

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

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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.

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 affect 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). Fewer men and women in their 20s submitted articles and more men in their 40s submitted articles. 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 two 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 the participation of women in AGU journals, the lag between research and writing/submitting may still be seen in later months. The stay-at-home orders may also have allowed people to devote time to writing up research conducted pre-pandemic; writing too can be done at 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 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 two 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.

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 teamwork. 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 (Vincent-Lamarre et al., 2020; Andersen et al., 2020; Cui et al., 2021) and specifically affected women in more advanced career stages (Squazzoni et al., 2020). Other studies examining specific fields found that submissions during the pandemic increased from both men and women authors, but the percent increases of submissions from men were larger than those from women (Bell & Fong, 2020; King & Frederickson, 2021). However, other studies of other disciplines found little to no difference in submission rates of women during the pandemic (Fox & Meyer, 2020 (ecology); Mogensen et al., 2021; Quak et al., 2021 (radiology) Jordan & Carlezon, 2020 (biological psychiatry); Babicz et al., 2021 (neuropsychology)).

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 didn’t have the kind of time or resources men had to pivot their research and write

papers 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. STEMM faculty and found that men reported no difference in productivity, while women reported a significant decrease in submissions. Staniscuaski at al., 2020 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 (Feng & Savani, 2020; Aubry et al., 2021). Myers et al., 2020 surveyed more than 4500 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 women, independent of having children, had a small, but negative effect on time devoted to research during the pandemic. Kim & Patterson 2020 suggest this increase in time parenting was expressed in social media; they analyzed tweets of men and women academics and found women tweeted more about family related issues and less about work than before the pandemic and compared to their male counterparts during the pandemic.

In the geosciences, the American Geosciences Institute (AGI) regularly surveyed U.S. geoscientists throughout 2020 and 2021. Both academic and non-academic geoscientists reported that 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 reported that the decrease in access to facilities and decrease in personnel was affecting their work (Gonzales & Keene, 2021a). The most recent data showed that of academic faculty, women in all tenure-related career stages spent more time teaching than their male peers (Gonzales & Keane, 2021b) and more women academics reported reduced work hours due to childcare and other domestic responsibilities than male academics and male and women non-academic geoscientists (Gonzales & Keane, 2021c).

To explore these impacts further for Earth and space scientists, we examined the participation of authors and reviewers by age and gender in AGU journals during the pandemic in comparison to that for several years before it.

Methodology

AGU has assesses submissions and publications by author gender, country of residence, age, and race/ethnicity (Hanson et al., 2020; Lerback *et al.* 2020)

and review invitations and reviewer demographics (Hanson and Lerback, 2017). 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 time when most universities and agencies required remote work.

Submission and peer review data, including the country of address of all authors, comes from our submission and peer review system while gender, race/ethnicity, and year of birth are from AGU’s members’ profiles. We matched author and reviewer data with member data using primary email address. For the time period analyzed, we matched 81% of corresponding authors for gender, 50% for age, and 36% for race/ethnicity (U.S. only) (Table S1). 90% of our reviewers had known gender, 49% known age and gender, and 36% race/ethnicity of U.S.-based reviewers (Table S2).

2020 was the first year the AGU member profile included the gender choice “non-binary,” and several individuals selected this option, but only two who appeared as authors or reviewers in our dataset. In all cases, participation in our journals program of non-binary is less than .01% so is excluded from figures in this analysis.

We also used the third-party gender-name database Gender-API to infer the gender of those for whom we did not have gender data. Gender-API returns a binary gender based on first name and country and a confidence score of the guess; for this analysis, we used results higher than 89% confidence, but gender analysis without guessed gender produced similar results. The resulting gender proportions were: 22% distinct corresponding authors were women, 62% men, and 16% with no gender identification (Table S3). 21% of invited reviewers were women, 64% men, and 15% unknown gender (Table S4).

Collectively, gender, age, and ethnicity 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 & Hanson, 2021.

Submissions Before the COVID-19 Pandemic

Annual submissions to AGU journals have increased annually since 2015, and this trend continued into the pandemic. Between the two periods before the pandemic (March- February) submissions increased 7%--from just over 15,000 to almost 16,500 (Figure 1a). In both 2018 and 2019, we saw a slight decrease in submissions each season as the year progressed (Figure 1a).

Throughout this analysis, we analyze gender, age, and country of the corresponding author (typically the person submitting the paper), since this is the person doing the immediate work of finalizing the manuscript, coordinating

with co-authors, submitting, and overseeing article revisions. About 85% of our submissions have the corresponding author listed first in the author list. We reviewed the same data for 1st authors, and similar annual trends emerged.

In the two periods before the pandemic, women represented 23.4% and 22.7% of the submitting authors (Figure 1c). Submissions from women by season varied between 2018 and 2019 with (Northern Hemisphere) summer 2018 seeing the most submissions from women that year and fall 2019 seeing the most in that year (Figure 1d). In the two periods before the pandemic, men in their 30s submitted the most manuscripts, representing almost 30% of all submissions from corresponding authors with known age and gender, while women's largest age group were also those in their 30s contributing almost 10% of submissions (Figure 2).

