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# **Author Gender and Career Progression in *Environmental Science & Technology***

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Gender disparity within science, technology, engineering, mathematics, and medicine (STEMM) is a critical problem that can diminish the potential of scientific achievement and the impact of resources dedicated to science on an international scale. Women are entering undergraduate and graduate programs in STEMM subjects in record numbers<sup>1</sup>; however, progression of women into senior scientific posts is not increasing as rapidly, is static, or may even be decreasing within some STEMM subjects<sup>2</sup>. Perhaps the most frequently used metric of academic achievement to evaluate readiness for promotion into senior scientific posts is assessment of the number, quality, and impact of research publications. While assessment of the relative frequency of female first authorship of scientific journal publications can be informative, first authorship is not necessarily an indication that females are progressing into senior scientific positions. First authors may often be the scientists that have performed the experimentation, analyzed results, and written the manuscript; however, these efforts are frequently directed and supervised by a senior scientist. Within the author list of a scientific article, the corresponding (or reprint) author is frequently the scientist with overall responsibility for the work (e.g., the principal investigator), and the last author may be the senior author (may or may not be the corresponding author) or perhaps overall group or institute leader. Nonetheless, designation of authorship is not always straightforward and differences can exist among disciplines, journals, and within individual research groups. Despite limitations of the metric of scientific article authorship gender, the importance of authorship in terms of a scientist's reputation, career progression, and impact within a discipline also dictate that the metric has potential importance for assessment of gender-disparity and career progression within a discipline.

We considered 15,098 articles (research articles and critical review articles) published from 2006-2016 in *Environmental Science & Technology* (ES&T), and evaluated first and reprint

author gender over time, by geographical location, and by citation frequency. The Web of Science™ (WoS, Core Collection) was used to identify articles, and gender was determined by manual examination of author name and use of online resources (i.e., Research Gate, Linked in, institutional websites) as in previous studies<sup>3</sup>. To assess accuracy of our ability to assign author gender, 600 articles were randomly selected from the 15,098 articles in which we evaluated author gender, and independent re-evaluation of author gender for these 600 articles found our original gender assignment to be in 98% agreement overall [sub-sample of 600 articles ( $98.0 \pm 0.4\%$  mean  $\pm$  SE, N=6 groups of 100 articles)], which is consistent with other author gender assessments of scientific literature<sup>3</sup>. Assignment of first author gender was possible for 8,265 articles [ $55.6 \pm 1.9\%$ , mean  $\pm$  SE, N=11 (i.e., each year: 2006-2016)] and reprint author gender was able to be assigned for 7,926 articles ( $53.0 \pm 0.8\%$ , mean  $\pm$  SE, N=11). Assignment of author gender was highest for articles in which reprint author country was from the United States or the European Union (gender assigned to 70% and 79% of articles respectively), whereas gender was assigned for only 2% of articles when the reprint author address was China. For citation frequency, only articles published in years 2006-2012 (5110 articles) were considered to avoid potential bias of more recently published articles that have not had sufficient time to accrue stable citation profiles. All statistical analyses were conducted with R version 3.2.2 [(2015-08-14) Copyright © 2015, The R Foundation for Statistical Computing]. Please contact the authors for details of statistical methods (<https://epaquatic.org/gender-disparity-in-stemm/>).

Female first authorship and female reprint authorship of ES&T articles increased continuously between 2006 and 2016 (Figure 1). If current trend in female first authorship continues, then parity in proportion of female and male first authorship (50% for each) will occur

in 2021. The proportion of female reprint author articles was significantly lower than the proportion of female first authored articles, and the rate of increase over time was also significantly lower. If the trend in female reprint authorship continues, then parity in the proportion of female and male reprint authorship will not be reached until 2046 (i.e., 26 years after gender parity is reached for first authored articles). For the 6,331 articles considered (i.e., those with EU or US reprint address) over 2006-2016, a significantly ( $P < 0.001$ ) higher proportion of female first authors was found when reprint author address was in the EU; however, gender proportions of reprint authors did not differ significantly between the EU and US.

We found that for five of seven years there was no relation between ES&T article citation frequency and gender; however, in years 2009 and 2012, as number of citations increased, the likelihood of female first authorship decreased based on the significant logistic regression model we developed. Broadly, across STEMM disciplines, articles with women in senior author positions are reported to receive significantly lower citations than male authors<sup>4</sup>. The observation that female authorship did not consistently associate with reduced article citation frequency in ES&T could indicate that female-authored articles are not subject to the citation bias reported for journals associated with other STEMM subjects, or perhaps female authored ES&T articles are actually over-performing relative to male-authored ES&T articles (i.e., the importance of the articles leads to increased citations that offset any gender bias).

