female (agreed) reviewers.

Women in their 20s and 40s took more time to complete their reviews, about 2 and 3 additional days, respectively, during the pandemic than in the two earlier periods. Review periods of men showed negligible differences before and during the pandemic (Figure 9). This difference by age and gender may be a signal in our data that women had less time for reviewing activities.

3. Conclusion

The COVID-19 pandemic has had many and sometimes dramatic effects on the science workforce and students, career development, teaching, mentoring, and more. Greater impacts have been reported for especially women with children and to a lesser extent, men with children (Aubry et al., 2021; Byrom, 2020; Feng & Savani, 2020; Kim & Patterson, 2020; Krukowski et al., 2021; Myers et al., 2020; Squazzoni et al., 2020; Staniscuaski et al., 2021; Vincent-Lamarre et al., 2020). Effects on scholarly publishing and other activities (such as meeting participation) have varied by discipline (Fox & Meyer, 2021; Korbel & Stegle, 2020; Mogensen et al., 2021). Some research in the Earth and space sciences has been particularly impacted as field campaigns were canceled or delayed, lab access interrupted, and hands-on instruction canceled (Gonzales & Keane, 2021a, 2021b, 2021c). Overall, after 1 year of the pandemic, the effects on submissions and participation as reviewers for AGU journals are not readily apparent. Most differences seen from earlier years are slight (a few percent variations) and generally within year-to-year variability.

AGU journal submissions continued to increase during the pandemic, perhaps due to the reported increase in writing and online research, tasks conducive to staying at home. Any reduction in laboratory and on-site research might manifest itself later in 2022, but as of the publication of this paper, we had a 3.7% decrease in submissions