Submissions from China-based authors continued to outpace the growth in submissions from the U.S., and in the two years before the pandemic, submissions from each country accounted for 30% of total submissions. Submissions from Europe remained steady between these two years and accounted for around 20% of submissions, with annual submission counts shown in Figure 3.

AGU's race/ethnicity categories have been based on U.S. census categories and currently apply to U.S.-based authors (these will be updated soon to apply more broadly to a global community). In the periods before the pandemic, of U.S. submitting authors with known/declared 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 S3).

Submissions During the COVID-19 Pandemic

During the pandemic March 2020- February 2021, submissions increased by almost 900, a 5% increase from the earlier period. This was smaller growth than the increase in 2019 from 2018 (7% growth) but in the range of typical year-to-year increases for the past several years (Figure 1a). Submissions increased noticeably during the Northern Hemisphere summer of 2020 compared to other seasons and compared to the summer months in 2018 and 2019 (Figure 1b). This increase was likely a result of restrictions on travel and field and lab work that allowed time for writing papers as suggested by aforementioned AGI survey results (Gonzales & Keene, 2021a).

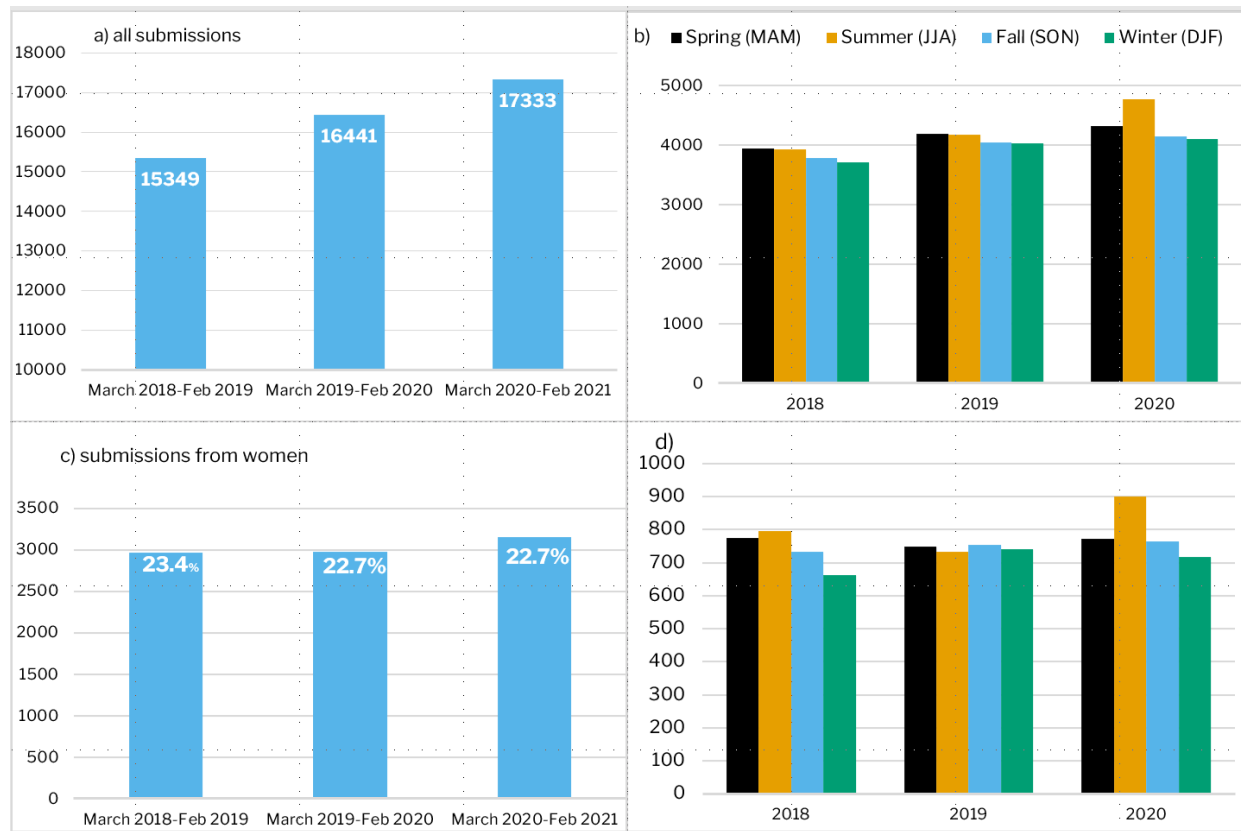


Figure 1: Article submissions in periods before and during the pandemic with a) total articles each period, b) submissions in each Northern Hemisphere season March 2018-February 2021, c) submissions from women, and d) submissions from women by season March 2018-February 2021. Spring season includes March, April, May; summer - June, July, August; fall - September, October, November; winter includes the December of that year and January and February of the following year.

