

Water Resources Research®



COMMENTARY

10.1029/2021WR030930

Key Points:

- Hydrologists' research contributions are diverse, not limited to publications
- COVID-19 pandemic disrupted and required reprioritization of research efforts
- Hydrologists should have actionable, meaningful plans on how to incorporate pandemic impact statements in promotion and hiring decisions

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Citation:

CUAHSI Board of Directors & Officers. (2022). COVID-19 impacts highlight the need for holistic evaluation of research in the hydrologic sciences. *Water Resources Research*, 58, e2021WR030930. <https://doi.org/10.1029/2021WR030930>

Received 28 JUL 2021

Accepted 9 DEC 2021

COVID-19 Impacts Highlight the Need for Holistic Evaluation of Research in the Hydrologic Sciences

CUAHSI Board of Directors & Officers¹

¹See Appendix A

Abstract As we reckon with the effect of COVID-19 on the research enterprise in hydrologic science, it is important to acknowledge that disruptions will be persistent and that institutional-level adjustments, while helpful, are not sufficient to mitigate all impacts on hydrologic scientists. Here, we describe the breadth of research contributions in the hydrologic sciences, consider how the pandemic has impacted this portfolio of contributions, document one impact that is already being realized in publication of research, and suggest guidance to the hydrologic science community, institutions, review panels, and funding organizations in considering these impacts at various stages of hiring and promotion in our community. Acknowledging the diversity of contributions to research is particularly valuable because it provides a more objective, transparent, and holistic basis for evaluating individuals within the context of norms of the hydrologic science community. With clearly established values, it is easier to identify impacts of life events, such as those related to the COVID-19 pandemic, as they are manifested in individuals under a diversity of circumstances.

The impacts of the COVID-19 pandemic on research have been widespread, severe, and will continue to require consideration in the evaluation of research productivity over the lifespan of hydrologists' research careers (e.g., Aubry et al., 2020; Krukowski et al., 2021; Malisch et al., 2020; National Academies of Sciences, 2021; Shillington et al., 2020; Sotto-Santiago et al., 2021). As we reckon with the effect of COVID-19 on the global research enterprise and individual researchers, it is important to acknowledge that impacts may be persistent and that institutional-level adjustments (e.g., extended tenure clocks), while helpful, may not be sufficient to mitigate all impacts on hydrologic scientists. At the same time, the pandemic occurred against the backdrop of a broader discourse in higher education about the evolving nature of what constitutes scholarly activity and how increasingly diverse contributions should be valued and evaluated (e.g., Davies et al., 2021; Klein & Falk-Krzesinski, 2017; Klenk & Meehan, 2015; Montoya et al., 2021; National Research Council, 2015). Thus, our objective in this commentary is to describe the breadth of research contributions in the hydrologic sciences, consider how the pandemic has impacted this portfolio of contributions, document one impact that is already being realized in publication of research, and to suggest guidance as to how these impacts could be taken into account at various stages of hiring and promotion in our community.

Acknowledging the diversity of contributions to research is particularly valuable because it provides a more objective, transparent, and holistic basis for evaluating individuals within the context of norms of the hydrologic science community. A holistic evaluation is one that recognizes that advances in scientific fields can take many forms and may be shared and communicated in many ways. It recognizes the impact of research beyond simply counting publications; it looks to see how that research shapes our understanding of nature, our management practices, or the future direction of our field. With clearly established values, it is easier to identify impacts, such as those related to the COVID-19 pandemic, as they manifest, rather than leaving individuals to assert the impacts on an ad-hoc basis for their present and future careers. Establishing holistic evaluations in the hydrological sciences will also support individuals facing either future individual-level or societal-level challenges or disruptions to their research programs.

This comment refines and builds upon a statement from the leadership of the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI, 2021), adding empirical data and raising its visibility to the community. As the Board and officers of an organization that represents and serves the hydrological science community, we are uniquely positioned to provide this perspective and to inform hiring, promotion, tenure and other evaluative bodies about the norms, expectations, and values in our community.