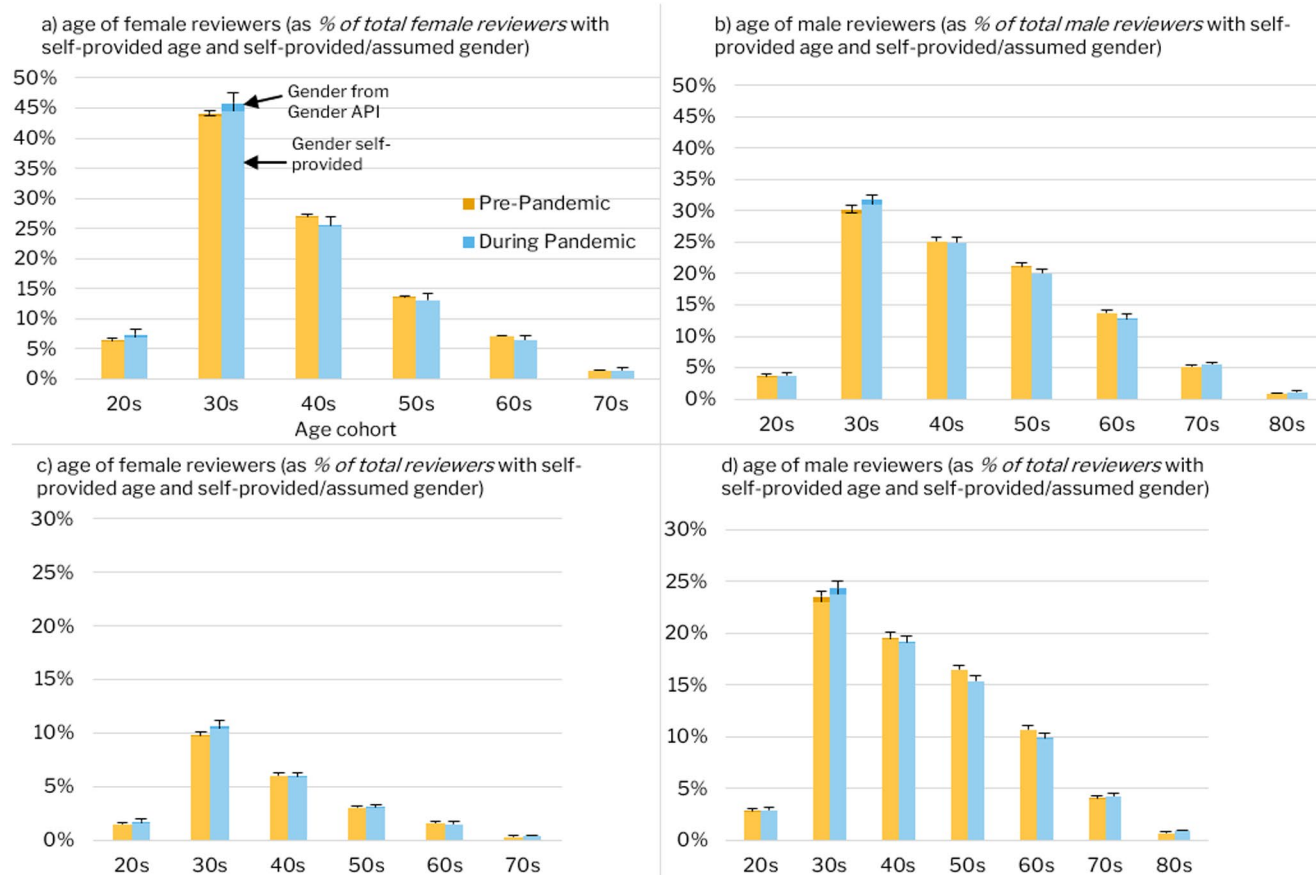


Figure 7. Distribution of reviewers by age and gender before the pandemic (March 2018–February 2020) and during the pandemic (March 2020–February 2021). (a) Age of female reviewers calculated as a percentage of total female reviewers with known age and self-provided or assumed gender; (b) age of male reviewers calculated as a percentage of total male reviewers with known age and self-provided or assumed gender; (c) age of female reviewers calculated as a percentage of all reviewers with known age and self-provided or assumed gender; and (d) age of male reviewers calculated as a percentage of all reviewers with known age and self-provided or assumed gender.

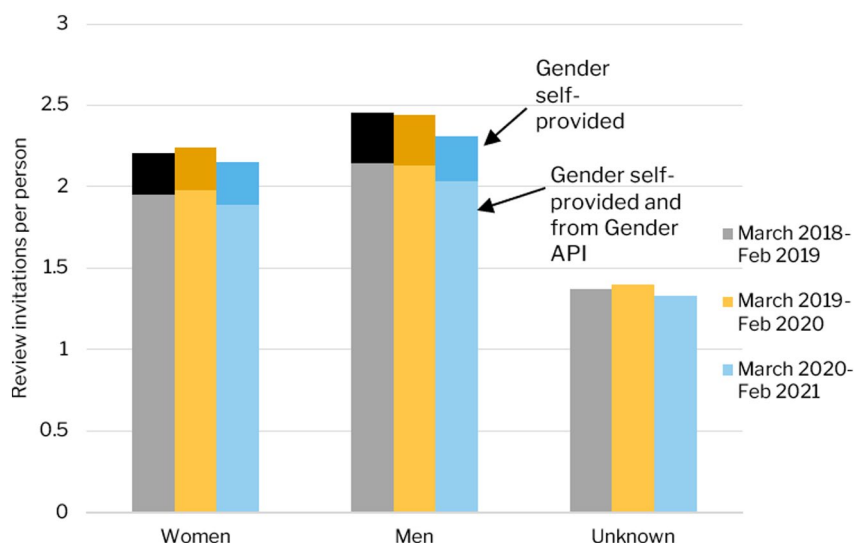


Figure 8. Review invitations per person (determined by email address) by gender of invited reviewer.