The pandemic did not curtail submissions to AGU journals from women overall, which was a concern at the start of the pandemic. Women corresponding authors submitted 176 more papers to AGU journals during the pandemic compared to the earlier period and at essentially the same proportion as earlier periods. Submissions from women also contributed to the spike in submissions during summer 2020, with a 16% increase in June, July, and August 2020 compared to the spring months of 2020 and 23% increase compared to summer 2019 (Figure 1).

By age, the proportion of submitting authors two years before the pandemic was similar to the proportion during the pandemic though both men and women in their 20s submitted proportionally fewer manuscripts during the pandemic

compared to the two periods prior. Differences were found in the decrease in submissions from women in their 20s and the increase in submissions from men in their 40s during the pandemic compared to two preceding periods (Figure 2), though not statistically significant.

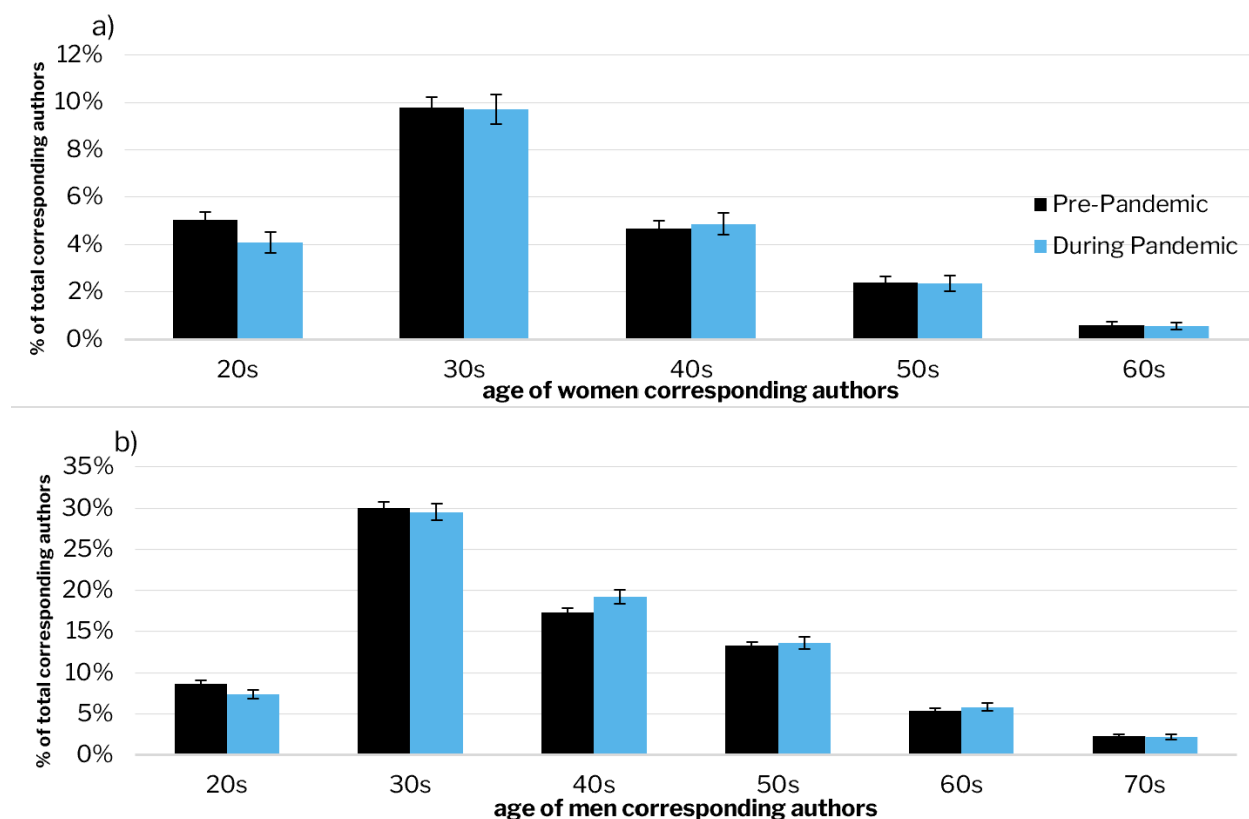


Figure 2: Proportions of submissions pre-pandemic and during by age and gender of submitting author with a) showing age of women corresponding authors with known age as a percentage of total authors with known age and gender and b) men corresponding authors with known age as a percentage of all corresponding 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 showing error bars.

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 7, submissions increased from most regions during the pandemic. Though we received many more submissions from China during the pandemic compared to prior periods, submissions from China have been growing strongly in the past

5 years and this difference cannot be tied solely to the pandemic.