The increase in proportion of female first authors of ES&T articles suggests more rapid approach to first-author gender parity than some other STEMM disciplines. For example, in a combined assessment of six prominent medical journals, female first authors increased from 27% in 1994 to 37% in 2014<sup>3</sup>. If we extrapolate this reported trend, parity in gender for first authors

of these medical journal will occur in 2040, although frequency in female first author gender was actually decreasing in some journals (i.e., differences exist among the journals examined by Filardo et al.<sup>3</sup>). Progression of female scientists into senior roles (designated in our assessment by the reprint author) was not consistent with the increase in female first authored articles in ES&T, and likely reflects the under-representation of women in senior scientific positions that has been reported across other STEM disciplines<sup>4</sup>. The observation of a higher proportion of female first authors but not female reprint authors in the EU compared to the US could indicate greater challenges for women to progress into senior scientific positions in the EU compared to the USA. Our observation is consistent with employment reports that women in the US are less likely to work but that when they do they are more likely to be successful (e.g., reach senior positions) than their EU counterparts<sup>5</sup>. Blau and Khan<sup>5</sup> suggest longer career breaks (e.g., 12-month maternity leave) that are possible for women in EU compared to US may contribute to reduced career progression of women in the EU. If greater challenges exist for career progression of women in some areas, then measures to address regionally-based underlying factors that influence career progression should be considered (e.g., implementing actions to improve potential for career progression after a career break). Whether female first authors are not progressing to senior positions because they remain in junior positions longer or because they leave research positions that could have led to publications in ES&T is unknown. The present study does not investigate factors responsible for author gender bias; however, by elucidation of gender differences based on a prominent metric of scientific quality (i.e., article publication) the need for action to address gender disparity is further justified. Future use of author-gender evaluations of scientific publications can contribute to assessments of the effectiveness of actions taken to improve progression of females into senior positions.

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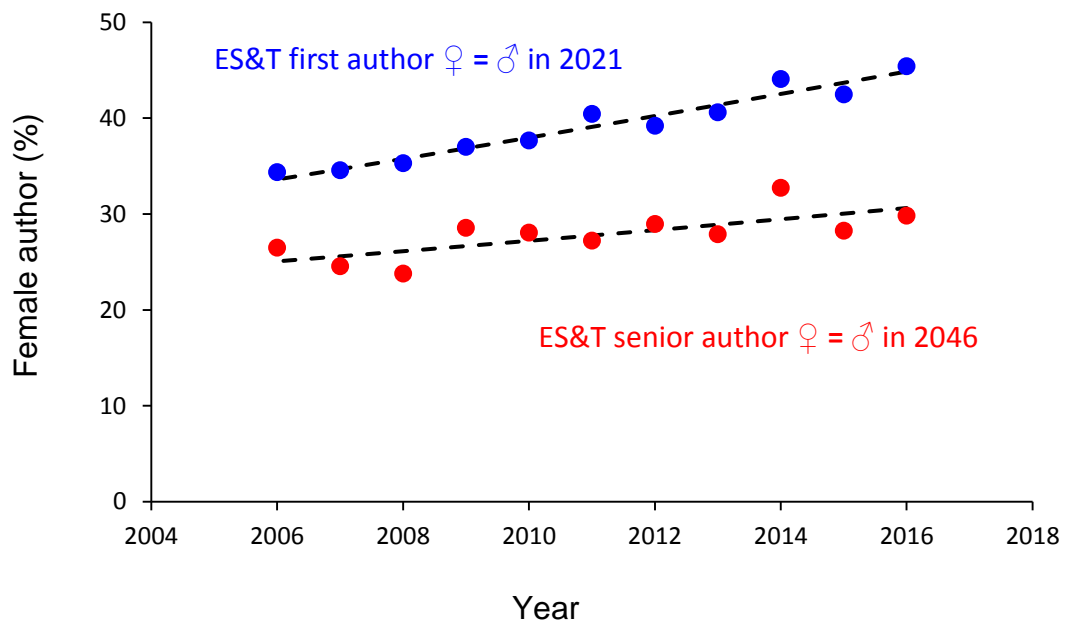


Figure 1. The proportion (%) of female first author articles (blue circles) and female reprint author articles (red circles) published in ES&T over time.