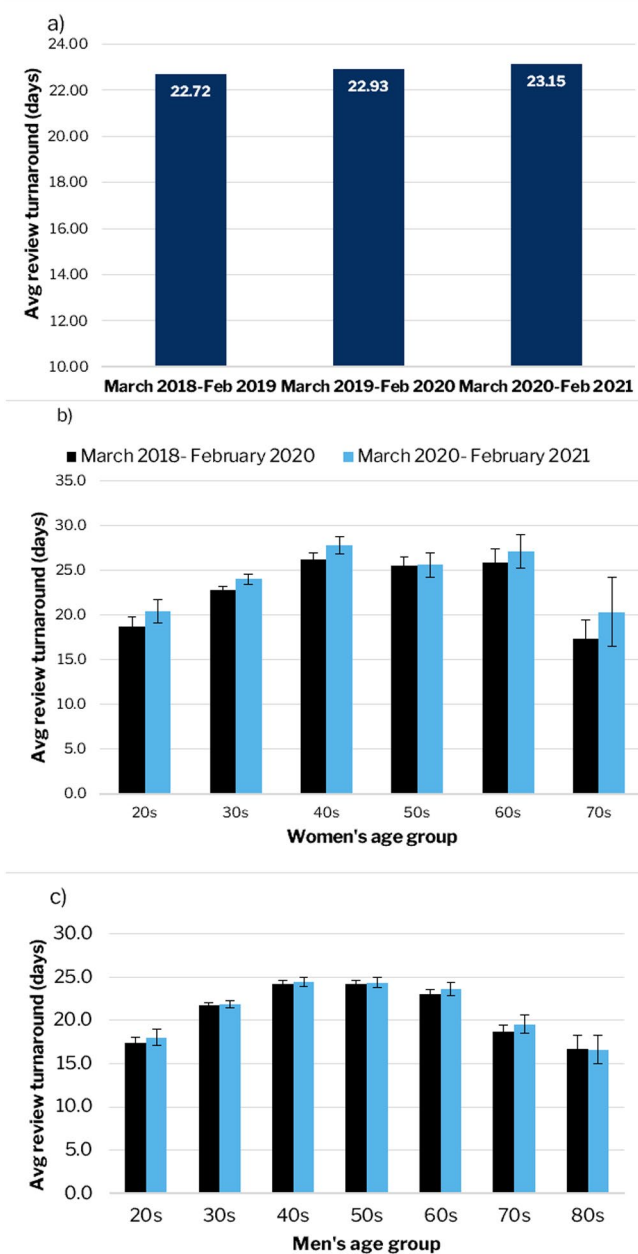


Figure 9. Average review duration (days) before and during pandemic of (a) all reviewers in each period before the pandemic and during the pandemic, and (b) women, and (c) men by age in the two periods (combined) before the pandemic and during the pandemic. Average review turnaround times between self-provided and assumed gender vary only in men and women in their 20s (and each by 0.1 day), so self-provided and Gender API genders are not distinguished in Figures 9b and 9c.

compared to 2020. During the pandemic, although total counts of submissions from women increased, the proportion of submissions from women stayed consistent with previous years. This flattening of the proportion of submissions from women is partly from the increase in submissions from China (and to a lesser extent India). In 2020, submissions increased from all countries with historically the most submissions to AGU journals, and especially from China. The increase in submissions during the summer months of 2020 perhaps were due to travel restrictions and a lull in university teaching and homeschooling, and submissions from women contributed to this seasonal increase. Submissions from U.S.-based men and women in their 20s decreased during the pandemic while submissions from men and women in their 30s increased, although none of the differences were statistically significant. The increased submission rate did not seem to decrease manuscript quality: the rate of desk rejects during the pandemic were similar to those in the 2 years before, and the proportion of submissions receiving a revise decision increased.

An increase in total manuscripts sent to review required an increase in invitations to reviewers during the pandemic. Women, reviewers in their 20s, and China-based reviewers were invited more during the pandemic compared to the 2 years before. And fewer invites per person and an increase in final reviewers suggest editors expanded their reviewer pool. Review turnaround times remained relatively similar during the pandemic except with women in their 20s and 40s, while differences among male age cohorts were not observed.

It is difficult to assign any of these relatively slight changes to the effects of the pandemic. There may be several reasons that, despite the known impacts, large changes in publishing activities are not apparent. One is that this is an activity that could continue relatively easily, and given the importance of publishing in career advancement, was prioritized, including by those who were particularly impacted by the pandemic such as women and early career researchers. This is borne out in some survey results regarding how researchers prioritized their time (Gonzales & Keane, 2021a, 2021b, 2021c). As shown earlier, manuscripts authored by women have higher acceptance rates than those of men in AGU and other journals (and this continued during the pandemic) (Lerback et al., 2020; Squazzoni et al., 2020). This may indicate that women are taking greater care and fewer risks, and prioritizing quality submissions, and this behavior and attention may have continued during the pandemic. Another explanation is that the impacts were not immediate and will emerge in later studies. This is certainly the case for delayed research, as manuscript completion may lag by months to years. We will continue to monitor these dynamics and publish updated reports as appropriate.