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1. Hydrologists' Research Contributions Are Diverse

Advancement of the hydrologic sciences requires progress in diverse arenas (Figure 1), and the types of contributions by researchers in the hydrologic sciences vary substantially from individual to individual. While each individual's portfolio will be unique and will involve different activities, it is critical to recognize that many types of research contributions are valued by our community. Notably, the balance and weighting of these activities will vary as a function of individual, institution, and position. Still, acknowledging the breadth of research contributions in our field provides a framework to organize our understanding of not only the holistic contributions, but also the interconnected impacts of life-events such as a pandemic.

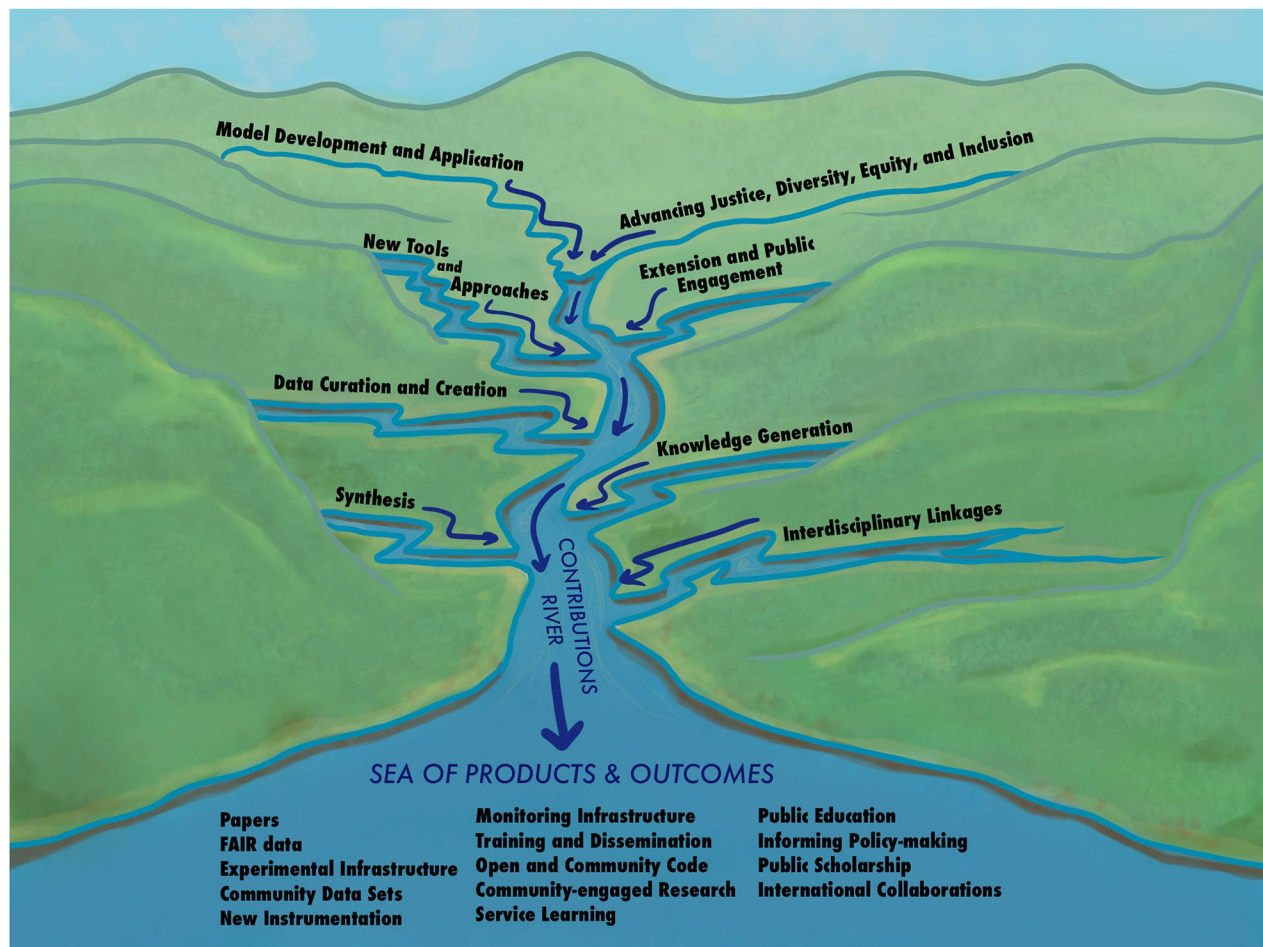


Figure 1. Hydrologic science relies upon diverse research contributions from our community (terrestrial system, above). Examples of contributions valued in the field include: (a) *Generating new knowledge*: improved understanding of hydrologic processes and generation of new theory describing these processes. (b) *Interdisciplinary linkages and feedbacks*: efforts to merge hydrologic theory with knowledge from allied disciplines to understand synergistic and symbiotic processes, including those that may occur at physical and disciplinary boundaries. (c) *Data creation*: generation, curation, and sharing of data from field and laboratory studies, which are a cornerstone of development of hydrologic understanding. (d) *Synthesis efforts*: synthesis of place-based studies into generalizable frameworks and the proactive testing of