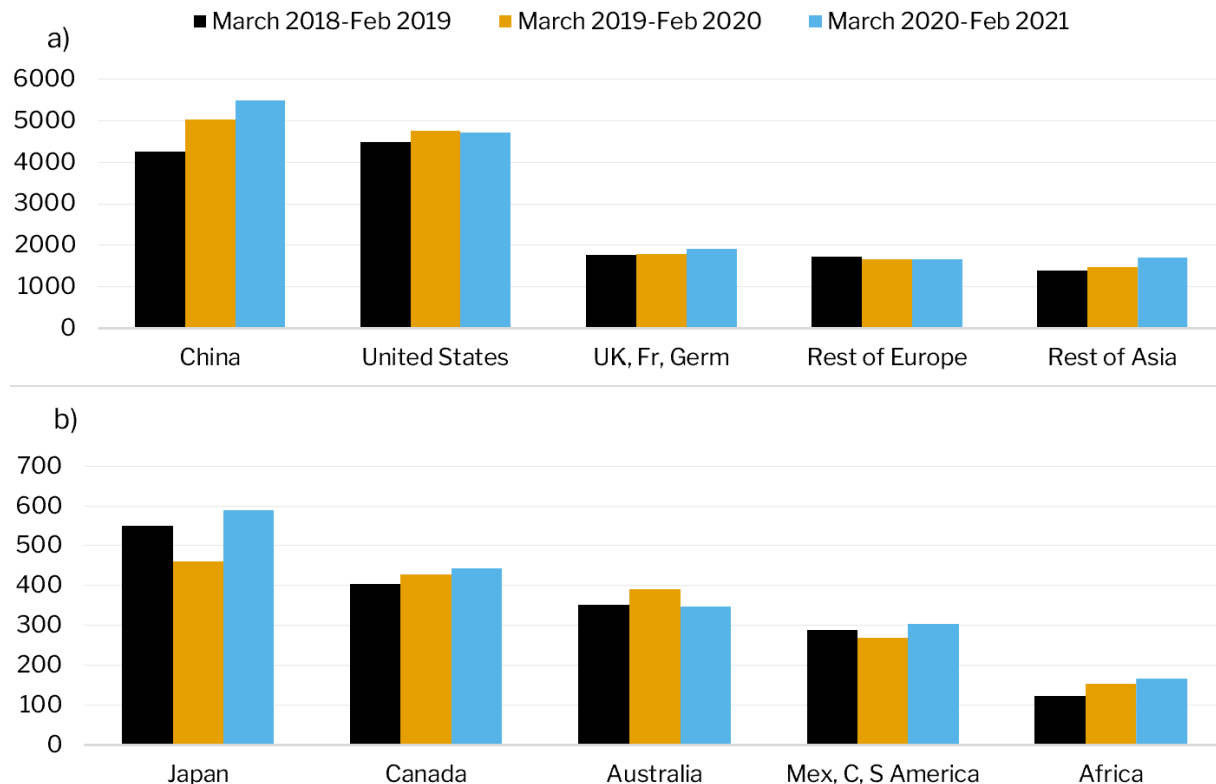


Figure 3: Submissions by country-region of corresponding author in two periods before the pandemic and year of the pandemic; divided into a) regions submitting the most manuscripts and b) regions submitting the fewest for scale legibility.

Of the other top submitting countries, we see a statistically significant increase in submissions from Germany during the pandemic compared to the two previous periods (Figure S1). We see a statistically significant increase in submissions from Japan during the pandemic compared to the year before, but not compared to two years before (Figure S1).

The increase in counts of submissions from China and India, which are predominantly by men compared to other countries, contributed to the smaller proportional growth in submissions from women during the pandemic and in earlier years. See for example, Figure S2 which shows that from March 2020- February 2021, China based corresponding authors were 47% men, 8% women, and 45% unknown gender. India-based corresponding authors were 11% women, while other top-submitting countries like the U.S. and U.K constituted 25% women corresponding authors and only 5-10% 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 currently most of the categories are based on American groups, e.g., "African American") and a very slight increase in the submissions from those identifying as Hispanic/Latinx (Figure S3) though none of the differences in submissions pre- and during the pandemic are statistically significant.

Quality of Submissions

One question we had is whether the increase in submissions during the pandemic would give rise to lower quality submissions if researchers were able to work on manuscripts they had not given priority to before the pandemic. One test of this hypothesis would be to consider the desk rejections by editors, which occur before peer review. However, we do not see any differences: During the pandemic 25% of submissions were rejected without peer review compared to 26% in the earlier period. Of the papers that went through external review, the rejection rate decreased 2%--from 40% in March 2018- February 2019 to 38% during the pandemic (Figure S4).

Since AGU has been analyzing author gender data, submissions from women corresponding 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 papers were treated more favorably by editors and reviewers than submissions from men (Squazzoni et al., 2021).

In the two years before the pandemic and the year of the pandemic, 6-7% more papers with women corresponding authors were accepted than those with male corresponding authors, as seen in Figure 4. The acceptance rates in 2020 are lower overall because many manuscripts submitted at the end of 2020 were still undergoing revision/re-review at the time we collated the data for this analysis.

