

# Evolution of paleontology: Long-term gender trends in an earth-science discipline

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The historical development of gender diversity in paleontology may be representative of similar changes across the geosciences. An analysis of the programs of the ten North American Paleontological Conventions held since 1969 shows a steady increase in the participation by women in the discipline. Notably, the proportion of male authorship on abstracts was stable while female authorship contribution increased. Much of the growth in female authorship is due to increased collaboration and recognition of student participation with junior authorship. These changes are just starting to be reflected at more senior levels; strategies need to be implemented to ensure that young female geoscientists are retained and developed.

Studies of long-term trends in gender dynamics in science can help identify strategies that are working and highlight additional actions to further reduce barriers to full participation. We examined such long-term changes in meeting participation in paleontology. By examining meeting participation, rather than employment trends (e.g., Holmes and O'Connell 2003), we investigate gender dynamics within the intellectual development of a discipline.

Paleontology is a diverse field, and workers in the various subdisciplines often attend different conferences. Every four to five years, however, all flavors of paleontologist converge for the North American Paleontological Convention (NAPC). The first of these was held in 1969 (Yochelson, 1996); the tenth and most recent this past February. The programs of these meetings reflect transformations in how, and by whom, the science of paleontology is practiced.

The first NAPC was limited to 79 presentations in organized symposia. Nearly all of the presentations were single-authored, and only two talks were presented by women. In contrast, the 2014 meeting included 315 separate talks, many in posters and contributed sessions. Most were multi-authored, and 130 of the presenters were women, a two order of magnitude increase in female participation since 1969.

There clearly have been some fundamental changes in the nature of paleontological conferences and, by implication, the field of paleontology. To track how these changes occurred over time, we analyzed the program and abstract volumes for all ten

NAPCs. For each, we counted the total number of abstracts; the number of authors per abstract; whether an abstract had at least one female or male author and if so, how many; and whether a woman was the senior or sole author. Gender was determined either by first name or by personal knowledge of the author in ambiguous cases. To measure how many times an author appeared on multiple abstracts, we divided the total number of authors on abstracts by the number of unique names of authors (multiple authorship index). We standardized the data by dividing each value by the number of published abstracts. When possible, we recorded whether a woman chaired or co-chaired a session and whether a woman was a keynote or plenary session presenter; this data was incomplete. Key results are summarized in Figure 1.

Notably, participation by women has increased over the past 45 years (Fig. 1). Women comprised only 2% of authors in 1969, but were senior authors on 40% of abstracts and contributed to 58% of abstracts in 2014. This increased participation occurred largely due to collaboration with, rather than replacement of, male paleontologists. Indeed, ~90% of all abstracts included a male author at each NAPC. In addition, the proportion of papers with female authors has increased faster than the proportion of women who are lead authors. At the 2014 NAPC, there was a statistically significant difference (Kolmogorov-Smirnov test) in the median number of authors on papers with at least one female author (3.0;  $n = 222$ ) and those without a women author (2.0;  $n = 158$ ). Thus women are more likely to work in larger groups and are less likely to be the sole author, which explains the discrepancy between the proportion of total authorship and proportion of lead authorship by women. When women were senior authors on multi-authored abstracts, they had female co-authors 55% of the time, whereas 44% of the male senior authors had at least one female co-author. Both the trend lines and statistical comparisons indicate that much of the increased female involvement is as secondary authors and that women tend to publish with other women.

The increases in authors per abstract and multiple authorship index indicate both increasingly collaborative projects and changing social patterns whereby junior project participants are increasingly recognized with authorship. The coincident increases in female authorship and authors per abstract may be related to the documented propensity for female scientists to collaborate more broadly (van Rijnsoever and Hessels, 2011) and to more often pursue “mentoring” collaboration strategies compared to the “expertise” strategies of men (Bozeman and Gaughan, 2011). The inclusion of junior collaborators in authorships is a likely mechanism for increased female authorship because there are more paleontologists at junior than senior ranks.

The attrition of women from student to senior scientist ranks has been well studied (e.g., deWet et al., 2002; Shen, 2013).