transferability of models and techniques. (e) *Development of new tools, techniques, and approaches*: the development, validation, and sharing of new methodologies and technologies for observing the hydrologic cycle, and the effort to proliferate these across the community. (f) *Model development and use*: physical, numerical, and statistical modeling approaches to interpret and forecast hydrological processes, including model development, building computational infrastructure, and using models to inform decision-making. (g) *Applied research, extension, and public engagement*: the transfer of hydrologic science to practice through applied research, extension, and public engagement. We value the time, skill, and expertise required to conduct or co-create timely research-based knowledge and share via cooperative extension programs and through policy engagement. (h) *Advancing diversity, equity, inclusion, and justice*: the contributions that advance justice in hydrologic science in broad ways including for environmental justice and to ensure greater diversity, equity, and inclusion within our community. These contributions (the watershed and stream network) contribute to a host of products and outcomes (only examples of which are explicitly pictured above), all of which are valued by our community. See CUAHSI (2021) for additional details and further examples (Figure 2).

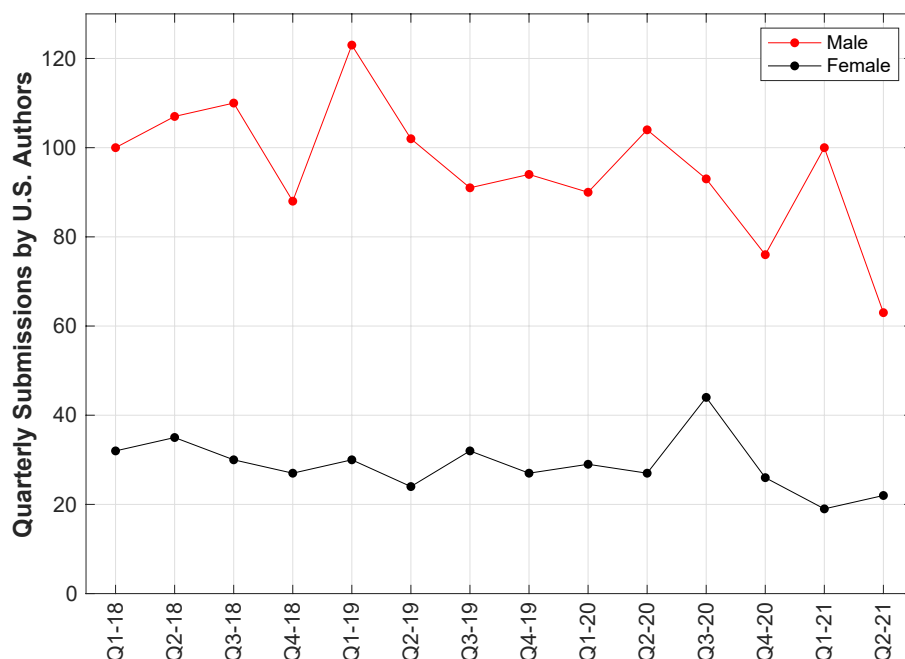


Figure 2. Quarterly submission of papers submitted to *Water Resources Research* (published by the American Geophysical Union, AGU) by U.S.-based lead authors. The precipitous drop in submittals during the pandemic (since Q3-2020) is an early signal of the lack of new research being completed during the pandemic.