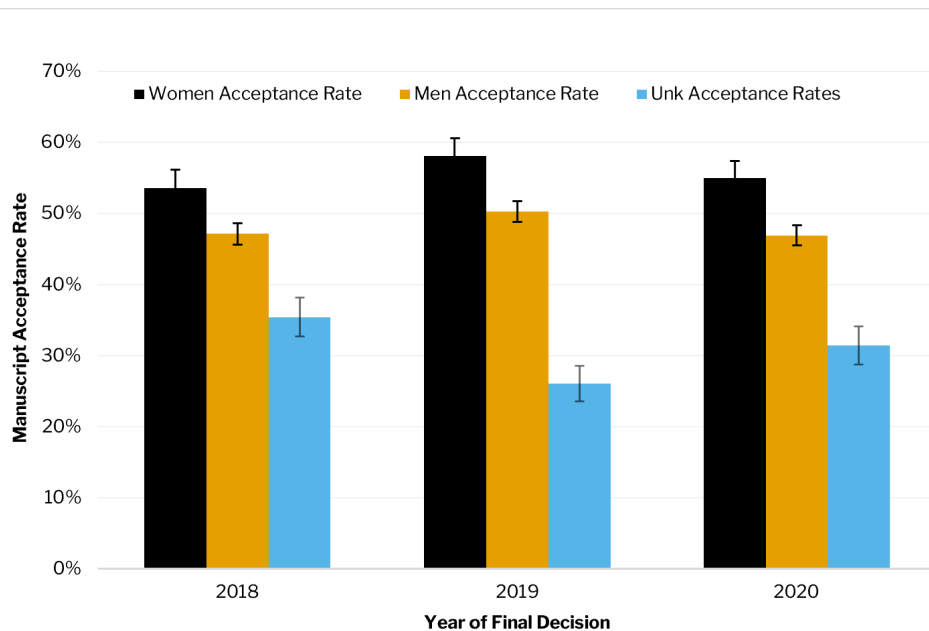


Figure 4: Acceptance rates by gender of corresponding author.

Peer Review Before the Pandemic

Before the pandemic, 76% (2018) and 73% (2019), of all submissions were sent to peer review, which required more than 54,000 and more than 58,000 reviewer invitations, respectively (Figure 5a). Reviewers agreed at similar rates during both years at 46.5% and 45.8% (Figure 6a). In both periods 22-23% of the review invitations were to women—more than 12,000 requests each year. 45% of the invitations went to those in the U.S. and 33% in Europe; although proportionally still low, the review invitations sent to scientists in China increased over the past few years (Figure 5c).

Before the pandemic, women accepted 45% and 43% of the invitation each year, only slightly lower than men did, at 46% in both periods (Figure 6a). Younger reviewers accepted more often than older 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 group (Figure 6b, Figure 6d).

Women reviewers were younger than men, in part reflecting the overall demographics of the AGU membership and median age of physical sciences doctorates in the U.S. (median age for women is 40; men 50, SESTAT Data Tool). Figure 7 shows the proportion of women reviewers and male reviewers by age: Figure 7a and b show the proportion of final (agreed) reviewers with known age calculated as a percentage of *reviewers of their respective genders* with known age while Figures 7c and 7d show the proportion of women and men, respectively, by age

group calculated as a percentage of *all reviewers* with known age. Women in their 30s made up 45% of the women reviewers (Figure 7a) while men in their 30s only accounted for 31% of male reviewers (Figure 7b). Men in their 50s and 60s make up a larger proportion of male reviewers (Figure 7b) than do women in their 50s and 60s (Figure 7a).

Peer Review During the Pandemic

During the year of the pandemic, 470 more submissions were sent to review, or 72% of submissions compared to 73% in the year before. Total review invitations increased by about 1400 during the pandemic, a 2% increase in the number of invitations sent (Figure 7a).



Figure 5: a) Submissions sent to review and reviewer invitation counts in periods before and during the pandemic. B) Proportion of review invitations to women calculated from the total invitations to people with known or assumed gender. Invitation counts indicated in bar graph overlays. C) Proportion of review invitation by invited reviewer region.

Invitations to women increased by ~1000, a 1% increase in the proportion of invitations to women (Figure 5).

Invitations to reviewers in most country-regions increased slightly, and especially in China, continuing a trend seen before the pandemic. In the on 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, so the cause of the change may be unrelated to the pandemic. And, as we know from anecdotes, some people had more time to review while others had less.