Data Availability Statement

All data supporting this analysis are available through <https://doi.org/10.5281/zenodo.5879313>.

Acknowledgments

The authors thank two anonymous reviewers for their comments. This analysis merges a data set on unpublished AGU manuscripts with member-provided data on year of birth, gender, and personal emails. Analysis and publication of aggregate summary data are consistent with AGU's privacy policy (<https://www.agu.org/Privacy-Policy>) and can be found in Zenodo (10.5281/zenodo.5879313). The matched member data are covered under AGU's privacy policy and cannot be released publicly. Further availability of member data is possible for research under specific nondisclosure agreements by contacting AGU at AGU's discretion.

References

- Amano-Patiño, N., Faraglia, E., Giannitsarou, C., & Hasna, Z. (2020). *The unequal effects of COVID-19 on economists' research productivity*. *Cambridge working papers in economics* (Vol. 22). Retrieved from <https://econpapers.repec.org/RePEc:cam:camdae:2038>
- Andersen, J. P., Wullum Nielsen, M., Simone, N. L., Lewiss, R. E., & Jagsi, R. (2020). Meta-research: COVID-19 medical papers have fewer women first authors than expected. *Elife*, 9, e58807. <https://doi.org/10.7554/elife.58807>
- Aubry, L. M., Laverty, T. M., & Ma, Z. (2021). Impacts of COVID-19 on ecology and evolutionary biology faculty in the United States. *Ecological Applications*, 31(2), e02265. <https://doi.org/10.1002/eap.2265>
- Babicz, M. A., Matchanova, A., Broomfield, R., DesRuisseaux, L. A., Gereau, M. M., Brothers, S. L., et al. (2021). Was the COVID-19 pandemic associated with gender disparities in authorship of manuscripts submitted to clinical neuropsychology journals? *PsyArXiv*. <https://doi.org/10.31234/osf.io/5e6sm>
- Bell, M. L., & Fong, K. C. (2020). Gender differences in first and corresponding authorship in public health research submissions during the COVID-19 pandemic (2020). *American Journal of Public Health*, 111(1). <https://doi.org/10.2105/ajph.2020.305975>
- Byrom, N. (2020). COVID-19 and the research community: The challenges of lockdown for early-career researchers. *Elife*, 9, e59634. <https://doi.org/10.7554/elife.59634>
- Cui, R., Ding, H., & Zhu, F. (2021). Gender inequality in research productivity during the COVID-19 pandemic. *Manufacturing & service operations management*, forthcoming, available at SSRN: <https://doi.org/10.2139/ssrn.3623492>
- Cushman, M. (2020). Gender gap in women authors is not worse during COVID-19 pandemic: Results from research and practice in thrombosis and haemostasis. *Research and Practice in Thrombosis and Haemostasis*, 4(5), 672–673. <https://doi.org/10.1002/rth2.12399>
- Feng, Z., & Savani, K. (2020). Covid-19 created a gender gap in perceived work productivity and job satisfaction: Implications for dual-career parents working from home. *Gender in Management*, 35(7/8), 719–736. <https://doi.org/10.1108/gm-07-2020-0202>
- Fox, C. W., & Meyer, J. (2021). The influence of the global COVID-19 pandemic on manuscript submissions and editor and reviewer performance at six ecology journals. *Functional Ecology*, 35, 4–10. <https://doi.org/10.1111/1365-2435.13734>
- Gonzales, L., & Keane, C. (2021a). *COVID-19 impacts to geoscience research, June–December 2020*. *Geoscience currents*, January 2021. American Geosciences Institute. Data Brief 2021-002. Retrieved from <https://www.americangeosciences.org/geoscience-currents/covid-19-impacts-geoscience-research-june-december-2020>
- Gonzales, L., & Keane, C. (2021b). *Academic activities by gender and faculty rank during the pandemic*. *Geoscience currents*. American Geosciences Institute. Data Brief 2021-019(AGI). Retrieved from <https://www.americangeosciences.org/geoscience-currents/academic-activities-gender-and-faculty-rank-during-pandemic>