In addition to traditional research products (e.g., manuscripts, books and book chapters, competitive funding), other products and services are valued as research outputs in hydrologic science (Figure 1). We seek to articulate research outputs and activities that are consistent with types of contributions we value as a discipline, but which may not always be fully acknowledged in hiring, promotion, and tenure decisions. During the pandemic, the effort to sustain research efforts (e.g., the integrity of long-term data sets and experiments) may have been prioritized over more traditional research products. For example, the hydrologic scientist who maintained the integrity of a long-term data set or experiment will have faced substantial challenges in logistics, safety planning, approvals, and working alone when teams would have traditionally worked in close proximity. Thus, the pandemic has precipitated an urgent need to document the range of contributions that we value in our field. The full breadth of these endeavors must be accounted for as we assess the productivity of individuals in light of COVID-19 and beyond.

2. Effects of Pandemic Disruptions on Hydrologic Sciences Research

While many of the commonly identified impacts of the pandemic on scientific research are mirrored in the hydrologic sciences (e.g., loss of lab access, cancellation of conferences), we believe it important to articulate some specific examples through which these disruptions are manifest and are particularly acute in the hydrologic sciences. Below we provide a non-exhaustive list of examples to help readers envision the specific impacts on research within the hydrologic sciences. We identify six major categories of impacts on hydrologic science research (Figure 2):

1. *Hydrologic sciences research is sensitive to temporal disruptions.* Missing an important event such as snow-melt, postponement of field experiments, and interruption of long-term data sets, including those collected by government agencies, challenged scientists during the pandemic.
2. *Hydrologic sciences research is sensitive to disruptions in site access and travel.* Many field sites and lab facilities continue to impose access restrictions. Travel to maintain field sites, collect data to validate sensor deployments, visit collaborators, conduct interviews or focus groups, and execute field experiments were limited or severely altered during the pandemic.
3. *Hydrologic sciences research is dependent on access to large-scale or distributed equipment.* Loss of access to shared infrastructure included reductions in coordinated deployment of specialized equipment (e.g., airborne data collection) and prioritization of COVID-related research on large-scale computing facilities.

4. *Hydrologic science is a multi-disciplinary collaborative field.* Pandemic conditions reduced opportunities to build collaborations through conferences, workshops, and site visits. Reduced density requirements meant students entered lab groups working remotely, and early career scientists contended with building collaborative networks and research groups in an online-only environment and limited collaboration, consultation, and information gatherings.
5. *Experimental and lab-based hydrologic research was disrupted by loss of access to research labs and maker spaces.* For example, access to lab spaces was restricted by many institutions, preventing experiments and sample analyses from being conducted during the pandemic and challenging the establishment of labs by early career researchers. Labs and lab supplies were repurposed to pandemic efforts.

3. Early Evidence of COVID-19 Impacts at Water Resources Research

To assess early evidence of the pandemic's impact on hydrologic science, we analyzed submissions to *Water Resources Research* from January 2018 to June 2021. First, we found evidence that submittals from female corresponding authors in the U.S. (the most represented country of origin for authors in our data set) were increased (Q3-20) or held steady early in the pandemic (Q4-20), consistent with reports that time spent on writing increased as time spent in the lab, field, and elsewhere decreased (Gonzales & Keane, 2020a, 2020b). Subsequently, these submissions decreased to their lowest levels in the period analyzed during Q1-21 and Q2-21. We interpret this decrease as an indicator of pandemic impacts across a demographic known to be disproportionately impacted by the pandemic (e.g., Myers et al., 2020; Viglione, 2020). Declines in productivity are also apparent across overall submissions, with projected 2021 submissions below pre-pandemic (2018–2019) levels for the U.S., Australia, Canada, China, and the Mexico, Central, & South America grouping (Figure 3). Finally, we acknowledge here that other demographics will have been disproportionately impacted (e.g., primary caregivers, families for whom education of children was disrupted), but data on these demographics were not available for analysis.