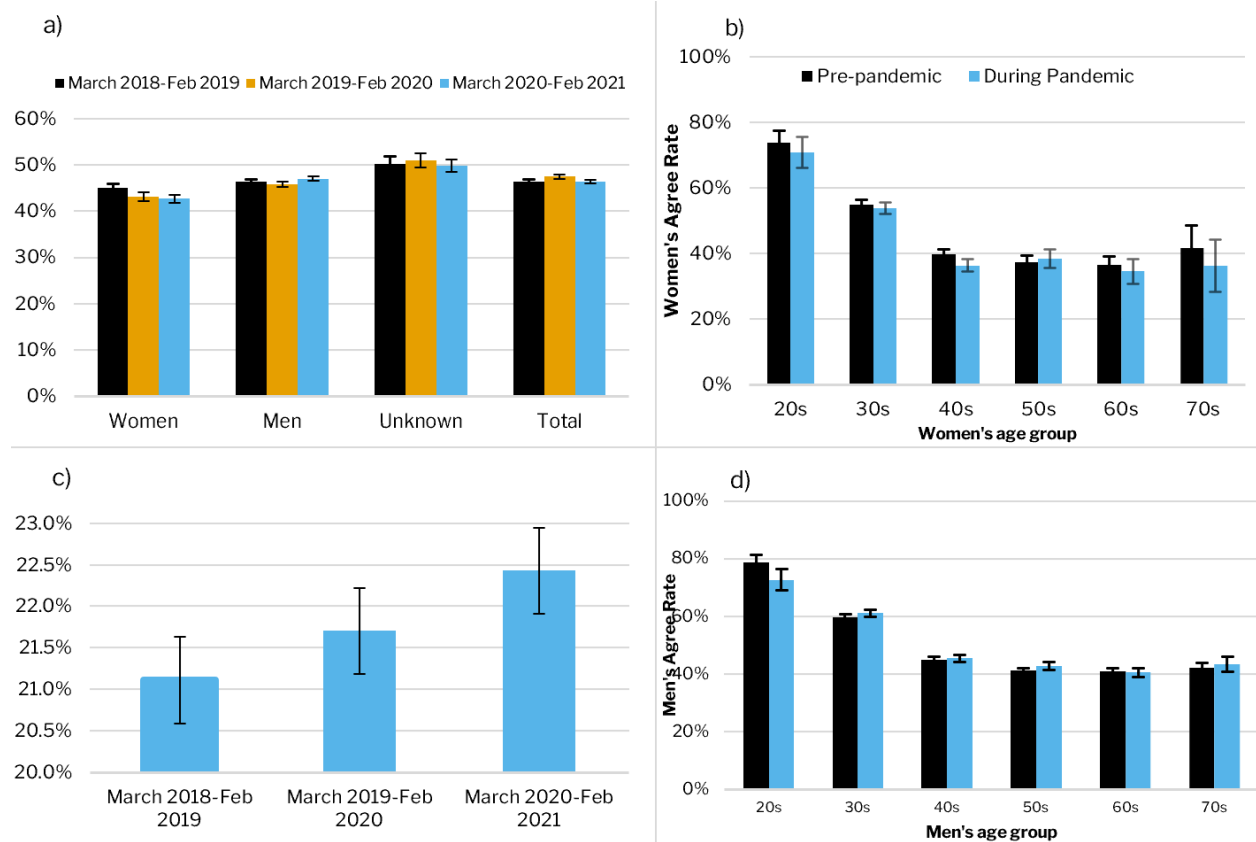


Figure 6: Reviewer agree rates by a) gender, b) women's age group and d) men's age group. C) shows proportion of women (agreed) reviewers.

During the pandemic, acceptance rates by reviewers in various countries showed little variation compared to pre-pandemic 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 pre-pandemic periods. In turn, relatively fewer men in their 20s accepted than before; however, these differences were not statistically significant (Figure 6b). In general, we see that younger scientists are 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, women comprised 22% of the total reviewers with known gender, a slight increase from the two previous periods (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. We also see in Figure 7a that women in their 30s made up a larger proportion of women's reviewer pool than 30s men's share in their respective (men's) reviewer pool even though both groups have the highest representation in membership of the respective genders.