- Gonzales, L., & Keane, C. (2021c). *Caregiving and domestic responsibility impacts from the pandemic*. *Geoscience currents*. American Geosciences Institute. Data Brief 2021-020(AGI). Retrieved from <https://www.americangeosciences.org/geoscience-currents/caregiving-and-domestic-responsibility-impacts-pandemic>
- Hanson, B., Wooden, P., & Lerback, J. (2020). Age, gender, and international author networks in the earth and space sciences: Implications for addressing implicit Bias. *Earth and Space Science*, 7, e2019EA000930. <https://doi.org/10.1029/2019ea000930>
- Jordan, C. J., & Carlezon, W. A. (2021). Effects of the COVID-19 pandemic on gender representation among corresponding authors of Neuropsychopharmacology (NPP) manuscripts: Submissions during January–June, 2020. *Neuropsychopharmacol*, 46, 269–270. <https://doi.org/10.1038/s41386-020-00869-4>
- Kim, E., & Patterson, S. (2020). *The pandemic and gender inequality in academia*. SSRN.
- King, M., & Frederickson, M. (2021). *The pandemic penalty: The gendered effects of COVID-19 on scientific productivity*. *Socius sociological research for a dynamic World*. <https://doi.org/10.1177/23780231211006977>
- Korbel, J. O., & Stegle, O. (2020). Effects of the COVID-19 pandemic on life scientists. *Genome Biology*, 21, 113. <https://doi.org/10.1186/s13059-020-02031-1>
- Krukowski, R. A., Jagsi, R., & Cardel, M. I. (2021). Academic productivity differences by gender and child age in science, technology, engineering, mathematics, and medicine faculty during the COVID-19 pandemic. *Journal of Women's Health*, 30(3), 341–347. <https://doi.org/10.1089/jwh.2020.8710>
- Lerback, J., & Hanson, B. (2017). Journals invite too few women to referee. *Nature*, 541, 455–457. <https://doi.org/10.1038/541455a>
- Lerback, J. C., Hanson, B., & Wooden, P. (2020). Association between author diversity and acceptance rates and citations in peer-reviewed earth science manuscripts. *Earth and Space Science*, 7, e2019EA000946. <https://doi.org/10.1029/2019ea000946>
- Mogensen, M. A., Lee, C. I., & Carlos, R. C. (2021). The impact of the COVID-19 pandemic on journal scholarly activity among women contributors. *Journal of the American College of Radiology*, 18(7), 1044–1047. <https://doi.org/10.1016/j.jacr.2021.01.011>
- Myers, K. R., Tham, W. Y., & Yin, Y. (2020). Unequal effects of the COVID-19 pandemic on scientists. *Nature Human Behaviour*, 4, 880–883. <https://doi.org/10.1038/s41562-020-0921-y>
- National Science Foundation. (2021). *National center for science and engineering statistics, Scientists and Engineers Statistical data system (SESTAT)*. Available at <http://www.nsf.gov/statistics/sestat/>
- Quak, E., Girault, G., Aude Thenint, M., Weyts, K., Lequesne, J., & Lasnon, C. (2021). Author gender inequality in medical imaging journals and the COVID-19 pandemic. *Radiology*, 300(1), E301–E307. <https://doi.org/10.1148/radiol.2021204417>
- Squazzoni, F., Bravo, G., Grimaldo, F., Garcia-Costa, D., Farjam, M., & Mehmani, B. (2020). Only second-class tickets for women in the COVID-19 race. A study on manuscript submissions and reviews in 2329 Elsevier Journals. *PLoS ONE*, 16(10), e0257919. <https://doi.org/10.2139/ssrn.3712813>
- Staniscuaski, F., Kmetzsch, L., Soletti, R. C., Reichert, F., Zandonà, E., Ludwig, Z. M. C., et al. (2021). *Gender, race and parenthood impact academic productivity during the COVID-19 pandemic: From survey to action*. *Frontiers in psychology*. <https://doi.org/10.3389/fpsyg.2021.663252>
- Vincent-Lamarre, P., Sugimoto, C., & Larivière, V. (2020). The decline of women's research production during the coronavirus pandemic. *Nature News*. Retrieved from <https://www.natureindex.com/news-blog/decline-women-scientist-research-publishing-production-coronavirus-pandemic>
- Wooden, P., & Hanson, B. (2021). Datasets for "effects of the COVID-19 pandemic on authors and reviewers of American Geophysical Union Journals". [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.5879313>