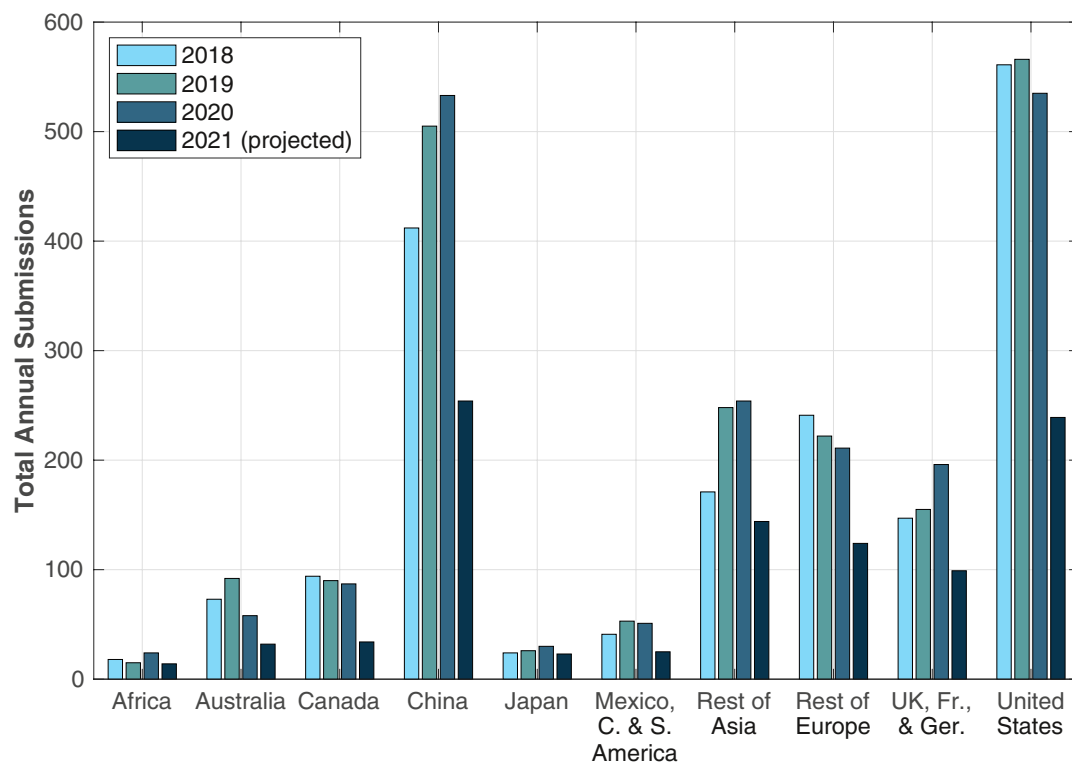


Figure 3. Annual submissions to *Water Resources Research* based on country of residence for the corresponding author. Declines in submittals from the U.S.—the most represented country of origin in the data set—were apparent in 2020 and are projected to further decline in 2021. Declines in 2021 relative to pre-pandemic years (2018–2019) are also projected in Australia, Canada, China, and the Mexico, Central, and South America grouping.

These trends suggest that research that was in an earlier phase when the pandemic began is now missing from the publication pipeline and it remains to be seen what proportion of this early stage research has been merely delayed or entirely aborted. We anticipate that submittals from some demographics may remain depressed for up to several years as the research slowed or stalled during the pandemic matures toward publication. Further, the return to pre-pandemic working conditions will not occur uniformly in time. Instead, access to vaccines, both in a global context (e.g., variability in access to vaccines in different locations) and relative to individual circumstances (e.g., primary caregiver for a person who cannot be vaccinated), will be differential in the immediate future.

A decline in publication productivity due to the pandemic has the potential to manifest later as a “less productive” CV for some individuals if not interpreted in context of (a) the pandemic's impact on research, and (b) the unequal impact across demographic groups and parts of the world. Importantly, we underscore that analysis of submittals to this journal is but one indicator of impact on one (itself not homogenous) demographic group in one geographic location and does not represent the totality of impact on any individual. Instead, we present this as representative of the breaking wave of impact that we expect will be felt for the next decade or longer, and as early evidence that the pandemic's effects are real, measurable, and therefore cannot be ignored.

4. Suggestions to the Community to Ensure the Holistic Evaluation of Hydrologic Scientists

The types of contribution and impacts outlined above and elsewhere (CUAHSI, 2021) provide a basis for the field of hydrologic science to consider how we evaluate candidates in a more holistic manner. This is particularly important as the pandemic impacts likely are only beginning to be fully realized and will ultimately have shaped and defined the essential training and/or early years in research for our present students, post-doctoral researchers, and early career faculty. How, then, shall we acknowledge and more importantly account for both the diversity of contributions to research in hydrologic science and the disparate impacts on individuals' training and careers?