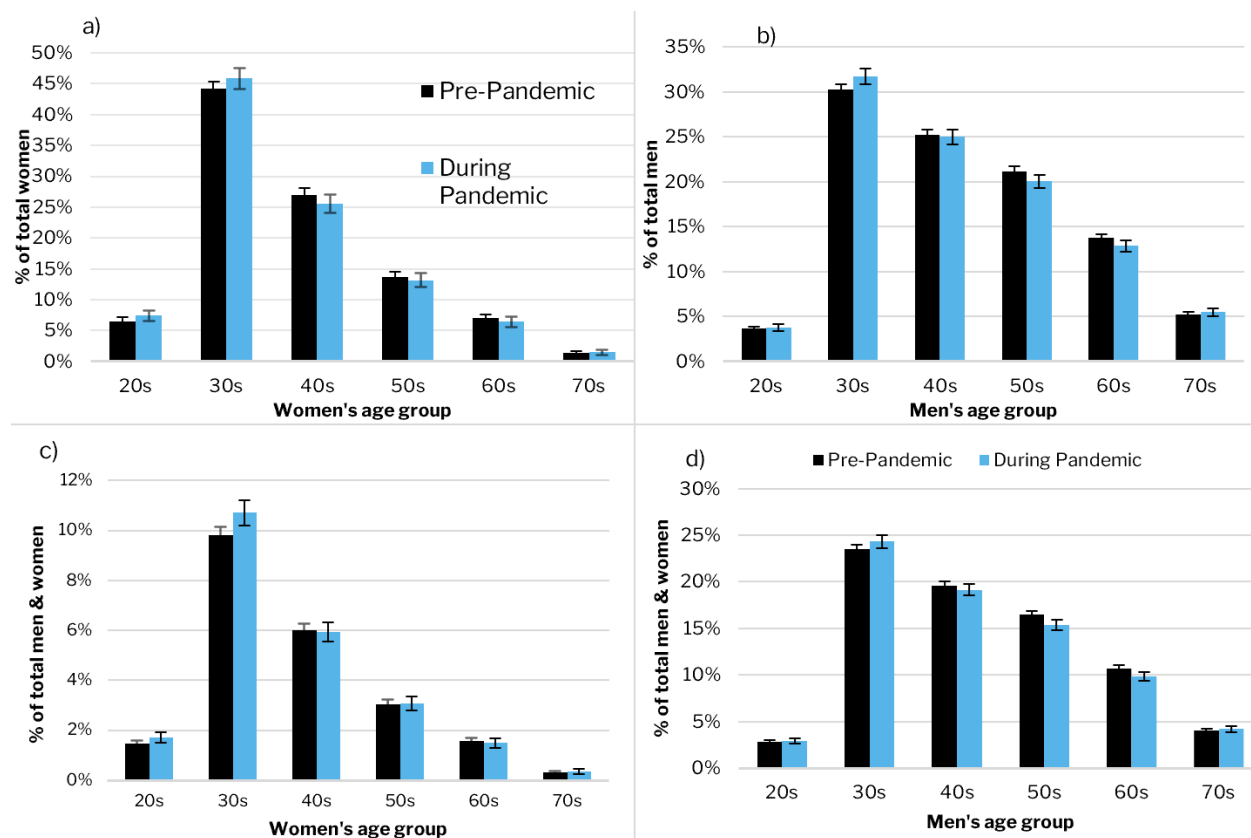


Figure 7: Distribution of reviewers by age and gender before the pandemic (March 2018- February 2020) and during the pandemic (March 2020-February 2021). A) Age of women reviewers calculated as a percentage of total women reviewers with known age; b) age of men reviewers calculated as a percentage of total men reviewers with known age; c) age of women reviewers calculated

as a percentage of all reviewers with known age and gender; and d) age of male reviewers calculated as a percentage of all reviewers with known age and gender.

The age and gender distribution across the *entire* reviewer pool varied insignificantly (by 1% or less) pre-pandemic compared to during it (Figure 7c and 7d).

Some editors feared inviting women to review too often because they perceived that they were burdened with increased childcare and teaching responsibilities. We do see that editors invited the same people less often during the pandemic—both men and women—and editors expanded the number of distinct individuals (assessed by email address) invited to review from more than 31,000 in the year before the pandemic to more than 34,000 during the pandemic. In all three years, before and during the pandemic, editors invited the same women less often than the same men as shown in Figure 8.

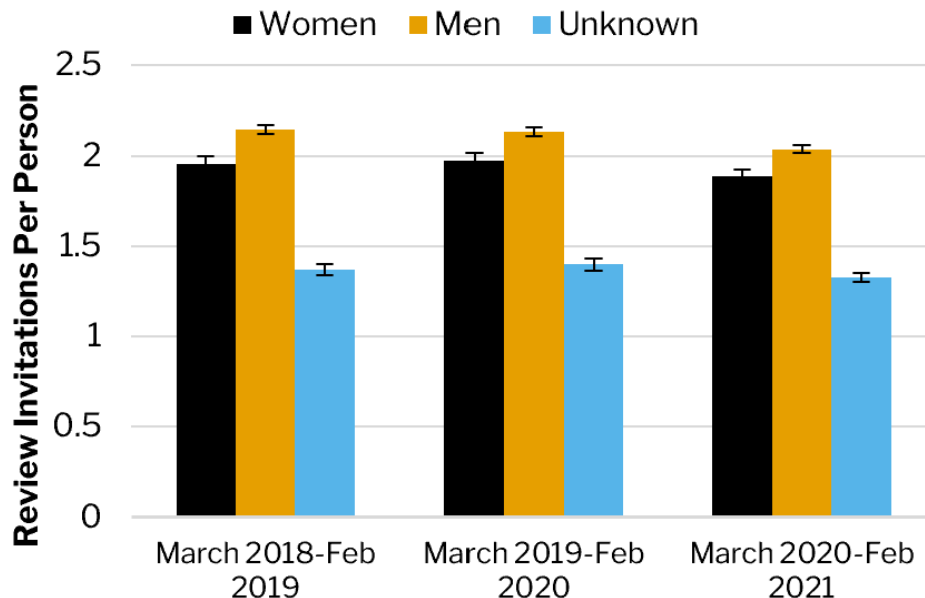


Figure 8: Reviews per person by gender two periods before and during the pandemic.