Membership data for the Paleontological Society (PS), which includes a diversity of paleontologists similar to the demographic sampled by NAPC, indicates that women comprise 48% of student members but only 23% of professional members (Stigall, 2013). These values compare closely with the demographics of The Geological Society of America (GSA) in which women comprise 45% and 27% of student and professional members, respectively (GSA, 2014). The substantially higher percentage of student versus professional women in these data supports the earlier assertion that increased collaboration with and participation by students may underlie the trends in increased participation by women, thereby linking the patterns of multi-authorship and higher proportions of women in meeting presentations.

The roles of female participants at NAPC also reflect the more limited female involvement at more advanced career stages observed in the membership data. Notably, participation by women in prominent roles at the NAPC as keynote/ plenary speakers or symposium conveners has increased much later and more sporadically than abstract participation. Only the recent Gainesville meeting had equal participation by women as symposia organizers or keynote speakers. Limited participation by women in high-profile roles is documented in other disciplines (Isbell et al., 2012) and cannot be fully attributed to historical lags.

The nearly continual increase in female participation and collaboration over the past 45 years as valued contributors in scientific presentations is encouraging. Gender equity, however, is only beginning to emerge within the prominent roles of conveners and keynote speakers. A 90% inclusion of males versus 60% inclusion of females on presentations and the continued underrepresentation of women in high-profile speaking or organizational roles underscores that more work is needed to achieve gender equity. The high participation by women in NAPC presentations and the high percentage of female student members of the PS and GSA clearly show that there is a pool of talented, engaged young women in paleontology and geosciences in general. Future studies should address how this is reflected in participation in meetings and publications among other geoscience disciplines.

Strategies to support these students and early-career women in all areas of geosciences, such as providing childcare at meetings (Williams and Ceci, 2012) and fostering mentoring opportunities, can promote retention of these talented scientists within the professional ranks. Further strategies to enhance representation by women in prominent conference roles, such as directed

invitations, flexible scheduling of organizational tasks, and confronting internal biases, are necessary to remove barriers to full participation by mid- and late-career women. The substantial improvements in gender equity over the past 45 years coupled with an awareness of and plans to mitigate current barriers and limitations has the potential to produce an historical record of a discipline much evolved from its mid-20th-century record.

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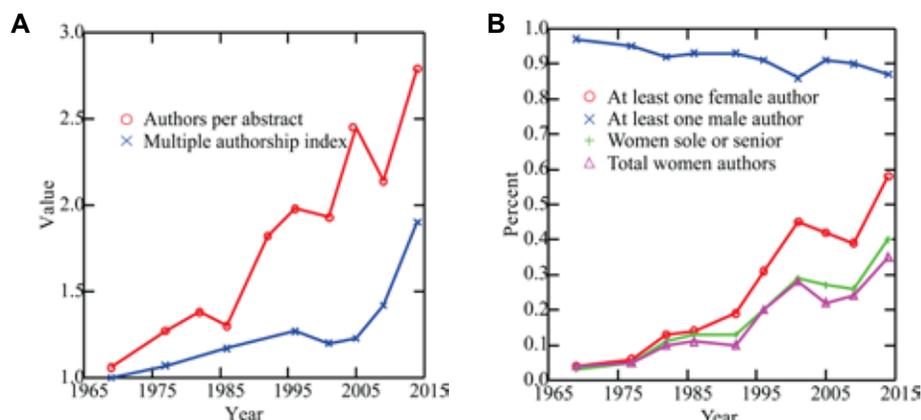


Figure 1. Authorship trends at the North American Paleontological Convention. Meetings were held in 1969, 1977, 1982, 1986, 1992, 1996, 2001, 2005, 2009, and 2014. (A) Average number of authors per abstract. Multiple authorship index is total number of authors on abstracts divided by number of unique authors in the program index. The number of authors per abstract has nearly tripled, whereas the number of authors appearing on multiple papers has almost doubled. (B) Proportion of papers with at least one male author, at least one female author, of total authors who are women, and with a woman as sole or senior author. The proportion of female authors has increased in all metrics, whereas the proportion of male authorship has been stable.