To those applying for positions, promotions, and/or tenure: Consider directly articulating your past, present, and potential contributions across the breadth of research areas and products that are valued by our community. Explicitly describe impacts across the breadth of research contributions and products that are valued by our community (Figure 1).

To external evaluators, reviewers, and those in positions to hire: Evaluations should be written in the context of COVID-19 impact, acknowledging the acute and long-lasting impacts on the candidate. Recognize that the contributions hydrologists value and products they generate should not be considered a checklist for assessment, but instead a demonstration of the diverse ways that contributions are made and documented in our field. In evaluation letters, consider it your obligation to discuss the hydrology-specific issues related to the COVID-19 pandemic that were faced by the candidate and contextualize these experiences in the discipline. It is essential to highlight impacts that may not have been ubiquitous across all disciplines to educate review committees whose composition frequently spans a diverse array of intellectual backgrounds.

To review committees and senior faculty: We encourage you to ask for statements about COVID-19 impacts on research, teaching, mentoring, and service and to take seriously the concerns raised by candidates and reviewers. Do this with care and intent as impact statements require significant time and effort. You play an incredibly important role, intermediary to candidates and administrators, that can provide important context about the impacts of the pandemic. With the breadth of research contributions and products in our discipline, candidates' experiences may not have mirrored your own. Importantly, while we may all “look like hydrologists” to other disciplines, the specific needs and impacts in our field are highly variable across our areas of expertise.

To academic and professional leaders: Voice support for the inclusion of the full breadth of research products and contributions that are valued in our discipline and consider how COVID-19 impacted them. Inclusion of this information, with guidance, and explicit requests asking for consideration of how COVID-19 impacted the candidate should be considered requisite in external review requests and internal review processes. Finally, recognize that—while often helpful and appreciated—extended tenure clocks or delays of mandatory merit and promotion review may not adequately or equitably address all possible long-term impacts of the pandemic (Manchester et al., 2013). The effects of COVID-19 on hydrologic science researchers are non-uniform. Consequently, uniform policies to address these impacts may exacerbate inequalities. Instead, particular focus should be given to

support groups that have been especially impacted, and care taken to address individuals' needs rather than apply generic, universal policies.

To funding agencies: Program officers should continue to proactively engage with their communities to understand pandemic impacts and identify creative ways to mitigate the impacts. Agencies should consider differential COVID-19 impacts across subdisciplines in allocating recovery funds among disciplines, programs, and projects. Future review panels should explicitly consider COVID-19 impacts as research progress, products, and experience by PIs may have been delayed or diminished.

In summary, taking a holistic approach to evaluate and recognize the diverse and critical ways that hydrologists contribute to the hydrological sciences is necessary in light of the COVID-19 pandemic. Holistic evaluation will help hydrologists navigate and mitigate the impacts of COVID-19 and provide a consistent basis for evaluation of hydrologists. Our response as a discipline to the COVID-19 pandemic, and acknowledgement of the breadth of research types and products in our community, also provides a basis for evaluating impacts from other individual- or society- level disruptions that cause hydrologists to prioritize some investments of time over others.

Appendix A

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Acknowledgments

This commentary was primarily authored by Adam Ward, Alejandro Flores, Anne Jefferson, Steve Loheide, Jeanne M. VanBriesen, with concurrence from all members of the CUAHSI Board of Directors, officers, and the executive director in 2021. The authors recognize and thank Paige Wooden, Sr. Program Manager for AGU Publications for her efforts to derive, share, and help interpret data on WRR submittals. Effort to prepare this statement was supported in part by NSF Awards 1849458 and 2028737. Original artwork in Figure 1 was created by Dom Ciruzzi. The opinions expressed in this commentary reflect the views of the authors and should not be construed as endorsement nor concurrency of funding agencies nor the authors' individual institutions.