Review Process

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

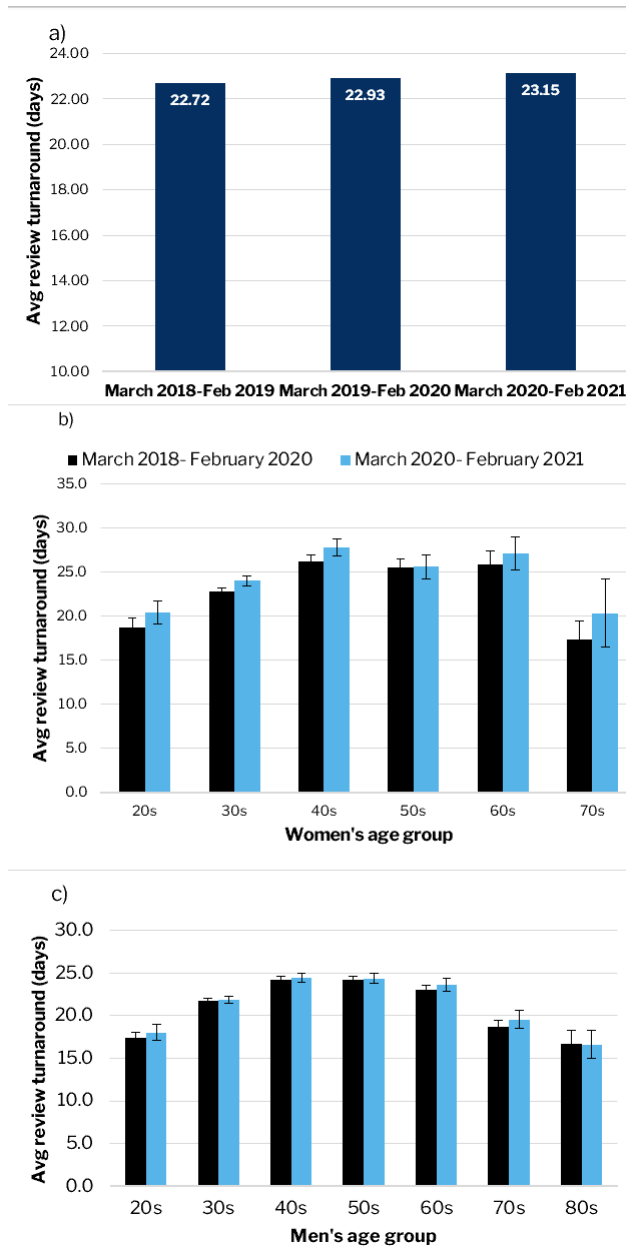


Figure 9: Average review duration (days) before and during pandemic of a) all reviewers in each period before the pandemic and during the pandemic, and b) women and c) men by age in the two periods (combined) before the pandemic and during the pandemic.

Women in their 20s and 40s took more time to complete their reviews, about

2 and 3 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 an additional signal in our data that women had less time for reviewing activities.

Conclusion

The COVID 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 (Vincent-Lamarre et. al., 2020; Krukowski et. al., 2021; Feng & Savani, 2020; Squazzoni et al, 2020; Byrom, 2020; Staniscuaski at al., 2020; Aubry et al., 2021; Myers et al., 2020; Kim & Patterson 2020). Effects on scholarly publishing and other activities (such as meeting participation) have varied by discipline (Korbel & Stegle, 2020; Fox & Meyer, 2020; Mogensen et al, 2021). Some research in the Earth and space sciences have been particularly impacted as field campaigns were cancelled or delayed, lab access interrupted, and hands-on instruction cancelled (Gonzales & Keane, 2021a, 2021b, 2021c). Overall, after one 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 journals 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 2021, and as of August 2021, we’ve had a 3.7% decrease in submissions compared year-to-date 2020. During the pandemic, though, total counts of submissions from women increased, while the proportion of submissions from women stayed consistent with previous years. This flattening of the proportion of submissions from women is contributed by the increase in submissions from China (and to a lesser extent India) with lower proportions of women authors than other countries. Counts of submissions from all top-submitting countries increased in 2020 with China-based authors continuing to submit the highest percentage, showing that the pandemic did not negatively affect their ability to write and submit their research results to AGU journals.

AGU journals saw a spike in submissions in the NH summer months (JJA) of 2020 perhaps due to travel restrictions and a lull in university teaching and homeschooling. 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, though none of the differences were statistically significant.

The increased submission rate did not prove to decrease the quality of the submissions as we saw similar rates of desk rejects during the pandemic as years

prior and a proportional increase in submissions receiving a revise decision.

An increase in total papers 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 period prior. And, fewer invites per person and an increase in final reviewers suggest editors are expanding their reviewer pool.

Review turnaround times remained relatively similar overall during the pandemic except with women in their 20s and 40s, while differences among male age groups were not observed.

It is difficult to assign any of these relatively slight changes to the effects of the pandemic. None of the differences seen during the pandemic are statistically significant. 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 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, papers authored by women have higher acceptance rates in AGU and other journals than those by men (and this continued during the pandemic) (Lerback et al. 2020; Squazzoni et al., 2021). 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 show up in later data. This is certainly the case for delayed research, as manuscript completion may lag by months to years. We will continue to monitor these dynamics.

Data Availability

All data supporting this analysis are available through <https://doi.org/10.5281/zenodo.5534669>.

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