References

- Aubry, L. M., Lavery, T. M., & Ma, Z. (2020). Impacts of COVID-19 on ecology and evolutionary biology faculty in the United States. *Ecological Applications*, 31(2). <https://doi.org/10.1002/eap.2265>
- CUAHSI (2021). *CUAHSI statement on holistic evaluation of research in the hydrologic sciences*. <https://doi.org/10.4211/hs.21e61fe839004fd399439a2a3391a763>
- Davies, S. W., Putnam, H. M., Ainsworth, T., Baum, J. K., Bove, C. B., Crosby, S. C., et al. (2021). Promoting inclusive metrics of success and impact to dismantle a discriminatory reward system in science. *PLoS Biology*, 19(6), e3001282. <https://doi.org/10.1371/JOURNAL.PBIO.3001282>
- Gonzales, L., & Keane, C. (2020a). *Caregiving and domestic responsibility impacts from the pandemic*. American Geosciences Institute. Data Brief 2021-020. Accessed 13 July 2021. Retrieved from <https://www.americangeosciences.org/geoscience-currents/caregiving-and-domestic-responsibility-impacts-pandemic>
- Gonzales, L., & Keane, C. (2020b). *Academic activities by gender and faculty rank during the pandemic*. American Geosciences Institute. Data Brief 2021-019. Accessed 13 July 2021. Retrieved from <https://www.americangeosciences.org/geoscience-currents/academic-activities-gender-and-faculty-rank-during-pandemic>
- Klein, J. T., & Falk-Krzesinski, H. J. (2017). Interdisciplinary and collaborative work: Framing promotion and tenure practices and policies. *Research Policy*, 46(6), 1055–1061. <https://doi.org/10.1016/j.respol.2017.03.001>
- Klenk, N., & Meehan, K. (2015). Climate change and transdisciplinary science. *Problematising the integration imperative*, 54, 160–167. <https://doi.org/10.1016/j.envsci.2015.05.017>
- 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, 341–347. <https://doi.org/10.1089/jwh.2020.8710>
- Malisch, J. L., Harris, B. N., Sherrer, S. H., Lewis, K. A., Shepherd, S. L., McCarthy, P. C., et al. (2020). Opinion: In the wake of COVID-19, academia needs new solutions to ensure gender equity. *Proceedings of the National Academy of Sciences*, 117(27), 15378–15381. <https://doi.org/10.1073/pnas.2010636117>
- Manchester, C. F., Leslie, L. M., & Kramer, A. (2013). Is the clock still ticking? An evaluation of the consequences of stopping the tenure clock. *Nature*, 66(1), 3–31. <https://doi.org/10.1177/001979391306600101>
- Montoya, L. D., Mendoza, L. M., Prouty, C., Trotz, M., & Verbyla, M. E. (2021). Environmental engineering for the 21st century: Increasing diversity and community participation to achieve environmental and social justice. *Environmental Engineering Science*, 38(5), 288–297. <https://doi.org/10.1089/ees.2020.0148>
- Myers, K. R., Tham, W. Y., Yin, Y., Cohodes, N., Thursby, J. G., Thursby, M. C., et al. (2020). Unequal effects of the COVID-19 pandemic on scientists. *Nature Human Behaviour*, 4(9), 880–883. <https://doi.org/10.1038/s41562-020-0921-y>

- National Academies of Sciences. (2021). *Impact of COVID-19 on the careers of women in academic sciences, engineering, and medicine*. The National Academies Press. <https://doi.org/10.17226/26061>
- National Research Council. (2015). *Enhancing the effectiveness of team science*. The National Academies Press. <https://doi.org/10.17226/19007>
- Shillington, A. M., Gehlert, S., Nuriu, P. S., Delva, J., Hooyman, N. R., Manderscheid, R. W., & Palinkas, L. A. (2020). Commentary: COVID-19 and long term impacts on tenure line careers. *Journal of the Society for Social Work and Research*, 11, 499–507. <https://doi.org/10.1086/712579>
- Sotto-Santiago, S., Dilly, C., O'Leary, H., Craven, H., Kara, A., Brown, C., et al. (2021). Reframing academic productivity, promotion and tenure as a results of the COLVID-19 pandemic. *The Journal of Faculty Development*, 35(1), 10–18.
- Viglione, G. (2020). Are women publishing less during the pandemic? Here's what the data say. *Nature*, 581(7809), 365–366. <https://doi.org/10.1038/D41586-020-01294-9>